Northwestern MSDS-498

Model #101: Credit Card Default Model

Performance Validation Results

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September 1, 2022

## The Production Model

To develop a logistic regression model, the feature importance from two of the other models developed for this study, Random Forest and XGboost, were calculated and the top three were taken from each. The resulting explanatory variables are: pay\_max, payment\_avg, payment\_max, ratio\_avg, balance\_growth\_6mo. Logistic regression is one of the simplest data science approaches to fitting a model – using an algebraic expression with the number of variables chosen as a hyperparameter. The coefficient for each variable is provided in table 1. A review of the p-values tells that all the input variables are likely to be relevant, as the p-values are very low.

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| **Table 1: Logistic Regression Model Summary** | | | | | |
|  |  | |  |  |  |
| Variable Name | | coef | std err | z | P-values |
|  |  | |  |  |  |
| payment\_avg | .55 | | 3.45E-06 | 0.715 | 1.66834366e-03 |
| ratio\_avg | -1.20 e-04 | | 0.003 | -0.62 | 0.00000000e+00 |
| balance\_growth\_6mo | 1.59 e-05 | | 0.088 | -3.351 | 0.00000000e+00 |
| payment\_max | -.11 | | 0.018 | -5.356 | 0.00000000e+00 |
| pay\_max | -4.88 e-04 | | 0.021 | 34.966 | 2.44573664e-04 |
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## Model Development Performance

The logistic regression model has proven to generalize well, as it performs similarly on the test data set in comparison to the training set. The overall performance, however, may not be sufficient to ensure business profitability, dependent on the cost function.

### Training Data Model Performance

It is expected that the model will perform best on the training data set, as this was where the optimization was performed for selecting the coefficients. The Kolmogorov-Smirnov (KS) test statistic measures “goodness of fit” through the degree of separation between the positive and negative distributions (Darling, 1957). A perfect score would be 100, with complete separation; a zero would be a completely useless model providing no separation. For the variable selection-based logistic regression model, the KS is 63.7% at decile 11. This indicates poor performance. This is confirmed with the ROC-AUC curve, displaying an AUC of only thirty-eight percent.

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| **Table 2: Logistic Regression Model Kolmogorov-Smirnov chart: Training Data** | | | | | | | | | | |
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|  |  | |  |  |  |  |  |  |  |  |
| Decile | | min\_prob | max\_prob | events | nonevents | event\_rate | nonevent\_rate | Cum  eventrate | Cum  noneventrate | Abs(KS) |
|  |  | |  |  |  |  |  |  |  |  |
| 1 | 0.847361 | | 1.000000 | 621 | 567 | 5.80% | 4.34% | 5.80% | 4.34% | 1.5 |
| 2 | 0.789447 | | 0.847201 | 873 | 317 | 8.15% | 2.43% | 13.94% | 6.77% | 7.2 |
| 3 | 0.751708 | | 0.789324 | 867 | 322 | 8.09% | 2.47% | 22.03% | 9.23% | 12.8 |
| 4 | 0.745929 | | 0.751694 | 1148 | 40 | 10.71% | 0.31% | 32.75% | 9.54% | 23.2 |
| 5 | 0.739833 | | 0.745928 | 1126 | 63 | 10.51% | 0.48% | 43.26% | 10.02% | 33.2 |
| 6 | 0.731642 | | 0.739803 | 1088 | 101 | 10.15% | 0.77% | 53.41% | 10.80% | 42.6 |
| 7 | 0.714909 | | 0.731622 | 1024 | 162 | 9.56% | 1.24% | 62.97% | 12.04% | 50.9 |
| 8 | 0.691021 | | 0.714889 | 859 | 328 | 8.02% | 2.51% | 70.98% | 14.55% | 56.4 |
| 9 | 0.657596 | | 0.690936 | 662 | 531 | 6.18% | 4.07% | 77.16% | 18.61% | 58.5 |
| 10 | 0.630473 | | 0.657556 | 349 | 626 | 3.26% | 4.79% | 80.42% | 23.41% | 57.0 |
| 11 | 0.618600 | | 0.630473 | 1027 | 374 | 9.58% | 2.86% | 90.00% | 26.27% | 63.7 |
| 12 | 0.594564 | | 0.618599 | 304 | 881 | 2.84% | 6.75% | 92.84% | 33.02% | 59.8 |
| 13 | 0.571472 | | 0.594539 | 164 | 1030 | 1.53% | 7.89% | 94.37% | 40.90% | 53.5 |
| 14 | 0.553281 | | 0.571454 | 112 | 1076 | 1.05% | 8.24% | 95.42% | 49.14% | 46.3 |
| 15 | 0.537969 | | 0.553279 | 51 | 1138 | 0.48% | 8.71% | 95.89% | 57.86% | 38.0 |
| 16 | 0.526030 | | 0.537948 | 44 | 1145 | 0.41% | 8.77% | 96.30% | 66.62% | 29.7 |
| 17 | 0.517093 | | 0.526028 | 14 | 1172 | 0.13% | 8.97% | 96.43% | 75.60% | 20.8 |
| 18 | 0.510239 | | 0.517059 | 39 | 1152 | 0.36% | 8.82% | 96.80% | 84.42% | 12.4 |
| 19 | 0.504224 | | 0.510236 | 132 | 1046 | 1.23% | 8.01% | 98.03% | 92.43% | 5.6 |
| 20 | 0.500010 | | 0.504222 | 211 | 989 | 1.97% | 7.57% | 100.00% | 100.00% | 0.0 |
|  | | |  |  |  |  |  |  |  |  |

Text

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**Figure 1: ROC: Training Performance**

### Test Data Model Performance

When the model was executed using the test data set, the KS is 57.4% at decile 10 – slightly improved from the training set, though the inclusion of the ROC-AUC plot reveals that overall performance is in fact slightly worse.

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| **Table 3: Logistic Regression Kolmogorov-Smirnov chart: Test Data** | | | | | | | | | | |
|  | | |  |  |  |  |  |  |  |  |
|  |  | |  |  |  |  |  |  |  |  |
| Decile | | min\_prob | max\_prob | events | nonevents | event\_rate | nonevent\_rate | Cum  eventrate | Cum  noneventrate | Abs(KS) |
|  |  | |  |  |  |  |  |  |  |  |
| 1 | 0.844020 | | 1.000000 | 132 | 232 | 5.31% | 4.85% | 5.31% | 4.85% | 0.5 |
| 2 | 0.761118 | | 0.843945 | 172 | 191 | 6.92% | 4.00% | 12.22% | 8.85% | 3.4 |
| 3 | 0.748044 | | 0.761095 | 316 | 47 | 12.71% | 0.98% | 24.93% | 9.83% | 15.1 |
| 4 | 0.740543 | | 0.748020 | 336 | 27 | 13.51% | 0.56% | 38.44% | 10.40% | 28.0 |
| 5 | 0.728590 | | 0.740524 | 312 | 52 | 12.55% | 1.09% | 50.99% | 11.49% | 39.5 |
| 6 | 0.708947 | | 0.728516 | 267 | 96 | 10.74% | 2.01% | 61.72% | 13.50% | 48.2 |
| 7 | 0.680528 | | 0.708897 | 210 | 153 | 8.44% | 3.20% | 70.16% | 16.70% | 53.5 |
| 8 | 0.652125 | | 0.680519 | 116 | 247 | 4.66% | 5.17% | 74.83% | 21.87% | 53.0 |
| 9 | 0.630474 | | 0.652074 | 63 | 225 | 2.53% | 4.71% | 77.36% | 26.57% | 50.8 |
| 10 | 0.615234 | | 0.630473 | 258 | 181 | 10.37% | 3.79% | 87.74% | 30.36% | 57.4 |
| 11 | 0.595886 | | 0.615219 | 75 | 288 | 3.02% | 6.03% | 90.75% | 36.39% | 54.4 |
| 12 | 0.575906 | | 0.595753 | 56 | 307 | 2.25% | 6.42% | 93.00% | 42.81% | 50.2 |
| 13 | 0.558044 | | 0.575895 | 25 | 339 | 1.01% | 7.09% | 94.01% | 49.91% | 44.1 |
| 14 | 0.544576 | | 0.558022 | 17 | 346 | 0.68% | 7.24% | 94.69% | 57.15% | 37.5 |
| 15 | 0.532980 | | 0.544536 | 7 | 356 | 0.28% | 7.45% | 94.97% | 64.60% | 30.4 |
| 16 | 0.523318 | | 0.532968 | 6 | 357 | 0.24% | 7.47% | 95.22% | 72.07% | 23.1 |
| 17 | 0.515433 | | 0.523315 | 9 | 355 | 0.36% | 7.43% | 95.58% | 79.49% | 16.1 |
| 18 | 0.509821 | | 0.515431 | 7 | 356 | 0.28% | 7.45% | 95.86% | 86.94% | 8.9 |
| 19 | 0.504226 | | 0.509784 | 26 | 337 | 1.05% | 7.05% | 96.90% | 93.99% | 2.9 |
| 20 | 0.500070 | | 0.504222 | 77 | 287 | 3.10% | 6.01% | 100.00% | 100.00% | 0.0 |
|  | | |  |  |  |  |  |  |  |  |

Graphical user interface

Description automatically generated with low confidence

**Figure 2: ROC: Test Performance**

## Performance Monitoring Plan

In order to ensure continued positive results, the model performance must be monitored through test statistics and thresholds must be established for when action is required. Specific performance values are not as relevant for a business as the impacts they produce. If a model accuracy reduction of five-percent results in twenty-percent increase in costs, 50-percent decrease in profits, five-percent is much worse in reality than it initially seems. A more relevant performance plan may require a more complex model. Classification of defaulting customers binarily may be insufficient. The model may also need to monitor and predict severity of that default, with high loss (either graduated or threshold of dollar amount) being recognized as another risk factor. To begin, a simple plan can be devised.

|  |  |  |  |
| --- | --- | --- | --- |
| **Table 4: RAG Thresholds** | | | |
|  |  | |  | |
| Status | | KS threshold | AUC threshold | |
|  |  | |  | |
| Green | >55% | | >80% | |
| Amber | 50-55% | | 75-80% | |
| Red | <50% | | <75% | |
|  | | |  | |

These thresholds are set assuming that current performance is sufficient – though that is not likely the case with the low initial performance values. It can also be helpful to monitor multiple measures if one is insufficient for recognizing all areas of potential loss. While the model continues to score in the green domain no action is necessary, and the model is considered healthy. Performance falling into the amber region would require more active monitoring and preparation for response within three months with re-validation. When KS or AUC falls below the red threshold, immediate redevelopment is required. The thresholds will also be periodically re-evaluated annually to determine if business impacts have changed and require corresponding adjustment of the monitoring plan.

## Performance Monitoring Results

When the model was executed using the validation data set, the KS is 57.4% at decile 10 – identical to the test data performance. This aligns with logic since the test and validation sets were not used in training the logistic regression model. The KS and AUC are both within Green status, so no action is necessary. Validation set will be retested at the next interval.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 5: Logistic Regression Kolmogorov-Smirnov chart: Validation Data** | | | | | | | | | | |
|  | | |  |  |  |  |  |  |  |  |
|  |  | |  |  |  |  |  |  |  |  |
| Decile | | min\_prob | max\_prob | events | nonevents | event\_rate | nonevent\_rate | Cum  eventrate | Cum  noneventrate | Abs(KS) |
|  |  | |  |  |  |  |  |  |  |  |
| 1 | 0.844855 | | 1.000000 | 129 | 244 | 5.21% | 4.90% | 5.21% | 4.90% | 0.3 |
| 2 | 0.763020 | | 0.844816 | 158 | 215 | 6.39% | 4.31% | 11.60% | 9.21% | 2.4 |
| 3 | 0.748299 | | 0.762923 | 332 | 41 | 13.42% | 0.82% | 25.02% | 10.03% | 15.0 |
| 4 | 0.739267 | | 0.748296 | 347 | 26 | 14.03% | 0.52% | 39.05% | 10.56% | 28.5 |
| 5 | 0.726594 | | 0.739214 | 310 | 62 | 12.53% | 1.24% | 51.58% | 11.80% | 39.8 |
| 6 | 0.705583 | | 0.726572 | 262 | 111 | 10.59% | 2.23% | 62.17% | 14.03% | 48.1 |
| 7 | 0.676429 | | 0.705561 | 197 | 176 | 7.96% | 3.53% | 70.13% | 17.56% | 52.6 |
| 8 | 0.643865 | | 0.676346 | 123 | 250 | 4.97% | 5.02% | 75.10% | 22.58% | 52.5 |
| 9 | 0.628869 | | 0.643736 | 199 | 174 | 8.04% | 3.49% | 83.14% | 26.07% | 57.1 |
| 10 | 0.610942 | | 0.628862 | 128 | 244 | 5.17% | 4.90% | 88.32% | 30.97% | 57.4 |
| 11 | 0.590840 | | 0.610860 | 72 | 301 | 2.91% | 6.04% | 91.23% | 37.01% | 54.2 |
| 12 | 0.572703 | | 0.590802 | 38 | 335 | 1.54% | 6.72% | 92.76% | 43.73% | 49.0 |
| 13 | 0.556909 | | 0.572681 | 29 | 344 | 1.17% | 6.90% | 93.94% | 50.63% | 43.3 |
| 14 | 0.542815 | | 0.556873 | 20 | 353 | 0.81% | 7.08% | 94.75% | 57.72% | 37.0 |
| 15 | 0.532046 | | 0.542763 | 10 | 362 | 0.40% | 7.26% | 95.15% | 64.98% | 30.2 |
| 16 | 0.522812 | | 0.532034 | 7 | 366 | 0.28% | 7.34% | 95.43% | 72.33% | 23.1 |
| 17 | 0.515352 | | 0.522782 | 6 | 364 | 0.24% | 7.30% | 95.68% | 79.63% | 16.0 |
| 18 | 0.509529 | | 0.515346 | 6 | 370 | 0.24% | 7.43% | 95.92% | 87.06% | 8.9 |
| 19 | 0.504222 | | 0.509512 | 38 | 324 | 1.54% | 6.50% | 97.45% | 93.56% | 3.9 |
| 20 | 0.500009 | | 0.504222 | 63 | 321 | 2.55% | 6.44% | 100.00% | 100.00% | 0.0 |
|  | | |  |  |  |  |  |  |  |  |

Graphical user interface

Description automatically generated with low confidence

**Figure 3: ROC: Validation Performance**

## Bibliography

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