Assigment 2

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# Libraries

library(skimr)

## Warning: package 'skimr' was built under R version 4.3.2

library(car)

## Loading required package: carData

library(FactoMineR)

## Warning: package 'FactoMineR' was built under R version 4.3.2

library(dplyr)

##   
## Attaching package: 'dplyr'

## The following object is masked from 'package:car':  
##   
## recode

## The following objects are masked from 'package:stats':  
##   
## filter, lag

## The following objects are masked from 'package:base':  
##   
## intersect, setdiff, setequal, union

# Load dataset

#setwd("/Users/ali/Desktop/MASTER/SIM/proj2")  
setwd("C:/Users/Brunil/Desktop/Bruna/Master/SIM/assignment\_2")  
df<-read.csv("customer.xls", sep=",")

# Data context

This dataset contains information about customers. Demographic data,

# Data exploration

dim(df)

## [1] 7043 21

names(df)

## [1] "customerID" "gender" "SeniorCitizen" "Partner"   
## [5] "Dependents" "tenure" "PhoneService" "MultipleLines"   
## [9] "InternetService" "OnlineSecurity" "OnlineBackup" "DeviceProtection"  
## [13] "TechSupport" "StreamingTV" "StreamingMovies" "Contract"   
## [17] "PaperlessBilling" "PaymentMethod" "MonthlyCharges" "TotalCharges"   
## [21] "Churn"

str(df)

## 'data.frame': 7043 obs. of 21 variables:  
## $ customerID : chr "7590-VHVEG" "5575-GNVDE" "3668-QPYBK" "7795-CFOCW" ...  
## $ gender : chr "Female" "Male" "Male" "Male" ...  
## $ SeniorCitizen : int 0 0 0 0 0 0 0 0 0 0 ...  
## $ Partner : chr "Yes" "No" "No" "No" ...  
## $ Dependents : chr "No" "No" "No" "No" ...  
## $ tenure : int 1 34 2 45 2 8 22 10 28 62 ...  
## $ PhoneService : chr "No" "Yes" "Yes" "No" ...  
## $ MultipleLines : chr "No phone service" "No" "No" "No phone service" ...  
## $ InternetService : chr "DSL" "DSL" "DSL" "DSL" ...  
## $ OnlineSecurity : chr "No" "Yes" "Yes" "Yes" ...  
## $ OnlineBackup : chr "Yes" "No" "Yes" "No" ...  
## $ DeviceProtection: chr "No" "Yes" "No" "Yes" ...  
## $ TechSupport : chr "No" "No" "No" "Yes" ...  
## $ StreamingTV : chr "No" "No" "No" "No" ...  
## $ StreamingMovies : chr "No" "No" "No" "No" ...  
## $ Contract : chr "Month-to-month" "One year" "Month-to-month" "One year" ...  
## $ PaperlessBilling: chr "Yes" "No" "Yes" "No" ...  
## $ PaymentMethod : chr "Electronic check" "Mailed check" "Mailed check" "Bank transfer (automatic)" ...  
## $ MonthlyCharges : num 29.9 57 53.9 42.3 70.7 ...  
## $ TotalCharges : num 29.9 1889.5 108.2 1840.8 151.7 ...  
## $ Churn : chr "No" "No" "Yes" "No" ...

#summary(df)  
#skim(df)  
summary(is.na(df)) #we only have NA values in TotalCharges

## customerID gender SeniorCitizen Partner   
## Mode :logical Mode :logical Mode :logical Mode :logical   
## FALSE:7043 FALSE:7043 FALSE:7043 FALSE:7043   
##   
## Dependents tenure PhoneService MultipleLines   
## Mode :logical Mode :logical Mode :logical Mode :logical   
## FALSE:7043 FALSE:7043 FALSE:7043 FALSE:7043   
##   
## InternetService OnlineSecurity OnlineBackup DeviceProtection  
## Mode :logical Mode :logical Mode :logical Mode :logical   
## FALSE:7043 FALSE:7043 FALSE:7043 FALSE:7043   
##   
## TechSupport StreamingTV StreamingMovies Contract   
## Mode :logical Mode :logical Mode :logical Mode :logical   
## FALSE:7043 FALSE:7043 FALSE:7043 FALSE:7043   
##   
## PaperlessBilling PaymentMethod MonthlyCharges TotalCharges   
## Mode :logical Mode :logical Mode :logical Mode :logical   
## FALSE:7043 FALSE:7043 FALSE:7043 FALSE:7032   
## TRUE :11   
## Churn   
## Mode :logical   
## FALSE:7043   
##

## Variables description

In total, we have 21 variables related to demographic, services, and accountant data. One is the ID, three are numerical variables, and 17 are categorical (? binary) variables. We will conduct a descriptive analysis and a data quality report for each variable, considering aspects such as the number of missing values, errors, and the distribution or balance of the variable… #### 1. customerID

### Demographic data

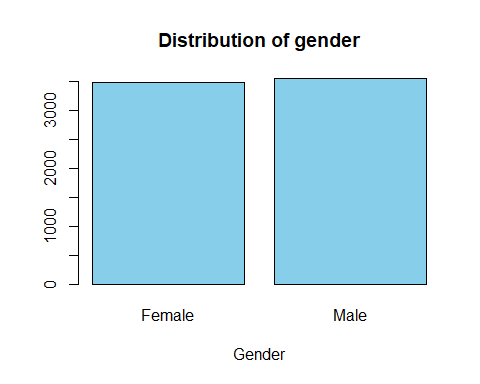
#### 2. gender

Is a binary variable (female/male).

sum(is.na(df$gender))

## [1] 0

barplot(table(df$gender), main = "Distribution of gender",xlab = "Gender",col = "skyblue")



#### 3. SeniorCitizen

It is a binary variable. Levels: 1(=yes)/0(=no).

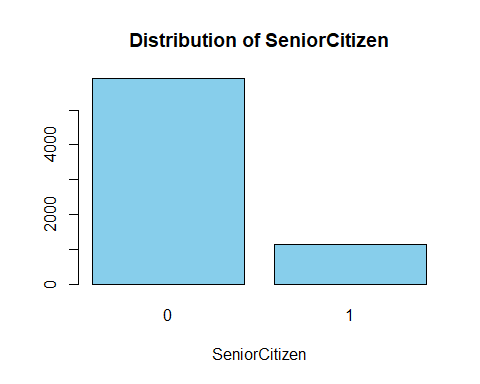
sum(is.na(df$SeniorCitizen))

## [1] 0

table(df$SeniorCitizen)

##   
## 0 1   
## 5901 1142

barplot(table(df$SeniorCitizen), main = "Distribution of SeniorCitizen",xlab = "SeniorCitizen",col = "skyblue")



#### 4. Partner

It is a binary variable. Levels: Yes/No.

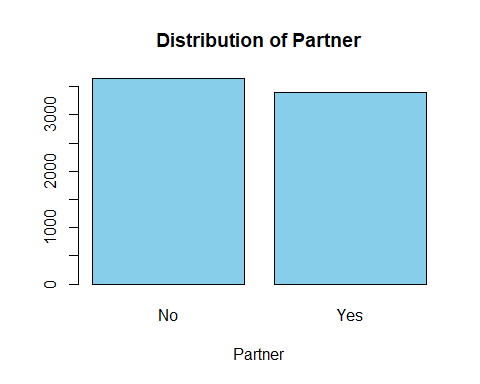
sum(is.na(df$Partner))

## [1] 0

table(df$Partner)

##   
## No Yes   
## 3641 3402

barplot(table(df$Partner), main = "Distribution of Partner",xlab = "Partner",col = "skyblue")



#### 5. Dependents

It is a binary variable. Levels: Yes/No.

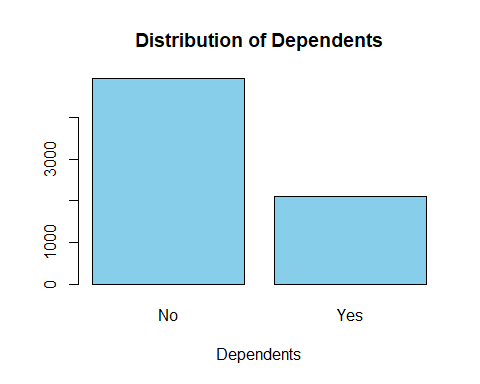
sum(is.na(df$Dependents))

## [1] 0

table(df$Dependents)

##   
## No Yes   
## 4933 2110

barplot(table(df$Dependents), main = "Distribution of Dependents",xlab = "Dependents",col = "skyblue")



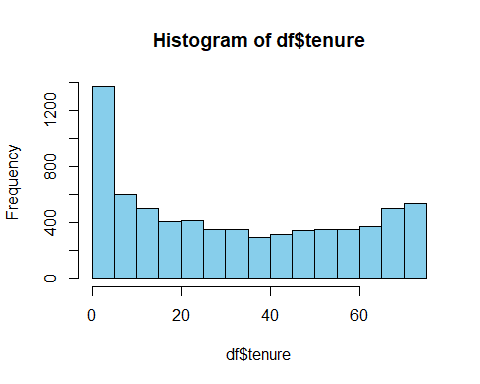
### Services of the costumer data

Services that each customer has signed up for : #### 6. tenure It is a numerical variable that indicates the duration, in months, that the customer has stayed with the company.

summary(df$tenure)

## Min. 1st Qu. Median Mean 3rd Qu. Max.   
## 0.00 9.00 29.00 32.37 55.00 72.00

hist(df$tenure,breaks=20, col="skyblue")

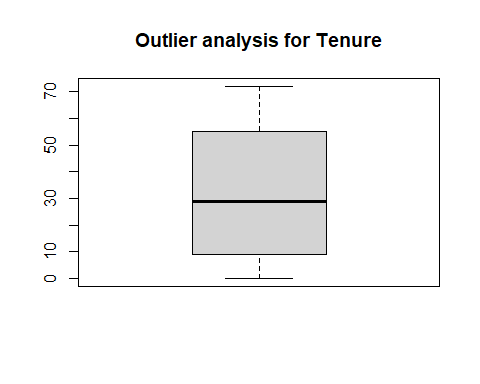


min(df$tenure)

## [1] 0

Let’s look for the *outliers*.

boxplot(df$tenure, main="Outlier analysis for Tenure")



sm\_t <- summary(df$tenure)  
iqr\_t <- sm\_t["3rd Qu."] - sm\_t["1st Qu."]  
# Mild Outliers  
mild\_ub\_t <- sm\_t["3rd Qu."] + 1.5 \* iqr\_t  
mild\_lb\_t <- sm\_t["1st Qu."] - 1.5 \* iqr\_t  
length(which(df$tenure > mild\_ub\_t | df$tenure < mild\_lb\_t)) # number of mild outliers

## [1] 0

# Severe Outliers  
severe\_ub\_t <- sm\_t["3rd Qu."] + 3 \* iqr\_t  
severe\_lb\_t <- sm\_t["1st Qu."] - 3 \* iqr\_t  
length(which(df$tenure > severe\_ub\_t | df$tenure < severe\_lb\_t)) # number of severe outliers

## [1] 0

There are *no mild nor severe outliers* in Tenure.

#### 7. PhoneService

It is a binary variable. Levels: Yes/No.

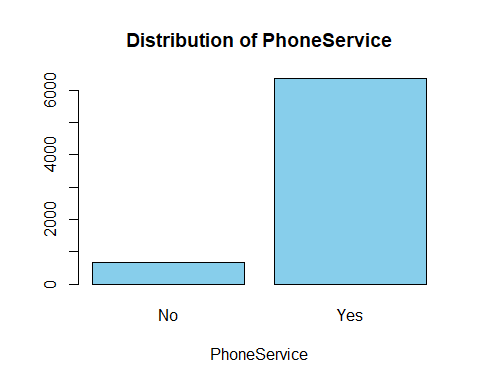
sum(is.na(df$PhoneService))

## [1] 0

table(df$PhoneService)

##   
## No Yes   
## 682 6361

barplot(table(df$PhoneService), main = "Distribution of PhoneService",xlab = "PhoneService",col = "skyblue") #unbalanced



#### 8. MultipleLines

Categorical variable with 3 levels, No/No phone service/Yes.

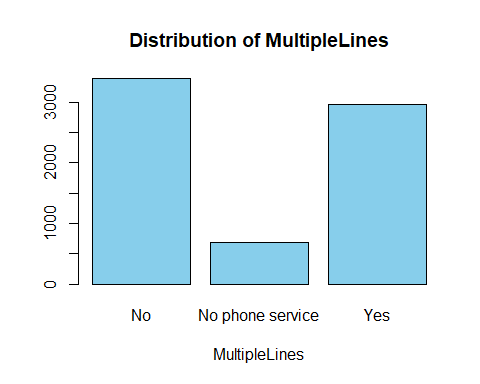
sum(is.na(df$MultipleLines))

## [1] 0

table(df$MultipleLines)

##   
## No No phone service Yes   
## 3390 682 2971

barplot(table(df$MultipleLines), main = "Distribution of MultipleLines",xlab = "MultipleLines",col = "skyblue") #unbalanced



Check inconsistencies: - Cannot happen that a costumer has not phoneservice and multiplelines.

subset(df, MultipleLines == "Yes" & PhoneService == "No")

## [1] customerID gender SeniorCitizen Partner   
## [5] Dependents tenure PhoneService MultipleLines   
## [9] InternetService OnlineSecurity OnlineBackup DeviceProtection  
## [13] TechSupport StreamingTV StreamingMovies Contract   
## [17] PaperlessBilling PaymentMethod MonthlyCharges TotalCharges   
## [21] Churn   
## <0 rows> (or 0-length row.names)

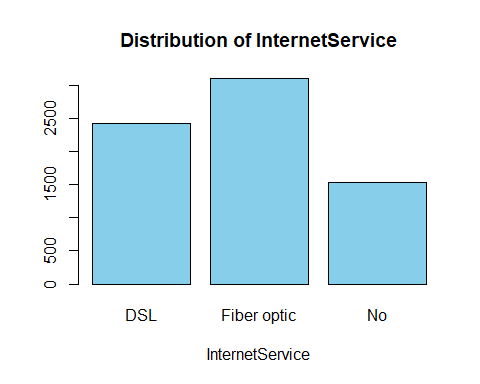
#### 9. InternetService

Categorical variable with 3 levels: DSL/Fiber optic/No.

table(df$InternetService)

##   
## DSL Fiber optic No   
## 2421 3096 1526

barplot(table(df$InternetService), main = "Distribution of InternetService",xlab = "InternetService",col = "skyblue")



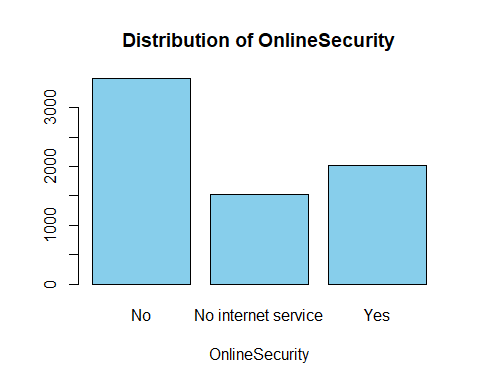
#### 10. OnlineSecurity

Categorical variable with 3 levels: No/No internet service/Yes

table(df$OnlineSecurity)

##   
## No No internet service Yes   
## 3498 1526 2019

barplot(table(df$OnlineSecurity), main = "Distribution of OnlineSecurity",xlab = "OnlineSecurity",col = "skyblue")



# Check concistency

sum(df$InternetService == "No")

## [1] 1526

sum(df$OnlineSecurity == "No internet service")

## [1] 1526

nrow(subset(df, InternetService == "No" & OnlineSecurity == "No internet service"))

## [1] 1526

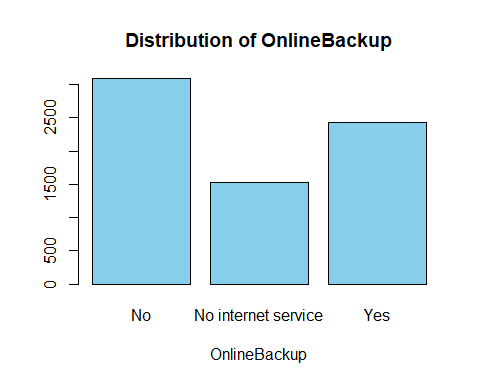
#### 11. OnlineBackup

Categorical variable with 3 levels: No/No internet service/Yes

table(df$OnlineBackup)

##   
## No No internet service Yes   
## 3088 1526 2429

barplot(table(df$OnlineBackup), main = "Distribution of OnlineBackup",xlab = "OnlineBackup",col = "skyblue")



# Check concistency  
sum(df$OnlineBackup == "No internet service") #1526

## [1] 1526

sum(df$OnlineSecurity == "No internet service") #1526

## [1] 1526

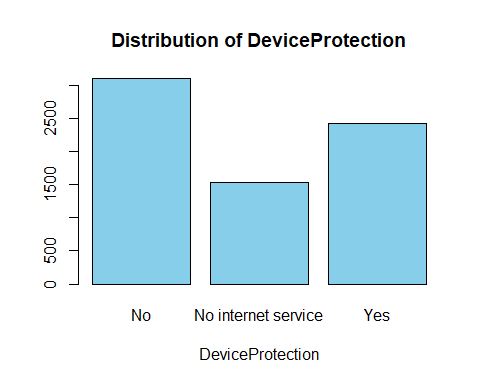
#### 12. DeviceProtection

Categorical variable with 3 levels: No/No internet service/Yes

table(df$DeviceProtection)

##   
## No No internet service Yes   
## 3095 1526 2422

barplot(table(df$DeviceProtection), main = "Distribution of DeviceProtection",xlab = "DeviceProtection",col = "skyblue")



# Check concistency  
sum(df$OnlineSecurity == "No internet service") #1526

## [1] 1526

sum(df$DeviceProtection == "No internet service") #1526

## [1] 1526

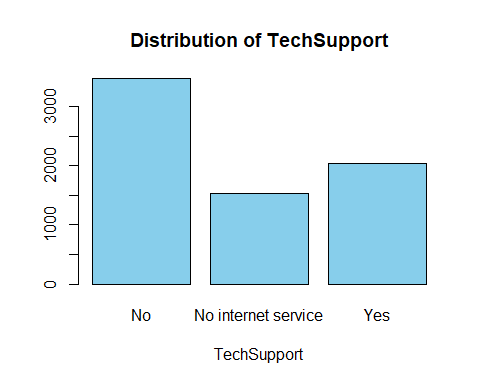
#### 13. TechSupport

Categorical variable with 3 levels: No/No internet service/Yes

table(df$TechSupport)

##   
## No No internet service Yes   
## 3473 1526 2044

barplot(table(df$TechSupport), main = "Distribution of TechSupport",xlab = "TechSupport",col = "skyblue")



#Check consistency  
sum(df$DeviceProtection == "No internet service") #1526

## [1] 1526

sum(df$TechSupport == "No internet service") #1526

## [1] 1526

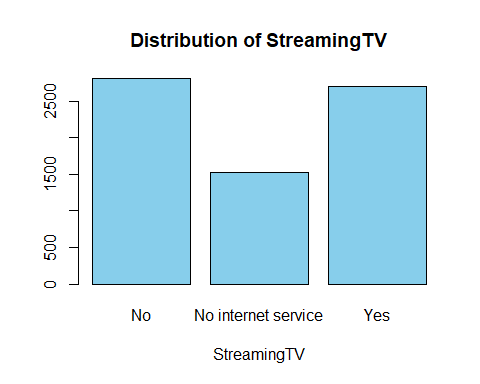
#### 14. StreamingTV

Categorical variable with 3 levels: No/No internet service/Yes

table(df$StreamingTV)

##   
## No No internet service Yes   
## 2810 1526 2707

barplot(table(df$StreamingTV), main = "Distribution of StreamingTV",xlab = "StreamingTV",col = "skyblue")



#Check consistency  
sum(df$TechSupport == "No internet service") #1526

## [1] 1526

sum(df$StreamingTV == "No internet service") #1526

## [1] 1526

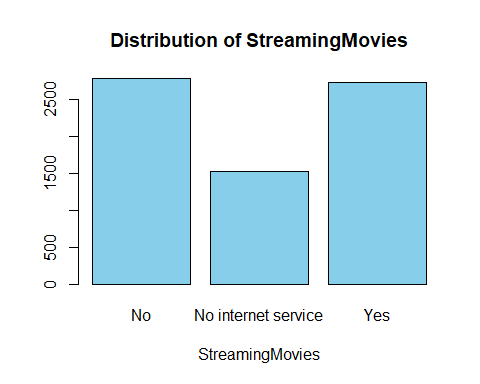
#### 15. StreamingMovies

Categorical variable with 3 levels: No/No internet service/Yes

table(df$StreamingMovies)

##   
## No No internet service Yes   
## 2785 1526 2732

barplot(table(df$StreamingMovies), main = "Distribution of StreamingMovies",xlab = "StreamingMovies",col = "skyblue")



#Check consistency  
sum(df$StreamingTV == "No internet service") #1526

## [1] 1526

sum(df$StreamingMovies == "No internet service") #1526

## [1] 1526

### Customer account data

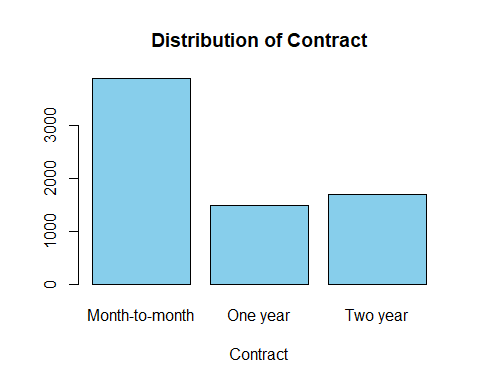
#### 16. Contract

Categorical variable with 3 levels: Month-to-month/One year/Two year

table(df$Contract)

##   
## Month-to-month One year Two year   
## 3875 1473 1695

barplot(table(df$Contract), main = "Distribution of Contract",xlab = "Contract",col = "skyblue")



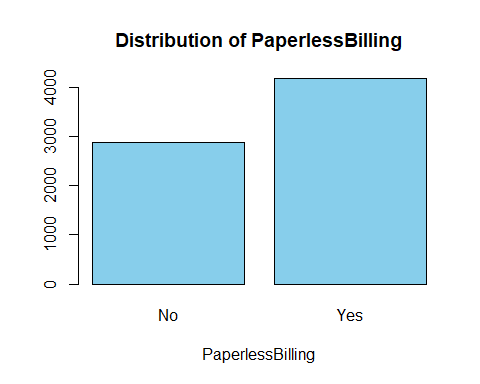
#### 17. PaperlessBilling

It is a binary variable. Levels: No/Yes

table(df$PaperlessBilling)

##   
## No Yes   
## 2872 4171

barplot(table(df$PaperlessBilling), main = "Distribution of PaperlessBilling",xlab = "PaperlessBilling",col = "skyblue")



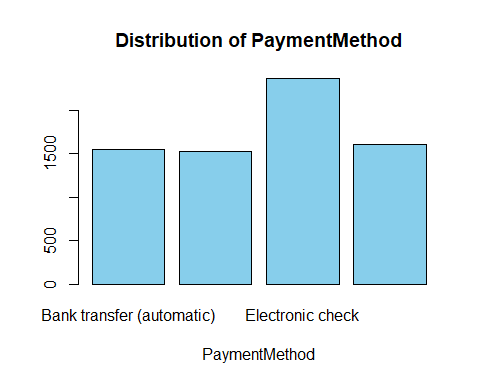
#### 18. PaymentMethod

Categorical variable with 4 levels: Bank transfer (automatic)/Credit card (automatic)/Electronic check/Mailed check

table(df$PaymentMethod)

##   
## Bank transfer (automatic) Credit card (automatic) Electronic check   
## 1544 1522 2365   
## Mailed check   
## 1612

barplot(table(df$PaymentMethod), main = "Distribution of PaymentMethod",xlab = "PaymentMethod",col = "skyblue")



Check inconsistencies:

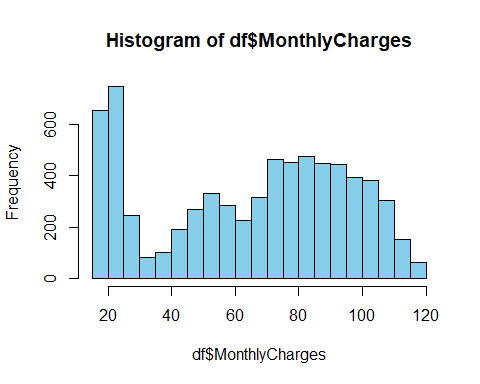
#### 19. MonthlyCharges

It is a numerical variable.

summary(df$MonthlyCharges)

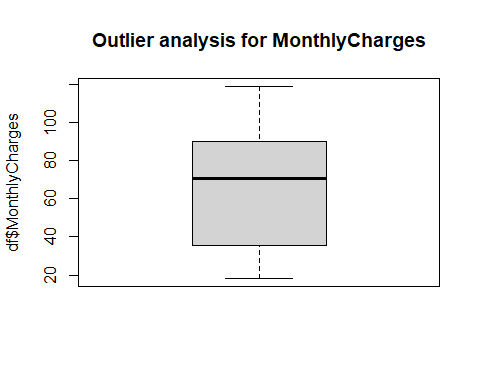
## Min. 1st Qu. Median Mean 3rd Qu. Max.   
## 18.25 35.50 70.35 64.76 89.85 118.75

hist(df$MonthlyCharges,breaks=20,col="skyblue")



Let’s look for *outliers*.

Boxplot(df$MonthlyCharges, main="Outlier analysis for MonthlyCharges")



sm <- summary(df$MonthlyCharges)  
iqr <- sm["3rd Qu."] - sm["1st Qu."]  
# Mild Outliers  
mild\_ub <- sm["3rd Qu."] + 1.5 \* iqr  
mild\_lb <- sm["1st Qu."] - 1.5 \* iqr  
length(which(df$MonthlyCharges > mild\_ub | df$MonthlyCharges < mild\_lb)) # number of mild outliers

## [1] 0

# Severe Outliers  
severe\_ub <- sm["3rd Qu."] + 3 \* iqr  
severe\_lb <- sm["1st Qu."] - 3 \* iqr  
length(which(df$MonthlyCharges > severe\_ub | df$MonthlyCharges < severe\_lb)) # number of severe outliers

## [1] 0

There are no mild nor severe outliers in MonthlyCharges.

#### 20. TotalCharges (numeric)

It is a numerical variable.

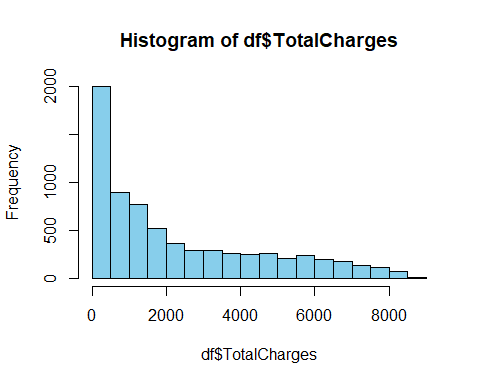
summary(df$TotalCharges)

## Min. 1st Qu. Median Mean 3rd Qu. Max. NA's   
## 18.8 401.4 1397.5 2283.3 3794.7 8684.8 11

sum(is.na(df$TotalCharges))

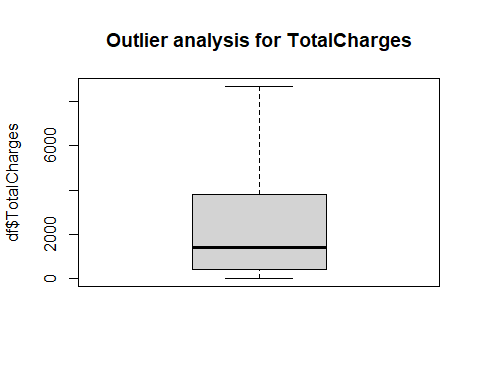
## [1] 11

hist(df$TotalCharges,breaks=20,col="skyblue")



Let’s look for *outliers*.

Boxplot(df$TotalCharges, main="Outlier analysis for TotalCharges")



sm <- summary(df$TotalCharges)  
iqr <- sm["3rd Qu."] - sm["1st Qu."]  
# Mild Outliers  
mild\_ub <- sm["3rd Qu."] + 1.5 \* iqr  
mild\_lb <- sm["1st Qu."] - 1.5 \* iqr  
length(which(df$TotalCharges > mild\_ub | df$TotalCharges < mild\_lb)) # number of mild outliers

## [1] 0

# Severe Outliers  
severe\_ub <- sm["3rd Qu."] + 3 \* iqr  
severe\_lb <- sm["1st Qu."] - 3 \* iqr  
length(which(df$TotalCharges > severe\_ub | df$TotalCharges < severe\_lb)) # number of severe outliers

## [1] 0

There are no mild nor severe outliers.

### Target:

#### 21. Churn

It is the target variable. It is binary, describes whether the customer churned or not (Yes or No). ?explicar que es churn una mica.

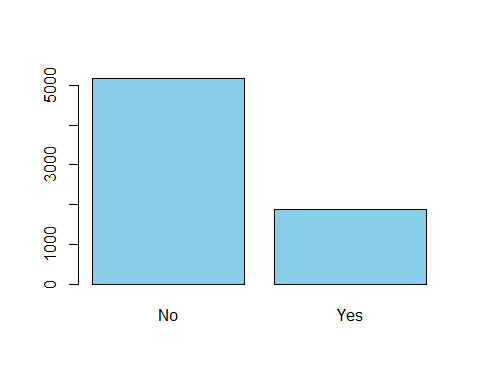
table(df$Churn)

##   
## No Yes   
## 5174 1869

prop.table(table(df$Churn))

##   
## No Yes   
## 0.7346301 0.2653699

barplot(table(df$Churn), col="skyblue")



## Data preprocessing

### Recode variables into correct type

We shall reconvert the type of certain variables that are encoded with wrong type. First, we convert the character variables (except the ID) into factors.

char\_cols <- which(sapply(df, is.character))  
df[, char\_cols[-1]]<- lapply(df[, char\_cols[-1]], as.factor)

Also, we convert the numerical variable SeniorCitizen into a factor.

df$SeniorCitizen<- factor(df$SeniorCitizen)

summary(df)

## customerID gender SeniorCitizen Partner Dependents  
## Length:7043 Female:3488 0:5901 No :3641 No :4933   
## Class :character Male :3555 1:1142 Yes:3402 Yes:2110   
## Mode :character   
##   
##   
##   
##   
## tenure PhoneService MultipleLines InternetService  
## Min. : 0.00 No : 682 No :3390 DSL :2421   
## 1st Qu.: 9.00 Yes:6361 No phone service: 682 Fiber optic:3096   
## Median :29.00 Yes :2971 No :1526   
## Mean :32.37   
## 3rd Qu.:55.00   
## Max. :72.00   
##   
## OnlineSecurity OnlineBackup   
## No :3498 No :3088   
## No internet service:1526 No internet service:1526   
## Yes :2019 Yes :2429   
##   
##   
##   
##   
## DeviceProtection TechSupport   
## No :3095 No :3473   
## No internet service:1526 No internet service:1526   
## Yes :2422 Yes :2044   
##   
##   
##   
##   
## StreamingTV StreamingMovies Contract   
## No :2810 No :2785 Month-to-month:3875   
## No internet service:1526 No internet service:1526 One year :1473   
## Yes :2707 Yes :2732 Two year :1695   
##   
##   
##   
##   
## PaperlessBilling PaymentMethod MonthlyCharges   
## No :2872 Bank transfer (automatic):1544 Min. : 18.25   
## Yes:4171 Credit card (automatic) :1522 1st Qu.: 35.50   
## Electronic check :2365 Median : 70.35   
## Mailed check :1612 Mean : 64.76   
## 3rd Qu.: 89.85   
## Max. :118.75   
##   
## TotalCharges Churn   
## Min. : 18.8 No :5174   
## 1st Qu.: 401.4 Yes:1869   
## Median :1397.5   
## Mean :2283.3   
## 3rd Qu.:3794.7   
## Max. :8684.8   
## NA's :11

str(df)

## 'data.frame': 7043 obs. of 21 variables:  
## $ customerID : chr "7590-VHVEG" "5575-GNVDE" "3668-QPYBK" "7795-CFOCW" ...  
## $ gender : Factor w/ 2 levels "Female","Male": 1 2 2 2 1 1 2 1 1 2 ...  
## $ SeniorCitizen : Factor w/ 2 levels "0","1": 1 1 1 1 1 1 1 1 1 1 ...  
## $ Partner : Factor w/ 2 levels "No","Yes": 2 1 1 1 1 1 1 1 2 1 ...  
## $ Dependents : Factor w/ 2 levels "No","Yes": 1 1 1 1 1 1 2 1 1 2 ...  
## $ tenure : int 1 34 2 45 2 8 22 10 28 62 ...  
## $ PhoneService : Factor w/ 2 levels "No","Yes": 1 2 2 1 2 2 2 1 2 2 ...  
## $ MultipleLines : Factor w/ 3 levels "No","No phone service",..: 2 1 1 2 1 3 3 2 3 1 ...  
## $ InternetService : Factor w/ 3 levels "DSL","Fiber optic",..: 1 1 1 1 2 2 2 1 2 1 ...  
## $ OnlineSecurity : Factor w/ 3 levels "No","No internet service",..: 1 3 3 3 1 1 1 3 1 3 ...  
## $ OnlineBackup : Factor w/ 3 levels "No","No internet service",..: 3 1 3 1 1 1 3 1 1 3 ...  
## $ DeviceProtection: Factor w/ 3 levels "No","No internet service",..: 1 3 1 3 1 3 1 1 3 1 ...  
## $ TechSupport : Factor w/ 3 levels "No","No internet service",..: 1 1 1 3 1 1 1 1 3 1 ...  
## $ StreamingTV : Factor w/ 3 levels "No","No internet service",..: 1 1 1 1 1 3 3 1 3 1 ...  
## $ StreamingMovies : Factor w/ 3 levels "No","No internet service",..: 1 1 1 1 1 3 1 1 3 1 ...  
## $ Contract : Factor w/ 3 levels "Month-to-month",..: 1 2 1 2 1 1 1 1 1 2 ...  
## $ PaperlessBilling: Factor w/ 2 levels "No","Yes": 2 1 2 1 2 2 2 1 2 1 ...  
## $ PaymentMethod : Factor w/ 4 levels "Bank transfer (automatic)",..: 3 4 4 1 3 3 2 4 3 1 ...  
## $ MonthlyCharges : num 29.9 57 53.9 42.3 70.7 ...  
## $ TotalCharges : num 29.9 1889.5 108.2 1840.8 151.7 ...  
## $ Churn : Factor w/ 2 levels "No","Yes": 1 1 2 1 2 2 1 1 2 1 ...

### Data imputation

summary(is.na(df))

## customerID gender SeniorCitizen Partner   
## Mode :logical Mode :logical Mode :logical Mode :logical   
## FALSE:7043 FALSE:7043 FALSE:7043 FALSE:7043   
##   
## Dependents tenure PhoneService MultipleLines   
## Mode :logical Mode :logical Mode :logical Mode :logical   
## FALSE:7043 FALSE:7043 FALSE:7043 FALSE:7043   
##   
## InternetService OnlineSecurity OnlineBackup DeviceProtection  
## Mode :logical Mode :logical Mode :logical Mode :logical   
## FALSE:7043 FALSE:7043 FALSE:7043 FALSE:7043   
##   
## TechSupport StreamingTV StreamingMovies Contract   
## Mode :logical Mode :logical Mode :logical Mode :logical   
## FALSE:7043 FALSE:7043 FALSE:7043 FALSE:7043   
##   
## PaperlessBilling PaymentMethod MonthlyCharges TotalCharges   
## Mode :logical Mode :logical Mode :logical Mode :logical   
## FALSE:7043 FALSE:7043 FALSE:7043 FALSE:7032   
## TRUE :11   
## Churn   
## Mode :logical   
## FALSE:7043   
##

Only the variable TotalCharges has NA’s.

df[is.na(df$TotalCharges), ]

## customerID gender SeniorCitizen Partner Dependents tenure PhoneService  
## 489 4472-LVYGI Female 0 Yes Yes 0 No  
## 754 3115-CZMZD Male 0 No Yes 0 Yes  
## 937 5709-LVOEQ Female 0 Yes Yes 0 Yes  
## 1083 4367-NUYAO Male 0 Yes Yes 0 Yes  
## 1341 1371-DWPAZ Female 0 Yes Yes 0 No  
## 3332 7644-OMVMY Male 0 Yes Yes 0 Yes  
## 3827 3213-VVOLG Male 0 Yes Yes 0 Yes  
## 4381 2520-SGTTA Female 0 Yes Yes 0 Yes  
## 5219 2923-ARZLG Male 0 Yes Yes 0 Yes  
## 6671 4075-WKNIU Female 0 Yes Yes 0 Yes  
## 6755 2775-SEFEE Male 0 No Yes 0 Yes  
## MultipleLines InternetService OnlineSecurity OnlineBackup  
## 489 No phone service DSL Yes No  
## 754 No No No internet service No internet service  
## 937 No DSL Yes Yes  
## 1083 Yes No No internet service No internet service  
## 1341 No phone service DSL Yes Yes  
## 3332 No No No internet service No internet service  
## 3827 Yes No No internet service No internet service  
## 4381 No No No internet service No internet service  
## 5219 No No No internet service No internet service  
## 6671 Yes DSL No Yes  
## 6755 Yes DSL Yes Yes  
## DeviceProtection TechSupport StreamingTV  
## 489 Yes Yes Yes  
## 754 No internet service No internet service No internet service  
## 937 Yes No Yes  
## 1083 No internet service No internet service No internet service  
## 1341 Yes Yes Yes  
## 3332 No internet service No internet service No internet service  
## 3827 No internet service No internet service No internet service  
## 4381 No internet service No internet service No internet service  
## 5219 No internet service No internet service No internet service  
## 6671 Yes Yes Yes  
## 6755 No Yes No  
## StreamingMovies Contract PaperlessBilling PaymentMethod  
## 489 No Two year Yes Bank transfer (automatic)  
## 754 No internet service Two year No Mailed check  
## 937 Yes Two year No Mailed check  
## 1083 No internet service Two year No Mailed check  
## 1341 No Two year No Credit card (automatic)  
## 3332 No internet service Two year No Mailed check  
## 3827 No internet service Two year No Mailed check  
## 4381 No internet service Two year No Mailed check  
## 5219 No internet service One year Yes Mailed check  
## 6671 No Two year No Mailed check  
## 6755 No Two year Yes Bank transfer (automatic)  
## MonthlyCharges TotalCharges Churn  
## 489 52.55 NA No  
## 754 20.25 NA No  
## 937 80.85 NA No  
## 1083 25.75 NA No  
## 1341 56.05 NA No  
## 3332 19.85 NA No  
## 3827 25.35 NA No  
## 4381 20.00 NA No  
## 5219 19.70 NA No  
## 6671 73.35 NA No  
## 6755 61.90 NA No

df[df$tenure==0,]

## customerID gender SeniorCitizen Partner Dependents tenure PhoneService  
## 489 4472-LVYGI Female 0 Yes Yes 0 No  
## 754 3115-CZMZD Male 0 No Yes 0 Yes  
## 937 5709-LVOEQ Female 0 Yes Yes 0 Yes  
## 1083 4367-NUYAO Male 0 Yes Yes 0 Yes  
## 1341 1371-DWPAZ Female 0 Yes Yes 0 No  
## 3332 7644-OMVMY Male 0 Yes Yes 0 Yes  
## 3827 3213-VVOLG Male 0 Yes Yes 0 Yes  
## 4381 2520-SGTTA Female 0 Yes Yes 0 Yes  
## 5219 2923-ARZLG Male 0 Yes Yes 0 Yes  
## 6671 4075-WKNIU Female 0 Yes Yes 0 Yes  
## 6755 2775-SEFEE Male 0 No Yes 0 Yes  
## MultipleLines InternetService OnlineSecurity OnlineBackup  
## 489 No phone service DSL Yes No  
## 754 No No No internet service No internet service  
## 937 No DSL Yes Yes  
## 1083 Yes No No internet service No internet service  
## 1341 No phone service DSL Yes Yes  
## 3332 No No No internet service No internet service  
## 3827 Yes No No internet service No internet service  
## 4381 No No No internet service No internet service  
## 5219 No No No internet service No internet service  
## 6671 Yes DSL No Yes  
## 6755 Yes DSL Yes Yes  
## DeviceProtection TechSupport StreamingTV  
## 489 Yes Yes Yes  
## 754 No internet service No internet service No internet service  
## 937 Yes No Yes  
## 1083 No internet service No internet service No internet service  
## 1341 Yes Yes Yes  
## 3332 No internet service No internet service No internet service  
## 3827 No internet service No internet service No internet service  
## 4381 No internet service No internet service No internet service  
## 5219 No internet service No internet service No internet service  
## 6671 Yes Yes Yes  
## 6755 No Yes No  
## StreamingMovies Contract PaperlessBilling PaymentMethod  
## 489 No Two year Yes Bank transfer (automatic)  
## 754 No internet service Two year No Mailed check  
## 937 Yes Two year No Mailed check  
## 1083 No internet service Two year No Mailed check  
## 1341 No Two year No Credit card (automatic)  
## 3332 No internet service Two year No Mailed check  
## 3827 No internet service Two year No Mailed check  
## 4381 No internet service Two year No Mailed check  
## 5219 No internet service One year Yes Mailed check  
## 6671 No Two year No Mailed check  
## 6755 No Two year Yes Bank transfer (automatic)  
## MonthlyCharges TotalCharges Churn  
## 489 52.55 NA No  
## 754 20.25 NA No  
## 937 80.85 NA No  
## 1083 25.75 NA No  
## 1341 56.05 NA No  
## 3332 19.85 NA No  
## 3827 25.35 NA No  
## 4381 20.00 NA No  
## 5219 19.70 NA No  
## 6671 73.35 NA No  
## 6755 61.90 NA No

df[df$TotalCharges==0, ]

## customerID gender SeniorCitizen Partner Dependents tenure PhoneService  
## NA <NA> <NA> <NA> <NA> <NA> NA <NA>  
## NA.1 <NA> <NA> <NA> <NA> <NA> NA <NA>  
## NA.2 <NA> <NA> <NA> <NA> <NA> NA <NA>  
## NA.3 <NA> <NA> <NA> <NA> <NA> NA <NA>  
## NA.4 <NA> <NA> <NA> <NA> <NA> NA <NA>  
## NA.5 <NA> <NA> <NA> <NA> <NA> NA <NA>  
## NA.6 <NA> <NA> <NA> <NA> <NA> NA <NA>  
## NA.7 <NA> <NA> <NA> <NA> <NA> NA <NA>  
## NA.8 <NA> <NA> <NA> <NA> <NA> NA <NA>  
## NA.9 <NA> <NA> <NA> <NA> <NA> NA <NA>  
## NA.10 <NA> <NA> <NA> <NA> <NA> NA <NA>  
## MultipleLines InternetService OnlineSecurity OnlineBackup  
## NA <NA> <NA> <NA> <NA>  
## NA.1 <NA> <NA> <NA> <NA>  
## NA.2 <NA> <NA> <NA> <NA>  
## NA.3 <NA> <NA> <NA> <NA>  
## NA.4 <NA> <NA> <NA> <NA>  
## NA.5 <NA> <NA> <NA> <NA>  
## NA.6 <NA> <NA> <NA> <NA>  
## NA.7 <NA> <NA> <NA> <NA>  
## NA.8 <NA> <NA> <NA> <NA>  
## NA.9 <NA> <NA> <NA> <NA>  
## NA.10 <NA> <NA> <NA> <NA>  
## DeviceProtection TechSupport StreamingTV StreamingMovies Contract  
## NA <NA> <NA> <NA> <NA> <NA>  
## NA.1 <NA> <NA> <NA> <NA> <NA>  
## NA.2 <NA> <NA> <NA> <NA> <NA>  
## NA.3 <NA> <NA> <NA> <NA> <NA>  
## NA.4 <NA> <NA> <NA> <NA> <NA>  
## NA.5 <NA> <NA> <NA> <NA> <NA>  
## NA.6 <NA> <NA> <NA> <NA> <NA>  
## NA.7 <NA> <NA> <NA> <NA> <NA>  
## NA.8 <NA> <NA> <NA> <NA> <NA>  
## NA.9 <NA> <NA> <NA> <NA> <NA>  
## NA.10 <NA> <NA> <NA> <NA> <NA>  
## PaperlessBilling PaymentMethod MonthlyCharges TotalCharges Churn  
## NA <NA> <NA> NA NA <NA>  
## NA.1 <NA> <NA> NA NA <NA>  
## NA.2 <NA> <NA> NA NA <NA>  
## NA.3 <NA> <NA> NA NA <NA>  
## NA.4 <NA> <NA> NA NA <NA>  
## NA.5 <NA> <NA> NA NA <NA>  
## NA.6 <NA> <NA> NA NA <NA>  
## NA.7 <NA> <NA> NA NA <NA>  
## NA.8 <NA> <NA> NA NA <NA>  
## NA.9 <NA> <NA> NA NA <NA>  
## NA.10 <NA> <NA> NA NA <NA>

summary(df$TotalCharges)

## Min. 1st Qu. Median Mean 3rd Qu. Max. NA's   
## 18.8 401.4 1397.5 2283.3 3794.7 8684.8 11

The missing data corresponds to the individuals that have not payed yet the charges of the current month, we can guess that are new clients of the company.

Duplicate values: no

dim(df)

## [1] 7043 21

length(unique(df$customerID))

## [1] 7043

El significat d’aquestos NA son que l’individuu encara no se li ha cobrat el charges ja que no ha arribat a final de més. Una possible solució seria que la variable totalcharges prengui el valor de monthlycharges.

Suggerim quan tenure==0 eliminem les observacions enlloc d’imputar-les ja que representen un 0.1% de les dades. NO ELIMINEM FIQUEM 0

ll <- which(is.na(df$TotalCharges))  
df[ll,"TotalCharges"] <- 0  
summary(is.na(df$TotalCharges))

## Mode FALSE   
## logical 7043

Això crec que és un pas que està descrit al pdf però no sé perquè s’ha de fer

Create variable adding the total number missing values, outliers and errors. Describe these variables, to which other variables exist higher associations. Compute the correlation with all other variables. Rank these variables according the correlation Compute for every group of individuals (group of age, size of town, singles, married, …) the mean of missing/outliers/errors values. Rank the groups according the computed mean.

### Correlation btween numericals

(no cal)

num\_cols <- which(sapply(df, is.numeric))  
cor(df[,c(6,19,20)])

## tenure MonthlyCharges TotalCharges  
## tenure 1.0000000 0.2478999 0.8261784  
## MonthlyCharges 0.2478999 1.0000000 0.6511738  
## TotalCharges 0.8261784 0.6511738 1.0000000

### Correlation between categorical

The categorical variables MultipleLines and PhoneService are 100% correlated.

contingency\_table<-table(df$MultipleLines,df$PhoneService)  
sqrt(chisq.test(contingency\_table)$statistic / (sum(contingency\_table) \* (min(dim(contingency\_table)) - 1)))

## X-squared   
## 1

contingency\_table<-table(df$StreamingTV,df$InternetService)  
contingency\_table<-table(df$OnlineSecurity,df$InternetService)  
  
contingency\_table

##   
## DSL Fiber optic No  
## No 1241 2257 0  
## No internet service 0 0 1526  
## Yes 1180 839 0

### Profiling

res.cat=catdes(df, 21)  
res.cat$test.chi2

## p.value df  
## Contract 5.863038e-258 2  
## OnlineSecurity 2.661150e-185 2  
## TechSupport 1.443084e-180 2  
## InternetService 9.571788e-160 2  
## PaymentMethod 3.682355e-140 3  
## OnlineBackup 2.079759e-131 2  
## DeviceProtection 5.505219e-122 2  
## StreamingMovies 2.667757e-82 2  
## StreamingTV 5.528994e-82 2  
## PaperlessBilling 2.614597e-58 1  
## Dependents 3.276083e-43 1  
## SeniorCitizen 9.477904e-37 1  
## Partner 1.519037e-36 1  
## MultipleLines 3.464383e-03 2

res.cat$category

## $No  
## Cla/Mod Mod/Cla Global  
## Contract=Two year 97.16814 31.83224 24.06645  
## StreamingMovies=No internet service 92.59502 27.30963 21.66690  
## StreamingTV=No internet service 92.59502 27.30963 21.66690  
## TechSupport=No internet service 92.59502 27.30963 21.66690  
## DeviceProtection=No internet service 92.59502 27.30963 21.66690  
## OnlineBackup=No internet service 92.59502 27.30963 21.66690  
## OnlineSecurity=No internet service 92.59502 27.30963 21.66690  
## InternetService=No 92.59502 27.30963 21.66690  
## PaperlessBilling=No 83.66992 46.44376 40.77808  
## Contract=One year 88.73048 25.26092 20.91438  
## OnlineSecurity=Yes 85.38881 33.32045 28.66676  
## TechSupport=Yes 84.83366 33.51372 29.02172  
## Dependents=Yes 84.54976 34.48009 29.95882  
## Partner=Yes 80.33510 52.82180 48.30328  
## SeniorCitizen=0 76.39383 87.12795 83.78532  
## PaymentMethod=Credit card (automatic) 84.75690 24.93235 21.61011  
## InternetService=DSL 81.04089 37.92037 34.37456  
## PaymentMethod=Bank transfer (automatic) 83.29016 24.85504 21.92248  
## PaymentMethod=Mailed check 80.89330 25.20294 22.88797  
## OnlineBackup=Yes 78.46851 36.83804 34.48814  
## DeviceProtection=Yes 77.49794 36.27754 34.38875  
## MultipleLines=No 74.95575 49.11094 48.13290  
## MultipleLines=Yes 71.39010 40.99343 42.18373  
## StreamingMovies=Yes 70.05857 36.99266 38.79029  
## StreamingTV=Yes 69.92981 36.58678 38.43533  
## StreamingTV=No 66.47687 36.10359 39.89777  
## StreamingMovies=No 66.31957 35.69772 39.54281  
## SeniorCitizen=1 58.31874 12.87205 16.21468  
## Partner=No 67.04202 47.17820 51.69672  
## Dependents=No 68.72086 65.51991 70.04118  
## PaperlessBilling=Yes 66.43491 53.55624 59.22192  
## DeviceProtection=No 60.87237 36.41283 43.94434  
## OnlineBackup=No 60.07124 35.85234 43.84495  
## PaymentMethod=Electronic check 54.71459 25.00966 33.57944  
## InternetService=Fiber optic 58.10724 34.77000 43.95854  
## TechSupport=No 58.36453 39.17665 49.31137  
## OnlineSecurity=No 58.23328 39.36993 49.66634  
## Contract=Month-to-month 57.29032 42.90684 55.01917  
## p.value v.test  
## Contract=Two year 3.588830e-187 29.178937  
## StreamingMovies=No internet service 6.584621e-98 20.999812  
## StreamingTV=No internet service 6.584621e-98 20.999812  
## TechSupport=No internet service 6.584621e-98 20.999812  
## DeviceProtection=No internet service 6.584621e-98 20.999812  
## OnlineBackup=No internet service 6.584621e-98 20.999812  
## OnlineSecurity=No internet service 6.584621e-98 20.999812  
## InternetService=No 6.584621e-98 20.999812  
## PaperlessBilling=No 1.072745e-60 16.435085  
## Contract=One year 3.593041e-57 15.935502  
## OnlineSecurity=Yes 1.606459e-50 14.947938  
## TechSupport=Yes 1.323174e-46 14.334963  
## Dependents=Yes 3.572324e-46 14.265846  
## Partner=Yes 6.170871e-37 12.696658  
## SeniorCitizen=0 3.024931e-34 12.202212  
## PaymentMethod=Credit card (automatic) 6.408166e-32 11.758206  
## InternetService=DSL 2.545367e-26 10.614727  
## PaymentMethod=Bank transfer (automatic) 1.180908e-24 10.250207  
## PaymentMethod=Mailed check 3.226893e-15 7.881803  
## OnlineBackup=Yes 3.021982e-12 6.976698  
## DeviceProtection=Yes 2.173366e-08 5.597602  
## MultipleLines=No 6.262488e-03 2.733712  
## MultipleLines=Yes 7.843169e-04 -3.358271  
## StreamingMovies=Yes 2.922571e-07 -5.128373  
## StreamingTV=Yes 1.283457e-07 -5.281193  
## StreamingTV=No 6.049871e-27 -10.748094  
## StreamingMovies=No 1.092934e-27 -10.904833  
## SeniorCitizen=1 3.024931e-34 -12.202212  
## Partner=No 6.170871e-37 -12.696658  
## Dependents=No 3.572324e-46 -14.265846  
## PaperlessBilling=Yes 1.072745e-60 -16.435085  
## DeviceProtection=No 1.116896e-99 -21.192627  
## OnlineBackup=No 3.366400e-112 -22.509287  
## PaymentMethod=Electronic check 1.790860e-136 -24.864755  
## InternetService=Fiber optic 2.289126e-148 -25.941138  
## TechSupport=No 1.899538e-183 -28.883947  
## OnlineSecurity=No 6.171504e-190 -29.396034  
## Contract=Month-to-month 3.620915e-283 -35.959308  
##   
## $Yes  
## Cla/Mod Mod/Cla Global  
## Contract=Month-to-month 42.709677 88.550027 55.01917  
## OnlineSecurity=No 41.766724 78.170144 49.66634  
## TechSupport=No 41.635474 77.367576 49.31137  
## InternetService=Fiber optic 41.892765 69.395399 43.95854  
## PaymentMethod=Electronic check 45.285412 57.303371 33.57944  
## OnlineBackup=No 39.928756 65.971108 43.84495  
## DeviceProtection=No 39.127625 64.794007 43.94434  
## PaperlessBilling=Yes 33.565092 74.906367 59.22192  
## Dependents=No 31.279140 82.557517 70.04118  
## Partner=No 32.957979 64.205457 51.69672  
## SeniorCitizen=1 41.681261 25.468165 16.21468  
## StreamingMovies=No 33.680431 50.187266 39.54281  
## StreamingTV=No 33.523132 50.401284 39.89777  
## StreamingTV=Yes 30.070188 43.552702 38.43533  
## StreamingMovies=Yes 29.941435 43.766720 38.79029  
## MultipleLines=Yes 28.609896 45.478866 42.18373  
## MultipleLines=No 25.044248 45.425361 48.13290  
## DeviceProtection=Yes 22.502064 29.159979 34.38875  
## OnlineBackup=Yes 21.531494 27.982879 34.48814  
## PaymentMethod=Mailed check 19.106700 16.479401 22.88797  
## PaymentMethod=Bank transfer (automatic) 16.709845 13.804173 21.92248  
## InternetService=DSL 18.959108 24.558587 34.37456  
## PaymentMethod=Credit card (automatic) 15.243101 12.413055 21.61011  
## SeniorCitizen=0 23.606168 74.531835 83.78532  
## Partner=Yes 19.664903 35.794543 48.30328  
## Dependents=Yes 15.450237 17.442483 29.95882  
## TechSupport=Yes 15.166341 16.586410 29.02172  
## OnlineSecurity=Yes 14.611194 15.783842 28.66676  
## Contract=One year 11.269518 8.881755 20.91438  
## PaperlessBilling=No 16.330084 25.093633 40.77808  
## StreamingMovies=No internet service 7.404980 6.046014 21.66690  
## StreamingTV=No internet service 7.404980 6.046014 21.66690  
## TechSupport=No internet service 7.404980 6.046014 21.66690  
## DeviceProtection=No internet service 7.404980 6.046014 21.66690  
## OnlineBackup=No internet service 7.404980 6.046014 21.66690  
## OnlineSecurity=No internet service 7.404980 6.046014 21.66690  
## InternetService=No 7.404980 6.046014 21.66690  
## Contract=Two year 2.831858 2.568218 24.06645  
## p.value v.test  
## Contract=Month-to-month 3.620915e-283 35.959308  
## OnlineSecurity=No 6.171504e-190 29.396034  
## TechSupport=No 1.899538e-183 28.883947  
## InternetService=Fiber optic 2.289126e-148 25.941138  
## PaymentMethod=Electronic check 1.790860e-136 24.864755  
## OnlineBackup=No 3.366400e-112 22.509287  
## DeviceProtection=No 1.116896e-99 21.192627  
## PaperlessBilling=Yes 1.072745e-60 16.435085  
## Dependents=No 3.572324e-46 14.265846  
## Partner=No 6.170871e-37 12.696658  
## SeniorCitizen=1 3.024931e-34 12.202212  
## StreamingMovies=No 1.092934e-27 10.904833  
## StreamingTV=No 6.049871e-27 10.748094  
## StreamingTV=Yes 1.283457e-07 5.281193  
## StreamingMovies=Yes 2.922571e-07 5.128373  
## MultipleLines=Yes 7.843169e-04 3.358271  
## MultipleLines=No 6.262488e-03 -2.733712  
## DeviceProtection=Yes 2.173366e-08 -5.597602  
## OnlineBackup=Yes 3.021982e-12 -6.976698  
## PaymentMethod=Mailed check 3.226893e-15 -7.881803  
## PaymentMethod=Bank transfer (automatic) 1.180908e-24 -10.250207  
## InternetService=DSL 2.545367e-26 -10.614727  
## PaymentMethod=Credit card (automatic) 6.408166e-32 -11.758206  
## SeniorCitizen=0 3.024931e-34 -12.202212  
## Partner=Yes 6.170871e-37 -12.696658  
## Dependents=Yes 3.572324e-46 -14.265846  
## TechSupport=Yes 1.323174e-46 -14.334963  
## OnlineSecurity=Yes 1.606459e-50 -14.947938  
## Contract=One year 3.593041e-57 -15.935502  
## PaperlessBilling=No 1.072745e-60 -16.435085  
## StreamingMovies=No internet service 6.584621e-98 -20.999812  
## StreamingTV=No internet service 6.584621e-98 -20.999812  
## TechSupport=No internet service 6.584621e-98 -20.999812  
## DeviceProtection=No internet service 6.584621e-98 -20.999812  
## OnlineBackup=No internet service 6.584621e-98 -20.999812  
## OnlineSecurity=No internet service 6.584621e-98 -20.999812  
## InternetService=No 6.584621e-98 -20.999812  
## Contract=Two year 3.588830e-187 -29.178937

res.cat$quanti.var

## Eta2 P-value  
## tenure 0.12406504 7.999058e-205  
## TotalCharges 0.03933251 2.127212e-63  
## MonthlyCharges 0.03738671 2.706646e-60

res.cat$quanti

## $No  
## v.test Mean in category Overall mean sd in category  
## tenure 29.55784 37.56997 32.37115 24.11145  
## TotalCharges 16.64270 2549.91144 2279.73430 2329.72904  
## MonthlyCharges -16.22582 61.26512 64.76169 31.08964  
## Overall sd p.value  
## tenure 24.55774 5.207314e-192  
## TotalCharges 2266.63354 3.418341e-62  
## MonthlyCharges 30.08791 3.312724e-59  
##   
## $Yes  
## v.test Mean in category Overall mean sd in category  
## MonthlyCharges 16.22582 74.44133 64.76169 24.65945  
## TotalCharges -16.64270 1531.79609 2279.73430 1890.31709  
## tenure -29.55784 17.97913 32.37115 19.52590  
## Overall sd p.value  
## MonthlyCharges 30.08791 3.312724e-59  
## TotalCharges 2266.63354 3.418341e-62  
## tenure 24.55774 5.207314e-192

Regarding to the results of the test all correlations with the variables are significant since the is less than 0,05. Since the response variable is binary, we have different results for each answer and also for all outcomes of the categorical parameters.

For example, we can analyse in detail the variable “Contract”. For the customers that haven’t churned, the correlation between the ones that have a contract of two year is directly proportional and it’s the highest relation. However, we can see that is the costumer has churned the ones that have a two-year contract have an strong negative correlation. The ones that have a month-to-month contract are the opposite of the previous answer; they have the highest positive correlation with the costumers that have churned and the negative with the ones that haven’t.

Besides the latter variable, we can observe the parameter that have a higher positive correlation with the costumers that churn is the parameter “OnlineSecurity” and “TechSupport” when the answer is “No”. The parameters that have a negative relation with the costumers that churn are when they haven’t hired an Internet Service. We can see that all parameters that have an answer that is “No internet service” have also a negative relation with the response variable “Yes”. We can deduce that they might have multicollinearity with the parameter Internet Service, but we will check it later.

The parameters that have a higher positive relation with the costumers that don’t churn are the ones that have a negative relation when the response variable is “Yes”, that we have analysed before. In the same vein, we can observe that the parameters that have a negative relation with the costumers that churn are “OnlineSecurity” and “TechSupport” when the answer is “No”, the same parameters that have a positive relation when the costumers churn. We can see that the target answer “Yes” and “No” have an approximate opposite correlations with the explanatory variables.

###Modelling

abans o despresss nose ###Data transformations:

Recall that the following variables:

OnlineSecurity

OnlineBackup

DeviceProtection

TechSupport

StreamingTV

StreamingMovies

are categorical variables with 3 levels: No/No internet service/Yes.

We observe that they contain “No internet service” as a response. We have a variable called *“InternetService”* that is a categorical variable with 3 levels: DSL/Fiber optic/No. Whenever InternetService=“No” implies -> var=“No internet service”. Therefore we decided to transform the level “No internet service” into “No” in the 6 variables above since this variable will specify.

df$OnlineSecurity[df$OnlineSecurity=="No internet service"] <- "No"  
df$OnlineBackup[df$OnlineBackup=="No internet service"] <- "No"  
df$DeviceProtection[df$DeviceProtection=="No internet service"] <- "No"  
df$TechSupport[df$TechSupport=="No internet service"] <- "No"  
df$StreamingTV[df$StreamingTV=="No internet service"] <- "No"  
df$StreamingMovies[df$StreamingMovies=="No internet service"] <- "No"  
### aqui el phone falta explicar  
df$MultipleLines[df$MultipleLines=="No phone service"] <- "No"  
summary(df)

## customerID gender SeniorCitizen Partner Dependents  
## Length:7043 Female:3488 0:5901 No :3641 No :4933   
## Class :character Male :3555 1:1142 Yes:3402 Yes:2110   
## Mode :character   
##   
##   
##   
## tenure PhoneService MultipleLines InternetService  
## Min. : 0.00 No : 682 No :4072 DSL :2421   
## 1st Qu.: 9.00 Yes:6361 No phone service: 0 Fiber optic:3096   
## Median :29.00 Yes :2971 No :1526   
## Mean :32.37   
## 3rd Qu.:55.00   
## Max. :72.00   
## OnlineSecurity OnlineBackup   
## No :5024 No :4614   
## No internet service: 0 No internet service: 0   
## Yes :2019 Yes :2429   
##   
##   
##   
## DeviceProtection TechSupport   
## No :4621 No :4999   
## No internet service: 0 No internet service: 0   
## Yes :2422 Yes :2044   
##   
##   
##   
## StreamingTV StreamingMovies Contract   
## No :4336 No :4311 Month-to-month:3875   
## No internet service: 0 No internet service: 0 One year :1473   
## Yes :2707 Yes :2732 Two year :1695   
##   
##   
##   
## PaperlessBilling PaymentMethod MonthlyCharges   
## No :2872 Bank transfer (automatic):1544 Min. : 18.25   
## Yes:4171 Credit card (automatic) :1522 1st Qu.: 35.50   
## Electronic check :2365 Median : 70.35   
## Mailed check :1612 Mean : 64.76   
## 3rd Qu.: 89.85   
## Max. :118.75   
## TotalCharges Churn   
## Min. : 0.0 No :5174   
## 1st Qu.: 398.6 Yes:1869   
## Median :1394.5   
## Mean :2279.7   
## 3rd Qu.:3786.6   
## Max. :8684.8

Modelling: Train - test → dubte: abans o després de balancejar les dades? The dataset is imbalanced. Use only glm() modeling tools (parametric and traditional statistical models, baseline for comparison to ML approaches being developed in other subjects) Assessment metric: area under the ROC curve score and confusion table prediction capability analysis (recall, F1-score, etc) for train sample and confusion table for test sample

set.seed(1234)  
m <- floor(0.7\*nrow(df))  
train\_d <- sample(seq\_len(nrow(df)),size = m)  
  
train <- df[train\_d,]  
test <- df[-train\_d,]  
  
names(df)

## [1] "customerID" "gender" "SeniorCitizen" "Partner"   
## [5] "Dependents" "tenure" "PhoneService" "MultipleLines"   
## [9] "InternetService" "OnlineSecurity" "OnlineBackup" "DeviceProtection"  
## [13] "TechSupport" "StreamingTV" "StreamingMovies" "Contract"   
## [17] "PaperlessBilling" "PaymentMethod" "MonthlyCharges" "TotalCharges"   
## [21] "Churn"

Target variable is Churn.

We start the modeling by the null model.

mod0 <- glm(Churn ~ 1, data=train, family=binomial)  
mod0$deviance

## [1] 5694.218

We continue by adding the numerical variables and assessing the model.

which(sapply(df, is.numeric))

## tenure MonthlyCharges TotalCharges   
## 6 19 20

We start by *tenure*

mod1 <- glm(Churn ~ tenure, data=train, family=binomial)  
mod1$deviance;AIC(mod0,mod1) #summary(mod1)

## [1] 5040.677

## df AIC  
## mod0 1 5696.218  
## mod1 2 5044.677

anova( mod0, mod1, test="Chisq")

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ 1  
## Model 2: Churn ~ tenure  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4929 5694.2   
## 2 4928 5040.7 1 653.54 < 2.2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

we use a second order variable

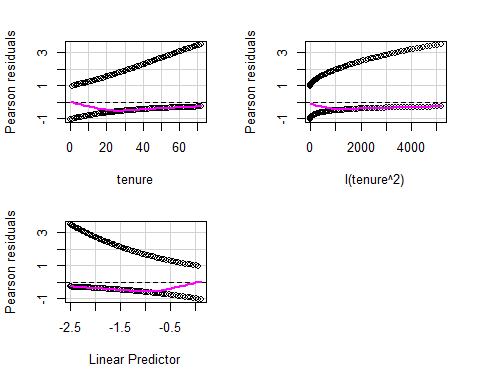
mod1q <- glm(Churn ~ tenure + I(tenure^2), data=train, family=binomial)  
summary(mod1q)

##   
## Call:  
## glm(formula = Churn ~ tenure + I(tenure^2), family = binomial,   
## data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) 1.184e-01 6.469e-02 1.831 0.06709 .   
## tenure -5.271e-02 5.639e-03 -9.347 < 2e-16 \*\*\*  
## I(tenure^2) 2.268e-04 8.428e-05 2.691 0.00713 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5033.5 on 4927 degrees of freedom  
## AIC: 5039.5  
##   
## Number of Fisher Scoring iterations: 5

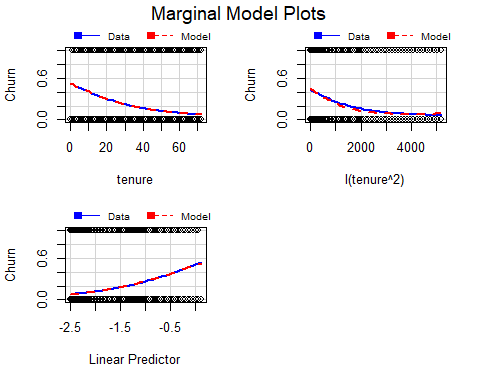
anova( mod1, mod1q, test="Chisq")

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure  
## Model 2: Churn ~ tenure + I(tenure^2)  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4928 5040.7   
## 2 4927 5033.5 1 7.153 0.007484 \*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

residualPlots(mod1q); marginalModelPlots(mod1q)



## Test stat Pr(>|Test stat|)   
## tenure 0.000 1   
## I(tenure^2) 42.054 8.88e-11 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1



Add MonthlyCharges

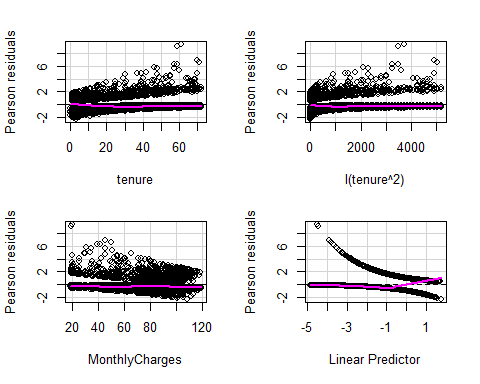
mod2 <- glm(Churn ~ tenure + I(tenure^2)+ MonthlyCharges, data=train, family=binomial)  
mod2$deviance

## [1] 4451.056

anova( mod1, mod2, test="Chisq")

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure  
## Model 2: Churn ~ tenure + I(tenure^2) + MonthlyCharges  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4928 5040.7   
## 2 4926 4451.1 2 589.62 < 2.2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

residualPlots(mod2)



## Test stat Pr(>|Test stat|)   
## tenure 0.0000 1.0000   
## I(tenure^2) 60.6733 6.772e-15 \*\*\*  
## MonthlyCharges 0.1444 0.7039   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

consider interactions

mod2i <- glm(Churn ~ (tenure + I(tenure^2) ) \*MonthlyCharges, data=train, family=binomial)  
mod2i$deviance

## [1] 4430.823

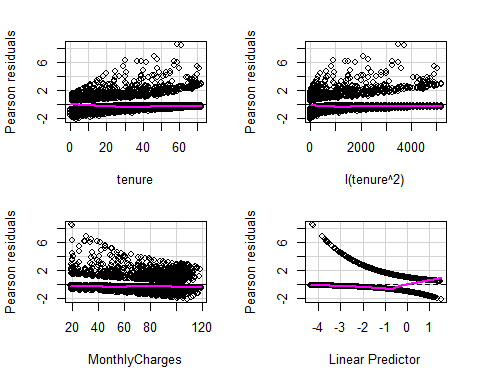
anova( mod2, mod2i, test="Chisq")

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + I(tenure^2) + MonthlyCharges  
## Model 2: Churn ~ (tenure + I(tenure^2)) \* MonthlyCharges  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4926 4451.1   
## 2 4924 4430.8 2 20.233 4.04e-05 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

summary(mod2i)

##   
## Call:  
## glm(formula = Churn ~ (tenure + I(tenure^2)) \* MonthlyCharges,   
## family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.218e+00 1.721e-01 -7.076 1.48e-12 \*\*\*  
## tenure -1.591e-01 1.932e-02 -8.232 < 2e-16 \*\*\*  
## I(tenure^2) 1.631e-03 3.039e-04 5.368 7.96e-08 \*\*\*  
## MonthlyCharges 2.658e-02 2.662e-03 9.983 < 2e-16 \*\*\*  
## tenure:MonthlyCharges 1.058e-03 2.415e-04 4.382 1.18e-05 \*\*\*  
## I(tenure^2):MonthlyCharges -1.607e-05 3.607e-06 -4.456 8.36e-06 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4430.8 on 4924 degrees of freedom  
## AIC: 4442.8  
##   
## Number of Fisher Scoring iterations: 6

residualPlots(mod2i)



## Test stat Pr(>|Test stat|)   
## tenure 0.0000 1.0000   
## I(tenure^2) 42.1055 8.648e-11 \*\*\*  
## MonthlyCharges 2.2123 0.1369   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Add TotalCharges

mod3 <- glm(Churn ~ (tenure + I(tenure^2) ) \*MonthlyCharges + TotalCharges, data=train, family=binomial)  
mod3$deviance

## [1] 4429.874

anova( mod2i, mod3, test="Chisq")

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ (tenure + I(tenure^2)) \* MonthlyCharges  
## Model 2: Churn ~ (tenure + I(tenure^2)) \* MonthlyCharges + TotalCharges  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)  
## 1 4924 4430.8   
## 2 4923 4429.9 1 0.94858 0.3301

summary(mod3)

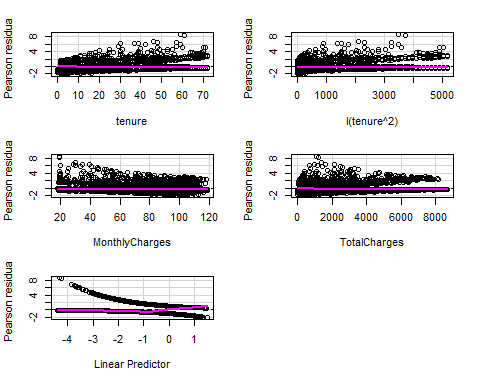
##   
## Call:  
## glm(formula = Churn ~ (tenure + I(tenure^2)) \* MonthlyCharges +   
## TotalCharges, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.219e+00 1.722e-01 -7.082 1.42e-12 \*\*\*  
## tenure -1.590e-01 1.933e-02 -8.228 < 2e-16 \*\*\*  
## I(tenure^2) 1.631e-03 3.040e-04 5.365 8.10e-08 \*\*\*  
## MonthlyCharges 2.659e-02 2.663e-03 9.987 < 2e-16 \*\*\*  
## TotalCharges 5.823e-04 5.983e-04 0.973 0.330   
## tenure:MonthlyCharges 4.768e-04 6.441e-04 0.740 0.459   
## I(tenure^2):MonthlyCharges -1.610e-05 3.608e-06 -4.461 8.16e-06 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4429.9 on 4923 degrees of freedom  
## AIC: 4443.9  
##   
## Number of Fisher Scoring iterations: 6

vif(mod3)

## there are higher-order terms (interactions) in this model  
## consider setting type = 'predictor'; see ?vif

## tenure I(tenure^2)   
## 128.619300 143.500220   
## MonthlyCharges TotalCharges   
## 3.705695 1197.593887   
## tenure:MonthlyCharges I(tenure^2):MonthlyCharges   
## 1383.184568 185.756036

residualPlots(mod3)



## Test stat Pr(>|Test stat|)   
## tenure 0.0000 1.0000   
## I(tenure^2) 41.9283 9.468e-11 \*\*\*  
## MonthlyCharges 2.1996 0.1380   
## TotalCharges 0.7990 0.3714   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

It is not significant enough. We don’t add it in our model. We can also see that *TotalCHarges* has a high VIF, so it has high multicollinearity.

mod3.1 <- glm(Churn ~ (tenure + I(tenure^2) ) + MonthlyCharges , data=train, family=binomial)  
mod3.1$deviance

## [1] 4451.056

anova( mod3, mod3.1, test="Chisq")

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ (tenure + I(tenure^2)) \* MonthlyCharges + TotalCharges  
## Model 2: Churn ~ (tenure + I(tenure^2)) + MonthlyCharges  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4923 4429.9   
## 2 4926 4451.1 -3 -21.182 9.651e-05 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

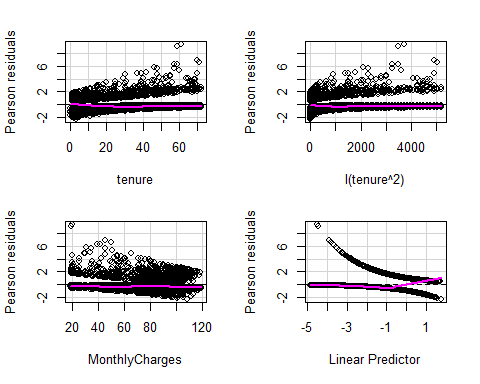
summary(mod3.1)

##   
## Call:  
## glm(formula = Churn ~ (tenure + I(tenure^2)) + MonthlyCharges,   
## family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.737e+00 1.112e-01 -15.616 < 2e-16 \*\*\*  
## tenure -7.836e-02 6.219e-03 -12.601 < 2e-16 \*\*\*  
## I(tenure^2) 3.624e-04 8.887e-05 4.078 4.55e-05 \*\*\*  
## MonthlyCharges 3.432e-02 1.603e-03 21.412 < 2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4451.1 on 4926 degrees of freedom  
## AIC: 4459.1  
##   
## Number of Fisher Scoring iterations: 5

vif(mod3.1)

## tenure I(tenure^2) MonthlyCharges   
## 13.254769 12.452456 1.360702

residualPlots(mod3.1)



## Test stat Pr(>|Test stat|)   
## tenure 0.0000 1.0000   
## I(tenure^2) 60.6733 6.772e-15 \*\*\*  
## MonthlyCharges 0.1444 0.7039   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

mod3.2 <- glm(Churn ~ tenure + MonthlyCharges , data=train, family=binomial)  
mod3.2$deviance

## [1] 4467.45

anova( mod3.1, mod3.2, test="Chisq")

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ (tenure + I(tenure^2)) + MonthlyCharges  
## Model 2: Churn ~ tenure + MonthlyCharges  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4926 4451.1   
## 2 4927 4467.5 -1 -16.394 5.145e-05 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

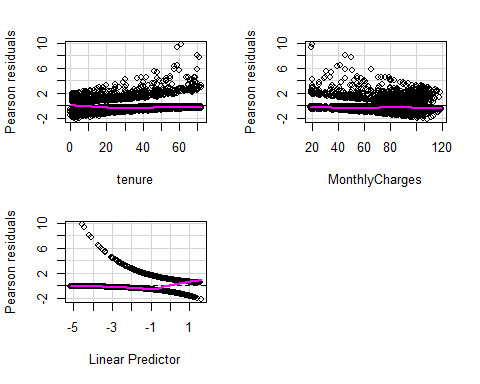
summary(mod3.2) #aic 4473.5

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges, family = binomial,   
## data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.878261 0.105561 -17.79 <2e-16 \*\*\*  
## tenure -0.054752 0.002028 -27.00 <2e-16 \*\*\*  
## MonthlyCharges 0.033675 0.001574 21.39 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4467.5 on 4927 degrees of freedom  
## AIC: 4473.5  
##   
## Number of Fisher Scoring iterations: 5

vif(mod3.2)

## tenure MonthlyCharges   
## 1.299246 1.299246

residualPlots(mod3.2)



## Test stat Pr(>|Test stat|)   
## tenure 16.3940 5.145e-05 \*\*\*  
## MonthlyCharges 0.0131 0.909   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Better without , we improved the multicollinearity.

##Overdispersion

##Inlfuential data

infl <- influence.measures(mod3.2)  
infl$infmat

## dfb.1\_ dfb.tenr dfb.MntC dffit cov.r  
## 1004 -4.705574e-03 -3.787582e-03 5.292657e-03 -0.005854628 1.0009602  
## 623 9.059121e-04 -7.963159e-03 -1.499590e-03 -0.015517483 1.0006727  
## 2693 -1.158549e-02 -4.140950e-03 9.211314e-03 -0.013771673 1.0007065  
## 934 -3.335792e-03 -2.062208e-02 1.681893e-02 0.027236985 1.0009595  
## 4496 5.830630e-03 -2.211316e-02 9.832611e-03 0.029194187 1.0007031  
## 2948 2.198892e-03 -9.926836e-03 -1.103374e-03 -0.015220879 1.0008719  
## 2146 -5.570203e-03 1.519402e-02 -8.442557e-03 -0.027320150 1.0001914  
## 3175 -2.242920e-03 -3.814933e-03 3.160539e-03 -0.004384476 1.0008751  
## 2774 -1.000293e-02 -4.949480e-03 9.685159e-03 -0.011036895 1.0010013  
## 5722 -9.347516e-03 -5.531310e-03 8.091928e-03 -0.012226978 1.0007175  
## 2374 -1.545802e-03 -3.286155e-03 2.413433e-03 -0.003613914 1.0008556  
## 1103 1.980117e-02 -1.846418e-02 -3.129006e-03 0.033279643 1.0002213  
## 4046 8.120226e-03 -1.158516e-02 5.275162e-03 0.027381287 0.9999062  
## 7028 -5.194455e-03 1.245565e-02 -7.409518e-03 -0.025211041 1.0002092  
## 4366 -7.552108e-04 -7.336138e-03 2.525313e-03 -0.008248610 1.0009643  
## 3454 1.800524e-03 -9.025556e-03 5.552238e-04 -0.010917923 1.0011308  
## 2232 8.135681e-03 -1.560529e-02 6.452551e-03 0.028180162 1.0001247  
## 2622 -6.281615e-04 -5.829431e-03 2.204003e-03 -0.006317316 1.0009615  
## 6148 9.862832e-03 -5.494144e-03 -1.250824e-02 -0.024612210 1.0007241  
## 3972 4.908921e-02 2.580006e-02 -4.882180e-02 0.054411880 0.9977871  
## 1685 -6.797870e-03 -6.432884e-03 7.111023e-03 -0.009797184 1.0008335  
## 2600 -9.031211e-04 -4.877348e-03 2.242108e-03 -0.005208872 1.0009245  
## 5332 -4.498246e-03 -6.415571e-03 5.464571e-03 -0.008140779 1.0008688  
## 3000 -1.140344e-02 -4.370937e-03 1.078347e-02 -0.012017420 1.0011091  
## 5315 -1.224849e-03 -4.218765e-03 2.368270e-03 -0.004508913 1.0008921  
## 996 -2.953286e-03 1.090851e-02 7.470452e-03 0.033193380 0.9993170  
## 3583 1.734529e-03 3.422762e-02 -2.454166e-02 -0.044611011 0.9999865  
## 479 -8.043949e-03 -1.900121e-02 1.957647e-02 0.025874521 1.0012584  
## 3677 -5.116762e-03 -5.203936e-03 2.880929e-03 -0.013377383 1.0005344  
## 634 -1.696895e-02 -2.742946e-03 1.447490e-02 -0.017161411 1.0012176  
## 4997 -2.320680e-03 -8.415022e-03 3.457185e-03 -0.010698877 1.0008248  
## 578 -7.440318e-03 1.674313e-02 -7.397206e-03 -0.028382405 1.0002006  
## 3759 -2.168353e-02 1.525341e-02 7.367567e-03 -0.030593415 1.0005874  
## 3496 1.997544e-03 -2.201324e-02 1.283803e-02 0.028149253 1.0008463  
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## 794 2.434842e-05 0.0003148727  
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## 4046 7028 4366 3454 2232 2622   
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## 5228 131 3415 1014 4836 3912   
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## 6048 298 1835 258 79 3254   
## 9.233737e-05 1.628920e-04 3.948193e-04 1.827085e-04 3.701630e-05 2.025143e-04   
## 6449 2744 4403 902 5341 3808   
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## 595 434 6901 760 3290 1751   
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## 4.350444e-05 2.731113e-04 1.136579e-04 3.413186e-05 3.052162e-04 1.093198e-04   
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## 4.137215e-05 7.200789e-05 1.015118e-05 8.298561e-04 5.983736e-04 5.270040e-06   
## 644 2493 397 345 2151 3721   
## 3.749703e-05 3.027524e-04 3.621697e-04 3.886993e-06 1.254009e-04 1.183889e-05   
## 6681 1577 4596 5766 6265 3316   
## 7.349781e-04 2.964054e-06 1.049216e-05 2.197458e-03 9.291030e-05 4.429347e-05   
## 6290 6691 6908 1518 4700 666   
## 1.952461e-03 8.879861e-05 6.838635e-04 5.119338e-05 1.126346e-04 4.046556e-04   
## 6046 6294 1892 431 1394 3815   
## 4.827279e-06 1.898503e-05 3.948193e-04 6.602479e-03 1.057260e-04 9.787948e-06   
## 3549 1152 1339 3502 2855 1233   
## 1.762812e-05 1.020891e-04 1.293582e-03 1.135342e-05 7.599089e-05 3.339936e-04   
## 445 2029 3193 1243 4641 5837   
## 3.777644e-05 3.111286e-05 9.116645e-07 2.401013e-05 1.676616e-04 6.623795e-05   
## 5873 5068 6569 3375 3892 2740   
## 1.689714e-04 2.754604e-05 5.644538e-05 2.630743e-04 1.241073e-05 4.025389e-05   
## 980 6648 5179 2306 1369 2698   
## 1.716536e-05 5.678104e-06 1.057626e-04 1.367685e-04 2.199214e-05 1.002099e-05   
## 2867 4422 1732 5235 5675 6950   
## 3.010437e-04 7.055013e-05 1.691605e-04 1.750023e-04 2.365552e-06 1.312371e-05   
## 5780 4585 2205 5183 1327 1251   
## 4.289367e-04 5.425009e-06 1.963088e-03 4.542871e-05 1.009862e-05 6.078471e-05   
## 1412 5169 47 5950 820 1987   
## 2.534642e-04 1.569166e-04 1.714539e-04 1.382509e-06 1.072580e-05 1.548916e-05   
## 6389 3657 3018 5040 6792 817   
## 1.279323e-03 6.653969e-06 5.042205e-05 1.415117e-04 8.174813e-04 1.258492e-04   
## 1 4969 2965 6586 1708 6720   
## 1.290231e-04 2.042475e-06 3.166946e-05 3.273126e-06 3.869158e-04 3.841145e-07   
## 5114 458 6542 4416 1980 4467   
## 4.838126e-05 5.126914e-05 2.292425e-05 4.445658e-06 2.781914e-06 1.466365e-04   
## 1925 470 3427 439 1873 6156   
## 1.261347e-04 2.816450e-04 1.684071e-04 7.174344e-05 3.802902e-06 1.459927e-03   
## 6022 4313 5159 1221 6931 622   
## 3.758819e-05 4.749304e-05 3.650825e-07 6.239887e-05 1.555183e-04 2.196783e-05   
## 7008 5619 5641 6888 5317 438   
## 2.507640e-06 4.437813e-05 1.383416e-04 7.272321e-06 4.717595e-05 4.645980e-05   
## 1141 5361 2565 6546 6840 4804   
## 3.651833e-04 1.404969e-04 1.741775e-04 1.654512e-04 1.403657e-04 6.991554e-05   
## 1928 2881 5244 4013 152 2927   
## 7.044142e-04 2.229758e-04 1.958582e-04 3.099480e-04 1.294631e-04 6.447971e-05   
## 1354 4516 3987 1541 1215 260   
## 4.894602e-07 2.059347e-04 2.267472e-05 1.092498e-05 1.807311e-04 1.947722e-05   
## 2384 4701 1863 4543 2166 4321   
## 2.262183e-05 1.590931e-04 5.628524e-06 4.236887e-05 3.735161e-05 3.263416e-07   
## 6592 624 1881 3035 187 5670   
## 1.702496e-04 2.065785e-05 1.263113e-04 1.259889e-04 3.736112e-05 1.011579e-04   
## 5174 2170 4245 1668 2717 906   
## 1.287915e-04 1.201567e-05 2.537108e-06 3.840038e-05 3.696378e-05 1.293601e-04   
## 3166 4146 5375 424 311 5520   
## 1.518186e-05 1.005351e-04 1.661250e-04 3.800068e-06 1.030574e-04 2.255446e-04   
## 3443 77 3199 4786 3792 4913   
## 2.072239e-04 9.836970e-06 1.782570e-04 1.734842e-04 2.255414e-04 3.545244e-04   
## 878 4976 3933 1602 3485 6753   
## 8.735643e-06 2.399856e-05 1.441482e-04 5.795891e-05 4.120079e-05 6.753759e-05   
## 6199 3867 4859 1923 5413 2245   
## 1.634645e-05 2.617606e-05 5.941868e-06 3.092296e-05 1.617823e-05 5.166898e-04   
## 973 2815 2710 2221 6707 2276   
## 8.906661e-06 2.598179e-06 1.227392e-05 5.840737e-06 1.046334e-04 1.526302e-04   
## 3823 6087 1483 5253 4221 2495   
## 8.634998e-04 7.373132e-06 6.021091e-04 3.247980e-05 1.192235e-06 3.808871e-04   
## 2323 630 34 3302 404 943   
## 2.044865e-06 8.070161e-04 1.053617e-04 1.691605e-04 2.351285e-06 7.194415e-05   
## 1029 5369 5908 4438 2182 4953   
## 2.125983e-04 1.700857e-04 1.695731e-04 4.262032e-05 2.615687e-05 1.498942e-03   
## 4559 5129 5251 6135 6159 6324   
## 2.224308e-04 7.735561e-05 5.653124e-04 1.066727e-04 9.521668e-05 1.776014e-04   
## 2390 1984 2791 4909 122 1175   
## 8.713586e-06 6.183730e-05 8.333250e-04 2.759095e-04 6.872015e-05 6.091108e-05   
## 116 1033 6897 4716 7042 3002   
## 8.699061e-04 1.391966e-04 4.166008e-04 1.424378e-05 1.594898e-04 5.268248e-05   
## 4041 3909 4031 3382 1943 4134   
## 1.733014e-06 1.140770e-04 1.327490e-04 3.032649e-05 2.478759e-06 4.523288e-05   
## 2540 1801 3291 6047 162 1551   
## 7.030808e-07 1.680229e-04 1.085456e-04 4.143582e-04 1.802199e-04 4.198444e-04   
## 2875 5259 4367 211 43 3524   
## 5.556251e-07 2.193677e-03 7.194415e-05 3.837708e-04 2.718404e-05 4.089798e-05   
## 2598 2670 508 6983 5055 337   
## 3.716660e-05 1.900862e-04 1.074482e-04 4.477580e-06 2.191364e-06 5.610020e-04   
## 4392 5003 3040 800 2425 313   
## 1.109802e-04 1.217592e-06 2.685634e-06 1.630188e-03 1.207299e-03 2.872182e-04   
## 1448 3934 5667 2795 4829 1368   
## 1.447190e-04 5.179527e-05 1.647808e-05 2.473646e-05 9.435413e-06 1.351168e-05   
## 4316 1012 2578 2008 1548 6104   
## 1.384728e-04 2.157732e-06 1.019295e-04 1.400310e-04 1.635326e-03 2.874580e-05   
## 6736 6992 4286 3758 1604 5309   
## 9.634137e-06 1.331806e-04 1.994234e-05 1.718540e-05 2.054355e-04 8.426254e-06   
## 6457 4336 6429 1066 6721 4343   
## 1.382337e-05 1.753959e-04 1.768526e-04 2.047155e-04 8.637292e-06 8.146946e-06   
## 837 2097 1305 2024 117 6170   
## 7.447168e-06 1.342963e-03 1.685259e-04 1.471351e-04 8.464818e-06 3.985025e-04   
## 6812 6316 6098 771 5556 4791   
## 3.125761e-04 1.504868e-05 6.385322e-06 4.448733e-05 3.373808e-07 6.312261e-05   
## 4216 5632 895 450 1633 48   
## 3.179426e-05 9.814138e-05 1.144765e-05 2.678379e-05 7.405577e-04 1.389312e-04   
## 5090 6072 3490 1400 3274 6628   
## 1.067767e-04 2.686838e-05 1.312268e-04 3.377910e-05 4.123089e-04 8.868532e-07   
## 3041 3113 5625 873 5866 3903   
## 2.364109e-03 1.968982e-05 1.932368e-05 4.798546e-07 8.963523e-05 1.291474e-04   
## 4485 6360 4567 5702 5851 4311   
## 3.979352e-04 1.624710e-05 2.507855e-05 1.318429e-04 1.903788e-04 2.847682e-06   
## 4101 6741 3512 3459 5335 3816   
## 1.830635e-06 5.029684e-04 1.770229e-06 2.212184e-04 7.861306e-04 1.579668e-04   
## 5440 5318 4835 3664   
## 3.021730e-04 3.408172e-04 5.560977e-07 4.986380e-04

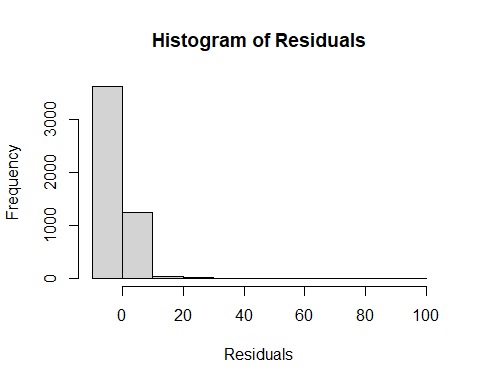
sum(residuals(mod3.2,'deviance')^2)

## [1] 4467.45

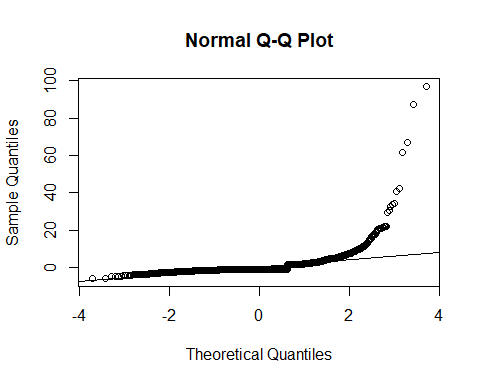
sum(residuals(mod3.2,'pearson')^2)

## [1] 4873.989

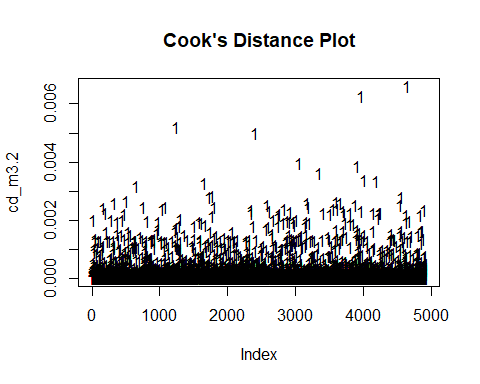
res\_3.2 <- mod3.2$residuals  
  
# Plotting a histogram of residuals  
hist(res\_3.2, main = "Histogram of Residuals", xlab = "Residuals")



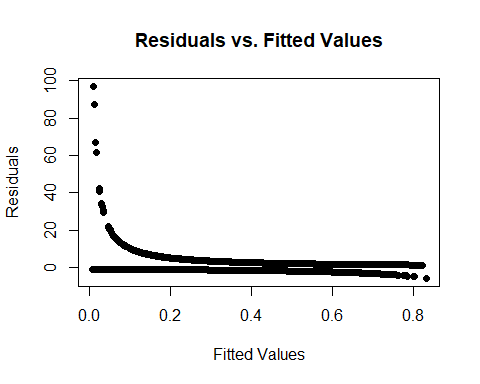
# Q-Q plot for normality  
qqnorm(res\_3.2)  
qqline(res\_3.2)



# Calculate Cook's distance  
cd\_m3.2 <- cooks.distance(mod3.2)  
  
# Plot Cook's distance  
plot(cd\_m3.2, pch = "18", main = "Cook's Distance Plot")  
abline(h = 4/(length(mod3.2$coefficients) - 1), col = "red")



#Check homoscedasticity (constant variance of residuals) by plotting residuals against fitted values:  
  
# Plotting residuals against fitted values  
  
plot(fitted(mod3.2), res\_3.2, pch = 16, main = "Residuals vs. Fitted Values", xlab = "Fitted Values", ylab = "Residuals")



##Categorical Variables

Now, we shall add the categorical variables. The order of addition is significant, therefore we start by adding the most correlated variables with the target.

Contract InternetService StreamingMovies StreamingTV TechSupport DeviceProtection OnlineBackup OnlineSecurity PaperlessBilling Dependents MultipleLines SeniorCitizen Partner PaymentMethod PhoneService

#Contract

We start with *Contract* variable.

mod4 <- glm(Churn ~ tenure + MonthlyCharges + Contract, data=train, family=binomial)  
summary(mod4) #4302.2 better

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract, family = binomial,   
## data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.687949 0.109108 -15.470 <2e-16 \*\*\*  
## tenure -0.035614 0.002450 -14.534 <2e-16 \*\*\*  
## MonthlyCharges 0.029457 0.001632 18.047 <2e-16 \*\*\*  
## ContractOne year -1.050590 0.120126 -8.746 <2e-16 \*\*\*  
## ContractTwo year -2.082901 0.204897 -10.166 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4292.2 on 4925 degrees of freedom  
## AIC: 4302.2  
##   
## Number of Fisher Scoring iterations: 6

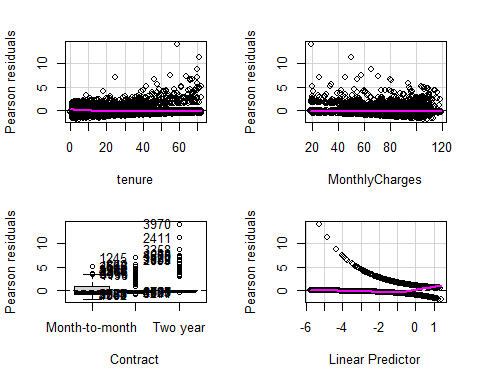
anova( mod3.2, mod4, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4927 4467.5   
## 2 4925 4292.2 2 175.22 < 2.2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod4)

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 1.707900 1 1.306867  
## MonthlyCharges 1.300967 1 1.140599  
## Contract 1.361428 2 1.080186

residualPlots(mod4)



## Test stat Pr(>|Test stat|)   
## tenure 53.7553 2.27e-13 \*\*\*  
## MonthlyCharges 1.7946 0.1804   
## Contract   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

We add the parameter because it improves the model.

#InternetService

mod5 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService, data=train, family=binomial)  
summary(mod5) #4254.1 better

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService,   
## family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -0.643248 0.186158 -3.455 0.00055 \*\*\*  
## tenure -0.032148 0.002479 -12.969 < 2e-16 \*\*\*  
## MonthlyCharges 0.006365 0.003559 1.788 0.07373 .   
## ContractOne year -0.865294 0.123069 -7.031 2.05e-12 \*\*\*  
## ContractTwo year -1.804983 0.208329 -8.664 < 2e-16 \*\*\*  
## InternetServiceFiber optic 0.980860 0.149013 6.582 4.63e-11 \*\*\*  
## InternetServiceNo -0.895142 0.181620 -4.929 8.28e-07 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4240.1 on 4923 degrees of freedom  
## AIC: 4254.1  
##   
## Number of Fisher Scoring iterations: 6

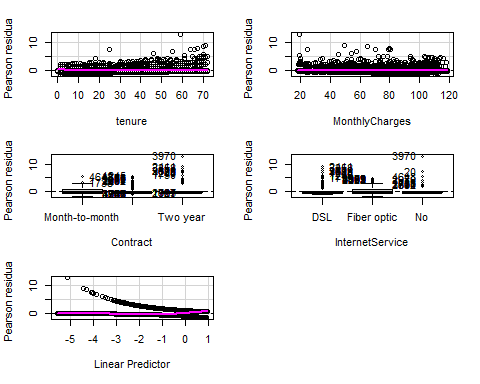
anova( mod4, mod5, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4925 4292.2   
## 2 4923 4240.1 2 52.12 4.811e-12 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod5)

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 1.738643 1 1.318576  
## MonthlyCharges 6.009378 1 2.451403  
## Contract 1.450931 2 1.097518  
## InternetService 5.338238 2 1.520021

residualPlots(mod5)



## Test stat Pr(>|Test stat|)   
## tenure 49.365 2.125e-12 \*\*\*  
## MonthlyCharges 26.266 2.975e-07 \*\*\*  
## Contract   
## InternetService   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

#StreamingMovies

mod6 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies, data=train, family=binomial)  
summary(mod6) #4238.6 better

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -0.219913 0.209784 -1.048 0.295   
## tenure -0.031968 0.002480 -12.888 < 2e-16 \*\*\*  
## MonthlyCharges -0.004380 0.004374 -1.001 0.317   
## ContractOne year -0.870117 0.123320 -7.056 1.72e-12 \*\*\*  
## ContractTwo year -1.795490 0.208231 -8.623 < 2e-16 \*\*\*  
## InternetServiceFiber optic 1.282307 0.167023 7.677 1.62e-14 \*\*\*  
## InternetServiceNo -1.100410 0.186826 -5.890 3.86e-09 \*\*\*  
## StreamingMoviesYes 0.441326 0.105641 4.178 2.95e-05 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4222.6 on 4922 degrees of freedom  
## AIC: 4238.6  
##   
## Number of Fisher Scoring iterations: 6

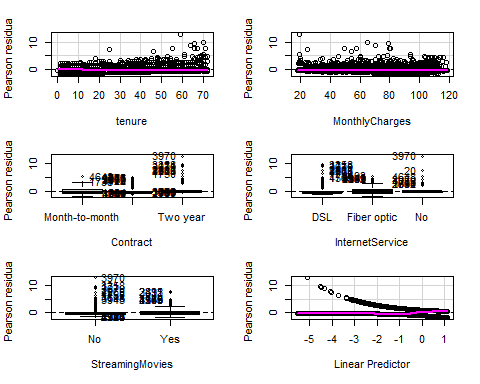
anova( mod5, mod6, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4923 4240.1   
## 2 4922 4222.6 1 17.563 2.78e-05 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod6)

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 1.734387 1 1.316961  
## MonthlyCharges 9.114445 1 3.019014  
## Contract 1.447519 2 1.096872  
## InternetService 6.680296 2 1.607677  
## StreamingMovies 1.878425 1 1.370556

residualPlots(mod6)



## Test stat Pr(>|Test stat|)   
## tenure 49.6 1.885e-12 \*\*\*  
## MonthlyCharges 17.2 3.364e-05 \*\*\*  
## Contract   
## InternetService   
## StreamingMovies   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

The model has improved but the VIF is becoming higher.

#StreamingTV

mod7 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies + StreamingTV, data=train, family=binomial)  
summary(mod7) #4213.5 better

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) 0.311672 0.230322 1.353 0.175990   
## tenure -0.031969 0.002487 -12.855 < 2e-16 \*\*\*  
## MonthlyCharges -0.017752 0.005047 -3.517 0.000436 \*\*\*  
## ContractOne year -0.870522 0.123651 -7.040 1.92e-12 \*\*\*  
## ContractTwo year -1.775038 0.208250 -8.524 < 2e-16 \*\*\*  
## InternetServiceFiber optic 1.650173 0.183107 9.012 < 2e-16 \*\*\*  
## InternetServiceNo -1.359915 0.191532 -7.100 1.25e-12 \*\*\*  
## StreamingMoviesYes 0.445782 0.105508 4.225 2.39e-05 \*\*\*  
## StreamingTVYes 0.552871 0.106924 5.171 2.33e-07 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4195.5 on 4921 degrees of freedom  
## AIC: 4213.5  
##   
## Number of Fisher Scoring iterations: 6

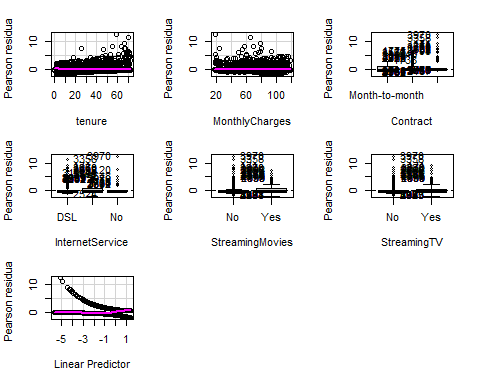
anova( mod6, mod7, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4922 4222.6   
## 2 4921 4195.5 1 27.002 2.033e-07 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod7)

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 1.732269 1 1.316157  
## MonthlyCharges 12.166459 1 3.488045  
## Contract 1.443988 2 1.096203  
## InternetService 7.954251 2 1.679383  
## StreamingMovies 1.860165 1 1.363878  
## StreamingTV 1.906895 1 1.380904

residualPlots(mod7)[01]



## Test stat Pr(>|Test stat|)   
## tenure 50.3544 1.283e-12 \*\*\*  
## MonthlyCharges 7.9167 0.004898 \*\*   
## Contract   
## InternetService   
## StreamingMovies   
## StreamingTV   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

## [1] 50.35436

*MonthlyCharges* has a high VIF. We’ll may need to add transformations or maybe discard this parameter. For now, we’ll keep the parameters that we have been adding.

#TechSupport

mod8 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies + StreamingTV + TechSupport, data=train, family=binomial)  
summary(mod8) #4208.3 better

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport, family = binomial,   
## data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) 0.159090 0.238689 0.667 0.505081   
## tenure -0.031943 0.002487 -12.843 < 2e-16 \*\*\*  
## MonthlyCharges -0.012766 0.005395 -2.366 0.017963 \*   
## ContractOne year -0.840485 0.124232 -6.765 1.33e-11 \*\*\*  
## ContractTwo year -1.697874 0.210219 -8.077 6.66e-16 \*\*\*  
## InternetServiceFiber optic 1.451761 0.197112 7.365 1.77e-13 \*\*\*  
## InternetServiceNo -1.320058 0.192969 -6.841 7.88e-12 \*\*\*  
## StreamingMoviesYes 0.406906 0.106602 3.817 0.000135 \*\*\*  
## StreamingTVYes 0.513242 0.108091 4.748 2.05e-06 \*\*\*  
## TechSupportYes -0.280916 0.104444 -2.690 0.007153 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4188.3 on 4920 degrees of freedom  
## AIC: 4208.3  
##   
## Number of Fisher Scoring iterations: 6

anova( mod7, mod8, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4921 4195.5   
## 2 4920 4188.3 1 7.2764 0.006987 \*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod8)

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 1.732344 1 1.316185  
## MonthlyCharges 13.838376 1 3.719997  
## Contract 1.475851 2 1.102201  
## InternetService 9.342986 2 1.748322  
## StreamingMovies 1.893830 1 1.376165  
## StreamingTV 1.943568 1 1.394119  
## TechSupport 1.294163 1 1.137613

#DeviceProtection

mod9 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies + StreamingTV + TechSupport + DeviceProtection, data=train, family=binomial)  
summary(mod9) #4209.3 worse

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + DeviceProtection,   
## family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) 0.20725 0.24332 0.852 0.394345   
## tenure -0.03217 0.00250 -12.868 < 2e-16 \*\*\*  
## MonthlyCharges -0.01417 0.00558 -2.539 0.011129 \*   
## ContractOne year -0.84846 0.12453 -6.813 9.54e-12 \*\*\*  
## ContractTwo year -1.71130 0.21068 -8.123 4.55e-16 \*\*\*  
## InternetServiceFiber optic 1.49636 0.20259 7.386 1.51e-13 \*\*\*  
## InternetServiceNo -1.33473 0.19328 -6.906 5.00e-12 \*\*\*  
## StreamingMoviesYes 0.41040 0.10661 3.850 0.000118 \*\*\*  
## StreamingTVYes 0.51843 0.10817 4.793 1.64e-06 \*\*\*  
## TechSupportYes -0.27817 0.10447 -2.663 0.007751 \*\*   
## DeviceProtectionYes 0.09141 0.09477 0.965 0.334789   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4187.3 on 4919 degrees of freedom  
## AIC: 4209.3  
##   
## Number of Fisher Scoring iterations: 6

anova( mod8, mod9, test="Chisq") #not significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + DeviceProtection  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)  
## 1 4920 4188.3   
## 2 4919 4187.3 1 0.93092 0.3346

We don’t add the parameter to the model. It does not improve it.

#OnlineBackup

mod10 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies + StreamingTV + TechSupport + OnlineBackup, data=train, family=binomial)  
summary(mod10) #4209.6 worse

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineBackup,   
## family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) 0.208031 0.246005 0.846 0.3978   
## tenure -0.032365 0.002543 -12.725 < 2e-16 \*\*\*  
## MonthlyCharges -0.014254 0.005701 -2.500 0.0124 \*   
## ContractOne year -0.840426 0.124233 -6.765 1.33e-11 \*\*\*  
## ContractTwo year -1.697207 0.210177 -8.075 6.74e-16 \*\*\*  
## InternetServiceFiber optic 1.501499 0.206770 7.262 3.82e-13 \*\*\*  
## InternetServiceNo -1.333854 0.193546 -6.892 5.51e-12 \*\*\*  
## StreamingMoviesYes 0.421961 0.108219 3.899 9.65e-05 \*\*\*  
## StreamingTVYes 0.528477 0.109739 4.816 1.47e-06 \*\*\*  
## TechSupportYes -0.274417 0.104746 -2.620 0.0088 \*\*   
## OnlineBackupYes 0.075863 0.094753 0.801 0.4233   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4187.6 on 4919 degrees of freedom  
## AIC: 4209.6  
##   
## Number of Fisher Scoring iterations: 6

anova( mod8, mod10, test="Chisq") #not significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineBackup  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)  
## 1 4920 4188.3   
## 2 4919 4187.6 1 0.64158 0.4231

We don’t add the parameter to the model. It does not improve it.

#OnlineSecurity

mod11 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity, data=train, family=binomial)  
summary(mod11) #4199 better

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity,   
## family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -0.008236 0.246066 -0.033 0.973301   
## tenure -0.031275 0.002499 -12.517 < 2e-16 \*\*\*  
## MonthlyCharges -0.006781 0.005721 -1.185 0.235905   
## ContractOne year -0.811442 0.124827 -6.501 8.00e-11 \*\*\*  
## ContractTwo year -1.641703 0.211038 -7.779 7.30e-15 \*\*\*  
## InternetServiceFiber optic 1.204840 0.210706 5.718 1.08e-08 \*\*\*  
## InternetServiceNo -1.292005 0.194222 -6.652 2.89e-11 \*\*\*  
## StreamingMoviesYes 0.339293 0.108944 3.114 0.001843 \*\*   
## StreamingTVYes 0.440566 0.110618 3.983 6.81e-05 \*\*\*  
## TechSupportYes -0.292683 0.104734 -2.795 0.005197 \*\*   
## OnlineSecurityYes -0.352840 0.105394 -3.348 0.000815 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4177.0 on 4919 degrees of freedom  
## AIC: 4199  
##   
## Number of Fisher Scoring iterations: 6

anova( mod8, mod11, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4920 4188.3   
## 2 4919 4177.0 1 11.321 0.0007665 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod11)

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 1.744624 1 1.320842  
## MonthlyCharges 15.487373 1 3.935400  
## Contract 1.492903 2 1.105371  
## InternetService 10.866851 2 1.815624  
## StreamingMovies 1.971177 1 1.403986  
## StreamingTV 2.028530 1 1.424265  
## TechSupport 1.296059 1 1.138446  
## OnlineSecurity 1.242751 1 1.114787

#residualPlot(mod11)

We keep the parameter

#PaperlessBilling

mod12 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling, data=train, family=binomial)  
summary(mod12) #4184.5 better

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -0.206715 0.251517 -0.822 0.411150   
## tenure -0.031980 0.002512 -12.730 < 2e-16 \*\*\*  
## MonthlyCharges -0.006893 0.005737 -1.202 0.229554   
## ContractOne year -0.774511 0.125366 -6.178 6.49e-10 \*\*\*  
## ContractTwo year -1.575801 0.211901 -7.436 1.03e-13 \*\*\*  
## InternetServiceFiber optic 1.162390 0.211629 5.493 3.96e-08 \*\*\*  
## InternetServiceNo -1.216241 0.195326 -6.227 4.76e-10 \*\*\*  
## StreamingMoviesYes 0.328093 0.109142 3.006 0.002646 \*\*   
## StreamingTVYes 0.412453 0.111023 3.715 0.000203 \*\*\*  
## TechSupportYes -0.293252 0.105072 -2.791 0.005255 \*\*   
## OnlineSecurityYes -0.325252 0.105781 -3.075 0.002107 \*\*   
## PaperlessBillingYes 0.354796 0.087670 4.047 5.19e-05 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4160.5 on 4918 degrees of freedom  
## AIC: 4184.5  
##   
## Number of Fisher Scoring iterations: 6

anova( mod11, mod12, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4919 4177.0   
## 2 4918 4160.5 1 16.478 4.923e-05 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod12)

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 1.760119 1 1.326695  
## MonthlyCharges 15.519259 1 3.939449  
## Contract 1.507661 2 1.108092  
## InternetService 10.973792 2 1.820075  
## StreamingMovies 1.970408 1 1.403712  
## StreamingTV 2.035605 1 1.426746  
## TechSupport 1.298079 1 1.139333  
## OnlineSecurity 1.247294 1 1.116823  
## PaperlessBilling 1.111928 1 1.054480

We keep the parameter

#Dependents

mod13 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling + Dependents, data=train, family=binomial)  
summary(mod13) #4177.2 better

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -0.160331 0.252462 -0.635 0.52538   
## tenure -0.031654 0.002520 -12.559 < 2e-16 \*\*\*  
## MonthlyCharges -0.006595 0.005749 -1.147 0.25137   
## ContractOne year -0.746604 0.125870 -5.932 3.00e-09 \*\*\*  
## ContractTwo year -1.536143 0.212595 -7.226 4.99e-13 \*\*\*  
## InternetServiceFiber optic 1.133942 0.212173 5.344 9.07e-08 \*\*\*  
## InternetServiceNo -1.193933 0.195766 -6.099 1.07e-09 \*\*\*  
## StreamingMoviesYes 0.317729 0.109348 2.906 0.00366 \*\*   
## StreamingTVYes 0.412210 0.111213 3.706 0.00021 \*\*\*  
## TechSupportYes -0.287327 0.105193 -2.731 0.00631 \*\*   
## OnlineSecurityYes -0.317077 0.105920 -2.994 0.00276 \*\*   
## PaperlessBillingYes 0.351625 0.087803 4.005 6.21e-05 \*\*\*  
## DependentsYes -0.291003 0.096298 -3.022 0.00251 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4151.2 on 4917 degrees of freedom  
## AIC: 4177.2  
##   
## Number of Fisher Scoring iterations: 6

anova( mod12, mod13, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4918 4160.5   
## 2 4917 4151.2 1 9.2692 0.00233 \*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod13)

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 1.773404 1 1.331692  
## MonthlyCharges 15.562560 1 3.944941  
## Contract 1.522708 2 1.110847  
## InternetService 10.992492 2 1.820849  
## StreamingMovies 1.973305 1 1.404744  
## StreamingTV 2.037770 1 1.427505  
## TechSupport 1.299374 1 1.139901  
## OnlineSecurity 1.247956 1 1.117120  
## PaperlessBilling 1.112626 1 1.054811  
## Dependents 1.027601 1 1.013706

We keep the parameter

#MultipleLines

mod14 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling + Dependents + MultipleLines, data=train, family=binomial)  
summary(mod14) #4162.2 better

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines, family = binomial,   
## data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) 0.325614 0.276930 1.176 0.239675   
## tenure -0.033818 0.002590 -13.059 < 2e-16 \*\*\*  
## MonthlyCharges -0.019128 0.006487 -2.949 0.003190 \*\*   
## ContractOne year -0.708250 0.126272 -5.609 2.04e-08 \*\*\*  
## ContractTwo year -1.505396 0.212577 -7.082 1.42e-12 \*\*\*  
## InternetServiceFiber optic 1.425577 0.223890 6.367 1.92e-10 \*\*\*  
## InternetServiceNo -1.452191 0.204587 -7.098 1.26e-12 \*\*\*  
## StreamingMoviesYes 0.434506 0.113253 3.837 0.000125 \*\*\*  
## StreamingTVYes 0.522217 0.114574 4.558 5.17e-06 \*\*\*  
## TechSupportYes -0.201538 0.107221 -1.880 0.060155 .   
## OnlineSecurityYes -0.241060 0.107617 -2.240 0.025093 \*   
## PaperlessBillingYes 0.337471 0.087923 3.838 0.000124 \*\*\*  
## DependentsYes -0.283338 0.096401 -2.939 0.003291 \*\*   
## MultipleLinesYes 0.422899 0.102860 4.111 3.93e-05 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4134.2 on 4916 degrees of freedom  
## AIC: 4162.2  
##   
## Number of Fisher Scoring iterations: 6

anova( mod13, mod14, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4917 4151.2   
## 2 4916 4134.2 1 17.026 3.688e-05 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod14)

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 1.860860 1 1.364133  
## MonthlyCharges 19.785122 1 4.448047  
## Contract 1.529039 2 1.112000  
## InternetService 12.562934 2 1.882664  
## StreamingMovies 2.104685 1 1.450753  
## StreamingTV 2.150829 1 1.466570  
## TechSupport 1.346109 1 1.160219  
## OnlineSecurity 1.283323 1 1.132838  
## PaperlessBilling 1.113149 1 1.055059  
## Dependents 1.028391 1 1.014096  
## MultipleLines 1.749163 1 1.322559

We keep the parameter

#SeniorCitizen

mod15 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling + Dependents + MultipleLines + SeniorCitizen, data=train, family=binomial)  
summary(mod15) #4155.7 better

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen,   
## family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) 0.267247 0.277985 0.961 0.336364   
## tenure -0.034666 0.002614 -13.260 < 2e-16 \*\*\*  
## MonthlyCharges -0.018721 0.006495 -2.883 0.003945 \*\*   
## ContractOne year -0.687576 0.126551 -5.433 5.54e-08 \*\*\*  
## ContractTwo year -1.471829 0.212912 -6.913 4.75e-12 \*\*\*  
## InternetServiceFiber optic 1.389895 0.224330 6.196 5.80e-10 \*\*\*  
## InternetServiceNo -1.414902 0.205187 -6.896 5.36e-12 \*\*\*  
## StreamingMoviesYes 0.427058 0.113402 3.766 0.000166 \*\*\*  
## StreamingTVYes 0.515559 0.114692 4.495 6.95e-06 \*\*\*  
## TechSupportYes -0.180640 0.107602 -1.679 0.093196 .   
## OnlineSecurityYes -0.227662 0.107759 -2.113 0.034627 \*   
## PaperlessBillingYes 0.330204 0.088016 3.752 0.000176 \*\*\*  
## DependentsYes -0.237905 0.097654 -2.436 0.014842 \*   
## MultipleLinesYes 0.409515 0.103119 3.971 7.15e-05 \*\*\*  
## SeniorCitizen1 0.289328 0.099257 2.915 0.003558 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4125.7 on 4915 degrees of freedom  
## AIC: 4155.7  
##   
## Number of Fisher Scoring iterations: 6

anova( mod14, mod15, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4916 4134.2   
## 2 4915 4125.7 1 8.4782 0.003594 \*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod15)

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 1.889241 1 1.374497  
## MonthlyCharges 19.790331 1 4.448632  
## Contract 1.536772 2 1.113403  
## InternetService 12.635139 2 1.885363  
## StreamingMovies 2.104216 1 1.450592  
## StreamingTV 2.148543 1 1.465791  
## TechSupport 1.353673 1 1.163474  
## OnlineSecurity 1.286526 1 1.134251  
## PaperlessBilling 1.114284 1 1.055597  
## Dependents 1.056349 1 1.027789  
## MultipleLines 1.752169 1 1.323695  
## SeniorCitizen 1.113813 1 1.055374

We keep the parameter

#Partner

mod16 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling + Dependents + MultipleLines + SeniorCitizen + Partner, data=train, family=binomial)  
summary(mod16) #4157.7 worse

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen +   
## Partner, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) 0.265985 0.278118 0.956 0.338882   
## tenure -0.034758 0.002679 -12.975 < 2e-16 \*\*\*  
## MonthlyCharges -0.018728 0.006495 -2.883 0.003934 \*\*   
## ContractOne year -0.687576 0.126545 -5.433 5.53e-08 \*\*\*  
## ContractTwo year -1.471574 0.212916 -6.912 4.79e-12 \*\*\*  
## InternetServiceFiber optic 1.389752 0.224333 6.195 5.83e-10 \*\*\*  
## InternetServiceNo -1.414725 0.205201 -6.894 5.41e-12 \*\*\*  
## StreamingMoviesYes 0.426914 0.113407 3.764 0.000167 \*\*\*  
## StreamingTVYes 0.515289 0.114703 4.492 7.04e-06 \*\*\*  
## TechSupportYes -0.180477 0.107609 -1.677 0.093512 .   
## OnlineSecurityYes -0.227837 0.107764 -2.114 0.034496 \*   
## PaperlessBillingYes 0.330424 0.088026 3.754 0.000174 \*\*\*  
## DependentsYes -0.244710 0.106734 -2.293 0.021864 \*   
## MultipleLinesYes 0.409511 0.103119 3.971 7.15e-05 \*\*\*  
## SeniorCitizen1 0.287578 0.099871 2.880 0.003983 \*\*   
## PartnerYes 0.014465 0.091544 0.158 0.874447   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4125.7 on 4914 degrees of freedom  
## AIC: 4157.7  
##   
## Number of Fisher Scoring iterations: 6

anova( mod15, mod16, test="Chisq") #not significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen +   
## Partner  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)  
## 1 4915 4125.7   
## 2 4914 4125.7 1 0.024971 0.8744

We don’t keep the parameter

#PaymentMethod

mod17 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling + Dependents + MultipleLines + SeniorCitizen + PaymentMethod, data=train, family=binomial)  
summary(mod17) #4139.4 better

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen +   
## PaymentMethod, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) 0.070752 0.297751 0.238 0.812174   
## tenure -0.033270 0.002671 -12.454 < 2e-16 \*\*\*  
## MonthlyCharges -0.017433 0.006529 -2.670 0.007580 \*\*   
## ContractOne year -0.660779 0.126880 -5.208 1.91e-07 \*\*\*  
## ContractTwo year -1.426923 0.213449 -6.685 2.31e-11 \*\*\*  
## InternetServiceFiber optic 1.293245 0.226310 5.714 1.10e-08 \*\*\*  
## InternetServiceNo -1.304750 0.208471 -6.259 3.88e-10 \*\*\*  
## StreamingMoviesYes 0.395594 0.113994 3.470 0.000520 \*\*\*  
## StreamingTVYes 0.472452 0.115512 4.090 4.31e-05 \*\*\*  
## TechSupportYes -0.157729 0.108022 -1.460 0.144247   
## OnlineSecurityYes -0.208169 0.108243 -1.923 0.054459 .   
## PaperlessBillingYes 0.310428 0.088576 3.505 0.000457 \*\*\*  
## DependentsYes -0.224946 0.097913 -2.297 0.021595 \*   
## MultipleLinesYes 0.396569 0.103521 3.831 0.000128 \*\*\*  
## SeniorCitizen1 0.264339 0.099866 2.647 0.008122 \*\*   
## PaymentMethodCredit card (automatic) -0.078607 0.135723 -0.579 0.562473   
## PaymentMethodElectronic check 0.364430 0.113262 3.218 0.001293 \*\*   
## PaymentMethodMailed check 0.011420 0.136200 0.084 0.933179   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4103.4 on 4912 degrees of freedom  
## AIC: 4139.4  
##   
## Number of Fisher Scoring iterations: 6

anova( mod15, mod17, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen +   
## PaymentMethod  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4915 4125.7   
## 2 4912 4103.4 3 22.269 5.735e-05 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod17)

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 1.963626 1 1.401295  
## MonthlyCharges 19.895259 1 4.460410  
## Contract 1.543913 2 1.114694  
## InternetService 13.046889 2 1.900539  
## StreamingMovies 2.110866 1 1.452882  
## StreamingTV 2.164001 1 1.471054  
## TechSupport 1.357356 1 1.165056  
## OnlineSecurity 1.291867 1 1.136603  
## PaperlessBilling 1.120742 1 1.058651  
## Dependents 1.057502 1 1.028349  
## MultipleLines 1.753352 1 1.324142  
## SeniorCitizen 1.116591 1 1.056689  
## PaymentMethod 1.332467 3 1.049001

#PhoneService

mod18 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling + Dependents + MultipleLines + SeniorCitizen + PaymentMethod + PhoneService, data=train, family=binomial)  
summary(mod18) #4139.4 it does not change anything

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen +   
## PaymentMethod + PhoneService, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -0.237709 0.366847 -0.648 0.516998   
## tenure -0.034292 0.002768 -12.387 < 2e-16 \*\*\*  
## MonthlyCharges -0.002716 0.012162 -0.223 0.823319   
## ContractOne year -0.666781 0.126959 -5.252 1.51e-07 \*\*\*  
## ContractTwo year -1.438924 0.213552 -6.738 1.61e-11 \*\*\*  
## InternetServiceFiber optic 0.961078 0.323676 2.969 0.002985 \*\*   
## InternetServiceNo -0.865765 0.370693 -2.336 0.019516 \*   
## StreamingMoviesYes 0.236356 0.158998 1.487 0.137138   
## StreamingTVYes 0.316047 0.158725 1.991 0.046463 \*   
## TechSupportYes -0.234653 0.120629 -1.945 0.051744 .   
## OnlineSecurityYes -0.275385 0.118024 -2.333 0.019632 \*   
## PaperlessBillingYes 0.308580 0.088640 3.481 0.000499 \*\*\*  
## DependentsYes -0.224714 0.097926 -2.295 0.021748 \*   
## MultipleLinesYes 0.336720 0.111645 3.016 0.002561 \*\*   
## SeniorCitizen1 0.259295 0.099923 2.595 0.009460 \*\*   
## PaymentMethodCredit card (automatic) -0.085694 0.135867 -0.631 0.528222   
## PaymentMethodElectronic check 0.362532 0.113278 3.200 0.001373 \*\*   
## PaymentMethodMailed check 0.008268 0.136324 0.061 0.951640   
## PhoneServiceYes -0.408196 0.284634 -1.434 0.151542   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4101.4 on 4911 degrees of freedom  
## AIC: 4139.4  
##   
## Number of Fisher Scoring iterations: 6

anova( mod17, mod18, test="Chisq") #not significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen +   
## PaymentMethod  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen +   
## PaymentMethod + PhoneService  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)  
## 1 4912 4103.4   
## 2 4911 4101.4 1 2.055 0.1517

##Interactions

str(train)

## 'data.frame': 4930 obs. of 21 variables:  
## $ customerID : chr "8917-FAEMR" "4851-BQDNX" "5445-GLVOT" "4750-ZRXIU" ...  
## $ gender : Factor w/ 2 levels "Female","Male": 1 2 1 1 1 2 2 2 2 1 ...  
## $ SeniorCitizen : Factor w/ 2 levels "0","1": 1 1 1 2 1 1 1 1 1 1 ...  
## $ Partner : Factor w/ 2 levels "No","Yes": 1 2 1 1 1 2 1 2 2 1 ...  
## $ Dependents : Factor w/ 2 levels "No","Yes": 1 2 1 1 1 2 1 1 1 1 ...  
## $ tenure : int 37 40 22 4 1 49 11 58 24 27 ...  
## $ PhoneService : Factor w/ 2 levels "No","Yes": 2 2 2 2 2 2 2 1 1 2 ...  
## $ MultipleLines : Factor w/ 3 levels "No","No phone service",..: 1 1 1 3 1 1 1 1 1 1 ...  
## $ InternetService : Factor w/ 3 levels "DSL","Fiber optic",..: 3 2 1 2 2 2 2 1 1 1 ...  
## $ OnlineSecurity : Factor w/ 3 levels "No","No internet service",..: 1 1 3 1 1 1 1 1 1 3 ...  
## $ OnlineBackup : Factor w/ 3 levels "No","No internet service",..: 1 1 1 1 1 3 1 1 1 3 ...  
## $ DeviceProtection: Factor w/ 3 levels "No","No internet service",..: 1 3 1 1 1 3 3 1 3 1 ...  
## $ TechSupport : Factor w/ 3 levels "No","No internet service",..: 1 1 1 1 1 1 1 1 1 1 ...  
## $ StreamingTV : Factor w/ 3 levels "No","No internet service",..: 1 3 1 1 1 3 1 3 1 1 ...  
## $ StreamingMovies : Factor w/ 3 levels "No","No internet service",..: 1 1 1 3 1 1 1 3 1 1 ...  
## $ Contract : Factor w/ 3 levels "Month-to-month",..: 3 2 1 1 1 1 1 2 1 3 ...  
## $ PaperlessBilling: Factor w/ 2 levels "No","Yes": 1 2 2 2 2 2 1 2 1 1 ...  
## $ PaymentMethod : Factor w/ 4 levels "Bank transfer (automatic)",..: 4 3 3 3 3 2 3 2 3 1 ...  
## $ MonthlyCharges : num 19.9 85 49.8 84.6 70.1 ...  
## $ TotalCharges : num 784.2 3355.7 1049 360.1 70.1 ...  
## $ Churn : Factor w/ 2 levels "No","Yes": 1 1 1 2 2 1 1 1 1 1 ...

We need to search for interactions. Possible interactions:

* Dependents and Multiple Lines

mod19 <- glm(Churn ~ tenure + MonthlyCharges + Contract + InternetService + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling + Dependents \* MultipleLines + SeniorCitizen + PaymentMethod, data=train, family=binomial)  
summary(mod19) #4140.4 worse

##   
## Call:  
## glm(formula = Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents \* MultipleLines + SeniorCitizen +   
## PaymentMethod, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) 0.052152 0.298076 0.175 0.861108   
## tenure -0.033288 0.002673 -12.452 < 2e-16 \*\*\*  
## MonthlyCharges -0.017353 0.006523 -2.660 0.007805 \*\*   
## ContractOne year -0.660307 0.126854 -5.205 1.94e-07 \*\*\*  
## ContractTwo year -1.425823 0.213425 -6.681 2.38e-11 \*\*\*  
## InternetServiceFiber optic 1.290777 0.226253 5.705 1.16e-08 \*\*\*  
## InternetServiceNo -1.304431 0.208303 -6.262 3.80e-10 \*\*\*  
## StreamingMoviesYes 0.395038 0.113980 3.466 0.000529 \*\*\*  
## StreamingTVYes 0.471360 0.115511 4.081 4.49e-05 \*\*\*  
## TechSupportYes -0.155875 0.108038 -1.443 0.149084   
## OnlineSecurityYes -0.210440 0.108257 -1.944 0.051909 .   
## PaperlessBillingYes 0.310985 0.088566 3.511 0.000446 \*\*\*  
## DependentsYes -0.143040 0.125091 -1.143 0.252835   
## MultipleLinesYes 0.437597 0.110848 3.948 7.89e-05 \*\*\*  
## SeniorCitizen1 0.260630 0.099962 2.607 0.009126 \*\*   
## PaymentMethodCredit card (automatic) -0.079231 0.135761 -0.584 0.559483   
## PaymentMethodElectronic check 0.361969 0.113331 3.194 0.001404 \*\*   
## PaymentMethodMailed check 0.009198 0.136248 0.068 0.946176   
## DependentsYes:MultipleLinesYes -0.201472 0.194277 -1.037 0.299720   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4102.4 on 4911 degrees of freedom  
## AIC: 4140.4  
##   
## Number of Fisher Scoring iterations: 6

anova( mod17, mod19, test="Chisq") #not significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen +   
## PaymentMethod  
## Model 2: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents \* MultipleLines + SeniorCitizen +   
## PaymentMethod  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)  
## 1 4912 4103.4   
## 2 4911 4102.4 1 1.0787 0.299

vif(mod19)

## there are higher-order terms (interactions) in this model  
## consider setting type = 'predictor'; see ?vif

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 1.963652 1 1.401304  
## MonthlyCharges 19.861675 1 4.456644  
## Contract 1.542611 2 1.114459  
## InternetService 13.037734 2 1.900205  
## StreamingMovies 2.108868 1 1.452194  
## StreamingTV 2.162588 1 1.470574  
## TechSupport 1.357407 1 1.165078  
## OnlineSecurity 1.291919 1 1.136626  
## PaperlessBilling 1.120772 1 1.058665  
## Dependents 1.727871 1 1.314485  
## MultipleLines 2.006866 1 1.416639  
## SeniorCitizen 1.117955 1 1.057334  
## PaymentMethod 1.333165 3 1.049093  
## Dependents:MultipleLines 1.920303 1 1.385750

* MonthlyCharges and InternetService

mod20 <- glm(Churn ~ tenure + InternetService \* MonthlyCharges + Contract + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling + Dependents + MultipleLines + SeniorCitizen + PaymentMethod, data=train, family=binomial)  
summary(mod20) #4133.7 better

##   
## Call:  
## glm(formula = Churn ~ tenure + InternetService \* MonthlyCharges +   
## Contract + StreamingMovies + StreamingTV + TechSupport +   
## OnlineSecurity + PaperlessBilling + Dependents + MultipleLines +   
## SeniorCitizen + PaymentMethod, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)  
## (Intercept) 0.375126 0.321672 1.166 0.243544  
## tenure -0.034642 0.002743 -12.631 < 2e-16  
## InternetServiceFiber optic -0.077307 0.611334 -0.126 0.899370  
## InternetServiceNo 1.574632 1.837650 0.857 0.391515  
## MonthlyCharges -0.021382 0.006719 -3.182 0.001460  
## ContractOne year -0.646656 0.127352 -5.078 3.82e-07  
## ContractTwo year -1.374625 0.214523 -6.408 1.48e-10  
## StreamingMoviesYes 0.301368 0.121057 2.489 0.012793  
## StreamingTVYes 0.378600 0.122216 3.098 0.001950  
## TechSupportYes -0.192043 0.109003 -1.762 0.078102  
## OnlineSecurityYes -0.233157 0.108835 -2.142 0.032170  
## PaperlessBillingYes 0.319228 0.088765 3.596 0.000323  
## DependentsYes -0.216616 0.098105 -2.208 0.027244  
## MultipleLinesYes 0.391234 0.107865 3.627 0.000287  
## SeniorCitizen1 0.260591 0.099762 2.612 0.008998  
## PaymentMethodCredit card (automatic) -0.078994 0.135960 -0.581 0.561235  
## PaymentMethodElectronic check 0.365063 0.113381 3.220 0.001283  
## PaymentMethodMailed check -0.015236 0.136746 -0.111 0.911284  
## InternetServiceFiber optic:MonthlyCharges 0.017486 0.007265 2.407 0.016083  
## InternetServiceNo:MonthlyCharges -0.150633 0.089703 -1.679 0.093104  
##   
## (Intercept)   
## tenure \*\*\*  
## InternetServiceFiber optic   
## InternetServiceNo   
## MonthlyCharges \*\*   
## ContractOne year \*\*\*  
## ContractTwo year \*\*\*  
## StreamingMoviesYes \*   
## StreamingTVYes \*\*   
## TechSupportYes .   
## OnlineSecurityYes \*   
## PaperlessBillingYes \*\*\*  
## DependentsYes \*   
## MultipleLinesYes \*\*\*  
## SeniorCitizen1 \*\*   
## PaymentMethodCredit card (automatic)   
## PaymentMethodElectronic check \*\*   
## PaymentMethodMailed check   
## InternetServiceFiber optic:MonthlyCharges \*   
## InternetServiceNo:MonthlyCharges .   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4093.7 on 4910 degrees of freedom  
## AIC: 4133.7  
##   
## Number of Fisher Scoring iterations: 6

anova( mod17, mod20, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen +   
## PaymentMethod  
## Model 2: Churn ~ tenure + InternetService \* MonthlyCharges + Contract +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen +   
## PaymentMethod  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4912 4103.4   
## 2 4910 4093.7 2 9.7694 0.007561 \*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod20)

## there are higher-order terms (interactions) in this model  
## consider setting type = 'predictor'; see ?vif

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 2.079881 1 1.442179  
## InternetService 9738.807709 2 9.934052  
## MonthlyCharges 21.386127 1 4.624514  
## Contract 1.550405 2 1.115864  
## StreamingMovies 2.374759 1 1.541025  
## StreamingTV 2.416906 1 1.554640  
## TechSupport 1.374225 1 1.172273  
## OnlineSecurity 1.300790 1 1.140522  
## PaperlessBilling 1.124965 1 1.060644  
## Dependents 1.056690 1 1.027954  
## MultipleLines 1.897486 1 1.377493  
## SeniorCitizen 1.115802 1 1.056315  
## PaymentMethod 1.346214 3 1.050797  
## InternetService:MonthlyCharges 11466.767397 2 10.348091

We improved the model but multicolinearity worse ??? ???DUBTE pk apareixen les variables com si estiguessin tambe per separat i no nomes com una interaccio? A l’anterior model ens surt nomes la interaccio.

* SeniorCitizen and PaymentMethod

mod21 <- glm(Churn ~ tenure + InternetService + MonthlyCharges + Contract + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling + Dependents + MultipleLines + SeniorCitizen \* PaymentMethod, data=train, family=binomial)  
summary(mod21) #4133 better and also better than mod20

##   
## Call:  
## glm(formula = Churn ~ tenure + InternetService + MonthlyCharges +   
## Contract + StreamingMovies + StreamingTV + TechSupport +   
## OnlineSecurity + PaperlessBilling + Dependents + MultipleLines +   
## SeniorCitizen \* PaymentMethod, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error  
## (Intercept) 0.141297 0.300816  
## tenure -0.033374 0.002679  
## InternetServiceFiber optic 1.282211 0.226985  
## InternetServiceNo -1.272943 0.209319  
## MonthlyCharges -0.017310 0.006552  
## ContractOne year -0.657185 0.127109  
## ContractTwo year -1.425156 0.213670  
## StreamingMoviesYes 0.401118 0.114247  
## StreamingTVYes 0.480398 0.115811  
## TechSupportYes -0.160516 0.108364  
## OnlineSecurityYes -0.210705 0.108492  
## PaperlessBillingYes 0.313662 0.088759  
## DependentsYes -0.232981 0.098228  
## MultipleLinesYes 0.402258 0.103847  
## SeniorCitizen1 -0.130083 0.241594  
## PaymentMethodCredit card (automatic) -0.268973 0.153765  
## PaymentMethodElectronic check 0.321001 0.126943  
## PaymentMethodMailed check -0.128290 0.146279  
## SeniorCitizen1:PaymentMethodCredit card (automatic) 0.888203 0.332890  
## SeniorCitizen1:PaymentMethodElectronic check 0.254924 0.271153  
## SeniorCitizen1:PaymentMethodMailed check 0.981702 0.380207  
## z value Pr(>|z|)   
## (Intercept) 0.470 0.638560   
## tenure -12.456 < 2e-16 \*\*\*  
## InternetServiceFiber optic 5.649 1.62e-08 \*\*\*  
## InternetServiceNo -6.081 1.19e-09 \*\*\*  
## MonthlyCharges -2.642 0.008248 \*\*   
## ContractOne year -5.170 2.34e-07 \*\*\*  
## ContractTwo year -6.670 2.56e-11 \*\*\*  
## StreamingMoviesYes 3.511 0.000446 \*\*\*  
## StreamingTVYes 4.148 3.35e-05 \*\*\*  
## TechSupportYes -1.481 0.138534   
## OnlineSecurityYes -1.942 0.052123 .   
## PaperlessBillingYes 3.534 0.000410 \*\*\*  
## DependentsYes -2.372 0.017700 \*   
## MultipleLinesYes 3.874 0.000107 \*\*\*  
## SeniorCitizen1 -0.538 0.590277   
## PaymentMethodCredit card (automatic) -1.749 0.080249 .   
## PaymentMethodElectronic check 2.529 0.011448 \*   
## PaymentMethodMailed check -0.877 0.380476   
## SeniorCitizen1:PaymentMethodCredit card (automatic) 2.668 0.007627 \*\*   
## SeniorCitizen1:PaymentMethodElectronic check 0.940 0.347141   
## SeniorCitizen1:PaymentMethodMailed check 2.582 0.009822 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4091.0 on 4909 degrees of freedom  
## AIC: 4133  
##   
## Number of Fisher Scoring iterations: 6

anova( mod17, mod21, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + MonthlyCharges + Contract + InternetService +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen +   
## PaymentMethod  
## Model 2: Churn ~ tenure + InternetService + MonthlyCharges + Contract +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen \*   
## PaymentMethod  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4912 4103.4   
## 2 4909 4091.0 3 12.396 0.006144 \*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

anova( mod20, mod21, test="Chisq") #not significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + InternetService \* MonthlyCharges + Contract +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen +   
## PaymentMethod  
## Model 2: Churn ~ tenure + InternetService + MonthlyCharges + Contract +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen \*   
## PaymentMethod  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)  
## 1 4910 4093.7   
## 2 4909 4091.0 1 2.6261 0.1051

vif(mod21) #better multicollinearity

## there are higher-order terms (interactions) in this model  
## consider setting type = 'predictor'; see ?vif

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 1.973899 1 1.404955  
## InternetService 13.127210 2 1.903457  
## MonthlyCharges 19.972402 1 4.469049  
## Contract 1.548154 2 1.115459  
## StreamingMovies 2.114568 1 1.454155  
## StreamingTV 2.168544 1 1.472598  
## TechSupport 1.359278 1 1.165881  
## OnlineSecurity 1.292280 1 1.136785  
## PaperlessBilling 1.120630 1 1.058598  
## Dependents 1.058287 1 1.028731  
## MultipleLines 1.759302 1 1.326387  
## SeniorCitizen 6.564344 1 2.562098  
## PaymentMethod 2.413718 3 1.158193  
## SeniorCitizen:PaymentMethod 10.225907 3 1.473274

mod22 <- glm(Churn ~ tenure + InternetService \* MonthlyCharges + Contract + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling + Dependents + MultipleLines + SeniorCitizen \* PaymentMethod, data=train, family=binomial)  
summary(mod22) #4126.8 better

##   
## Call:  
## glm(formula = Churn ~ tenure + InternetService \* MonthlyCharges +   
## Contract + StreamingMovies + StreamingTV + TechSupport +   
## OnlineSecurity + PaperlessBilling + Dependents + MultipleLines +   
## SeniorCitizen \* PaymentMethod, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error  
## (Intercept) 0.456138 0.325349  
## tenure -0.034778 0.002752  
## InternetServiceFiber optic -0.115161 0.612924  
## InternetServiceNo 1.691658 1.840678  
## MonthlyCharges -0.021370 0.006747  
## ContractOne year -0.642438 0.127587  
## ContractTwo year -1.371659 0.214758  
## StreamingMoviesYes 0.305263 0.121349  
## StreamingTVYes 0.384985 0.122509  
## TechSupportYes -0.195397 0.109349  
## OnlineSecurityYes -0.235747 0.109076  
## PaperlessBillingYes 0.322751 0.088957  
## DependentsYes -0.224786 0.098426  
## MultipleLinesYes 0.397526 0.108260  
## SeniorCitizen1 -0.145982 0.241757  
## PaymentMethodCredit card (automatic) -0.274207 0.154136  
## PaymentMethodElectronic check 0.318908 0.127152  
## PaymentMethodMailed check -0.159864 0.146983  
## InternetServiceFiber optic:MonthlyCharges 0.017835 0.007286  
## InternetServiceNo:MonthlyCharges -0.154986 0.089834  
## SeniorCitizen1:PaymentMethodCredit card (automatic) 0.907214 0.333083  
## SeniorCitizen1:PaymentMethodElectronic check 0.266655 0.271289  
## SeniorCitizen1:PaymentMethodMailed check 1.002326 0.379973  
## z value Pr(>|z|)   
## (Intercept) 1.402 0.160917   
## tenure -12.639 < 2e-16 \*\*\*  
## InternetServiceFiber optic -0.188 0.850965   
## InternetServiceNo 0.919 0.358074   
## MonthlyCharges -3.167 0.001538 \*\*   
## ContractOne year -5.035 4.77e-07 \*\*\*  
## ContractTwo year -6.387 1.69e-10 \*\*\*  
## StreamingMoviesYes 2.516 0.011884 \*   
## StreamingTVYes 3.142 0.001675 \*\*   
## TechSupportYes -1.787 0.073952 .   
## OnlineSecurityYes -2.161 0.030672 \*   
## PaperlessBillingYes 3.628 0.000285 \*\*\*  
## DependentsYes -2.284 0.022383 \*   
## MultipleLinesYes 3.672 0.000241 \*\*\*  
## SeniorCitizen1 -0.604 0.545951   
## PaymentMethodCredit card (automatic) -1.779 0.075241 .   
## PaymentMethodElectronic check 2.508 0.012139 \*   
## PaymentMethodMailed check -1.088 0.276756   
## InternetServiceFiber optic:MonthlyCharges 2.448 0.014369 \*   
## InternetServiceNo:MonthlyCharges -1.725 0.084483 .   
## SeniorCitizen1:PaymentMethodCredit card (automatic) 2.724 0.006456 \*\*   
## SeniorCitizen1:PaymentMethodElectronic check 0.983 0.325647   
## SeniorCitizen1:PaymentMethodMailed check 2.638 0.008342 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4080.8 on 4907 degrees of freedom  
## AIC: 4126.8  
##   
## Number of Fisher Scoring iterations: 6

anova( mod21, mod22, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + InternetService + MonthlyCharges + Contract +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen \*   
## PaymentMethod  
## Model 2: Churn ~ tenure + InternetService \* MonthlyCharges + Contract +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen \*   
## PaymentMethod  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4909 4091.0   
## 2 4907 4080.8 2 10.203 0.006088 \*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

anova( mod20, mod22, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + InternetService \* MonthlyCharges + Contract +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen +   
## PaymentMethod  
## Model 2: Churn ~ tenure + InternetService \* MonthlyCharges + Contract +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen \*   
## PaymentMethod  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4910 4093.7   
## 2 4907 4080.8 3 12.829 0.005021 \*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod22)

## there are higher-order terms (interactions) in this model  
## consider setting type = 'predictor'; see ?vif

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 2.092433 1 1.446525  
## InternetService 9747.368394 2 9.936235  
## MonthlyCharges 21.496711 1 4.636455  
## Contract 1.554570 2 1.116613  
## StreamingMovies 2.379677 1 1.542620  
## StreamingTV 2.420865 1 1.555913  
## TechSupport 1.375906 1 1.172990  
## OnlineSecurity 1.300799 1 1.140526  
## PaperlessBilling 1.124887 1 1.060607  
## Dependents 1.057390 1 1.028295  
## MultipleLines 1.905667 1 1.380459  
## SeniorCitizen 6.580622 1 2.565272  
## PaymentMethod 2.445976 3 1.160759  
## InternetService:MonthlyCharges 11487.448457 2 10.352754  
## SeniorCitizen:PaymentMethod 10.277317 3 1.474506

#deviance(ngm4);ngm4$df.residual  
#deviance(ngm6);ngm6$df.residual  
#deviance(ngm4)-deviance(ngm6)  
#((deviance(ngm4)-deviance(ngm6))/6)/1.1678  
#1-pf(1.533252,6,53)

Having both interactions improves the model but VIF gets worse. The best model is with SeniorCitizen and PaymentMethod interaction (mod21)

##Second Order variable

mod23 <- glm(Churn ~ tenure + I(tenure^2) + InternetService + MonthlyCharges + Contract + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling + Dependents + MultipleLines + SeniorCitizen \* PaymentMethod, data=train, family=binomial)  
summary(mod23) #4088.4 better

##   
## Call:  
## glm(formula = Churn ~ tenure + I(tenure^2) + InternetService +   
## MonthlyCharges + Contract + StreamingMovies + StreamingTV +   
## TechSupport + OnlineSecurity + PaperlessBilling + Dependents +   
## MultipleLines + SeniorCitizen \* PaymentMethod, family = binomial,   
## data = train)  
##   
## Coefficients:  
## Estimate Std. Error  
## (Intercept) 0.5107106 0.3092170  
## tenure -0.0771493 0.0070299  
## I(tenure^2) 0.0007065 0.0001032  
## InternetServiceFiber optic 1.3144174 0.2305726  
## InternetServiceNo -1.3024378 0.2114289  
## MonthlyCharges -0.0182734 0.0066490  
## ContractOne year -0.7035302 0.1300795  
## ContractTwo year -1.8604502 0.2303320  
## StreamingMoviesYes 0.4269526 0.1157338  
## StreamingTVYes 0.5127531 0.1175811  
## TechSupportYes -0.1235944 0.1090855  
## OnlineSecurityYes -0.1883864 0.1091173  
## PaperlessBillingYes 0.3134114 0.0898515  
## DependentsYes -0.2014632 0.0988339  
## MultipleLinesYes 0.4459449 0.1060891  
## SeniorCitizen1 -0.1252740 0.2393366  
## PaymentMethodCredit card (automatic) -0.2599261 0.1536875  
## PaymentMethodElectronic check 0.2743968 0.1276380  
## PaymentMethodMailed check -0.2024297 0.1486121  
## SeniorCitizen1:PaymentMethodCredit card (automatic) 0.8146949 0.3291341  
## SeniorCitizen1:PaymentMethodElectronic check 0.2817633 0.2695343  
## SeniorCitizen1:PaymentMethodMailed check 1.0361353 0.3844824  
## z value Pr(>|z|)   
## (Intercept) 1.652 0.098611 .   
## tenure -10.974 < 2e-16 \*\*\*  
## I(tenure^2) 6.844 7.70e-12 \*\*\*  
## InternetServiceFiber optic 5.701 1.19e-08 \*\*\*  
## InternetServiceNo -6.160 7.27e-10 \*\*\*  
## MonthlyCharges -2.748 0.005991 \*\*   
## ContractOne year -5.408 6.36e-08 \*\*\*  
## ContractTwo year -8.077 6.62e-16 \*\*\*  
## StreamingMoviesYes 3.689 0.000225 \*\*\*  
## StreamingTVYes 4.361 1.30e-05 \*\*\*  
## TechSupportYes -1.133 0.257212   
## OnlineSecurityYes -1.726 0.084265 .   
## PaperlessBillingYes 3.488 0.000486 \*\*\*  
## DependentsYes -2.038 0.041510 \*   
## MultipleLinesYes 4.203 2.63e-05 \*\*\*  
## SeniorCitizen1 -0.523 0.600681   
## PaymentMethodCredit card (automatic) -1.691 0.090786 .   
## PaymentMethodElectronic check 2.150 0.031571 \*   
## PaymentMethodMailed check -1.362 0.173155   
## SeniorCitizen1:PaymentMethodCredit card (automatic) 2.475 0.013314 \*   
## SeniorCitizen1:PaymentMethodElectronic check 1.045 0.295852   
## SeniorCitizen1:PaymentMethodMailed check 2.695 0.007041 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4044.4 on 4908 degrees of freedom  
## AIC: 4088.4  
##   
## Number of Fisher Scoring iterations: 6

anova( mod21, mod23, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + InternetService + MonthlyCharges + Contract +   
## StreamingMovies + StreamingTV + TechSupport + OnlineSecurity +   
## PaperlessBilling + Dependents + MultipleLines + SeniorCitizen \*   
## PaymentMethod  
## Model 2: Churn ~ tenure + I(tenure^2) + InternetService + MonthlyCharges +   
## Contract + StreamingMovies + StreamingTV + TechSupport +   
## OnlineSecurity + PaperlessBilling + Dependents + MultipleLines +   
## SeniorCitizen \* PaymentMethod  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4909 4091.0   
## 2 4908 4044.4 1 46.672 8.392e-12 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod23)

## there are higher-order terms (interactions) in this model  
## consider setting type = 'predictor'; see ?vif

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 15.110913 1 3.887276  
## I(tenure^2) 14.413478 1 3.796509  
## InternetService 13.143356 2 1.904042  
## MonthlyCharges 20.658589 1 4.545172  
## Contract 1.830861 2 1.163225  
## StreamingMovies 2.155609 1 1.468199  
## StreamingTV 2.220993 1 1.490300  
## TechSupport 1.373947 1 1.172155  
## OnlineSecurity 1.306102 1 1.142848  
## PaperlessBilling 1.124076 1 1.060225  
## Dependents 1.060211 1 1.029666  
## MultipleLines 1.824384 1 1.350697  
## SeniorCitizen 6.421969 1 2.534160  
## PaymentMethod 2.503172 3 1.165239  
## SeniorCitizen:PaymentMethod 10.118072 3 1.470674

mod23.1 <- glm(Churn ~ tenure + I(tenure^2) + InternetService + Contract + StreamingMovies + StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling + Dependents + MultipleLines + SeniorCitizen \* PaymentMethod, data=train, family=binomial)  
summary(mod23.1) #4093.9 worse

##   
## Call:  
## glm(formula = Churn ~ tenure + I(tenure^2) + InternetService +   
## Contract + StreamingMovies + StreamingTV + TechSupport +   
## OnlineSecurity + PaperlessBilling + Dependents + MultipleLines +   
## SeniorCitizen \* PaymentMethod, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error  
## (Intercept) -0.2266620 0.1556297  
## tenure -0.0772783 0.0070216  
## I(tenure^2) 0.0007013 0.0001031  
## InternetServiceFiber optic 0.7470363 0.0992282  
## InternetServiceNo -0.9173866 0.1597837  
## ContractOne year -0.7248815 0.1298952  
## ContractTwo year -1.8789493 0.2307197  
## StreamingMoviesYes 0.2445740 0.0944671  
## StreamingTVYes 0.3265157 0.0957678  
## TechSupportYes -0.2377202 0.1008359  
## OnlineSecurityYes -0.2941833 0.1020655  
## PaperlessBillingYes 0.3161947 0.0897272  
## DependentsYes -0.2077444 0.0986981  
## MultipleLinesYes 0.3089745 0.0929888  
## SeniorCitizen1 -0.1292747 0.2389069  
## PaymentMethodCredit card (automatic) -0.2615723 0.1535825  
## PaymentMethodElectronic check 0.2821311 0.1274583  
## PaymentMethodMailed check -0.2022035 0.1484063  
## SeniorCitizen1:PaymentMethodCredit card (automatic) 0.8216282 0.3286077  
## SeniorCitizen1:PaymentMethodElectronic check 0.2920587 0.2690766  
## SeniorCitizen1:PaymentMethodMailed check 1.0494607 0.3836744  
## z value Pr(>|z|)   
## (Intercept) -1.456 0.145277   
## tenure -11.006 < 2e-16 \*\*\*  
## I(tenure^2) 6.802 1.03e-11 \*\*\*  
## InternetServiceFiber optic 7.528 5.13e-14 \*\*\*  
## InternetServiceNo -5.741 9.39e-09 \*\*\*  
## ContractOne year -5.581 2.40e-08 \*\*\*  
## ContractTwo year -8.144 3.83e-16 \*\*\*  
## StreamingMoviesYes 2.589 0.009626 \*\*   
## StreamingTVYes 3.409 0.000651 \*\*\*  
## TechSupportYes -2.357 0.018399 \*   
## OnlineSecurityYes -2.882 0.003948 \*\*   
## PaperlessBillingYes 3.524 0.000425 \*\*\*  
## DependentsYes -2.105 0.035305 \*   
## MultipleLinesYes 3.323 0.000891 \*\*\*  
## SeniorCitizen1 -0.541 0.588432   
## PaymentMethodCredit card (automatic) -1.703 0.088542 .   
## PaymentMethodElectronic check 2.214 0.026862 \*   
## PaymentMethodMailed check -1.362 0.173040   
## SeniorCitizen1:PaymentMethodCredit card (automatic) 2.500 0.012408 \*   
## SeniorCitizen1:PaymentMethodElectronic check 1.085 0.277740   
## SeniorCitizen1:PaymentMethodMailed check 2.735 0.006233 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4051.9 on 4909 degrees of freedom  
## AIC: 4093.9  
##   
## Number of Fisher Scoring iterations: 6

anova( mod23, mod23.1, test="Chisq") #significant

## Analysis of Deviance Table  
##   
## Model 1: Churn ~ tenure + I(tenure^2) + InternetService + MonthlyCharges +   
## Contract + StreamingMovies + StreamingTV + TechSupport +   
## OnlineSecurity + PaperlessBilling + Dependents + MultipleLines +   
## SeniorCitizen \* PaymentMethod  
## Model 2: Churn ~ tenure + I(tenure^2) + InternetService + Contract + StreamingMovies +   
## StreamingTV + TechSupport + OnlineSecurity + PaperlessBilling +   
## Dependents + MultipleLines + SeniorCitizen \* PaymentMethod  
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)   
## 1 4908 4044.4   
## 2 4909 4051.9 -1 -7.5068 0.006147 \*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

vif(mod23.1) #better vif

## there are higher-order terms (interactions) in this model  
## consider setting type = 'predictor'; see ?vif

## GVIF Df GVIF^(1/(2\*Df))  
## tenure 15.094283 1 3.885136  
## I(tenure^2) 14.395726 1 3.794170  
## InternetService 1.753349 2 1.150713  
## Contract 1.832458 2 1.163479  
## StreamingMovies 1.439408 1 1.199753  
## StreamingTV 1.476549 1 1.215133  
## TechSupport 1.176693 1 1.084755  
## OnlineSecurity 1.145979 1 1.070504  
## PaperlessBilling 1.123469 1 1.059938  
## Dependents 1.059050 1 1.029102  
## MultipleLines 1.406194 1 1.185831  
## SeniorCitizen 6.416355 1 2.533052  
## PaymentMethod 2.500773 3 1.165053  
## SeniorCitizen:PaymentMethod 10.110887 3 1.470499

Removing *MonthlyCharges* from the model is getting a bit worse the AIC but the change is significant and it improves the VIF.

Això ho podem posar a l’annex i deixem els comentaris al report

Univariate

names(train)

## [1] "customerID" "gender" "SeniorCitizen" "Partner"   
## [5] "Dependents" "tenure" "PhoneService" "MultipleLines"   
## [9] "InternetService" "OnlineSecurity" "OnlineBackup" "DeviceProtection"  
## [13] "TechSupport" "StreamingTV" "StreamingMovies" "Contract"   
## [17] "PaperlessBilling" "PaymentMethod" "MonthlyCharges" "TotalCharges"   
## [21] "Churn"

mod <- glm(Churn ~ gender, data=train, family=binomial)  
summary(mod)

##   
## Call:  
## glm(formula = Churn ~ gender, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.00637 0.04542 -22.158 <2e-16 \*\*\*  
## genderMale -0.03499 0.06460 -0.542 0.588   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5693.9 on 4928 degrees of freedom  
## AIC: 5697.9  
##   
## Number of Fisher Scoring iterations: 4

mod2 <- glm(Churn ~ SeniorCitizen, data=train, family=binomial)  
summary(mod2)

##   
## Call:  
## glm(formula = Churn ~ SeniorCitizen, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.19026 0.03682 -32.33 <2e-16 \*\*\*  
## SeniorCitizen1 0.88226 0.08027 10.99 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5577.9 on 4928 degrees of freedom  
## AIC: 5581.9  
##   
## Number of Fisher Scoring iterations: 4

mod3 <- glm(Churn ~ Partner, data=train, family=binomial)  
summary(mod3)

##   
## Call:  
## glm(formula = Churn ~ Partner, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -0.70909 0.04215 -16.82 <2e-16 \*\*\*  
## PartnerYes -0.71326 0.06676 -10.68 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5576.5 on 4928 degrees of freedom  
## AIC: 5580.5  
##   
## Number of Fisher Scoring iterations: 4

mod4 <- glm(Churn ~ Dependents, data=train, family=binomial)  
summary(mod4)

##   
## Call:  
## glm(formula = Churn ~ Dependents, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -0.78158 0.03662 -21.34 <2e-16 \*\*\*  
## DependentsYes -0.97564 0.08228 -11.86 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5534.9 on 4928 degrees of freedom  
## AIC: 5538.9  
##   
## Number of Fisher Scoring iterations: 4

mod5 <- glm(Churn ~ tenure, data=train, family=binomial)  
summary(mod5)

##   
## Call:  
## glm(formula = Churn ~ tenure, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) 0.010348 0.050517 0.205 0.838   
## tenure -0.038339 0.001679 -22.837 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5040.7 on 4928 degrees of freedom  
## AIC: 5044.7  
##   
## Number of Fisher Scoring iterations: 4

mod6 <- glm(Churn ~ PhoneService, data=train, family=binomial)  
summary(mod6)

##   
## Call:  
## glm(formula = Churn ~ PhoneService, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.1415 0.1076 -10.611 <2e-16 \*\*\*  
## PhoneServiceYes 0.1299 0.1128 1.151 0.25   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5692.9 on 4928 degrees of freedom  
## AIC: 5696.9  
##   
## Number of Fisher Scoring iterations: 4

mod7 <- glm(Churn ~ MultipleLines, data=train, family=binomial)  
summary(mod7)

##   
## Call:  
## glm(formula = Churn ~ MultipleLines, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.12350 0.04348 -25.841 < 2e-16 \*\*\*  
## MultipleLinesYes 0.23006 0.06505 3.537 0.000405 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5681.7 on 4928 degrees of freedom  
## AIC: 5685.7  
##   
## Number of Fisher Scoring iterations: 4

mod8 <- glm(Churn ~ InternetService, data=train, family=binomial)  
summary(mod8)

##   
## Call:  
## glm(formula = Churn ~ InternetService, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.47098 0.06258 -23.506 <2e-16 \*\*\*  
## InternetServiceFiber optic 1.13842 0.07611 14.957 <2e-16 \*\*\*  
## InternetServiceNo -1.11658 0.13582 -8.221 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5132.9 on 4927 degrees of freedom  
## AIC: 5138.9  
##   
## Number of Fisher Scoring iterations: 5

mod9 <- glm(Churn ~ OnlineSecurity, data=train, family=binomial)  
summary(mod9)

##   
## Call:  
## glm(formula = Churn ~ OnlineSecurity, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -0.79719 0.03633 -21.94 <2e-16 \*\*\*  
## OnlineSecurityYes -0.96472 0.08405 -11.48 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5544.3 on 4928 degrees of freedom  
## AIC: 5548.3  
##   
## Number of Fisher Scoring iterations: 4

mod10 <- glm(Churn ~ OnlineBackup, data=train, family=binomial)  
summary(mod10)

##   
## Call:  
## glm(formula = Churn ~ OnlineBackup, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -0.91109 0.03891 -23.414 < 2e-16 \*\*\*  
## OnlineBackupYes -0.34507 0.07016 -4.919 8.72e-07 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5669.4 on 4928 degrees of freedom  
## AIC: 5673.4  
##   
## Number of Fisher Scoring iterations: 4

mod11 <- glm(Churn ~ DeviceProtection, data=train, family=binomial)  
summary(mod11)

##   
## Call:  
## glm(formula = Churn ~ DeviceProtection, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -0.93239 0.03909 -23.852 < 2e-16 \*\*\*  
## DeviceProtectionYes -0.27669 0.06963 -3.973 7.09e-05 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5678.1 on 4928 degrees of freedom  
## AIC: 5682.1  
##   
## Number of Fisher Scoring iterations: 4

mod12 <- glm(Churn ~ TechSupport, data=train, family=binomial)  
summary(mod12)

##   
## Call:  
## glm(formula = Churn ~ TechSupport, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -0.80594 0.03674 -21.94 <2e-16 \*\*\*  
## TechSupportYes -0.86397 0.08058 -10.72 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5566.6 on 4928 degrees of freedom  
## AIC: 5570.6  
##   
## Number of Fisher Scoring iterations: 4

mod13 <- glm(Churn ~ StreamingTV, data=train, family=binomial)  
summary(mod13)

##   
## Call:  
## glm(formula = Churn ~ StreamingTV, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.14795 0.04263 -26.931 < 2e-16 \*\*\*  
## StreamingTVYes 0.30561 0.06551 4.665 3.09e-06 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5672.6 on 4928 degrees of freedom  
## AIC: 5676.6  
##   
## Number of Fisher Scoring iterations: 4

mod14 <- glm(Churn ~ StreamingMovies, data=train, family=binomial)  
summary(mod14)

##   
## Call:  
## glm(formula = Churn ~ StreamingMovies, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.12512 0.04254 -26.449 < 2e-16 \*\*\*  
## StreamingMoviesYes 0.24849 0.06550 3.794 0.000148 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5679.9 on 4928 degrees of freedom  
## AIC: 5683.9  
##   
## Number of Fisher Scoring iterations: 4

mod15 <- glm(Churn ~ Contract, data=train, family=binomial)  
summary(mod15)

##   
## Call:  
## glm(formula = Churn ~ Contract, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -0.30975 0.03876 -7.992 1.33e-15 \*\*\*  
## ContractOne year -1.73958 0.10521 -16.535 < 2e-16 \*\*\*  
## ContractTwo year -3.29329 0.18611 -17.695 < 2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 4736.2 on 4927 degrees of freedom  
## AIC: 4742.2  
##   
## Number of Fisher Scoring iterations: 6

mod16 <- glm(Churn ~ PaperlessBilling, data=train, family=binomial)  
summary(mod16)

##   
## Call:  
## glm(formula = Churn ~ PaperlessBilling, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.62562 0.06013 -27.04 <2e-16 \*\*\*  
## PaperlessBillingYes 0.93196 0.07182 12.98 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5512.4 on 4928 degrees of freedom  
## AIC: 5516.4  
##   
## Number of Fisher Scoring iterations: 4

mod17 <- glm(Churn ~ PaymentMethod, data=train, family=binomial)  
summary(mod17)

##   
## Call:  
## glm(formula = Churn ~ PaymentMethod, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.59686 0.08266 -19.319 <2e-16 \*\*\*  
## PaymentMethodCredit card (automatic) -0.15101 0.11847 -1.275 0.202   
## PaymentMethodElectronic check 1.40923 0.09627 14.638 <2e-16 \*\*\*  
## PaymentMethodMailed check 0.13813 0.11233 1.230 0.219   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5246.3 on 4926 degrees of freedom  
## AIC: 5254.3  
##   
## Number of Fisher Scoring iterations: 4

mod18 <- glm(Churn ~ MonthlyCharges, data=train, family=binomial)  
summary(mod18)

##   
## Call:  
## glm(formula = Churn ~ MonthlyCharges, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -2.120267 0.090047 -23.55 <2e-16 \*\*\*  
## MonthlyCharges 0.016008 0.001166 13.73 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5491.4 on 4928 degrees of freedom  
## AIC: 5495.4  
##   
## Number of Fisher Scoring iterations: 4

mod19 <- glm(Churn ~ TotalCharges, data=train, family=binomial)  
summary(mod19)

##   
## Call:  
## glm(formula = Churn ~ TotalCharges, family = binomial, data = train)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -5.713e-01 4.451e-02 -12.84 <2e-16 \*\*\*  
## TotalCharges -2.257e-04 1.726e-05 -13.07 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 5694.2 on 4929 degrees of freedom  
## Residual deviance: 5494.9 on 4928 degrees of freedom  
## AIC: 5498.9  
##   
## Number of Fisher Scoring iterations: 4

AIC(mod)

## [1] 5697.925