

## Bank Churn Rate Final Project Report

### **Introduction & Problem Statement:**

Determining or predicting churn rate is key in increasing business effectiveness and allowing for targeted marketing and resources to increase customer retention. This is especially the case for a bank who released their user data on Kaggle for assistance on predicting churn in order to reduce it. The goal of this project is to provide a churn prediction model to mitigate the bank's churn rate and increase overall bank revenue by 20% for the next financial quarter.

### **Data Wrangling:**

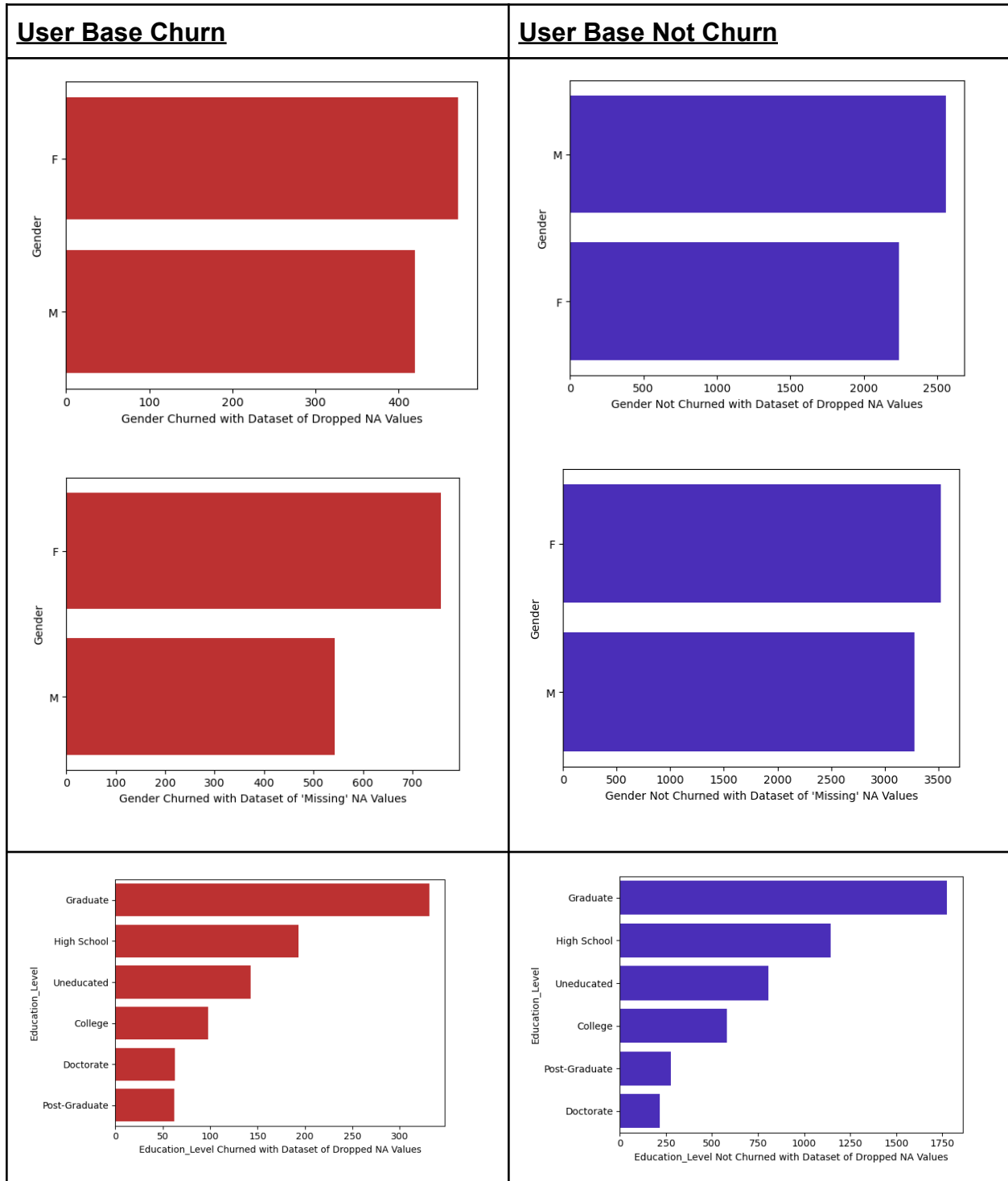
In order to begin steps of model development, the dataset was first assessed and evaluated. It seemed that applying the standard `df.isnull()` did not seem at first to locate any missing values for the dataset, however upon closer inspection the missing values were actually imputed with the value of 'Unknown.' Therefore, replacing all the 'Unknown' values with NaN retrieved the below results for the columns that had missing or null values and their respective percent of missingness from the dataset.

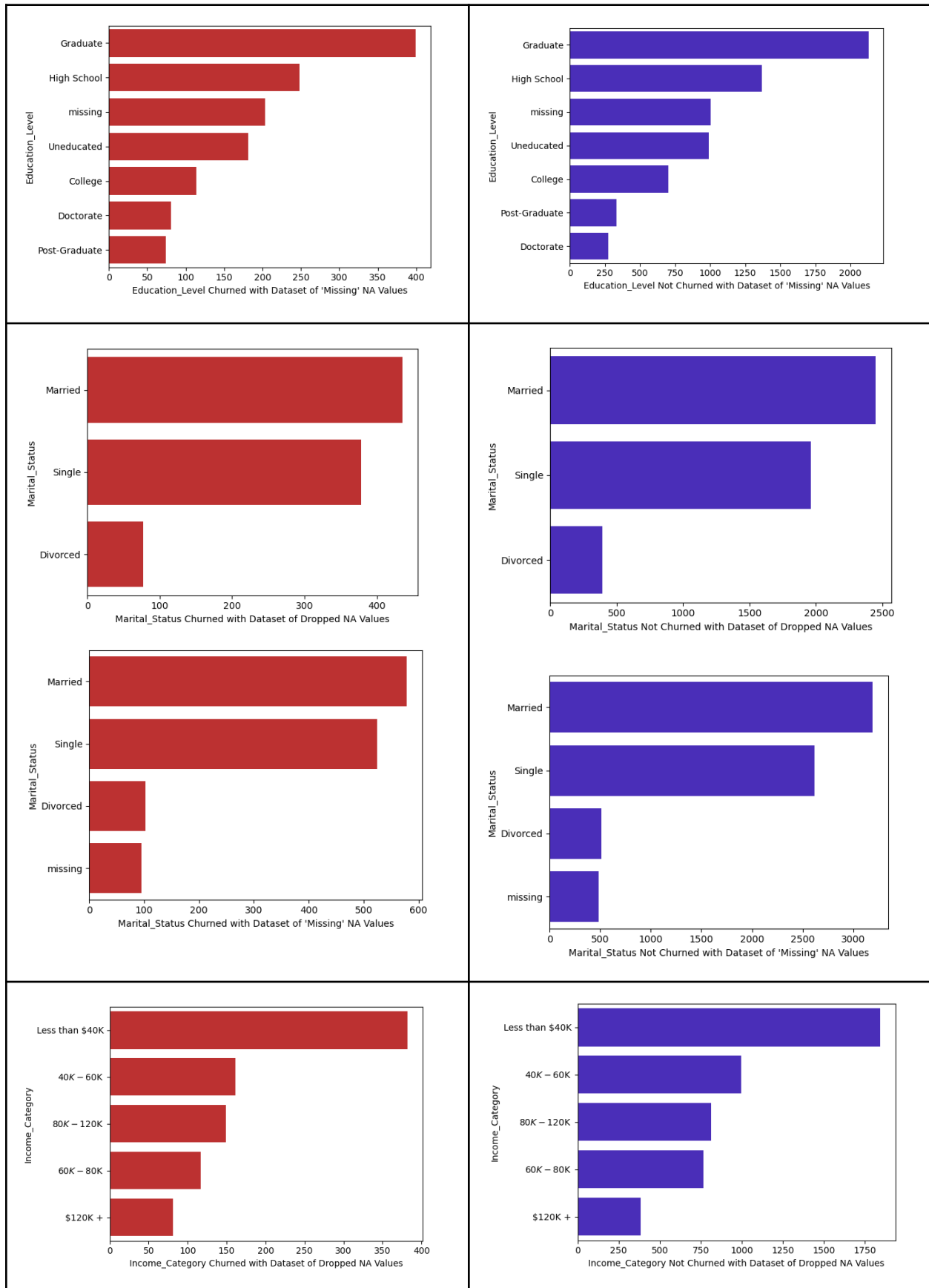
|                        | count | % missing |
|------------------------|-------|-----------|
| <b>Education_Level</b> | 1205  | 14.874707 |
| <b>Income_Category</b> | 889   | 10.973954 |
| <b>Marital_Status</b>  | 579   | 7.147266  |

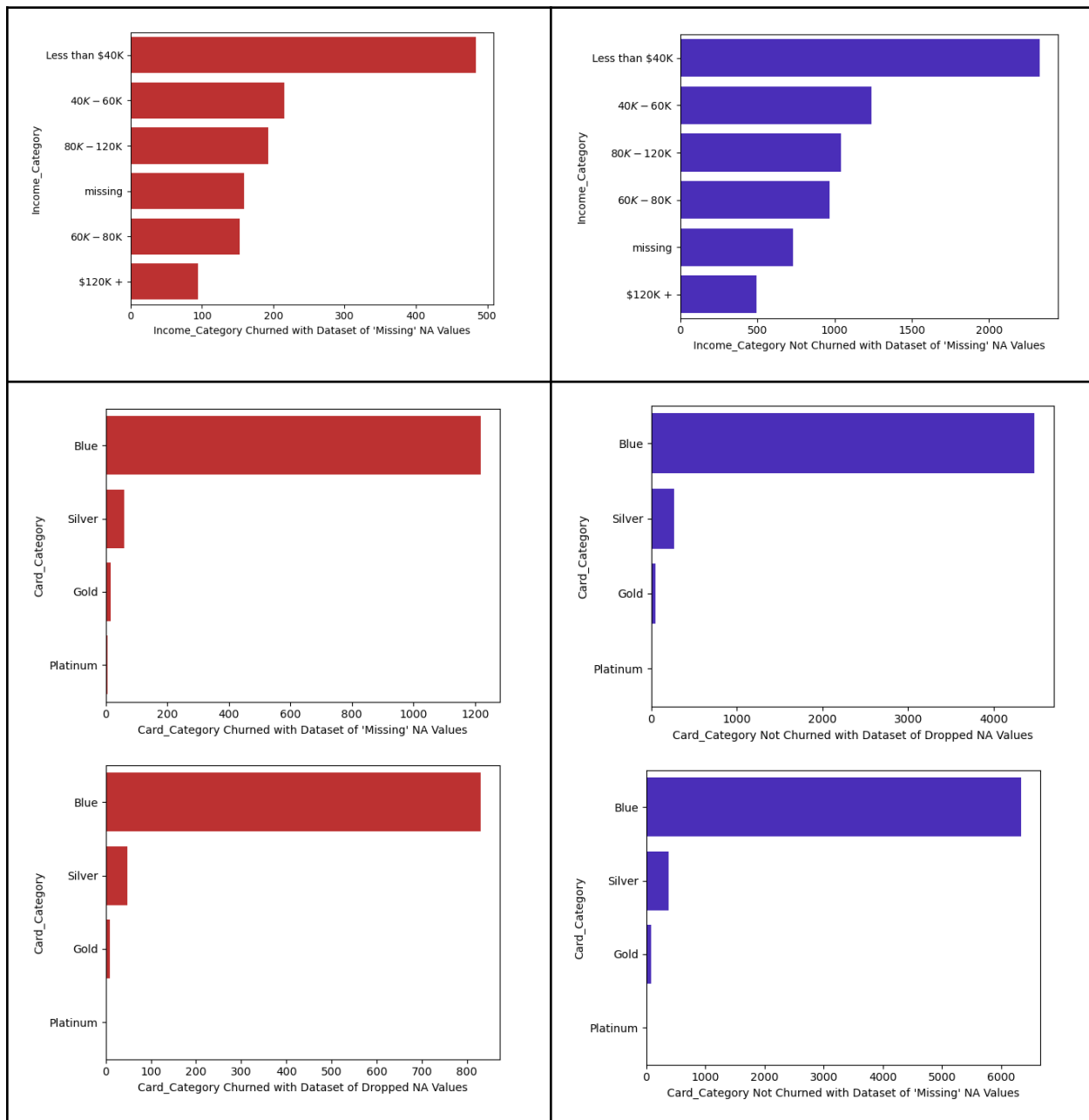
In order to deal with the 'missingness' for the above values, two datasets were created and then assessed throughout the project to assess future model performance. One where the above columns' null data were replaced with the categorical value or string of 'missing' and one where any observations in the above three columns that had null values were dropped. These two datasets as reference to subsequent steps are referred to respectively as 'missing' dataset and 'dropped' dataset respectively.

## Exploratory Data Analysis:

The two datasets were assessed based on categorical features to determine churn not churn user base:







Viewing the above analysis, it seems as a whole between both the 'missing' and 'dropped' datasets there are more females than males, the most common education level is graduate, the most common marital status are married, the most common income category are those in the less than 40k category, and most of the users are Blue card holders. A note to mention is that there is a seeming discrepancy in terms of data for gender between 'missing' and 'dropped' datasets where in the 'dropped' dataset males seemed to be larger than females. However, this seems to indicate that Females tended to leave more values unknown than males possibly for protecting their own personal information.

Taking this above assessment and all the features from the dataset, further analysis will be needed to determine which features have some correlation with the target feature of prediction 'Attrition\_Flag.'

| 'Dropped' Correlation List 'Attrition_Flag' |           | 'Missing' Correlation List 'Attrition_Flag' |           |
|---|-----------|---|-----------|
| Attrition_Flag                              | 1.000000  | Attrition_Flag                              | 1.000000  |
| Total_Trans_Ct                              | 0.364835  | Total_Trans_Ct                              | 0.380618  |
| Total_Ct_Chng_Q4_Q1                         | 0.281174  | Total_Ct_Chng_Q4_Q1                         | 0.288937  |
| Total_Revolving_Bal                         | 0.268979  | Total_Revolving_Bal                         | 0.263335  |
| Avg_Utilization_Ratio                       | 0.185690  | Avg_Utilization_Ratio                       | 0.179838  |
| Total_Trans_Amt                             | 0.170178  | Total_Trans_Amt                             | 0.178078  |
| Total_Relationship_Count                    | 0.149125  | Total_Relationship_Count                    | 0.150889  |
| Total_Amt_Chng_Q4_Q1                        | 0.133285  | Total_Amt_Chng_Q4_Q1                        | 0.128559  |
| Gender_M                                    | 0.045186  | Gender_M                                    | 0.047382  |
| Income_Category_\$60K - \$80K               | 0.028017  | Income_Category_\$60K - \$80K               | 0.026338  |
| Income_Category_\$40K - \$60K               | 0.023828  | Credit_Limit                                | 0.024437  |
| Education_Level_High School                 | 0.018403  | Education_Level_College                     | 0.018937  |
| Credit_Limit                                | 0.017750  | Marital_Status_Married                      | 0.017872  |
| Marital_Status_Married                      | 0.015278  | Income_Category_\$40K - \$60K               | 0.015050  |
| Education_Level_College                     | 0.012472  | Card_Category_Silver                        | 0.014854  |
| Education_Level_Uneducated                  | 0.007257  | Education_Level_High School                 | 0.009930  |
| Card_Category_Gold                          | 0.003949  | Education_Level_Uneducated                  | 0.006614  |
| Card_Category_Silver                        | 0.003173  | Income_Category_\$80K - \$120K              | 0.005148  |
| Income_Category_\$80K - \$120K              | 0.001899  | Education_Level_Graduate                    | 0.004847  |
| Card_Category_Blue                          | -0.001150 | Avg_Open_To_Buy                             | 0.000803  |
| Education_Level_Graduate                    | -0.001751 | Income_Category_\$120K +                    | -0.000831 |
| Avg_Open_To_Buy                             | -0.006245 | Marital_Status_missing                      | -0.002723 |
| Marital_Status_Divorced                     | -0.006688 | Card_Category_Gold                          | -0.003397 |
| Dependent_count                             | -0.008122 | Marital_Status_Divorced                     | -0.006305 |
| Marital_Status_Single                       | -0.011789 | Card_Category_Blue                          | -0.008463 |
| Income_Category_\$120K +                    | -0.014601 | Education_Level_missing                     | -0.009100 |
| Education_Level_Post-Graduate               | -0.018346 | Education_Level_Post-Graduate               | -0.013375 |
| Months_on_book                              | -0.018599 | Marital_Status_Single                       | -0.013437 |
| Card_Category_Platinum                      | -0.022579 | Income_Category_missing                     | -0.017580 |
| Customer_Age                                | -0.024498 | Card_Category_Platinum                      | -0.020284 |
| Income_Category_Less than \$40K             | -0.033687 | Dependent_count                             | -0.020550 |
| Education_Level_Doctorate                   | -0.043378 | Months_on_book                              | -0.022270 |
| Gender_F                                    | -0.045186 | Income_Category_Less than \$40K             | -0.023134 |
| Months_Inactive_12_mon                      | -0.160701 | Customer_Age                                | -0.035203 |
| Contacts_Count_12_mon                       | -0.203447 | Education_Level_Doctorate                   | -0.039483 |
|   |           | Gender_F                                    | -0.047382 |
|   |           | Months_Inactive_12_mon                      | -0.156552 |
|   |           | Contacts_Count_12_mon                       | -0.211327 |

After applying `pd.get_dummies()` and sorting the list based on its correlation level with the target feature 'Attrition\_Flag', a few relationships were seen with 'Attrition\_Flag.' It seems the moderate positive correlations come from feature values in the `Total_Trans_Ct`, `Total_Ct_Chng_Q4_Q1`, `Total_Revolving_Bal`, `Avg_Utilization_Ratio`, `Total_Trans_Amt`, `Total_Relationship_Count`, and `Total_Amt_Chng_Q4_Q1` columns. There is an intuitive sense to this, as the customer's spending pattern would seem to affect if the customer is in fact more likely to churn or not. However, what also seems of interest is that how many dependents the customer had or their total relationship count also positively affected some of the variance with the `Attrition_Flag` column. And that females had a negative correlation versus male users having a more positive level. Also it seems that the customers age is negatively correlated meaning

younger members seemed to be less likely to churn than the older demographic. Also between the 'Dropped' and 'Missing' datasets, the datasets seem to overall agree with each other as per the top positive and top negative correlation levels with variances in the middle due to differing datasets.

### Preprocessing & Training:

In order to avoid the dummy variable trap for model development or potentially having issues between because of multicollinearity within the dummy variables, the different categorical features were instead arranged to instead have k-1 features where k is the number of unique categories for the feature. The dropped values chosen were values that occurred the most frequently in the datasets as well as Gender\_F since this was the most common over most of the datasets.

Scikit learns train\_test\_split and StandardScaler functions were applied to both 'dropped' and 'missing' datasets in order to create arbitrary 70/30 splits of test and train data and appropriately scale each of the features for next steps of model development.

### Modeling:

Different predictive models for classification were developed and trained with the 70/30 train test sets as well as 5 fold cross-validated with a list of associated model hyperparameters and then assessed based on the overall Accuracy, Precision, Recall, F1 Score, ROC\_AUC and training time to determine best model performer. Models assessed were Logistic Regression, RandomForestClassifier with Bagging, Gradient Boosting Classifier which is random forest but with boosting, Support Vector Machines, AdaBoost Classifier to improve RandomForest with Optimal Parameters and GradientBoosting with Optimal Parameters, and Neural Network Multi-Layer Perceptron Classifier models.

Below are the following results table and ROC curves:

Results Table 'Missing' Dataset:

| Model Name               | Accuracy_score | Precision_score | Recall_score | f1_score | ROC_AUC_score | Training Time (Sec) |
|--------------------------|----------------|-----------------|--------------|----------|---------------|---------------------|
| Logistic Regression      | 0.906211       | 0.730769        | 0.580556     | 0.647059 | 0.771688      | 15.40               |
| Random Forest Classifier | 0.939120       | 0.886861        | 0.675000     | 0.766562 | 0.830016      | 62.87               |

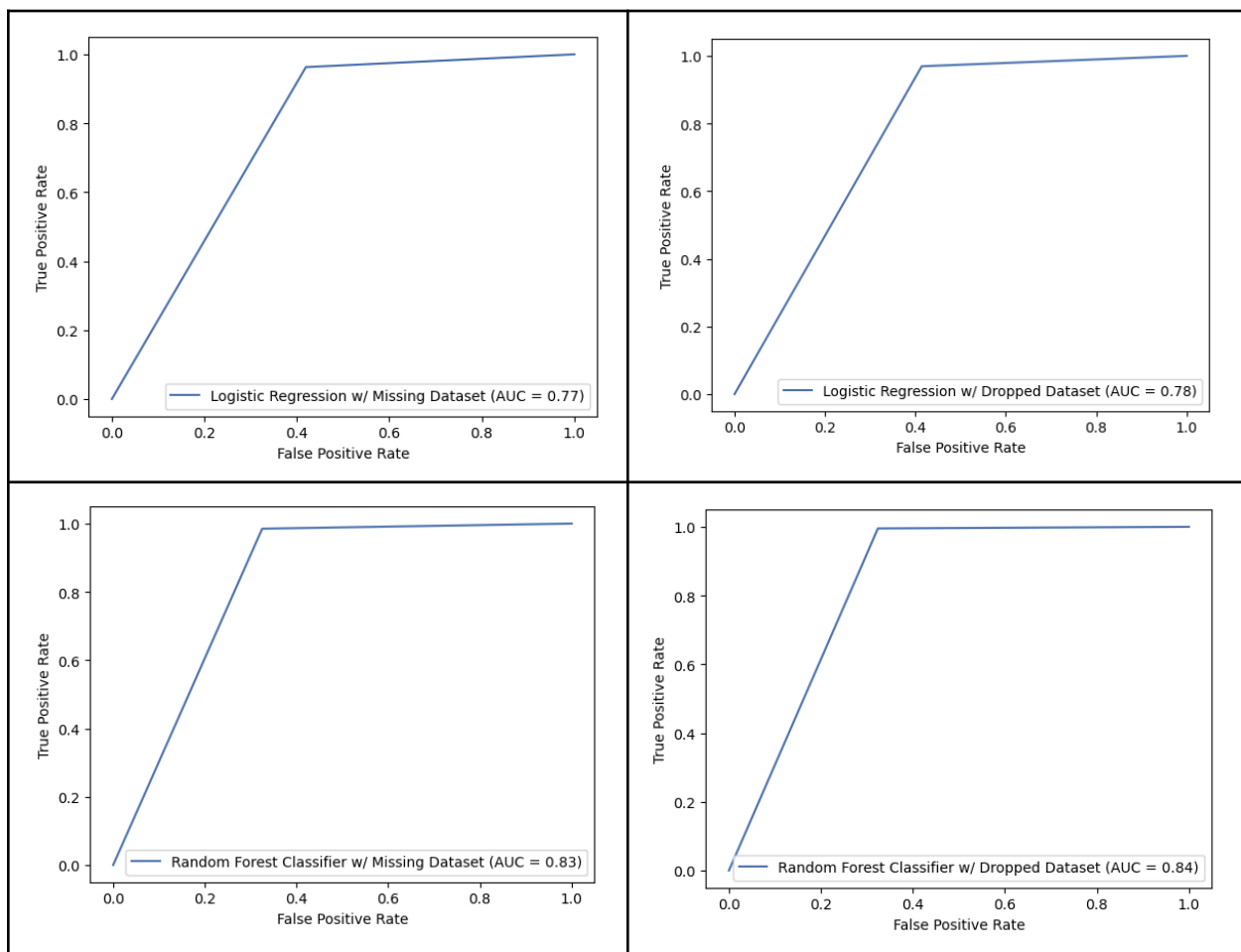
|   |          |          |          |          |          |         |
|---|----------|----------|----------|----------|----------|---------|
| <b>Gradient Boosting Classifier</b>             | 0.967914 | 0.927273 | 0.850000 | 0.886957 | 0.919206 | 846.87  |
| Support Vector Classifier                       | 0.915673 | 0.725948 | 0.691667 | 0.708393 | 0.823139 | 80.43   |
| AdaBoost w/ Random Forest Classifier            | 0.963801 | 0.944444 | 0.802778 | 0.867868 | 0.897285 | 1535.73 |
| <b>AdaBoost w/ Gradient Boosting Classifier</b> | 0.969148 | 0.930514 | 0.855556 | 0.891462 | 0.922225 | 213.50  |
| MLP Neural Network Classifier                   | 0.933772 | 0.806154 | 0.727778 | 0.961456 | 0.848679 | 514.61  |

Results Table 'Dropped' Dataset:

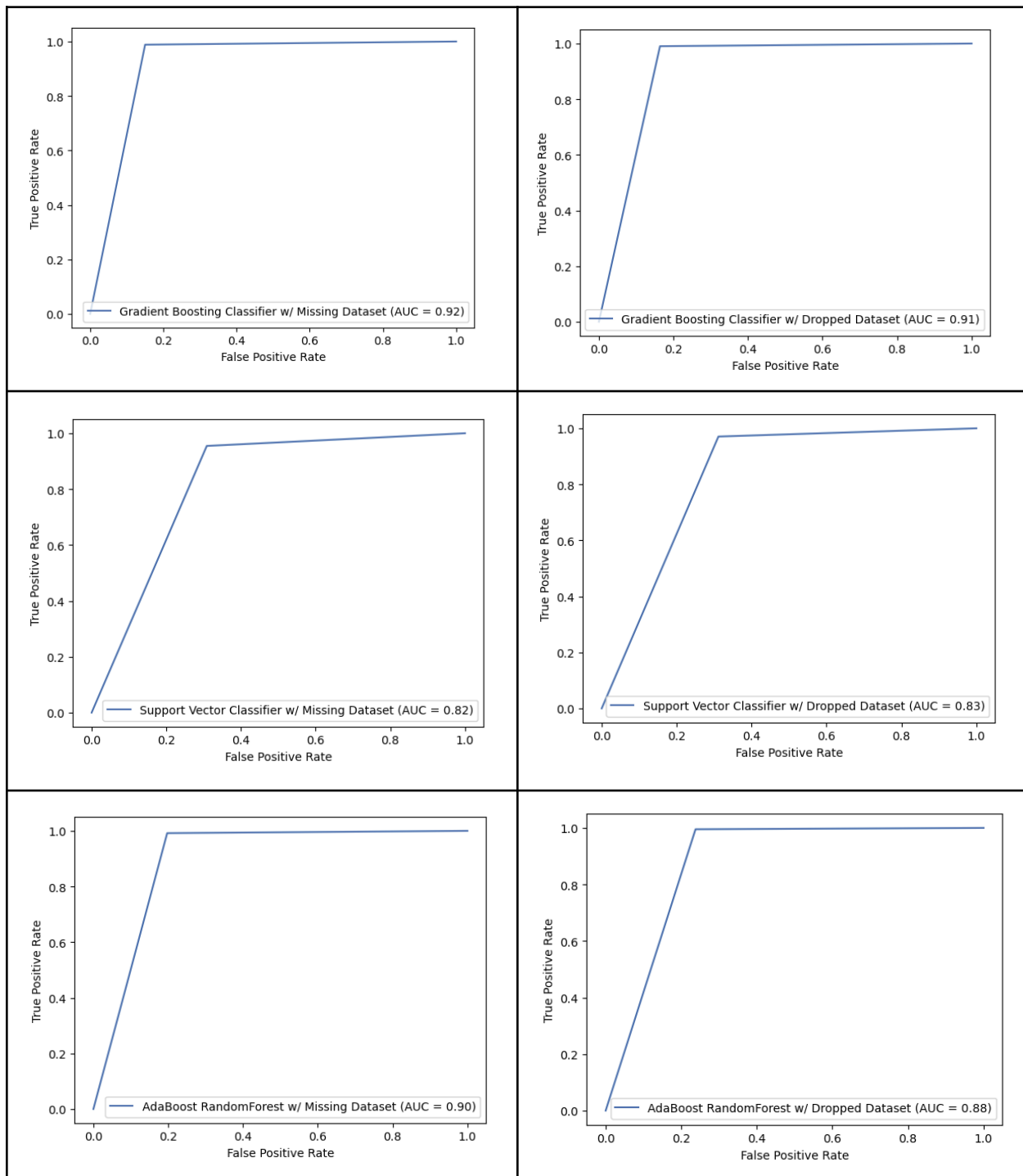
| <b>Model Name</b>                   | <b>Accuracy_score</b> | <b>Precision_score</b> | <b>Recall_score</b> | <b>f1_score</b> | <b>ROC_AUC_score</b> | <b>Training Time (Sec)</b> |
|-------------------------------------|-----------------------|------------------------|---------------------|-----------------|----------------------|----------------------------|
| Logistic Regression                 | 0.914470              | 0.760638               | 0.586066            | 0.662037        | 0.777653             | 14.31                      |
| Random Forest Classifier            | 0.949619              | 0.959302               | 0.676230            | 0.793269        | 0.835722             | 52.23                      |
| <b>Gradient Boosting Classifier</b> | 0.968366              | 0.935780               | 0.836066            | 0.883117        | 0.913248             | 603.65                     |
| Support Vector Classifier           | 0.930287              | 0.796209               | 0.688525            | 0.738462        | 0.829566             | 40.19                      |

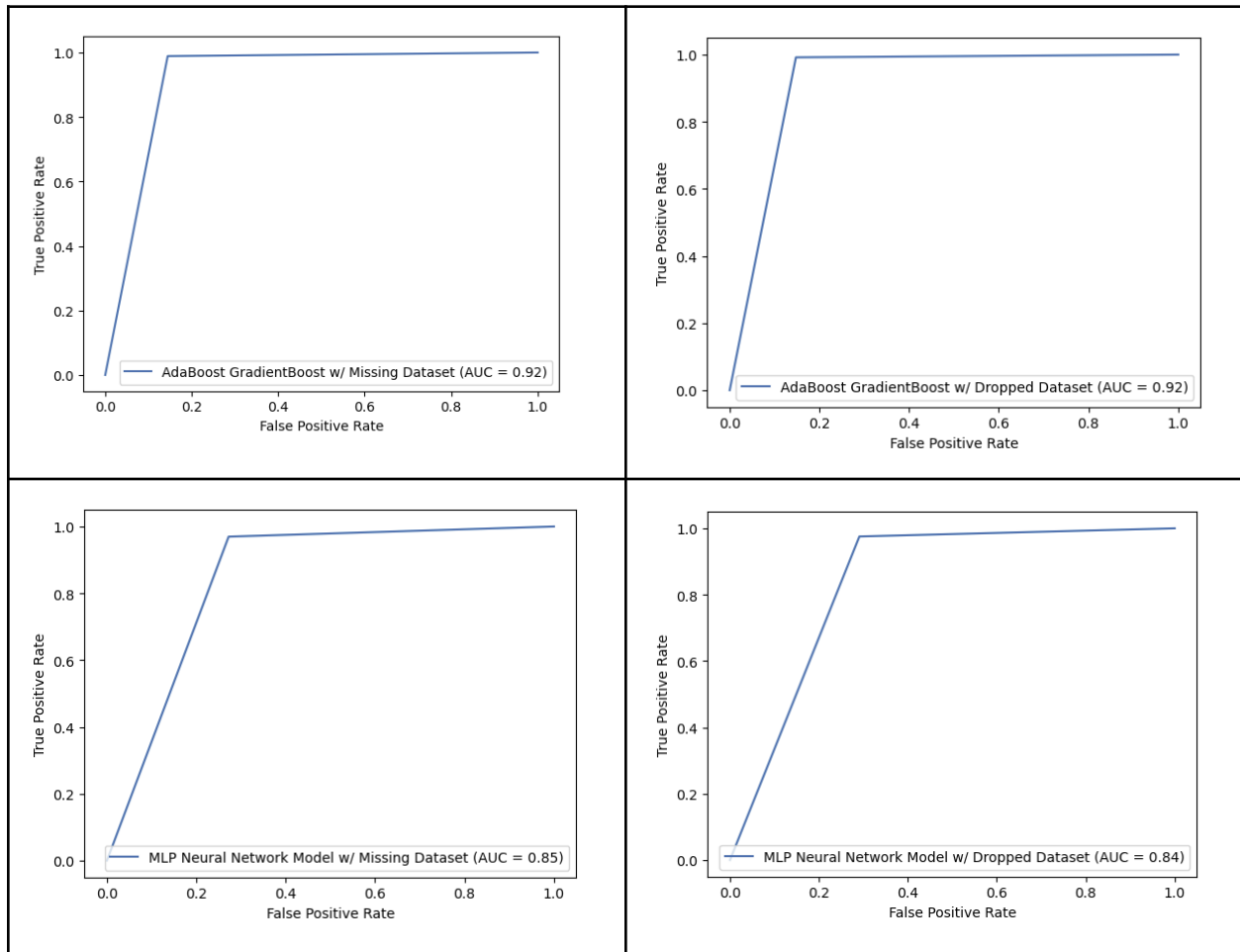
|   |          |          |          |          |          |         |
|---|----------|----------|----------|----------|----------|---------|
| AdaBoost w/ Random Forest Classifier            | 0.961921 | 0.963731 | 0.762295 | 0.851259 | 0.878755 | 1171.65 |
| <b>AdaBoost w/ Gradient Boosting Classifier</b> | 0.971880 | 0.945455 | 0.852459 | 0.896552 | 0.922128 | 926.41  |
| MLP Neural Network Classifier                   | 0.937317 | 0.827751 | 0.709016 | 0.963864 | 0.842205 | 351.12  |

### ROC Curves Modeling Metrics and Score Bar Graphs:

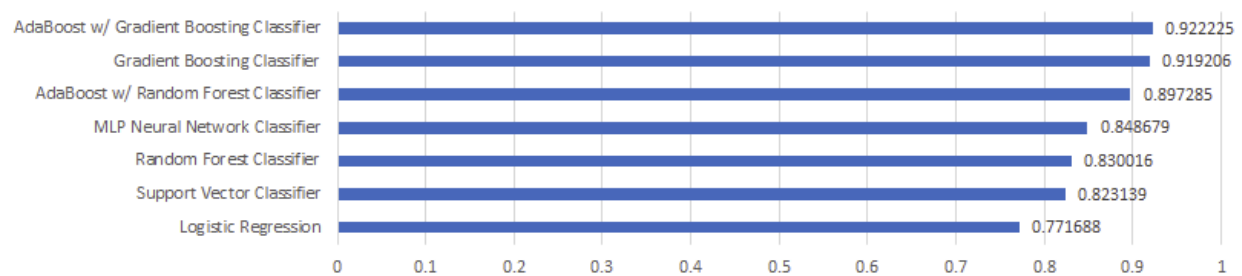




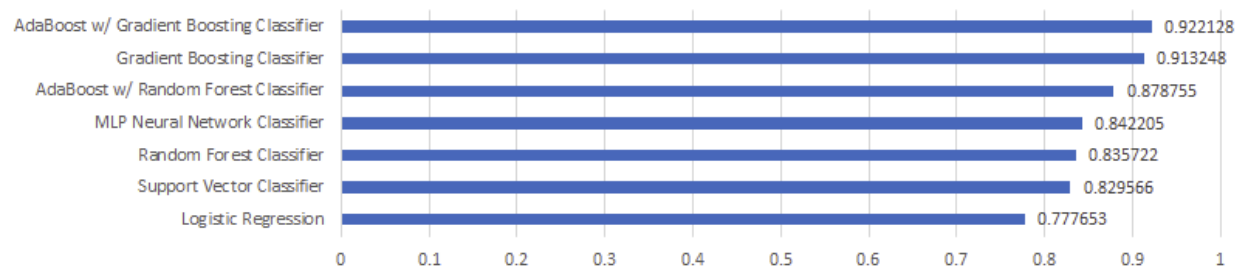




ROC\_AUC\_score Missing Dataset



ROC\_AUC\_score Dropped Dataset



## Results & Conclusion:

Looking at the above results table and ROC\_AUC curves and scores, Logistic Regression, though having the shortest training time, turned out to be one of the worst performers for both the missing and dropped datasets per predicting label of churn or '0'. The best performer overall for both the dropped and missing datasets appears to be the Gradient Boosting Classifier model when applied with an AdaBoost Classifier model, slightly outperforming its individual Gradient Boosting Classifier counterpart. However, the AdaBoost Classifier model with Optimal Gradient Boosting is not the most intuitive to reproduce as it requires first optimizing a Gradient Boosting model then also training with the AdaBoost classifier. Therefore, in terms of ease of reproducibility and scale, just training and deploying to production the sole Gradient Boosting Model seems sufficient as the prediction model as it was able to achieve ROC\_AUC scores of 0.92 and 0.91 for missing and dropped datasets respectively which is significantly greater than random guessing churn within the dataset.

The limitation, however, is the training time in order to acquire the optimal parameters for the Gradient Boosting model as it was on the higher end in terms of models and their respective training time.

In terms of whether initially dropping the observations that had null values or imputing them with the category of missing had any affect on the performance of the different models, the 'dropped' dataset lead to Logistic Regression, Random Forest, and Support Vector Classifier models having a slightly better performance than its imputed counterpart, however performance was slightly worse for the 'dropped' dataset when applied with the Gradient Boosting, and the AdaBoost Classifiers in terms of recall in predicting 0 label or churn, f1\_score, and ROC\_AUC\_score. And since the best performers were the Gradient Boosting and AdaBoost Classifier models, it seems that initially imputing the 'Unknown' value in the dataset with missing improved the already stronger performing models. Therefore, in terms of future modeling, imputing the dataset with 'missing' instead of just dropping the 'Unknown' values will be a suggested step moving forward.

In terms of correlations as well as per the datasets user base, it seems that additional efforts along with deploying the Gradient Boosting model can be made as well to potentially increase customer retention. It seems that females and the older audience are more likely to attrite therefore having market deals that are friendlier towards females or the older audience will help in customer retention. Or potential efforts can be made instead to maximize the seeming not churned population such as making marketing efforts towards the younger married male population with children or dependents.

## Future Work:

Future work will be to further fine tune the Gradient Boosting Model in order to reduce its respective training time as well as further optimize the Multi-Layer Perceptron Neural Network Classifier model in order to see if the model with further tuned hyperparameters can outperform the Gradient Boosting model as well as the Optimal Gradient Boosting Model with the AdaBoost Classifier model. Additional efforts would be to retrieve the feature importances of the Gradient Boosting to gather more insight as per what features significantly affect the model.

