

# **Project 2\***

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## **1 Introduction**

the motivation for the analysis

Can college readiness, staff demographics, and school demographics predict graduation rates in California high schools?

a brief overview of the broader context

the knowledge gap that is addressed by the paper

what was done in the analysis

the key findings and why they are important

the structure of the paper

This project draws from the data sources Common Core of Data, Small Area Income and Poverty Estimates, The Civil Rights Data Collection, *EDFacts*, Integrated Postsecondary Education Data System, College Scorecard, National Historical Geographic Information System, Federal Student Aid, National Association of College and University Business Officers, National Center for Charitable Statistics, Model Estimates of Poverty in Schools (MEPS), Equity in Athletics Data (EADA), and Campus Safety and Security (2025a).

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\*Project repository available at: [https://github.com/meganajoseph/261a\\_project2](https://github.com/meganajoseph/261a_project2).

## 2 Data

The data are from the Education Data Explorer from the Urban Institute's Center on Education Data and Policy. This tool compiles data from national data sources on schools, districts, and colleges in order to assist in creating insights to improve student outcomes (2025a).

I used this [query](#) to produce a dataset of high schools in California from 2016-2017 with information on school characteristics, absenteeism, college readiness, course offerings, student demographics, discipline, school safety, student outcomes, and teachers and staff (Education Data Portal (Version 0.23.0), Urban Institute 2023). The observational unit is an individual high school in California. The key variables of interest are student enrollment, whether or not a school is eligible for participation in either Target Assistance program or school-wide program authorized by Title I of Public Law 103-382, the number of students enrolled in the International Baccalaureate Diploma Program, the number of students enrolled in the gifted and talented programs, the number of students enrolled in at least one AP course, the number of students who took one or more AP exams, the number of students participating in the SAT and ACT tests, the number of suspensions, the number of full-time teachers, the number of first-year teachers, the number of full-time equivalent instructional aides or paraprofessionals, the number of full-time equivalent school counselors, and teacher salary.

Removing all NA values would result in an empty dataset, so I removed a few of them and left the for variables like number of students enrolled in the IB program because that would most likely mean it is not offered at that school while another program like AP is offered. After removing these, the dataset has 2125 observations while the original has 6111 observations.

### 2.1 Common Core of Data

The variables student enrollment and Title I eligibility are sourced from Common Core of Data (CCD) (Education Data Portal (Version 0.23.0), Urban Institute 2023). The CCD is the United States Department of Education's database on all public elementary and secondary schools and school districts (2025b).

Student enrollment reports the number of students enrolled in the school. Figure 1 (a) shows a logarithmic relationship, so a log transformation should be applied, but I will use a square root transformation because of the large number of zeros. A school is Title I eligible if it is in a school district for children from low-income families (2025c). Figure 1 (b) shows that schools that are not Title I eligible have a higher median graduation rate and is less varied, whereas schools that are Title I eligible are much more varied with a larger number of outliers. I picked these variables because small schools have been linked to higher graduation rates, and students from low-income families tend to have higher dropout rates ("High School Graduation," n.d.).

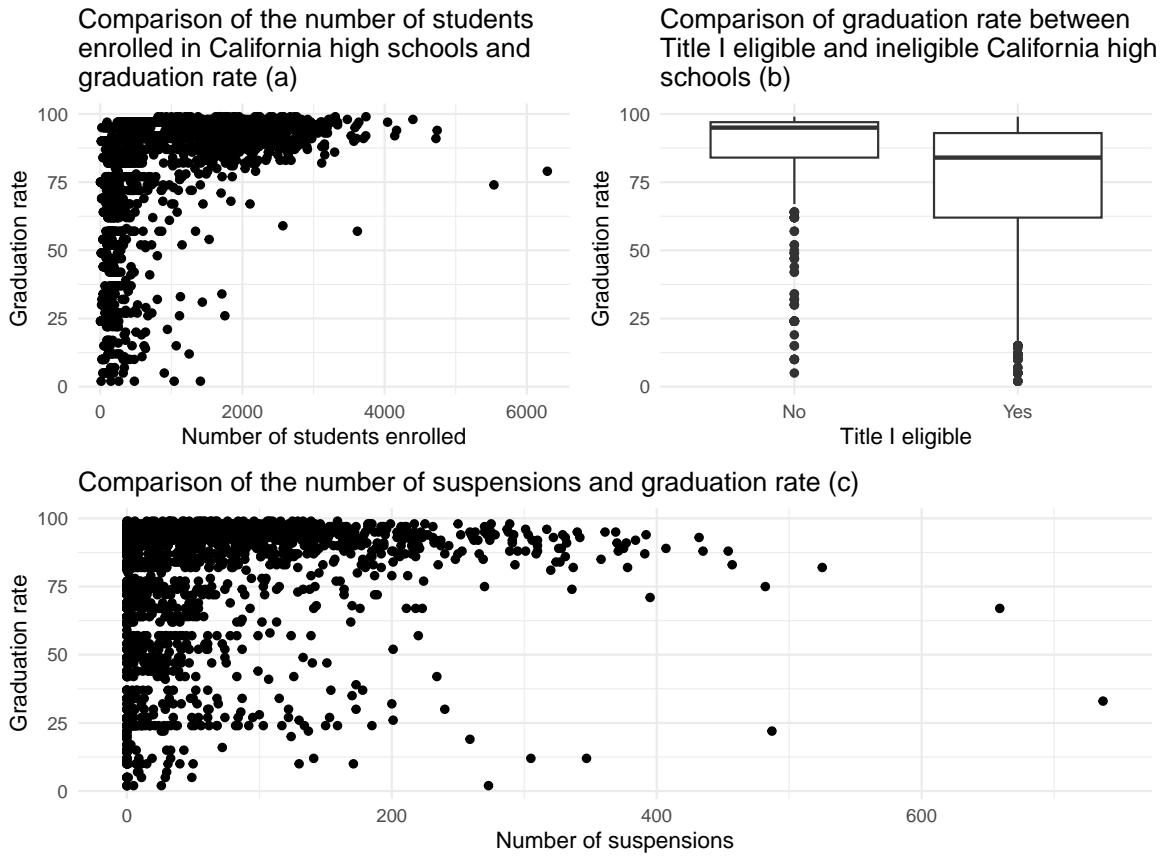


Figure 1: Plot (a) shows a scatter plot of the graduation rate over the number of students enrolled. Plot (b) shows a boxplot of graduation rate at Title I eligible and ineligible schools. Plot (c) shows the relationship between the number of suspensions in a school (x-axis) and graduation rate (y-axis).

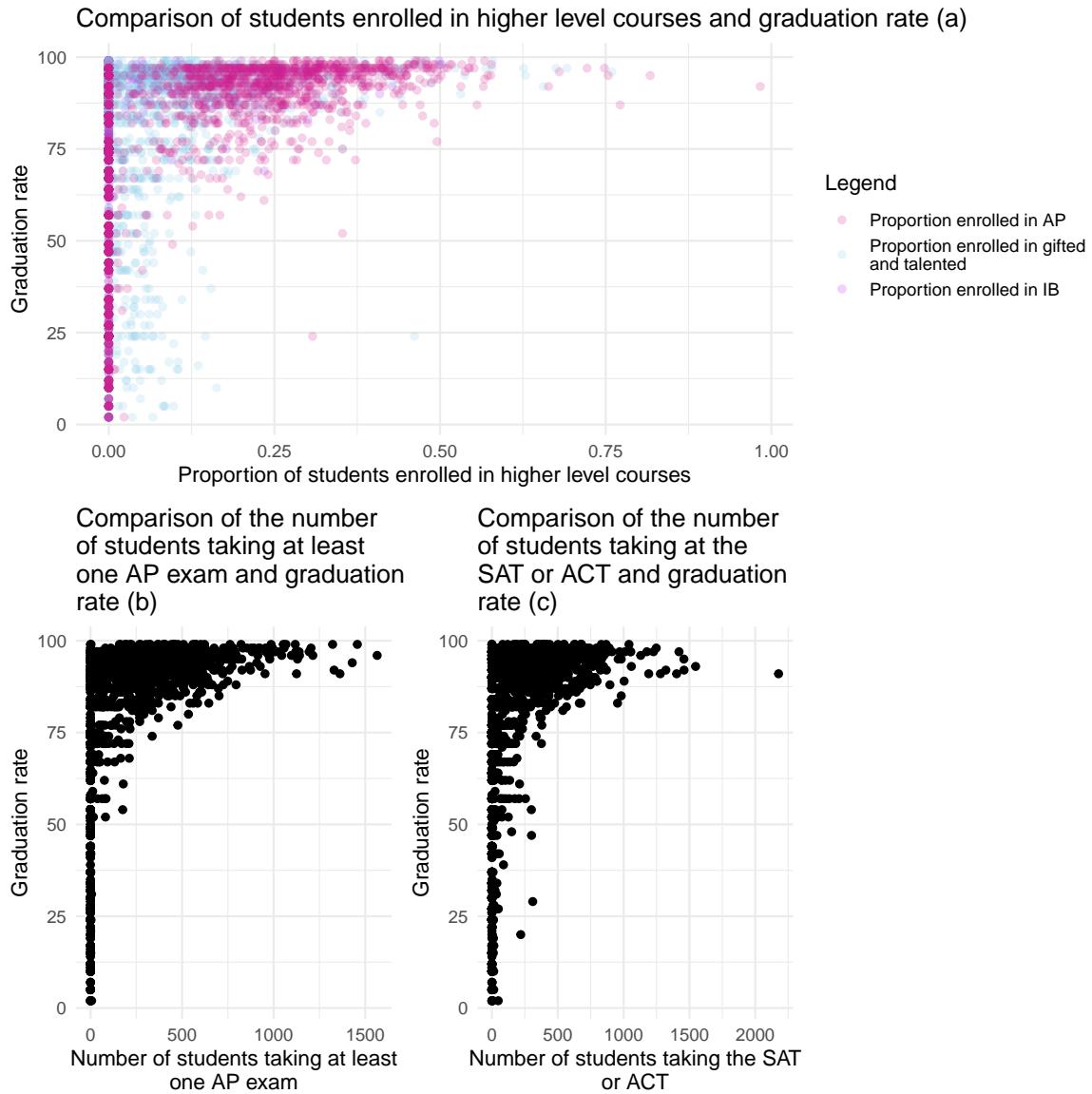


Figure 2: Plot (a) shows a scatter plot showing the relationship between the proportion of students enrolled in high level courses including the IB program (purple), AP program (pink), and gifted and talented programs (blue) (x-axis) and graduation rate (y-axis). Plot (b) shows a scatter plot of the graduation rate over the number of students taking at least one AP exam. Plot (c) shows a scatter plot of the graduation rate over the number of students taking either the SAT or ACT.

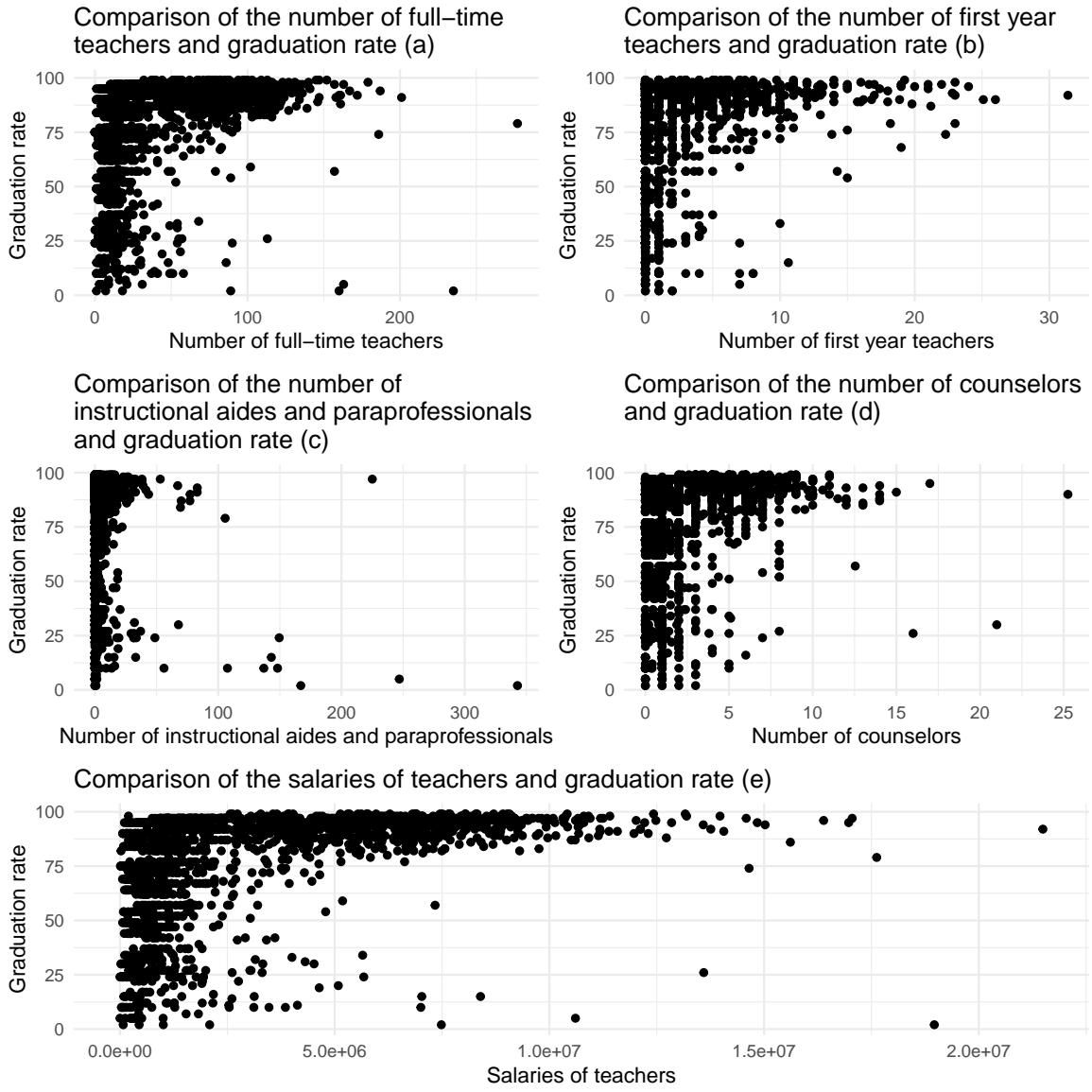


Figure 3: Plot (a) shows the relationship between the number of full-time teachers (x-axis) and graduation rate (y-axis). Plot (b) shows the relationship between the number of first year teachers (x-axis) and graduation rate (y-axis). Plot (c) shows the relationship between the number of instructional aides and paraprofessionals (x-axis) and graduation rate (y-axis). Plot (d) shows the relationship between the number of counselors (x-axis) and graduation rate (y-axis). Plot (e) shows the relationship between teacher salary (x-axis) and graduation rate (y-axis).

## 2.2 The Civil Rights Data Collection

The Civil Rights Data Collection (CRDC) comes from the United States Department of Education's Office for Civil Rights. This data is collection in order to ensure schools give students equal access to educational opportunities (2025e). Data are collected from public schools and districts, justice facilities, charter schools, alternative schools, and special education schools (2025e).

The variables from this dataset are the number of students enrolled in the International Baccalaureate Diploma Program, the number of students enrolled in the gifted and talented programs, the number of students enrolled in at least one AP course, the number of students that took one or more AP exams, the number of students participating in the SAT or ACT, the number of suspensions, the number of full-time teachers, number of first-year teachers, number of full-time equivalent instructional aides or paraprofessionals, number of full-time equivalent school counselors, and teacher salary. The number of students enrolled in the International Baccalaureate Diploma Program, the number of students enrolled in the gifted and talented programs, and the number of students enrolled in at least one AP course were transformed to the proportion of students enrolled in each respective program because that is more informative. Figure 2 (a) shows a logarithmic relationship between these programs and graduation rate. Figure 2 (b) and (c), Figure 1 (c), and all plots in Figure 3 also show logarithmic relationships between the selected variables and graduation rate, so a square root transformation is appropriate.

I picked these variables because students participating in higher level courses and/or participating in college-preparatory exams would be most interested in graduating and going to college. Suspensions would make it more difficult for students to graduate. Increased support from experienced teachers and other aides can motivate students to do well in school. Higher teacher salary will motivate teachers to put more effort in helping their students.

## 2.3 ED*Facts*

High school graduation rate comes from the ED*Facts* dataset. Figure 4 shows a left-skewed distribution in graduation rate.

ED*Facts* collects and analyzes data from pre-kindergarten through twelfth grade supplied by state education agencies with other data within the U.S. Department of Education (2025d).

## 2.4 Alternative Data Sources

A good alternate data source would be at the student level rather than the school level. This can be difficult to find, though, because the students are not legal adults and due to Family Educational Rights and Privacy Act (FERPA) which protects the distribution of educational records without the consent of parents or the student if they are over 18 years old. Information

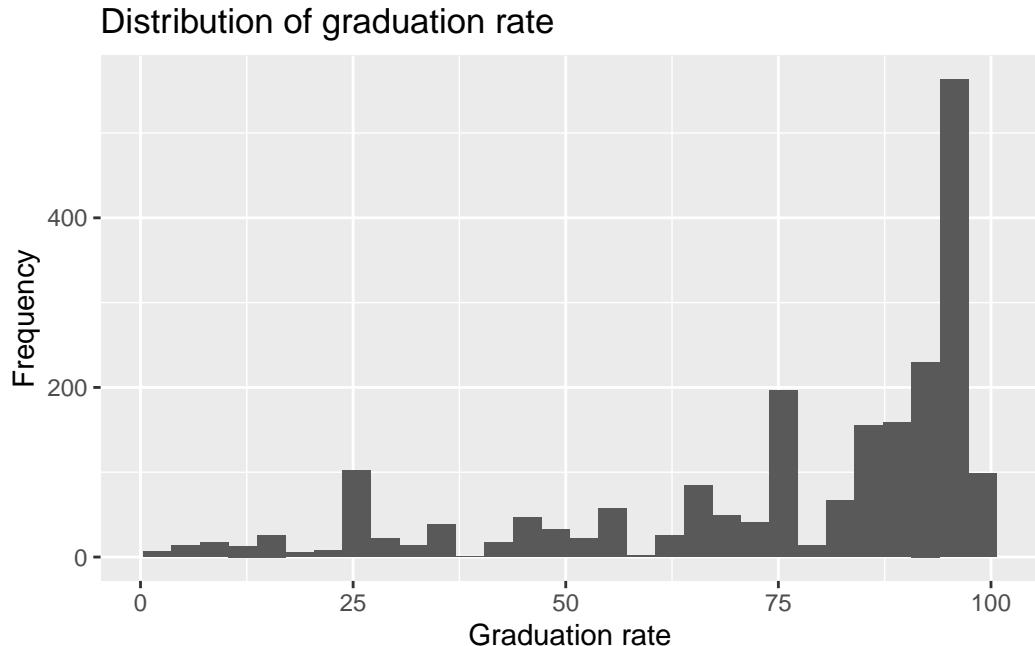


Figure 4: Histogram of graduation rate showing a left skewed distribution.

on absenteeism, family income level, extracurriculars of the students, involvement of parents and teachers, and reading level would also help in predicting graduation rates.

## 3 Methods

### 3.1 Base Model

In an attempt to answer this research question, I will first fit a multiple linear regression model using all variables and no transformations. Let  $Y$  be the  $2125 \times 1$  vector where each entry represents the graduation rate at each school. Let  $X$  be the  $2125 \times 13$  matrix where each column is a predictor. Let  $X_1$  be the vector representing the number of students enrolled,  $X_2$  be the vector equaling 1 if a school is Title I eligible and 0 if it's not,  $X_3$  be the vector representing the proportion of students enrolled in the International Baccalaureate Diploma Program,  $X_4$  be the vector representing the proportion of students enrolled in the AP program,  $X_5$  be the vector representing the proportion of students enrolled in the gifted and talented program,  $X_6$  be the vector representing the number of students that took one or more AP exams,  $X_7$  be the vector representing the number of students participating in the SAT or ACT,  $X_8$  be the vector representing the number of suspensions,  $X_9$  be the vector representing the number of full-time teachers,  $X_{10}$  be the vector representing the number of first-year teachers,  $X_{11}$  be the

vector representing the number of full-time equivalent instructional aides or paraprofessionals,  $X_{12}$  be the vector representing the number of full-time equivalent school counselors, and  $X_{13}$  be the vector representing teacher salary.

The model can be written as

$$Y = X\beta + \varepsilon$$

where  $\beta$  is the vector of coefficients for each predictor:  $\beta_0$  represents the mean of the probability distribution of the graduation rate when all predictors are 0,  $\beta_1$  represents the average change in graduation rate for an additional student enrolled, holding all other variables constant,  $\beta_2$  represents the average change in graduation rate for a Title I school, holding all other predictors constant,  $\beta_3$  represents the average change in graduation rate for an additional student enrolled in the IB program, holding all other variables constant,  $\beta_4$  represents the average change in graduation rate for an additional student enrolled in the AP program, holding all other variables constant,  $\beta_5$  represents the average change in graduation rate for an additional student enrolled in the gifted and talented program, holding all other variables constant,  $\beta_6$  represents the average change in graduation rate for an additional student that took one or more AP exams, holding all other variables constant,  $\beta_7$  represents the average change in graduation rate for an additional student participating in the SAT or ACT, holding all other variables constant,  $\beta_8$  represents the average change in graduation rate for an additional suspension instance, holding all other variables constant,  $\beta_9$  represents the average change in graduation rate for an additional full-time teacher, holding all other variables constant,  $\beta_{10}$  represents the average change in graduation rate for an additional first-year teacher, holding all other variables constant,  $\beta_{11}$  represents the average change in graduation rate for an additional full-time equivalent instructional aide or paraprofessional, holding all other variables constant,  $\beta_{12}$  represents the average change in graduation rate for an additional full-time equivalent school counselor, holding all other variables constant,  $\beta_{13}$  represents the average change in graduation rate for a one USD increase in teacher salary, holding all other variables constant.  $\varepsilon$  is the vector containing the error.

### 3.2 Transformed Model

The next model used is the model where each predictor except Title I eligibility is transformed using the square root. While a log transformation would have been ideal, there are many zeros in the dataset which is not an acceptable input in a logarithmic function. A square root transformation is similar to a logarithmic one and allows zeros in its domain which makes it a viable substitution.

The model can be written as:

$$Y = \sqrt{X}\beta + \varepsilon$$

where each variable is equivalent to those in the base model.

### 3.3 Least Absolute Shrinkage and Selection Operator (LASSO) Regression Model

The last model created is one using LASSO regression to perform variable selection. LASSO is a shrinkage or regularization regression method that has the ability to “shrink” estimated coefficients to zero, carrying out variable selection. Alongside this, it reduces the variance of parameter estimates. LASSO aims to minimize the equation:

$$\sum_{i=1}^n (Y_i - X_i^T \beta)^2 + \lambda \sum_{j=1}^{p-1} |\beta_j|$$

where  $\lambda \geq 0$  is a tuning parameter that controls the level of regularization, n represents the number of observations, and p is the number of predictors. Essentially, we are minimizing the error sum of squares (SSE) with a penalty term added to it.

I use the `lm()` function from the R programming language (R Core Team 2025) to create the base model and the transformed model. I use the `cv.glmnet()` function from the `glmnet` package to use LASSO regression to select the best model.

### 3.4 Assumptions of Linear Regression

The assumptions for linear regression are:

1. The variables used accurately reflect the quantities of interest, the model should include all predictors, and the model should be applicable for the research question.
2. The sample data is representative of the population of interest.
3. The mean function must be correct.
4. Errors must be independent.
5. The variance of the errors must be equal.
6. Errors must be normal.

Since the goal of this analysis is prediction, the most important assumption that should be met is linearity. After the transformations, there appears to be a linear relationship between the predictors and graduation rate.

### 3.5 Limitations of Analysis

present any model or statistical methods clearly using mathematical notation and plain English explanations.

Describe possible limitations of your analysis.

include any necessary steps taken for model selection and validation.

## 4 Results

describe the fitted model and its implications.

This section should include relevant tables, graphs, and quantitative results, as well as plain English explanations of all of these components.

Clearly explain what the model results show and connect your results to the central research question(s) and their broader context

## 5 Discussion

A brief summary of the paper

Discussion of your key findings and what their implications are for your research question

Discussion of some potential weaknesses of your study

Identification of potential improvements and extensions or future areas of related research.

## 6 Questions

1. should i be having this many graphs?? does figure 2 look ok only 4-5, maybe if 0 remove it as a proportion
2. still confused about interaction, esp how to check, fit a model and see
3. is there a reason to choose regularization vs stepwise selection for variable selection
4. how to add interactions in lasso
5. do i nee to explain what each beta values means for each model
6. do i need to explain lasso more
7. is assumption section ok

## References

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