**Student Risk Model Overview**

**Population**

First-time, first-year undergraduates on the Pullman campus.

**Outcome (w/ source) \***

*enrl\_ind (internal)*

An indicator variable for enrollment in the next year. The outcome is calculated as the predicted probability of non-enrollment in the next year.

**Features (w/ source)**

*first\_gen\_flag (internal)*

An indicator variable for first generation status with a reference category of non-first generation status.

*male (internal)*

An indicator variable for gender with a reference category of female.

*underrep\_minority (internal)*

An indicator variable for underrepresented minority status with a reference category of non-underrepresented minority status. Underrepresented minorities defined as Black, Hispanic, American Indian, Native Hawaiian and Pacific Islander, and two or more races.

*pct\_blk (supplemental)*

A continuous variable for the percentage of Black residents in the postal code where the student last attended school.

*pct\_hisp (supplemental)*

A continuous variable for the percentage of Hispanic residents in the postal code where the student last attended school.

*pct\_ai (supplemental)*

A continuous variable for the percentage of American Indian residents in the postal code where the student last attended school.

*pct\_hawi (supplemental)*

A continuous variable for the percentage of Native Hawaiian and Pacific Islander residents in the postal code where the student last attended school.

*pct\_two (supplemental)*

A continuous variable for the percentage of residents of two or more races in the postal code where the student last attended school.

*city\_large (supplemental)*

An indicator variable for the community being a large city in the postal code where the student last attended school with a reference category of non-large city. Large city defined as a territory inside an urbanized area and inside a principal city with population of 250,000 or more.

*city\_mid (supplemental)*

An indicator variable for the community being a midsize city in the postal code where the student last attended school with a reference category of non-midsize city. Midsize city defined as a territory inside an urbanized area and inside a principal city with population less than 250,000 and greater than or equal to 100,000.

*city\_small (supplemental)*

An indicator variable for the community being a small city in the postal code where the student last attended school with a reference category of non-small city. Small city defined as a territory inside an urbanized area and inside a principal city with population less than 100,000.

*suburb\_large (supplemental)*

An indicator variable for the community being a large suburban area in the postal code where the student last attended school with a reference category of non-large suburban area. Large suburban area defined as a territory outside a principal city and inside an urbanized area with population of 250,000 or more.

*suburb\_mid (supplemental)*

An indicator variable for the community being a midsize suburban area in the postal code where the student last attended school with a reference category of non-midsize suburban area. Midsize suburban area defined as a territory outside a principal city and inside an urbanized area with population less than 250,000 and greater than or equal to 100,000.

*suburb\_small (supplemental)*

An indicator variable for the community being a small suburban area in the postal code where the student last attended school with a reference category of non-small suburban area. Small suburban area defined as a territory outside a principal city and inside an urbanized area with population less than 100,000.

*pell\_eligibility\_ind (internal)*

An indicator variable for Pell grant eligibility with a reference category of non-Pell grant eligibility.

*avg\_pct\_withdrawn (internal)*

A continuous variable for the average percentage of withdrawals to enrollments for the courses in which the student is registered.

*class\_count (internal)*

A discrete variable for the number of courses in which the student is registered.

*lec\_contact\_hrs (internal)*

A discrete variable for the total number of contact hours for the lecture courses in which the student is registered.

*lab\_contact\_hrs (internal)*

A discrete variable for the total number of lab contact hours for the laboratory courses in which the student is registered.

*resident (internal)*

An indicator variable for residency with a reference category of non-residency.

*gini\_indx (supplemental)*

A continuous variable for the Gini index of income inequality for residents in the postal code where the student last attended school.

*median\_inc (supplemental)* \*\*

A continuous variable for the median income of residents in the postal code where the student last attended school.

*high\_school\_gpa (internal)*

A continuous variable for the high school grade point average of the student.

*remedial (internal)*

An indicator variable for remedial coursework with a reference category of non-remedial. Remedial coursework is defined as the student being registered in one or more courses designated as remedial.

*unmet\_need\_ofr (internal)*

A continuous variable for the unmet need of students relative to the amount of financial aid offered to them.

Footnotes:

\* The outcome is only used for model training based on prior years’ data. For the current year, the trained model tries to predict the enrollment outcome for next year.

\*\* These features have been adjusted for inflation in constant 2018 US dollars.

**Data**

*Internal*

All institutional characteristics of students are drawn from admissions or census data. These data adhere to the practices and procedures adopted by the Office of Institutional Research and the University.

*Supplemental*

The social and economic characteristics of the locales where students last attended school comes from the American Community Survey (ACS) TIGER/Line with Selected Demographic and Economic Data: <https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-data.html>. Complete coverage of each of the geographies provided by the US Census Bureau occurs by aggregating single-year estimates over five-year periods. For example, the 2018 ACS 5-year Summary File spans from 2014 to 2018, while the 2017 ACS 5-year Summary File spans from 2013 to 2017.

Although widely used in research, academic literature varies in its approach to these multi-year data. Some scholars elect to have the aggregated data correspond to the ending year. In effect, the 2018 data would then be treated as if it were representative of the social and economic characteristics of the locales in 2018. Other scholars elect to have the aggregated data correspond to the middle year. In effect, the 2017 data would then be treated as if it were representative of the social and economic characteristics of the locales in 2015.

Due to data limitations, as well as the practical needs of the predictive model, the decision was made to follow the former logic with the addition of a lag period of two years. This was done for two reasons. First, the 2018 ACS 5-year Summary File is the latest data available from the US Census Bureau, with these releases typically occurring on a yearly basis on or around December 10. (An example SAS code file for preparing ACS data for the student risk model can be found here: [Z:\Nathan\Models\student\_risk\student\_risk\_acs\_prep.sas](file:///Z:\Nathan\Models\student_risk)). Second, given that new students entering in the current year likely attended high school in the prior year, a lag of a year or more was appropriate to better capture the time-ordered effects that the social and economic characteristics of the locales would have on students’ last attended schools.

Theoretically speaking, these accommodations can be justified in this way: as the primary interest is treating the variables derived from the ACS as social and economic characteristics that load on the locale of the students’ last attended schools, and not on the students themselves, the use of multi-year data in conjunction with a two-year lag offers the most relevant temporal context. A student arriving in the 2020 academic year (Fall 2019 term) is using data from the 2018 ACS 5-year Summary File—spanning from 2014 to 2018—which covers the range of their high school career.

When necessary, the economic variables were adjusted for inflation according to the final year present in the released data. The methodology for this adjustment, as well as the annual average consumer price index data needed to calculate it, are provided by the US Census Bureau: <https://www.census.gov/topics/income-poverty/income/guidance/current-vs-constant-dollars.html>.

**Models**

The modeling strategy used is that of an ensemble model, which in this case employs four different machine learning algorithms commonly used for binary classification. The intuition behind this strategy is that each algorithm has its own inherent strengths and weaknesses that can be balanced against one another yielding an aggregate model that is more robust to overfitting while maintaining accuracy in its predictions.

*Logistic Regression*

Logistic regression with L2 regularization. Regularization is a method of penalizing complex models to prevent overfitting by including a penalty term along with the loss function being minimized. For this variant of L2 regularization, the penalty term is the sum of the squared regression coefficients scaled by the inverse of a hyperparameter, which is then added to the error term. A hyperparameter being a parameter that is external rather than internal to the model. Lowering the value of the inverse hyperparameter promotes model underfitting, while raising the value of the inverse hyperparameter promotes model overfitting. The ideal value for the inverse hyperparameter (C) produces a model that generalizes well to new data.

<https://scikit-learn.org/stable/modules/generated/sklearn.linear_model.LogisticRegression.html>

*Support Vector Classification*

Support vector classifier with a linear kernel. Support vector classification represents the data in an input space the dimension of the number of features. For a binary classifier, the goal is to split the multi-dimensional input space into two partitions that divide the classes using a hyperplane. A hyperplane being an affine subspace that is of one dimension less than the input space. With a linear kernel, this partitioning is done linearly and does not necessitate mapping the data to a higher-dimensional feature space as required by non-linear kernels. The general rule of thumb is parsimony. A linear kernel is preferred over non-linear kernels unless they are needed, especially when there are many features.

<https://scikit-learn.org/stable/modules/generated/sklearn.svm.SVC.html>

*Multi-Layer Perceptron*

Multi-layer perceptron neural network with a rectified linear unit (ReLU) activation function. While neural networks are mathematically more complex than other classification models, the intuition behind them is less complicated. The objective is to find a set of mathematical functions (as represented by the weights and activation functions) that map the features of observations (as represented by the input layer) to their target values (as represented by the output layer) with minimal error. Neural networks allow for the set of mathematical functions (as represented by the hidden layers) to be inherently nonlinear through the use of their activation functions. An activation function being a nonlinear monotonic function. The output of the ReLU activation is zero if its input is less than zero and the value of the input otherwise. One advantage of ReLU is its efficiency. More sophisticated activation functions can make it harder for the neural network to find the combination of weights that produce the minimal amount of error.

<https://scikit-learn.org/stable/modules/generated/sklearn.neural_network.MLPClassifier.html>

*Random Forest Classification*

Random forest classifier with a Gini impurity criterion. Random forest classification aggregates a number of decision tree classifiers that are fit to datasets which are sub-sampled from the original with replacement. Random forest classification searches for split points among the bootstrapped data that partition the classes so that the resulting Gini impurity is minimized. The Gini impurity of a split point is the weighted average of one minus the sum of the squared probabilities of an item having each classification after the split. The root node of every decision tree is that feature represented in the sub-sampled dataset (and its associated value) that would result in the lowest calculated Gini impurity. The decision tree algorithm then proceeds iteratively finding the next best feature in the sub-sampled dataset (and its associated value) that would result in the next lowest calculated Gini impurity for the nodes created by the previous split and so on until there is no improvement. The randomness of the bootstrapped datasets produces an aggregate classifier that is more robust to overfitting than standard decision tree classifiers, but it is still a concern. Diagnostic plots of are used to determine early stopping points that place constraints on the splitting process, which prevents an overfit model.

<https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.RandomForestClassifier.html>

**Classification**

*Voting Classification*

Voting classifier with weighted average probabilities. Voting classification is an ensemble method that combines the predictions of the base estimators to improve generalizability. The weighted average of the predicted probabilities for the base estimators is calculated for each observation. The chosen weights determine the relative contribution of the base estimators to the weighted average predicted probabilities.

<https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.VotingClassifier.html>

*Risk Thresholds*

The risk thresholds are set based on the predicted probabilities of non-enrollment in the next year set by the voting classifier. Those students with a predicted probabilities equal to or above the .6666 level are considered high risk, those equal to or above the .3333 level and below the .6666 level are considered medium risk, and those below the .3333 level are considered low risk.