**Multiple Linear Regression to Assess Customer Tenure**

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**A1. Research Question**

The question that will be addressed is, "What variables are associated with customer tenure, and what is their relationship?". Longer tenure means that the customers stayed with the same company for a longer period of time. This research question is important because understanding the factors that drive influence tenure will allow the business to implement targeted changes to increase customer tenure and retain customers for longer periods of time.

**A2. Goals**

The goal of this analysis is to use a multiple linear regression to identify features that are related to customer tenure in order to make predictions about how the related features will affect customer tenure.

**B1. Summary of Assumptions**

The assumptions of a multiple linear regression are: 1) there is a linear relationship between the independent variables and the dependent variable, 2) the independent variables are not highly correlated, 3) the observations are independent of each other, 4) the residuals have a constant variance and 5) the residuals are normally distributed.

**B2. Tool Benefits**

Python programming language was used to model the data. Python was chosen for its versatility, readability, and diverse functions. In addition, the syntax is consistent and simple to interpret, which is ideal when sharing your analysis with others who may not have coding experience. R does not have consistent syntax across libraries, making it more difficult to understand learn and understand.

Several python libraries were used, including pandas, numpy, matplotlib, scipy, sci-kit learn, and seaborn. Pandas is a common library used for working with data frames in python. It includes many tools for computations and analysis on data frames (McKinney, 2010). Numpy is used for many summary statistics throughout the analysis process (Harris et al., 2020; Larose & Larose, 2019). Scipy and sci-kit learn libraries work together to offer various statistical models used to impute missing data (Pedregosa et al., 2011; Virtanen et al., 2020). Matplotlib and seaborn offer data visualization tools (Hunter, 2007; Waskom, 2021).

**B3. Appropriate Technique**

Multiple linear regression allows us to assess the relationship between a numeric variable, like customer tenure, and multiple predictor variables of different types. This analysis will allow us to not only identify which variables have a significant relationship with customer tenure, but it will also tell us what type of relationship exists. This will allow us to make predictions about customer tenure based on other predictor variables.

**C1. Data Cleaning**

First, data was checked for missing values and duplicates. No missing values or duplicates were found in the provided dataset. Second, the categorical variables with high cardinality, specifically more than five groups, were dropped from the dataset. The annotated code is attached.

**C2. Summary Statistics**

Table

Description automatically generatedThe dependent variable for the analysis is tenure. The independent variables chosen for the analysis are Bandwidth\_GB\_Year, Churn, OnlineBackup, DeviceProtection, Area and Contract. These variables were identified using Pearson correlation and t-test statistics to identify potentially significant relationships between the variables.

Table 1: Summary Statistics of Relevant Quantitative Variables

The describe() function in python was used to calculate summary statistics (Table 1). The relevant categorical variables are not shown in the output as these summary statistics are not calculated for categorical variables, only for quantitative variables.

Table

Description automatically generated with medium confidenceThe mean customer tenure is 34.5 months, which means that customers stay enrolled in services for 34.5 months on average. The standard deviation is 26.4 months, with a minimum of 1 month and a maximum of almost 72 months. This means that there is a wide range in customer tenures. The mean falls close to the middle of the range. The mean bandwidth is 3392.3 GB per year, with a standard deviation of 2185.3 and a range from 155.5 to 7158.98. As with the tenure variable, the mean falls close the middle of the range.

To summarize categorical variables, I used the value\_counts() function in python to count the number of customers in each group of the categorical variables (Figure 1). For the “Churn” variable, there are almost three times as many “no” customers are there are “yes”. The variables “OnlineBackup”, “DeviceProtection”, and “Area” have pretty even distributions between groups. For the “Contract” variable, about half of the customers are month-to-month customers, while the other half is split fairly evenly between one-year and two-year contracts.

Figure : Summary Statistics for categorical variables

**C3. Visualizations**

Univariate and Bivariate graphs for all variables are provided in figure 2.

**C4. Data Transformation**

Categorical variables were transformed into dummy variables for the analysis. Dummy variables are binary values of 0 or 1, where 0 represents "no" or not being a member of that group and 1 A picture containing background pattern

Description automatically generatedrepresents "yes" or being a member of the group. Using dummy variables prevents us from having to make multiple models to represent different groups (Garavaglia and Sharma, 1998).

After creation of dummy variables, the data were scaled using the StandardScaler() function from the sci-kit learn library in python (Pedregosa et. al 2011). This function scales features so that they will have a Gaussian normal distribution with a mean of zero and a standard deviation of 1. Scaling data is important so that all features carry the same weight in the model and so that regression coefficients can be directly compared between features. This is also important for the recursive feature elimination used during model reduction.

**C5. Prepared Dataset**

Figure : Univariate and Bivariate graphs

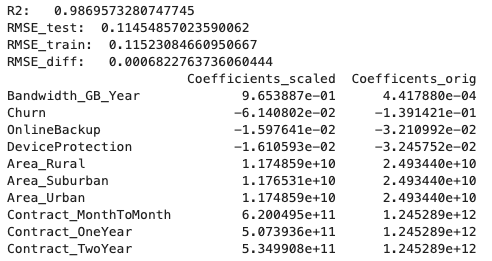
The final prepared dataset is attached.

**D1. Initial Model**

The initial multiple linear regression model is:

*Tenure = b1* *Bandwidth\_GB\_Year + b2 Churn + b3 OnlineBackup + b4 DeviceProtection + b5 Area\_Rural + b6 Area\_Suburban + b7 Area\_Urban + b8 Contract\_MonthToMonth +  
b9 Contract\_OneYear + b10 Contract\_TwoYear*

where and *bi (i= 1-10)* are the regression coefficients. The regression output is provided below, including both scaled and unscaled (original) coefficients.



**D2. Justification of Model Reduction**

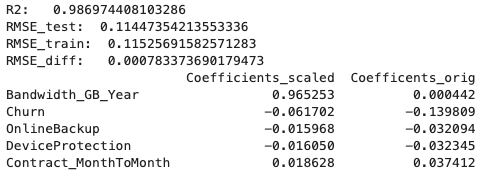
Recursive feature elimination (RFE) was used to identify which features should be dropped from the model. RFE eliminates features by fitting the model multiple times while recursively eliminating the weakest features based on their importance. RFE is preferred over stepwise feature selection because stepwise feature selection can sometimes include features that do not directly impact the dependent variable but are correlated with another feature that does (Smith 2018). The RFE function from the sci-kit learn python library was used for this analysis (Pedregosa et al. 2011).

**D3. Reduced Linear Regression Model**

The reduced multiple linear regression model is:

*Tenure = b1* *Bandwidth\_GB\_Year + b2 Churn + b3 OnlineBackup + b4 DeviceProtection + b5 Contract\_MonthToMonth*

where and *bi (i= 1-5)* are the regression coefficients. The regression output is provided below.



**E1. Model Comparison**

RFE removed five of the features from the dataset, resulting in a multiple regression model with five independent variables: Bandwidth\_GB\_Year, Churn, OnlineBackup, DeviceProtection, and Contract\_MonthToMonth. The R2 value increased slightly in the reduced model, but the change in R2 and RMSE is almost zero. Cross validation tests of the two models produced similar results, with the average R2 of the reduced model being slightly higher than the initial model.

*Cross validation results for initial model:*

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*Cross validation results for reduced model:*

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**E2. Output and Calculations**

The RMSE of the initial model was 0.011454. The RMSE of the reduced model was slightly lower at 0.011447. For both models, the RMSE difference between the training dataset and test dataset were small, indicating that the models were not overfit to the training data. The difference in RMSE was slightly higher for the reduced model, but the difference is so small it is negligible. Residual qqplots were created for each model, which yielded nearly identical results.

|  |  |
| --- | --- |
| **Initial Model** | **Reduced Model** |
|  |  |

**E3. Code**

The python code written in jupyter lab notebook is attached.

**F1. Results**

The reduced regression model equation with predicted unscaled coefficients is:

*Tenure = 0.00044\*Bandwidth\_GB\_Year - 0.13\*Churn – 0.032\*OnlineBackup -0.032\*DeviceProtection + 0.037\*Contract\_MonthToMonth*

Based on the regression coefficients, Bandwidth\_GB\_Year and Contract\_MonthToMonth have positive relationships with customer tenure. The remaining variables, Churn, Onlinebackup, and DeviceProtection all have negative relationships with customer tenure. For every one unit change in Bandwidth\_GB\_Year, tenure increases by 0.00044 when all other variables are held constant. For every one unit change in Churn, tenure decreases by 0.13 when all other variables are held constant. For every one unit change in OnlineBackup, tenure decreases by 0.032 when all other variables are held constant. For every one unit change in DeviceProtection, tenure decreases by 0.032 when all other variables are held constant. Finally, for every one unit change in Contract\_MonthToMonth, meaning if more customers switch to one or two year contracts, tenure increases by 0.037 when all other variables are held constant.

By analyzing scaled coefficients we can directly compare the compare the effect each independent variable has on the dependent variable. If we look at the scaled coefficients, the coefficient for Bandwidth\_GB\_Year is the largest number (0.96). Because the data were standardized before the regression, we can interpret this to mean that bandwidth has the largest effect on customer tenure.

A picture containing text, receipt

Description automatically generated Based on the high R2 values, both models are statistically significant. The reduced model statistics were checked using the OLS function in the statsmodels python library (Figure 2). The F-statistic is well above 4, indicating a statistically significant model, and all predicted coefficients are statistically significant based on the P-value being less than 0.01 (Figure 2).

Figure : Reduced model statistics from OLS function in statsmodels python library

The model is also practically significant, because it tells us there is a very strong positive relationship between the amount of bandwidth a customer uses and customer tenure. The more bandwidth a customer uses each year, typically the longer the tenure for that customer. However, one limitation of linear regressions is that correlation does not necessarily mean causation. So, just because bandwidth and tenure are very strongly correlated, that does not necessarily mean the increase in bandwidth causes the increase in customer tenure. There could be another reason the two variables are related that we do not have data for or that is not accounted for in our model.

**F2. Recommendations**

My recommendation for next steps would be to test a follow up research question, which is: “What causes increased bandwidth usage?”. This is an important question to answer to tease apart the relationship between bandwidth and tenure and assess if the correlation relationship is also causal. We could survey customers about how they use their internet (entertainment, work, etc.) to gain additional data about bandwidth use each year. Understanding what drives the increased bandwidth use would 1) give us more information to assess the causality of the relationship between bandwidth and tenure, and 2) allow us to better plan for ways to increase bandwidth use and therefore increase tenure if the relationship is causal.

**G. Panopto Video**

A Panopto video was attached and submitted with the performance task. The link can also be accessed here: LINK

1. **Sources of Third-Party Code**

No additional web sources of data or third-party code were used.

**H. Sources**

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