A few months ago, in the state of Idaho, a bill was under consideration that would have a significant impact on the amount of funding public schools would receive. This has been a long-running discussion nationwide. Increasingly, conversations around this bill highlight unsubstantiated claims about the impact of spending on student outcomes; there is a lack empirical support, prompting this data-driven analysis to answer:

Does increased school spending directly correlate with improved academic performance?

I began to address this problem by ensuring I could find the graduation rate, as I figured it to be the best overall metric to determine how successful a school is in educating its students.

Before beginning, I chose not to use any data from 2020 or beyond, owing to the extraordinary circumstances of the global pandemic. Many students were relocated, including to homeschool education. The Federal government passed multiple funding acts including the CARES, CRRSA, and ARP Acts and more that drastically shifted the spending and graduation rate data. In short, the additional variables introduced because of the pandemic are too complicated and will obscure what past consistencies may reveal, so all data from 2020 and onward will not be included as part of the analysis.

Information regarding graduation rates and per-student funding expenditures were gathered from the National Center for Education Statistics, or NCES. The NCES is the second oldest and among the largest federal statistical agencies, and it provides nonpartisan and unbiased information on important education indicators.

I collected the data directly from their full source, shaving off rows and columns that were not necessary for this data study. These columns included information regarding the number of children in foster care and racial status, and some of the extra rows contained footnotes to the table data, empty rows, and legal disclaimers. Sometimes the data tables had to be flattened and relabeled accordingly.

A few row labels had to be renamed, as their footnotes were copied across as a part of the item name. The first row was set as the column names. Once the data had been sufficiently cleaned up, I saved the student graduation rate as a dataframe labeled “ACGR,” short for Adjusted Cohort Graduation Rate.

The ACGR refers to the percentage of public high school freshmen who graduate with a regular diploma within 4 years of starting the 9th grade. This would help eliminate outliers from other states who could potentially skew the numbers through relocation.

Because schools track grades and budgeting by school year and not calendar year, for the sake of simplicity, I labeled all dates and measures that cover two years by their first year. For example, the school year spanning August 2018 through April 2019 was labeled as the data for 2018. I was consistent in this measure for all data points.

Spending data was measured as a per-student, adjusted-inflated dollar amount. This helped to ensure consistent perspective between years and without allowing for states with significantly more students to unfairly bias the data compared to states with fewer students.

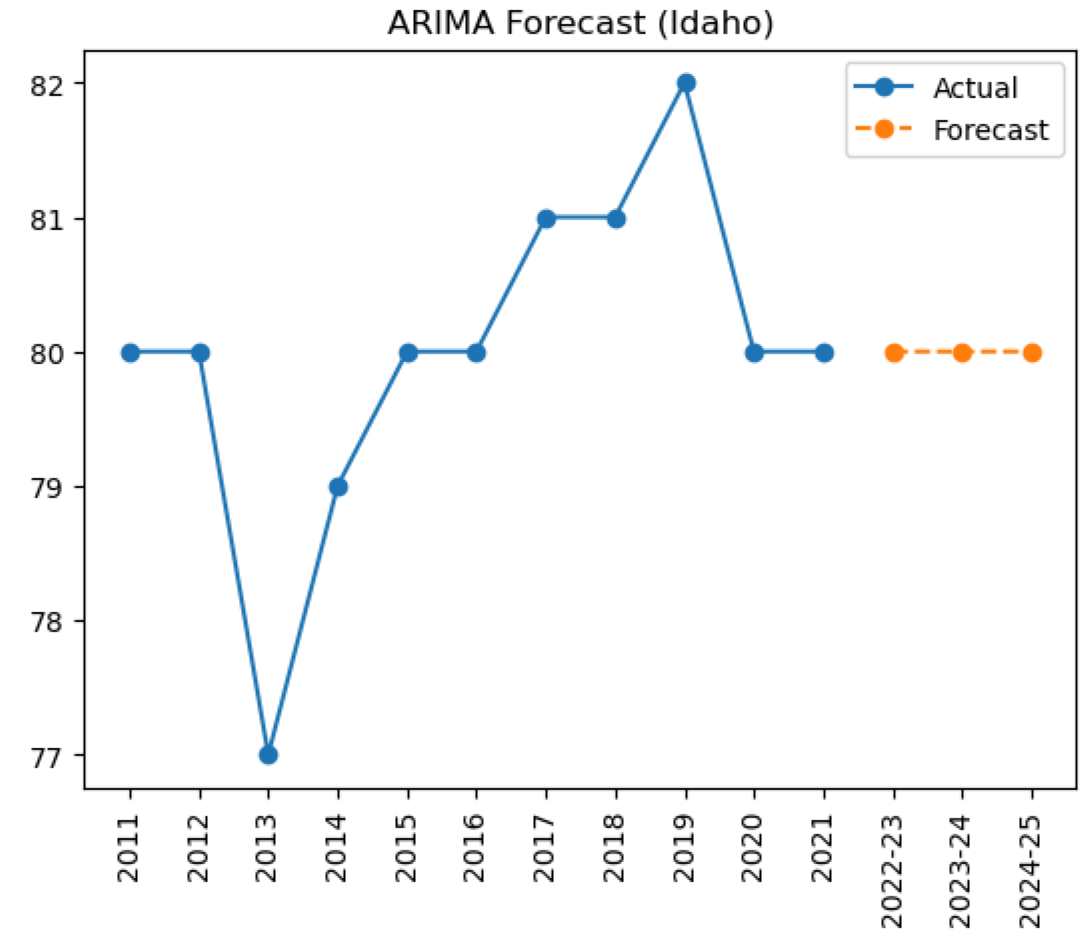
For graduation rates that contained null values for some years in some states, there were fewer than 10 missing out of hundreds of values, so I filled those using the mean value for the state.

I plotted the estimated trends in graduation rate using four different models to see which worked best with my data. This preparatory effort would help me later in the study.

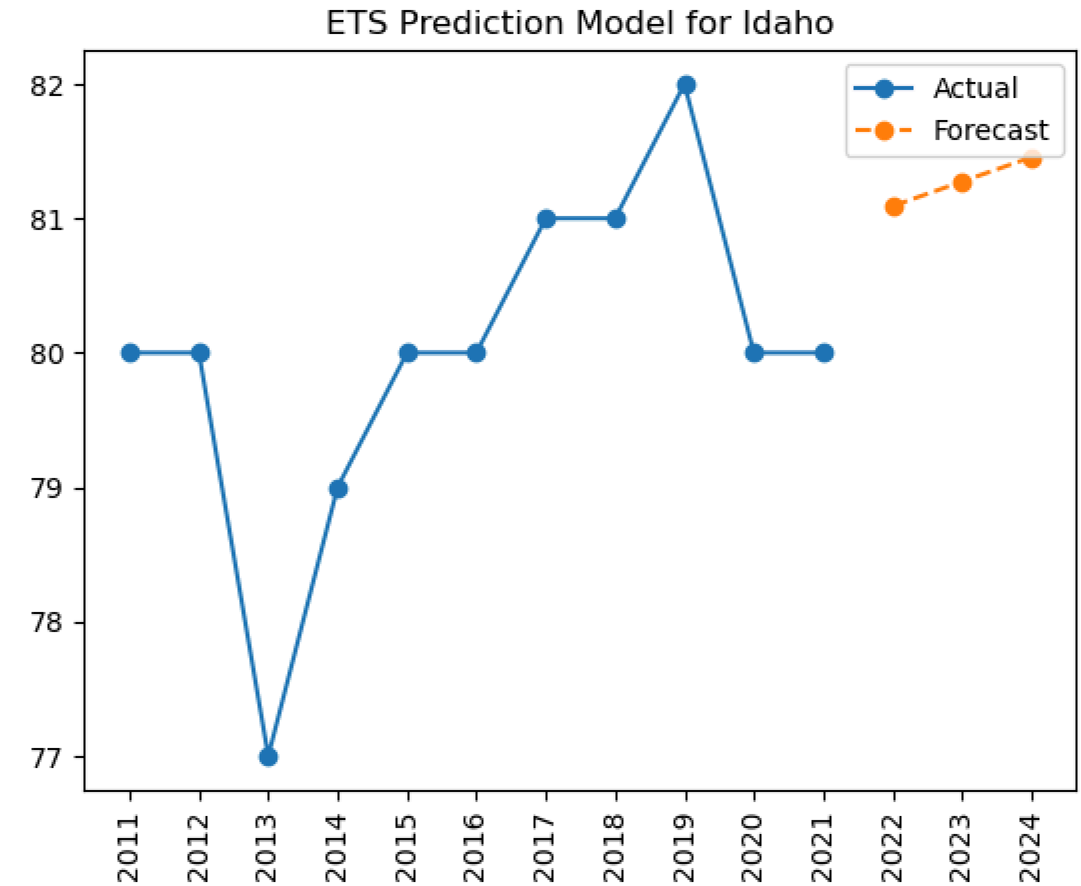
Here are the four models I used and why:

- **ARIMA**: Handles individual state data best, and can look into the future
- **ETS**: Also good for future estimation, well-suited for data over time
- **Linear Regression**: Great for trendlines for multiple states simultaneously
- **Random Forest Regression**: Similar to Linear Regression, but also able to handle complex information

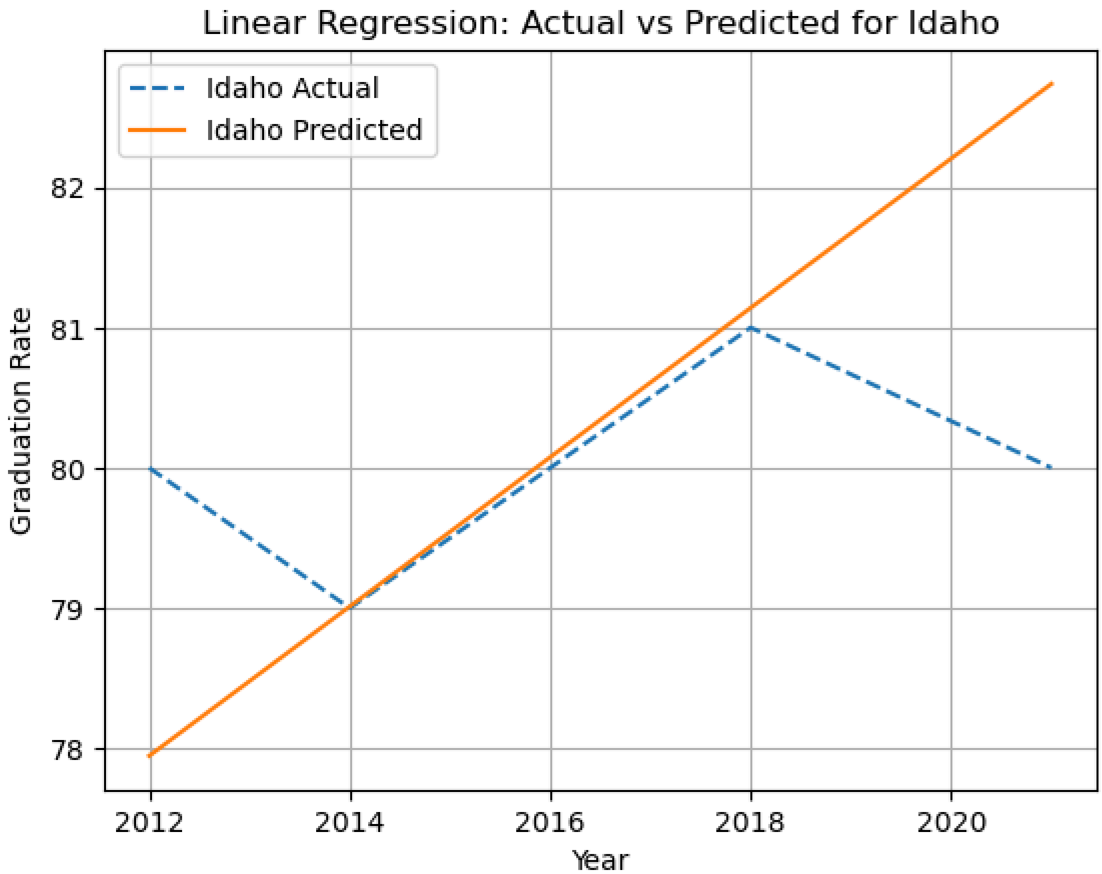
I chose my home state of Idaho for the tests. Here were the results:



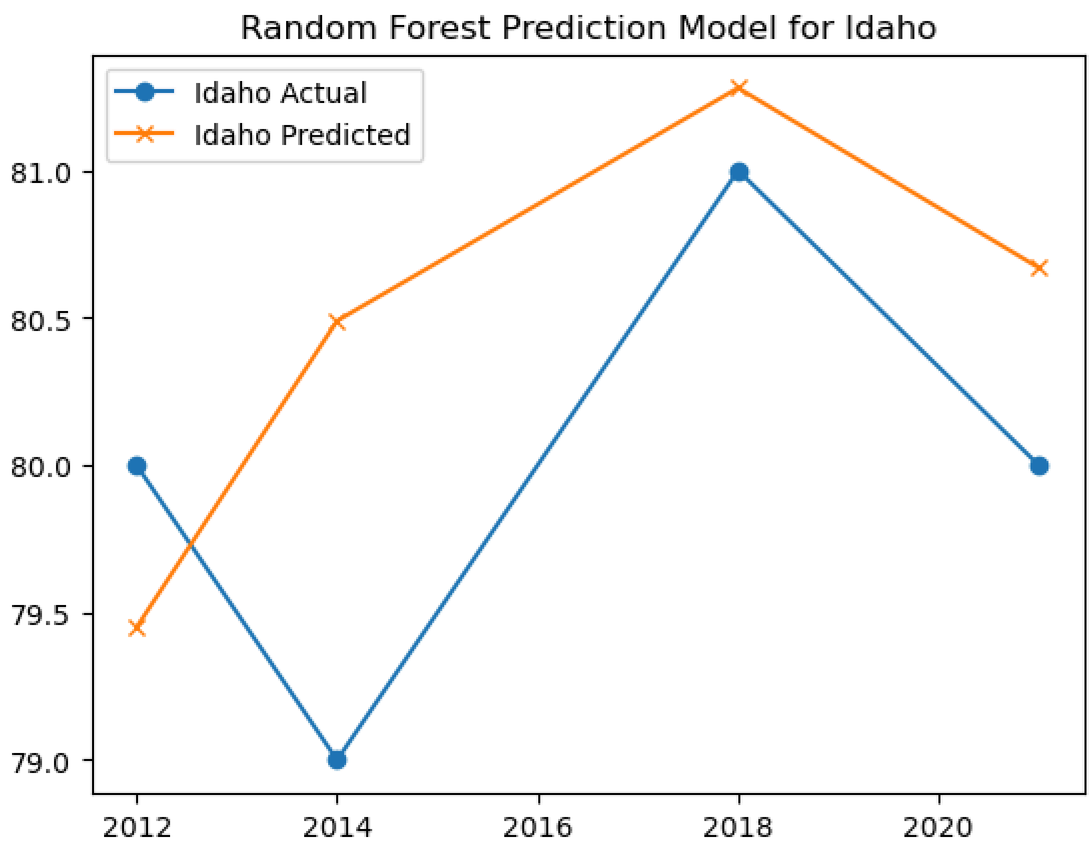

```
Covariance Type:                 opg
==============================================================================
======
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.4616      0.990      0.466      0.641      -1.479       2.403
ma.L1         -0.9992    164.364     -0.006      0.995    -323.147     321.149
sigma2         1.3881    227.254      0.006      0.995    -444.021     446.797
```



2022-01-01	81.091318
2023-01-01	81.273205
2024-01-01	81.455092



Linear Regression RMSE: 2.0044137196024665

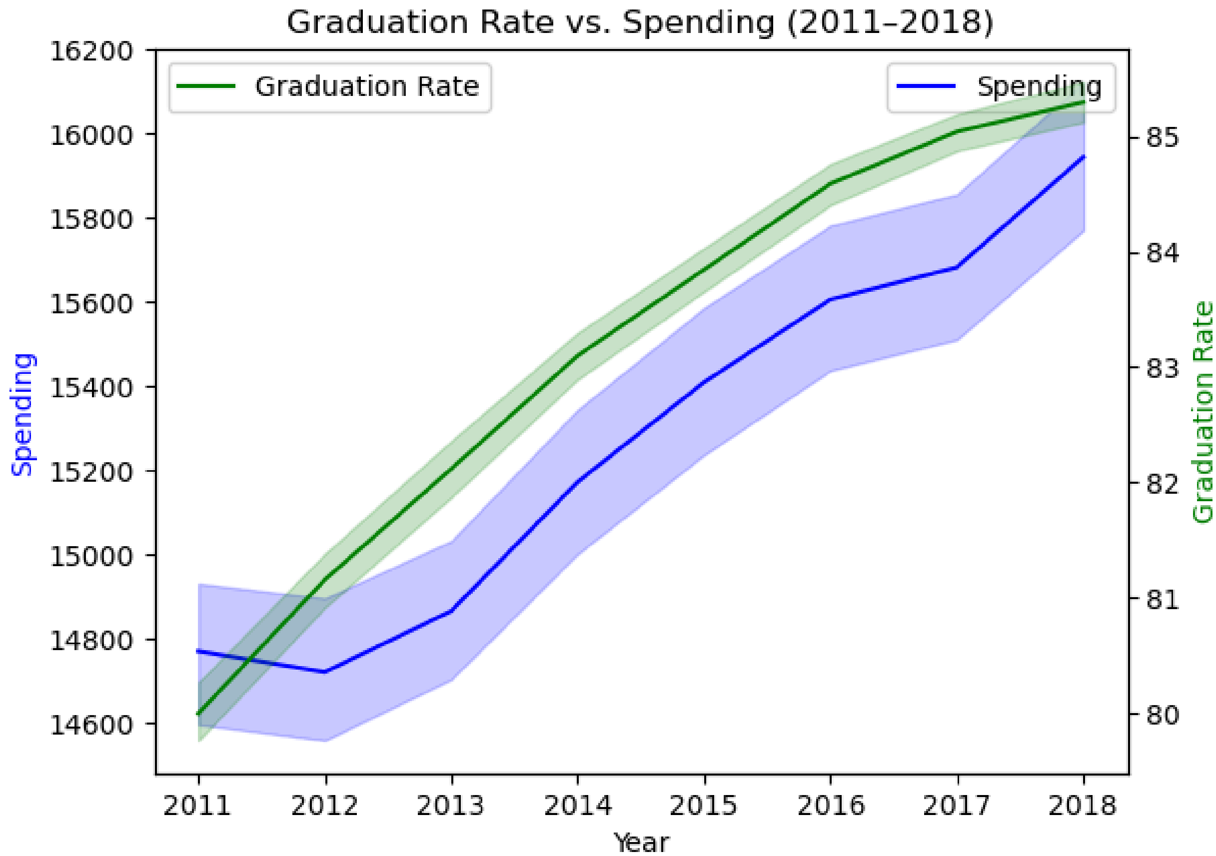


Random Forest RMSE: 2.086397157145574

The Linear Regression model most closely matched Actual and Predicted outcomes. It can also handle multiple states simultaneously, which would facilitate my effort. To ensure I was getting the best results, I also chose to use Random Forest Regression.

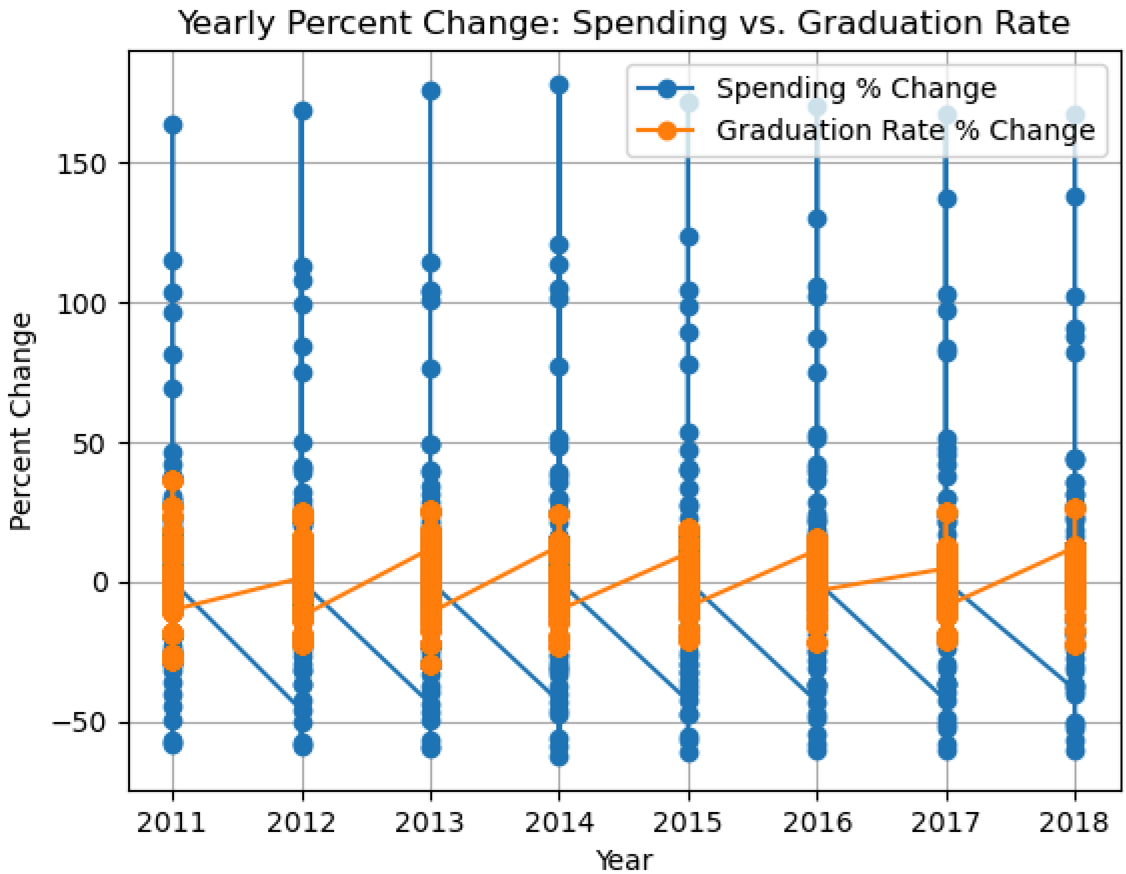
I plotted the spending data (labeled as a dataframe called ‘spending’) and the initial analysis did not show any obvious problems within the boxplot.

I plotted the graduation rate compared to the amount of spending for the eight years of data that were available:



There seems to be a strong correlation between the two variables, as we can see a trend with spending increasing and the graduation rate increasing as well. I did note the inverse relationship at the beginning of this plot, which would be worth additional investigation, but is beyond the scope of this effort.

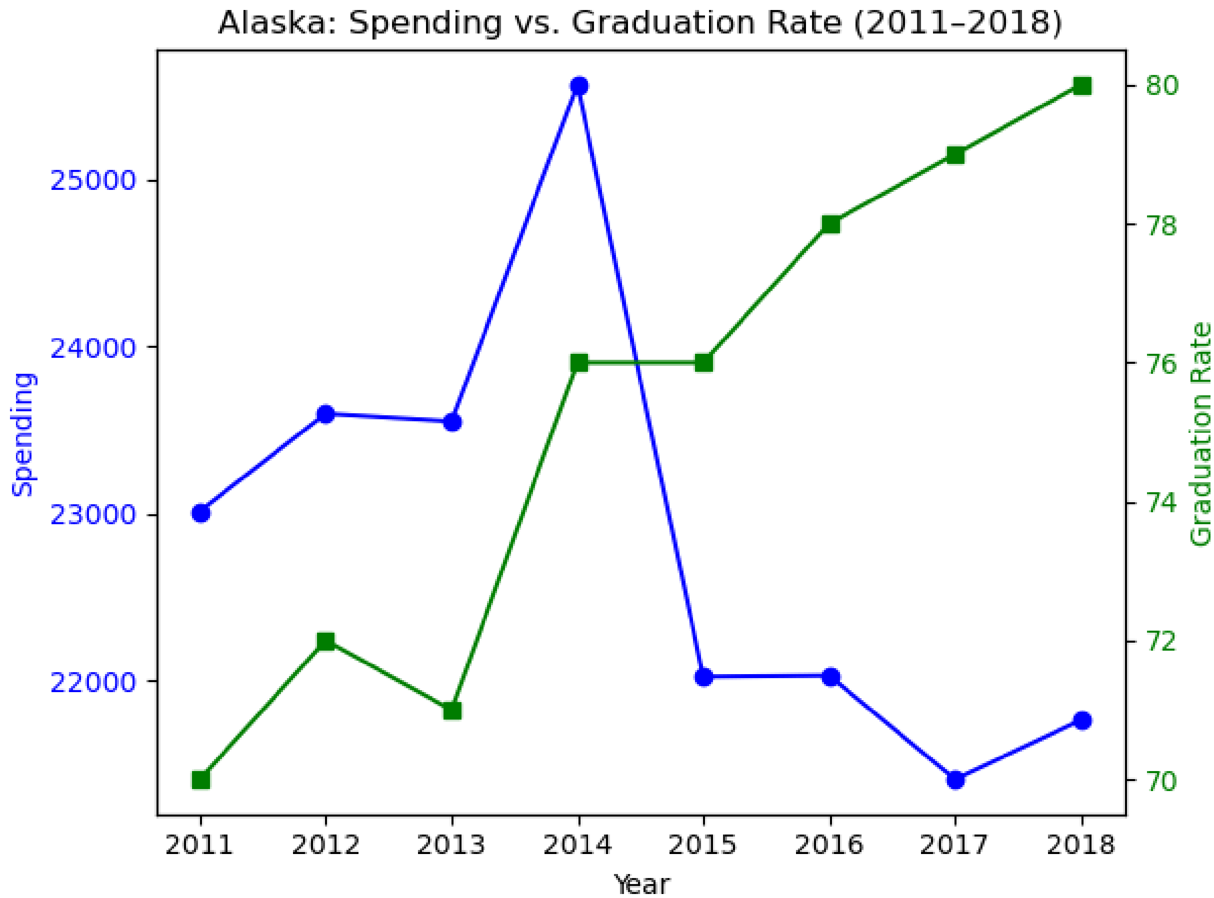
I attempted to see if there was a more obvious relationship between changes in spending and changes in the graduation rate, but saw that the graduation rate does not change much, or slowly when it does change, but the picture is still unclear.

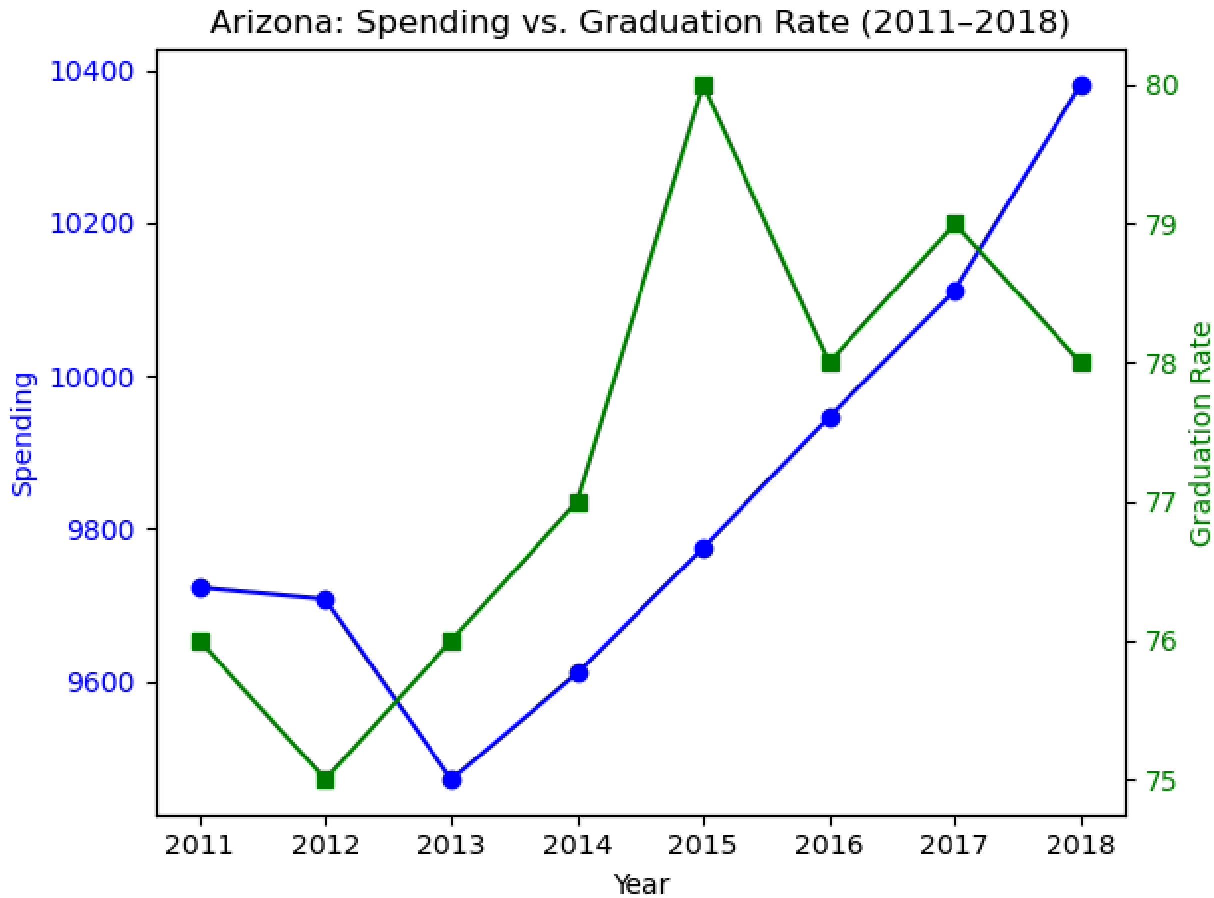


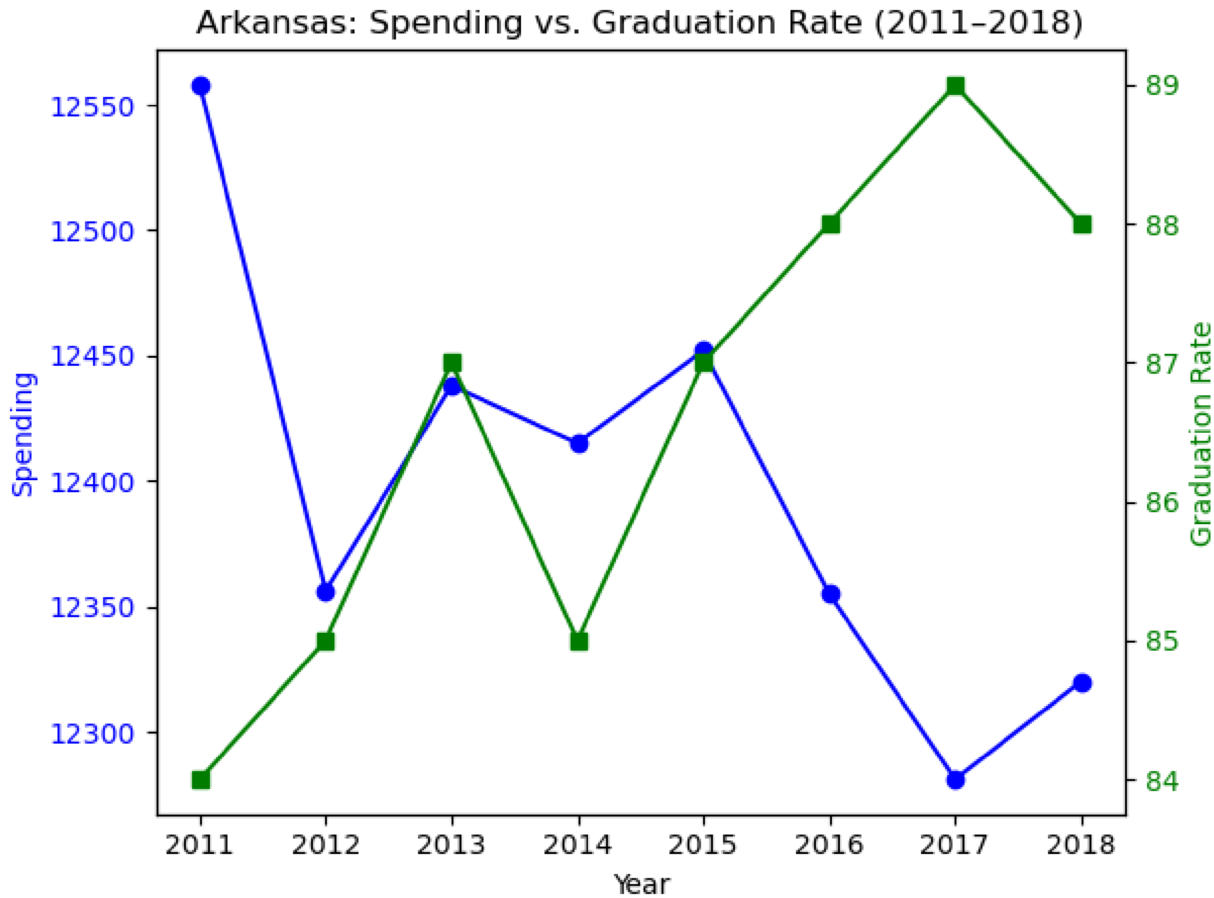
I ran a Pearson correlation between the two variables (Graduation Rate and Spending Amount) and got a Pearson correlation coefficient of 0.02823.

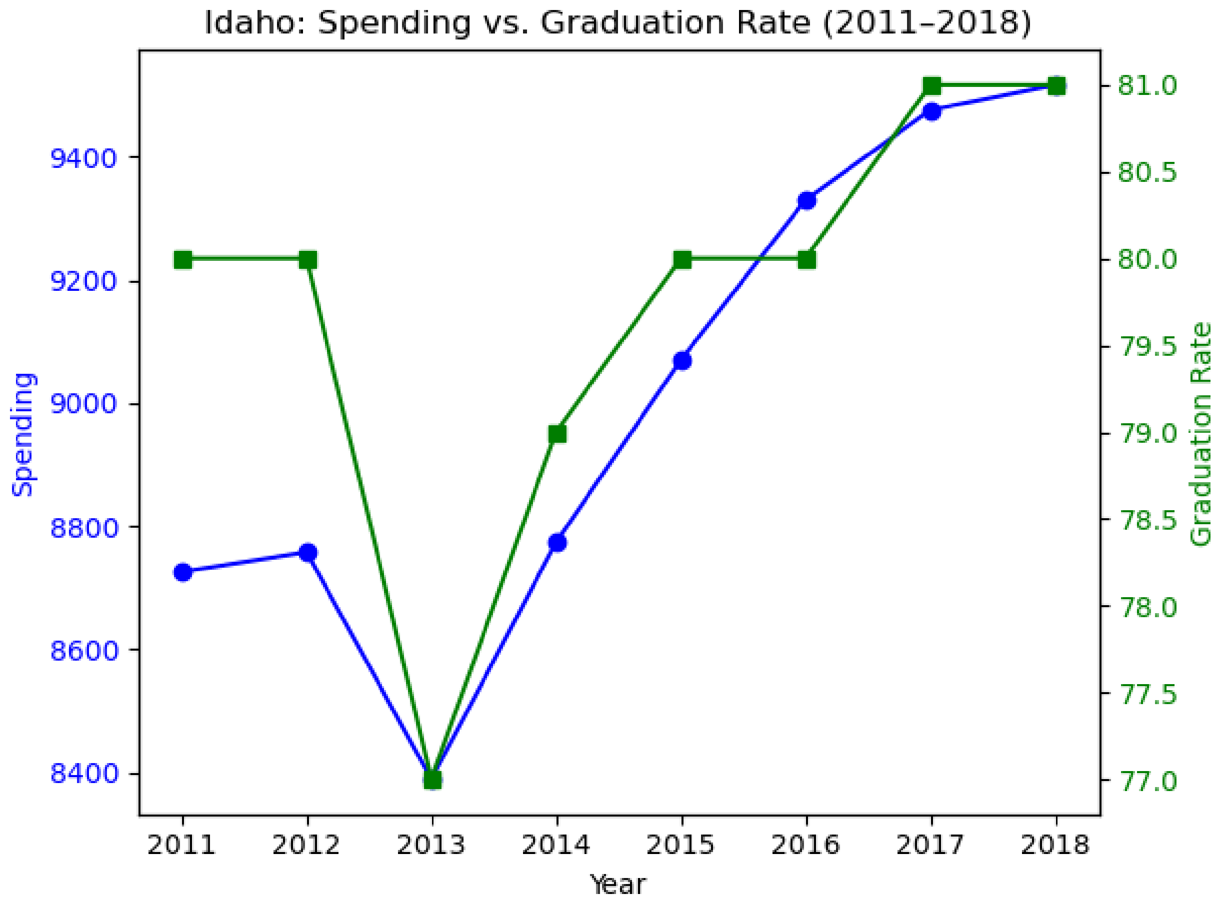
A Pearson R correlation on the spending merged with the graduation rate returned a Pearson r of 0.02823 and p-value of 0.00005. A Pearson correlation that low suggests there is almost no confirmed correlation between the two, and the p-value suggests there is a real relationship between the two, even though it appears to be weak.

I was quite curious about this result, so I looked a plot of each state individually to see if I could see it more clearly. Here are a handful of examples:

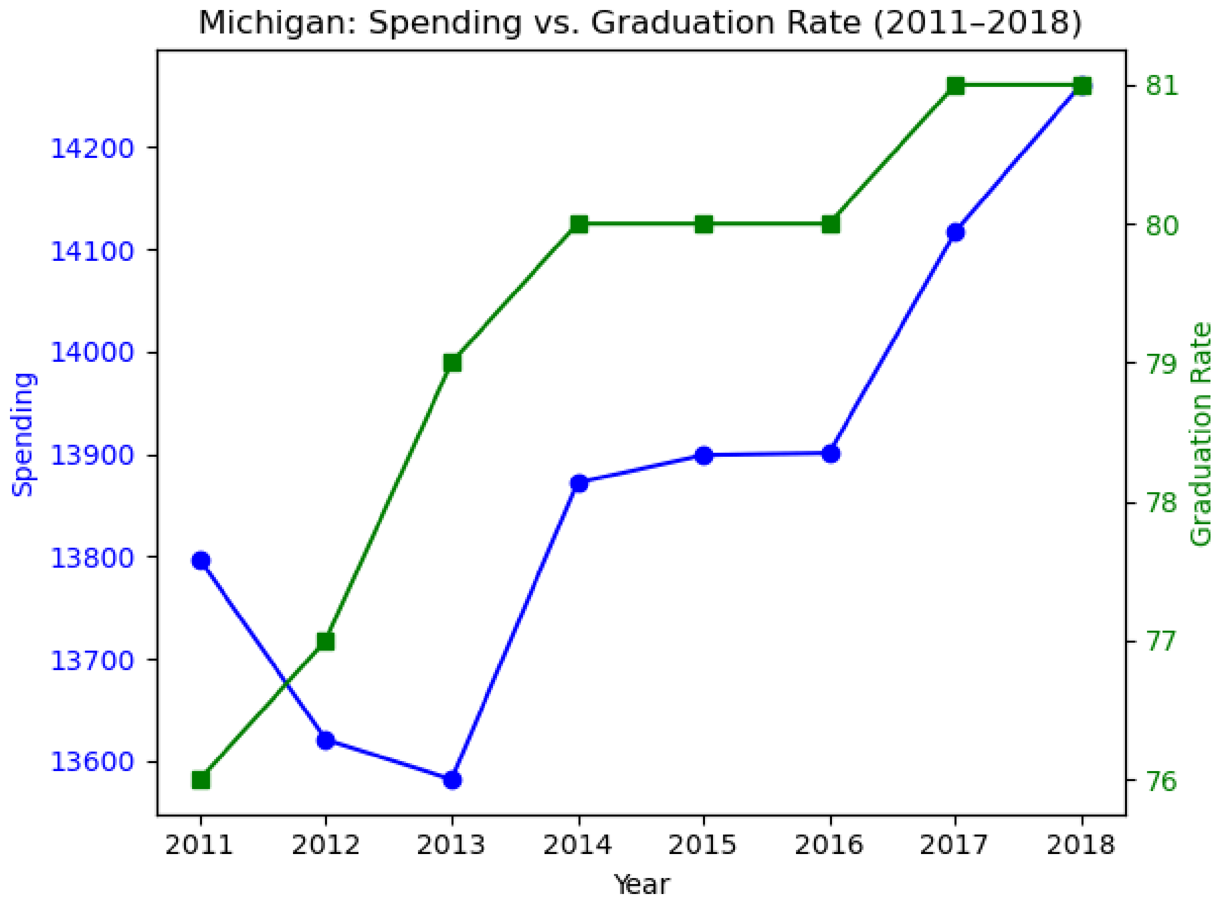

Alaska: Spending vs. Graduation Rate (2011–2018)
Spending
25000
24000
23000
22000
Graduation Rate
80
78
76
74
72
70
2011
2012
2013
2014
2015
2016
2017
2018
Year


Arizona: Spending vs. Graduation Rate (2011–2018)
Spending
10400
10200
10000
9800
9600
Graduation Rate
80
79
78
77
76
75
Year
2011
2012
2013
2014
2015
2016
2017
2018

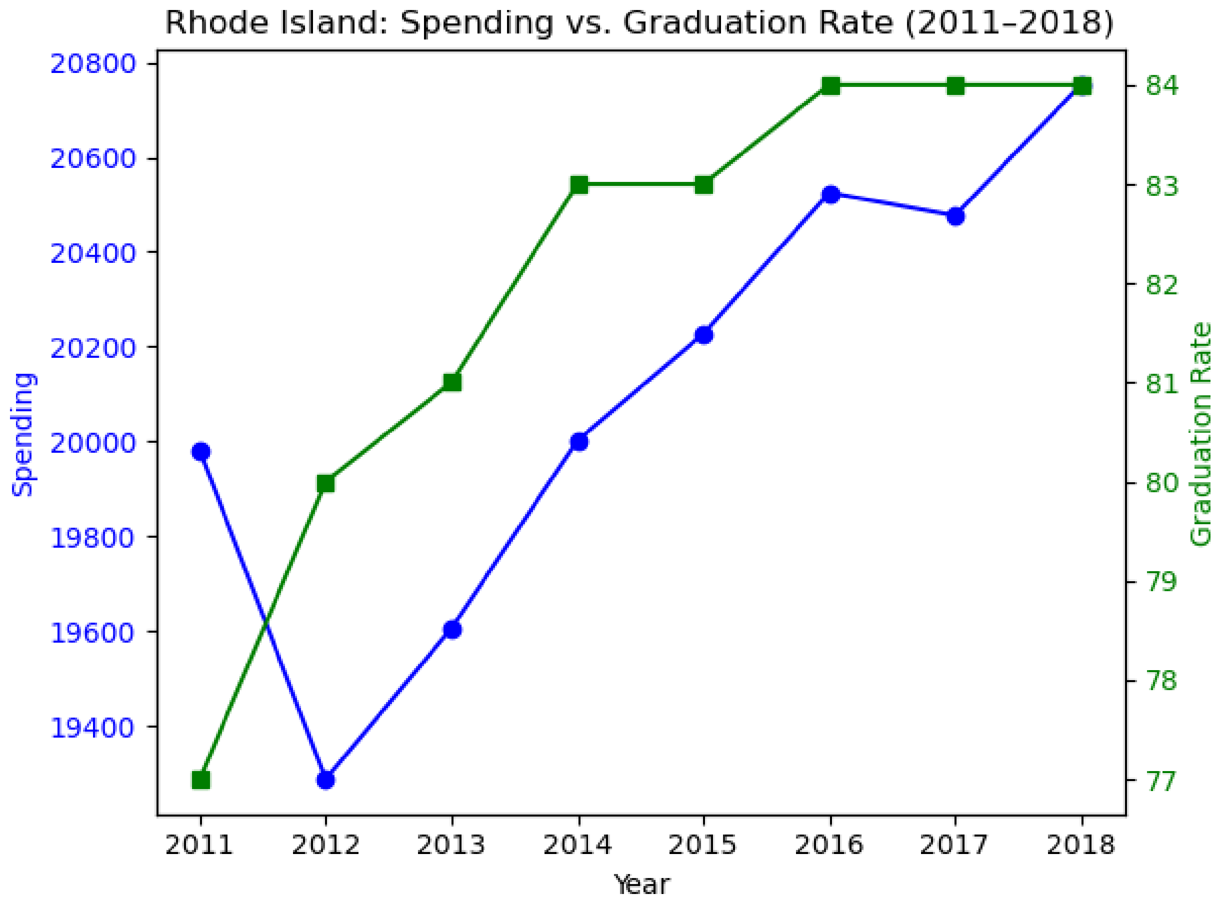

Arkansas: Spending vs. Graduation Rate (2011–2018)
Spending
12550
12500
12450
12400
12350
12300
Graduation Rate
89
88
87
86
85
84
2011
2012
2013
2014
2015
2016
2017
2018
Year



Idaho: Spending vs. Graduation Rate (2011–2018)
Spending
9400
9200
9000
8800
8600
8400
Graduation Rate
81.0
80.5
80.0
79.5
79.0
78.5
78.0
77.5
77.0
2011
2012
2013
2014
2015
2016
2017
2018
Year

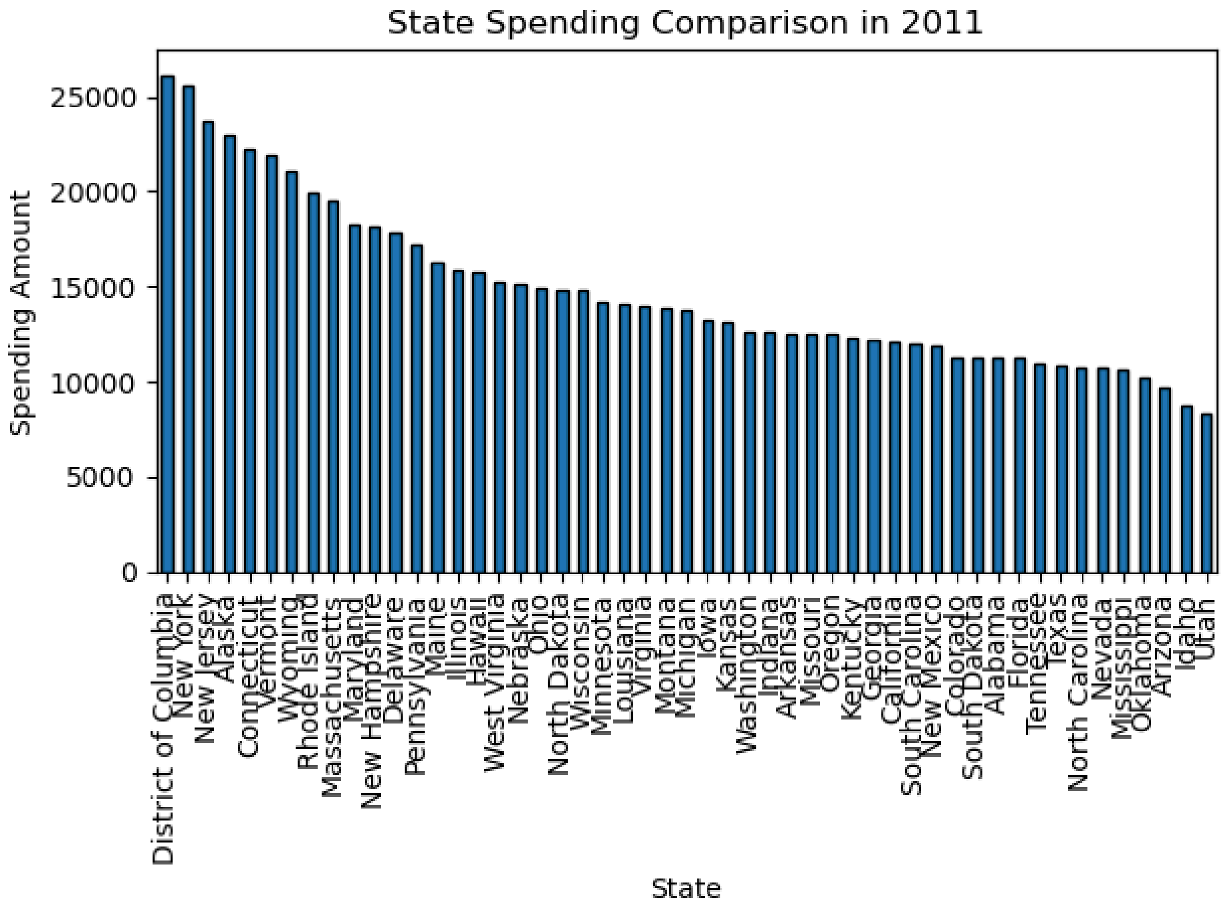


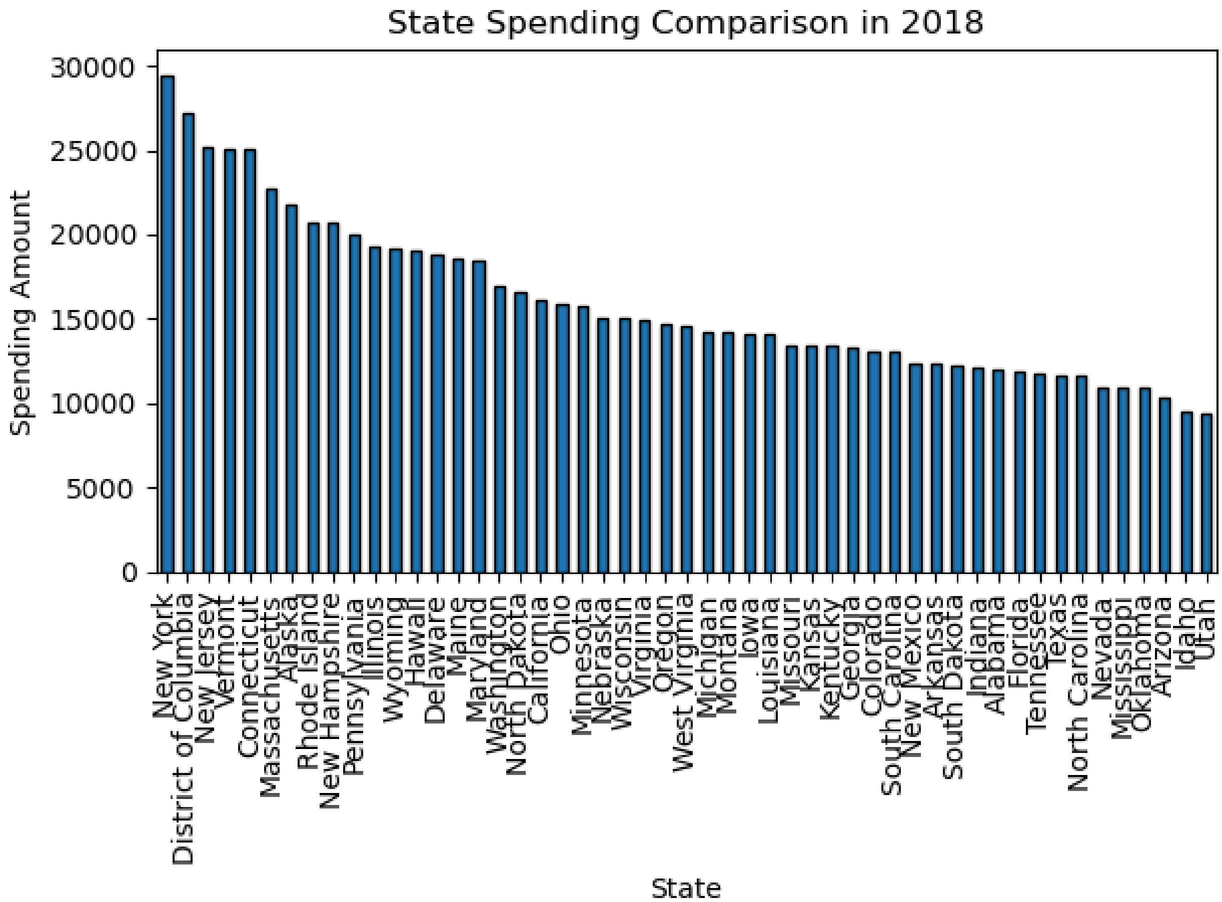
Michigan: Spending vs. Graduation Rate (2011–2018)
Spending
14200
14100
14000
13900
13800
13700
13600
Graduation Rate
81
80
79
78
77
76
2011
2012
2013
2014
2015
2016
2017
2018
Year



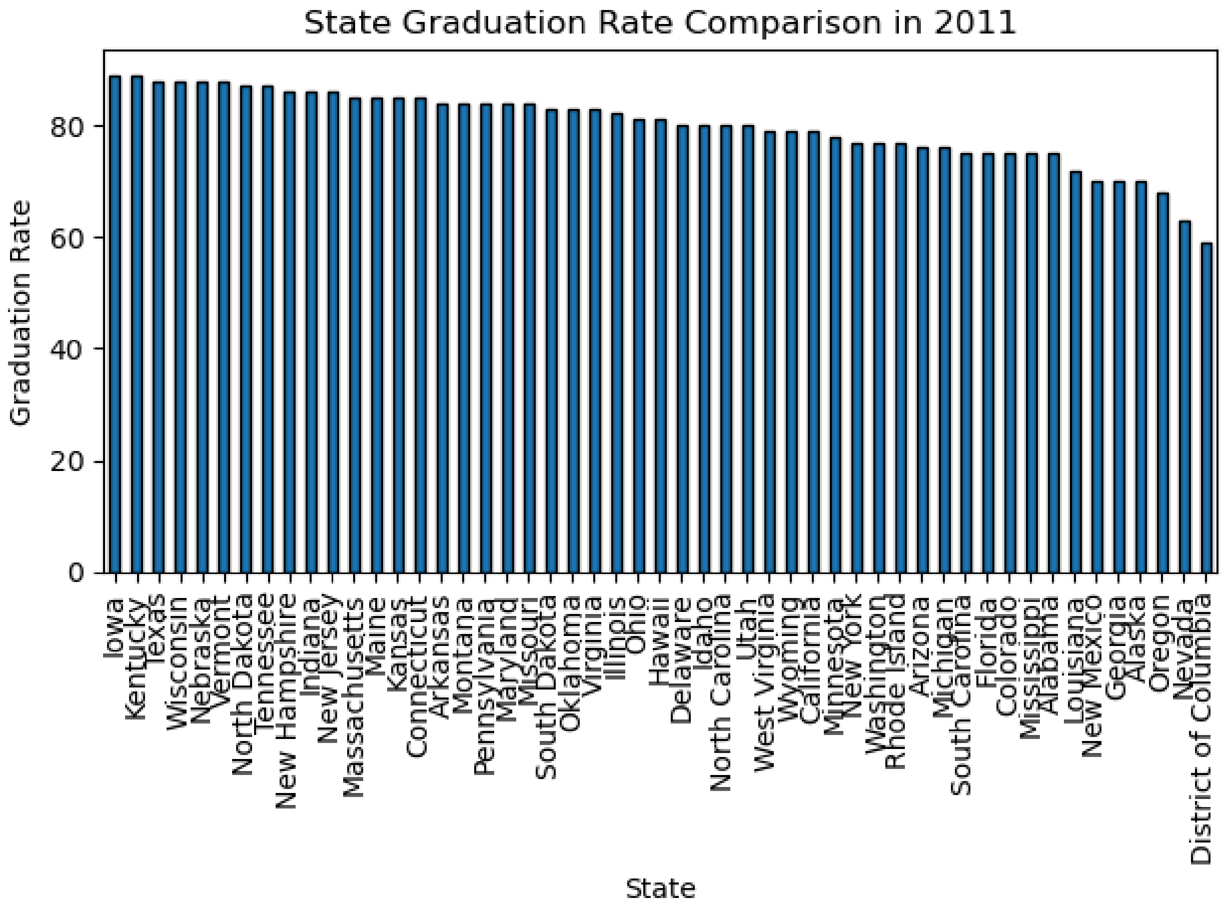
When we look at all of them together, it looks like there is a very close linear relationship, but the state-by-state information is much more informative; there is some matching, but there are also many instances of a negative relationship between spending and graduation rate.

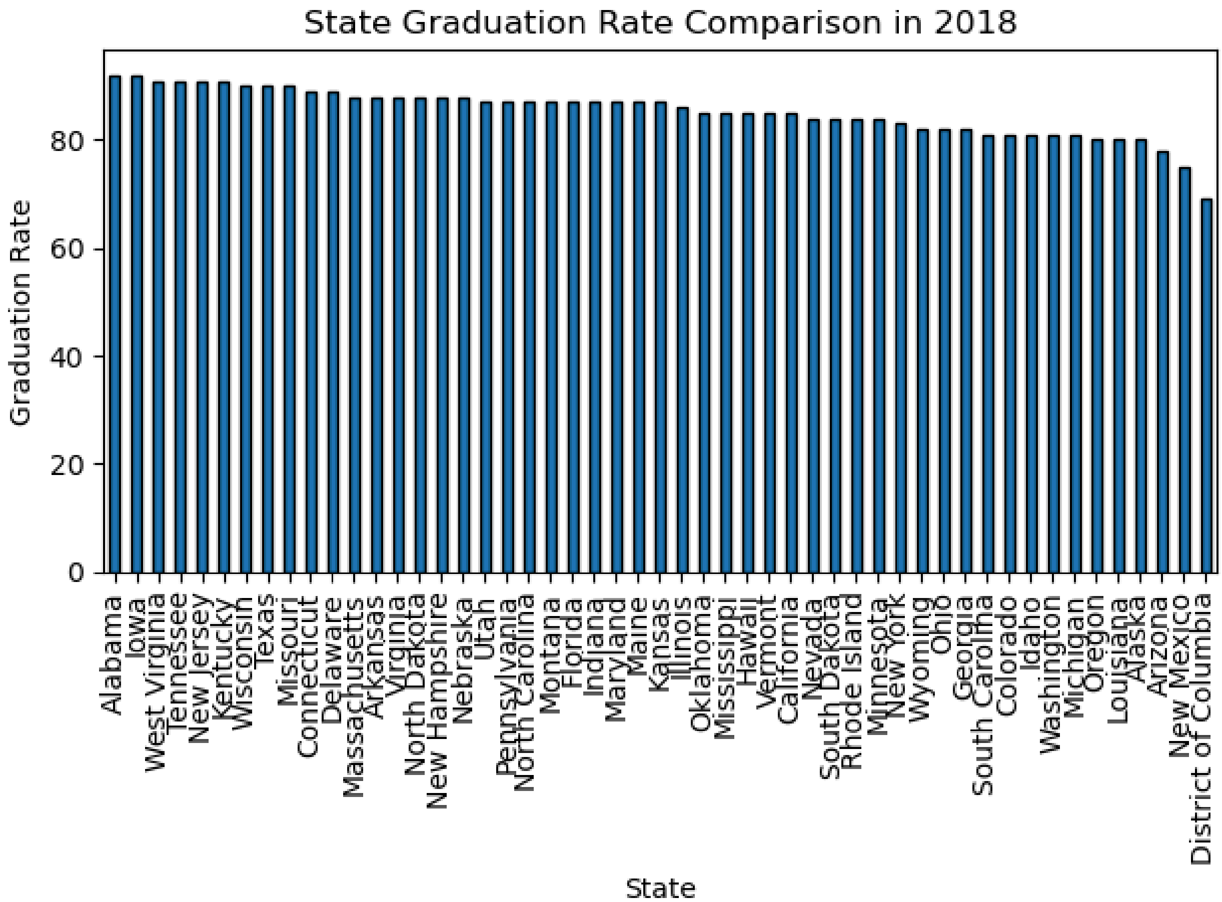
Because the numbers are calculated on a cost per-student basis, I decided to plot each year as a whole, looking at the overall spending trend between states here are the first and last:


State Spending Comparison in 2011
Spending Amount
0
5000
10000
15000
20000
25000
District of Columbia
New York
New Jersey
Alaska
Connecticut
Vermont
Wyoming
Rhode Island
Massachusetts
Maryland
New Hampshire
Delaware
Pennsylvania
Maine
Illinois
Hawaii
West Virginia
Nebraska
Ohio
North Dakota
Wisconsin
Minnesota
Louisiana
Virginia
Montana
Michigan
Iowa
Kansas
Washington
Indiana
Arkansas
Missouri
Oregon
Kentucky
Georgia
California
South Carolina
New Mexico
Colorado
South Dakota
Alabama
Florida
Tennessee
Texas
North Carolina
Nevada
Mississippi
Oklahoma
Arizona
Idaho
Utah
State



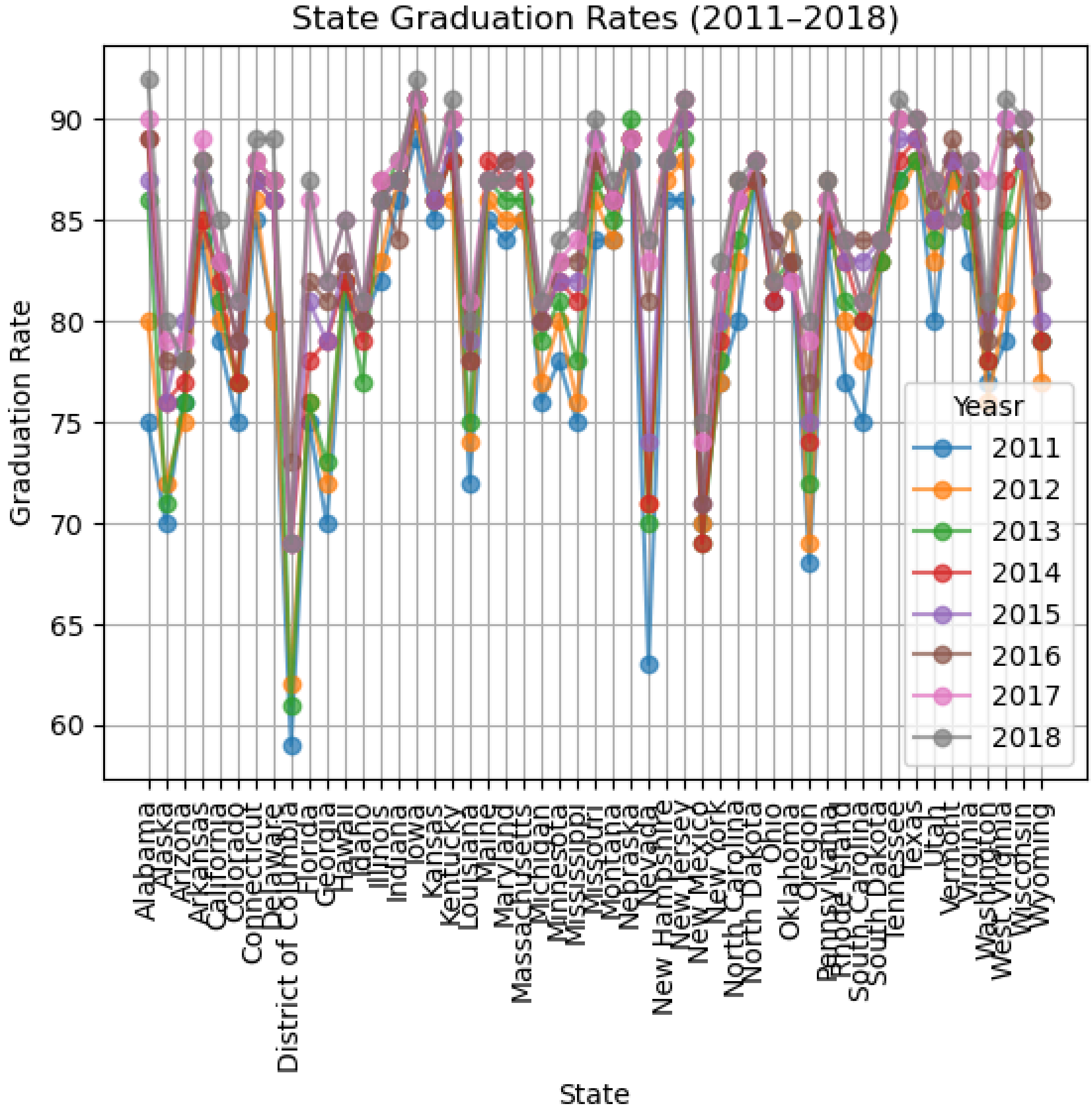
Here is the same comparison of the graduation rate between the first and last years:


State Graduation Rate Comparison in 2011
Graduation Rate
0
20
40
60
80
State
Iowa
Kentucky
Texas
Wisconsin
Nebraska
Vermont
North Dakota
Tennessee
New Hampshire
Indiana
New Jersey
Massachusetts
Maine
Kansas
Connecticut
Arkansas
Montana
Pennsylvania
Maryland
Missouri
South Dakota
Oklahoma
Virginia
Illinois
Ohio
Hawaii
Delaware
Idaho
North Carolina
Utah
West Virginia
Wyoming
California
Minnesota
New York
Washington
Rhode Island
Arizona
Michigan
South Carolina
Florida
Colorado
Mississippi
Alabama
Louisiana
New Mexico
Georgia
Alaska
Oregon
Nevada
District of Columbia



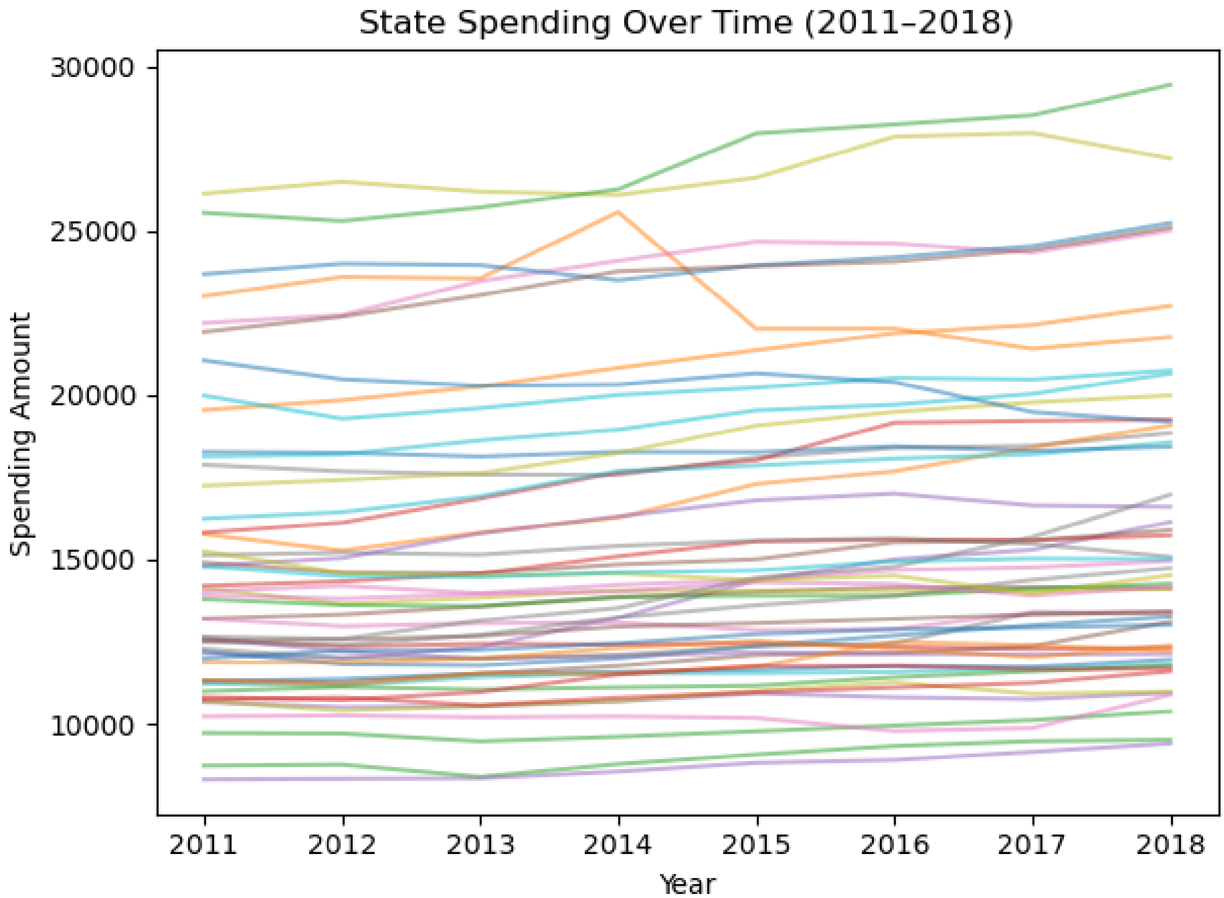
The states at the top and bottom of the list (which are easiest to distinguish like this) change from year to year, in terms of both Graduation Rate and Spending.

Plotting each year to compare against the remaining states shows that, while the states differ from one another significantly, there are not wild shifts within the state itself.



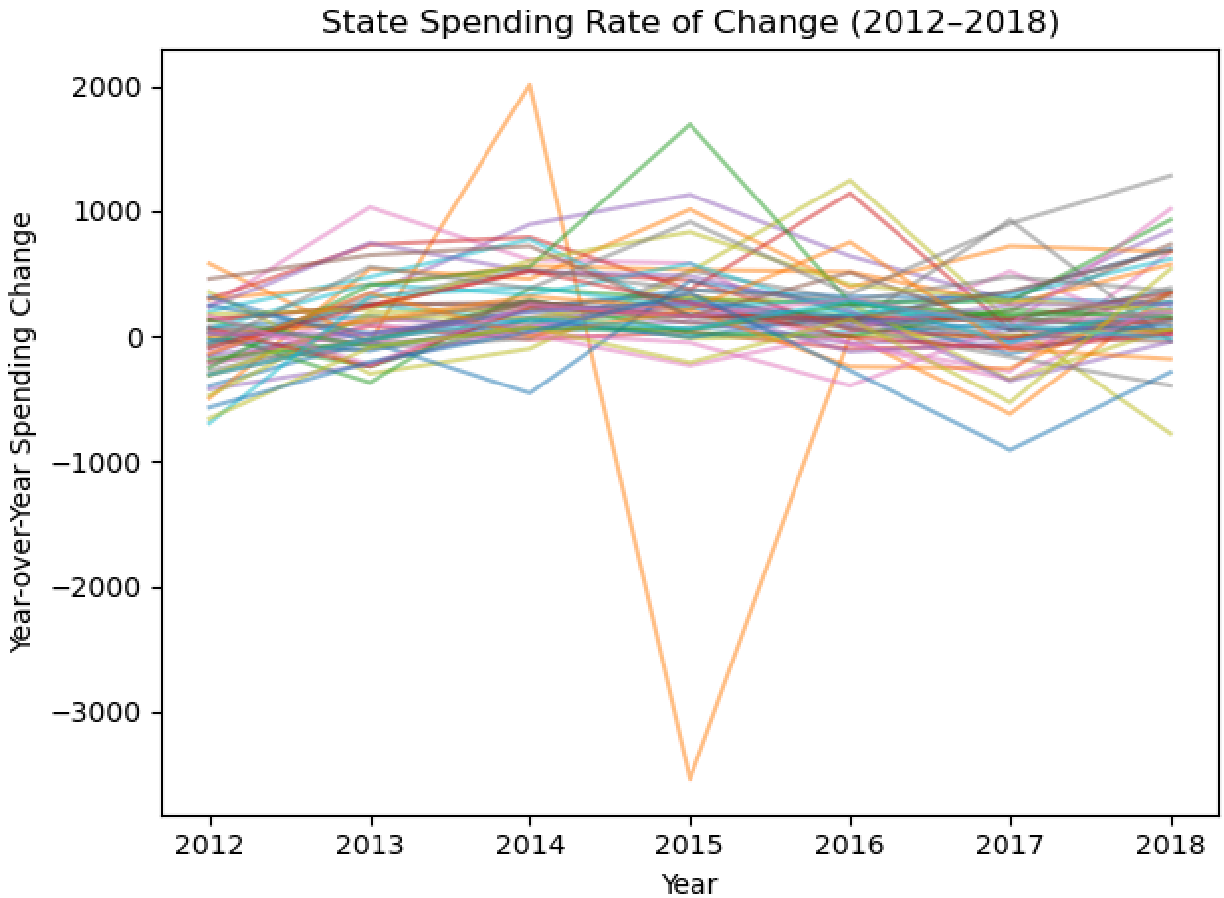
The spending rate did not have nearly this much variability to it.

Evaluating the general spending trend of 50 states on a single plot is not clear:



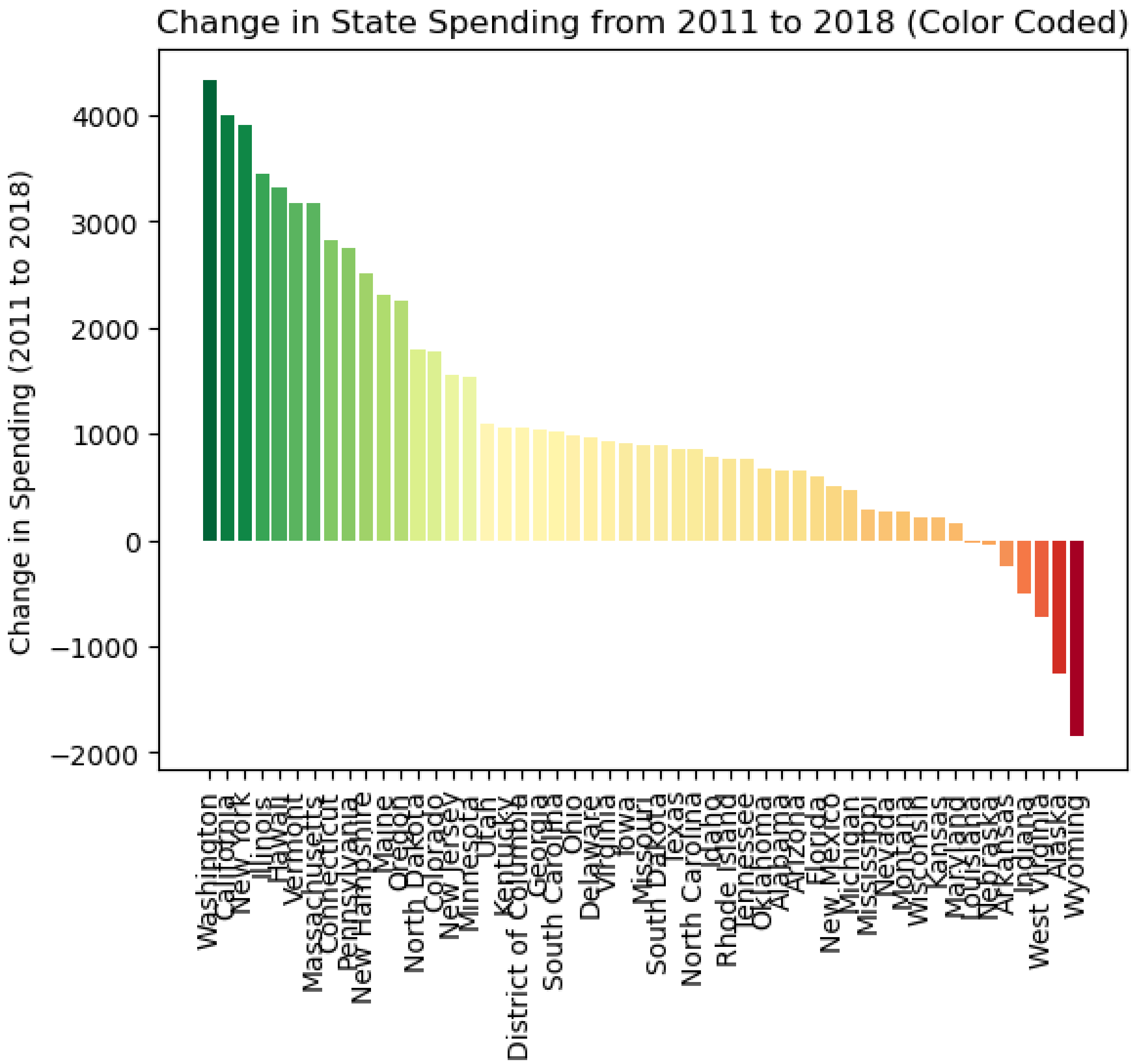
But there does seem to be a positive upward trend in spending overall.

As such, I plotted the rate of changes year over year:



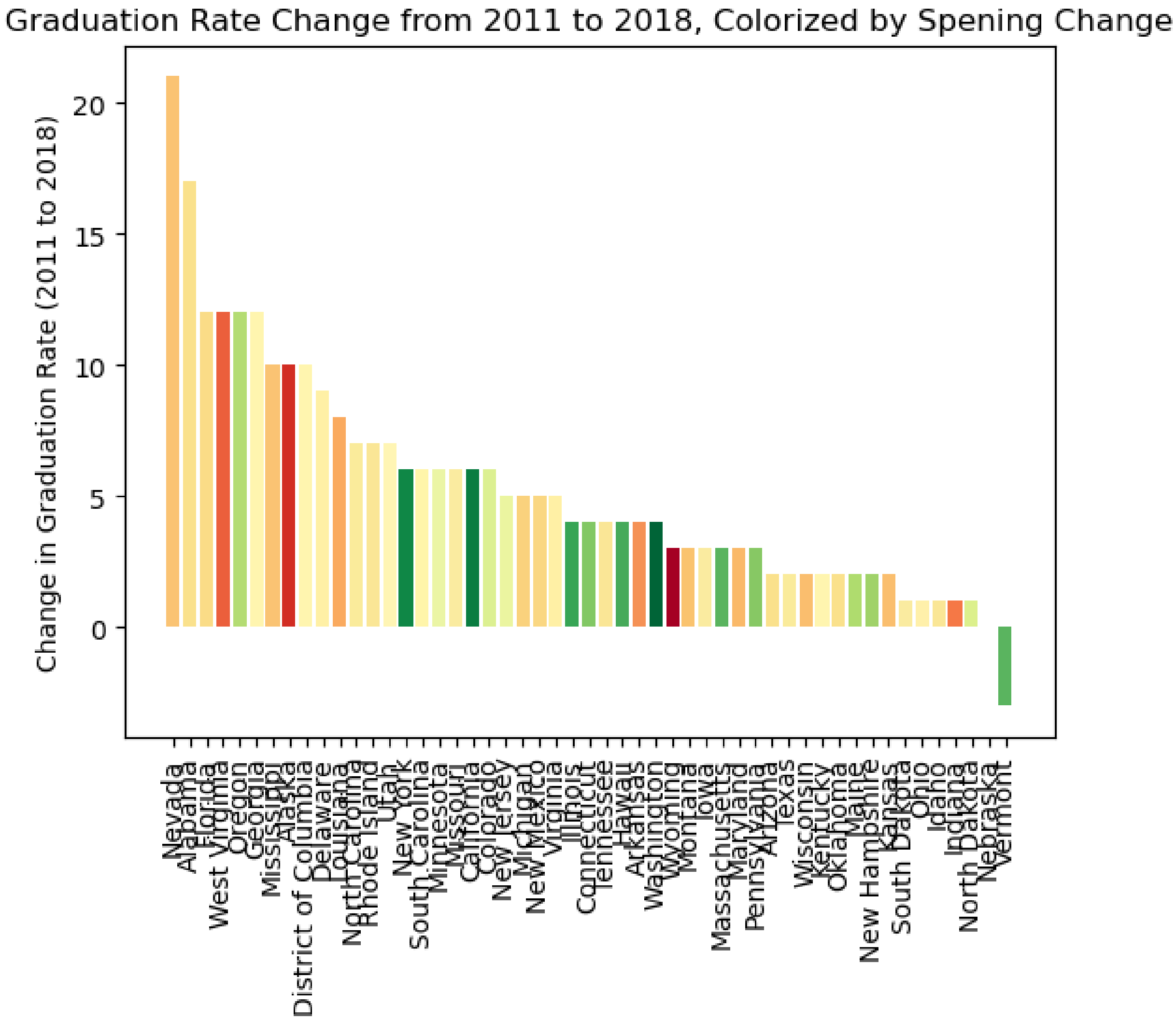
With a few exceptions, this seems to confirm the increasing spending rate over time.

I plotted the change in spending, color-coding it to show a difference in degree: dark green representing large spending changes, red to show a decrease in spending:



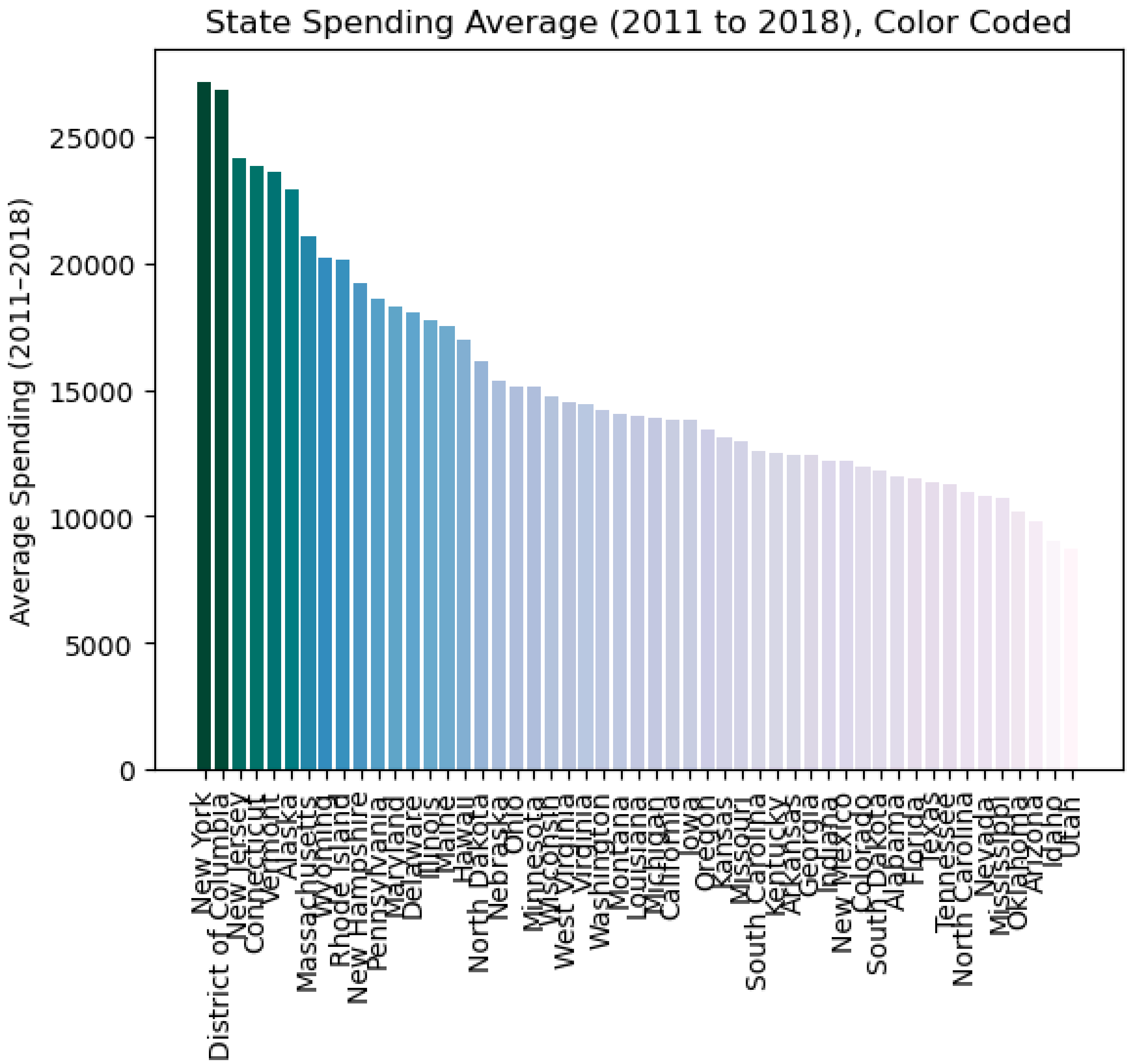
Only a handful of states have reduced spending.

I locked in the color for each state, then plotted the graduation rate:

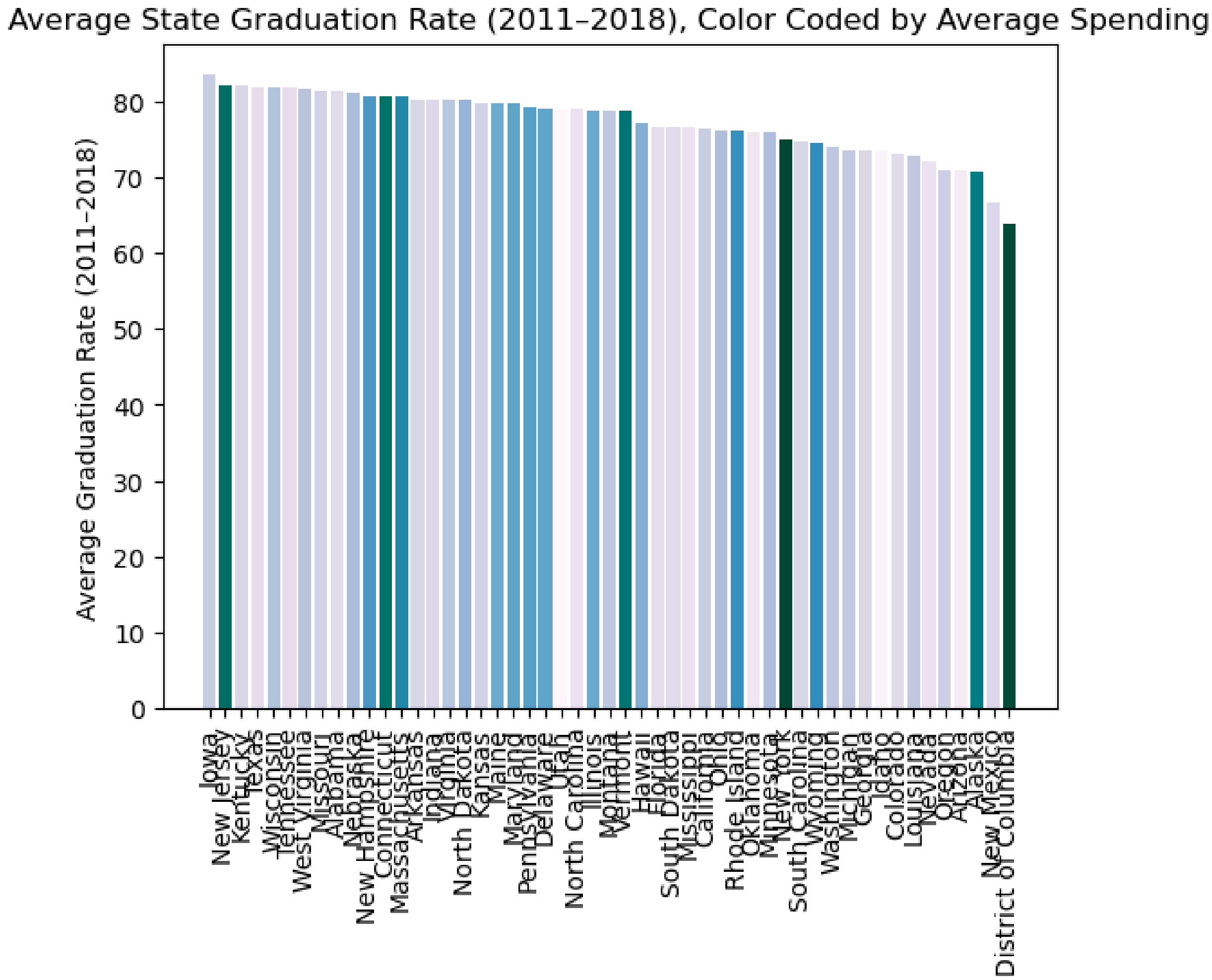


As a reminder, the green color represents a positive increase in spending and red indicates a decrease in spending, but the result of this plot shows what appears to be a randomization in the graduation rate. Deep red and deep green can be found in the middle of the graduation rate grouping, a state that spent much more has significantly decreased their graduation rate.

To be thorough, let’s look at the absolute dollar amount instead of changes:



I’m using different colors so as not to confuse the two plots. Deeper green indicating the highest amount of average spending per child, fading to white for the lowest dollar amount in spending per child.



The result is very much the same: a seemingly random distribution of graduation rates that do not show an obvious correlation for the total dollar amount spent.

In order to know which state would be the most likely to prepare a student for graduation from secondary school, and compare it to the state least likely, I ran a Linear Regression and a Random Forest Regression against the data to predict future graduation rates.

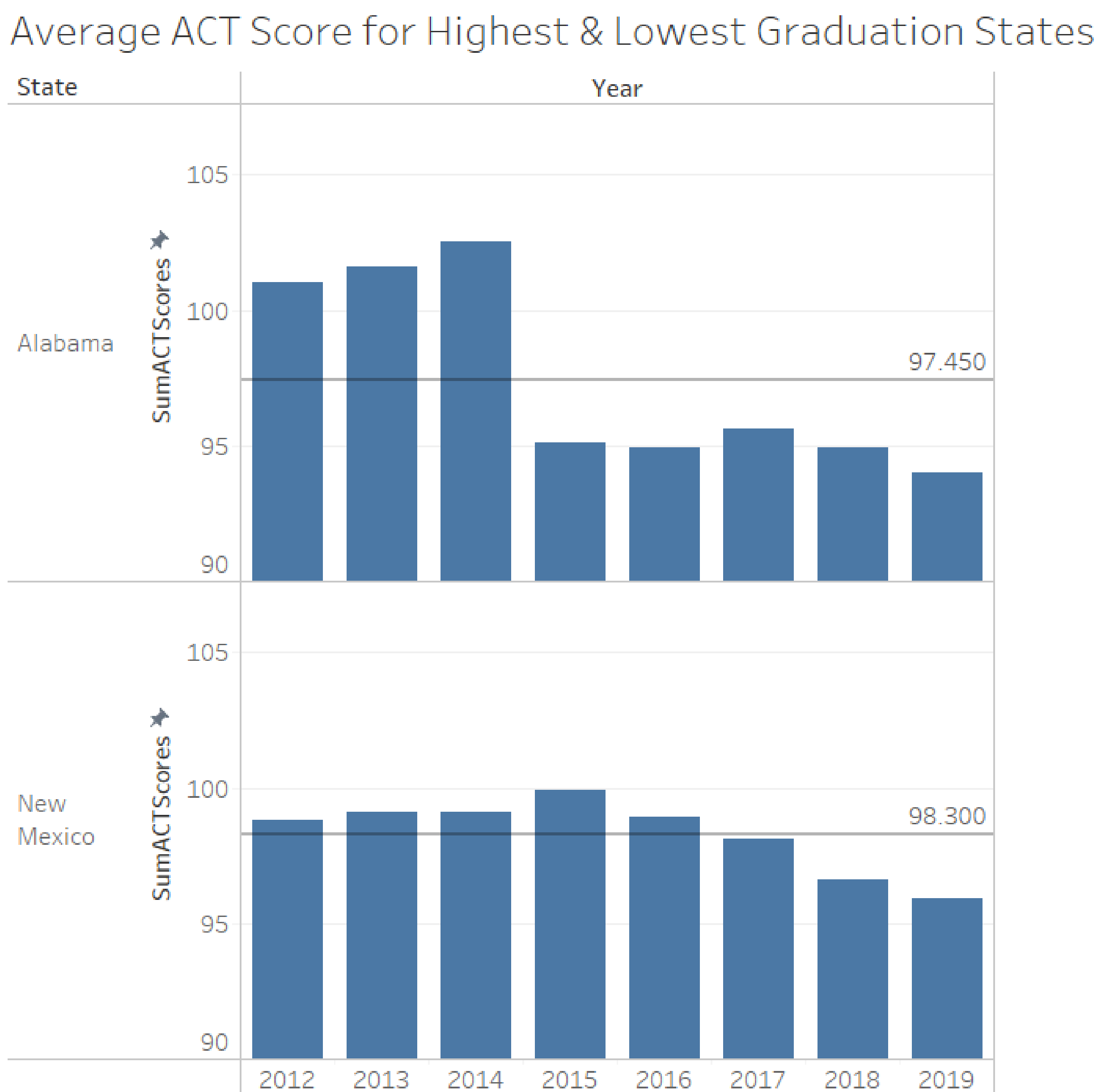
The Random Forest predicted almost zero future increase in graduation based on the available data (it may not have enough data to make a proper prediction), so the Linear Regression data is what was used. According to it, the state of Alabama has the highest estimated graduation rate at 99.62% and New Mexico has the lowest estimated graduation rate at 76.00%.

I realized at this point that the ability to graduate from high school is not a nationwide standard. Some states could be more lenient in allowing graduation than others, which would necessarily skew the data.

There does not exist a standard metric to determine secondary school graduation readiness. The best option for a standardized test is to consider the American College Testing (ACT) and Scholastic Aptitude Test (SAT) examinations, which are standardized at the national level, so state-by-state differentiations will not exist.

Unfortunately, this data does not show metrics for the student body as a whole, only those who voluntarily wish to take the exam in preparation for post-secondary education. Also, as an additional complicating factor, the SAT changed its format in 2016, rendering any more recent data irrelevant to the data gathered prior to 2016.

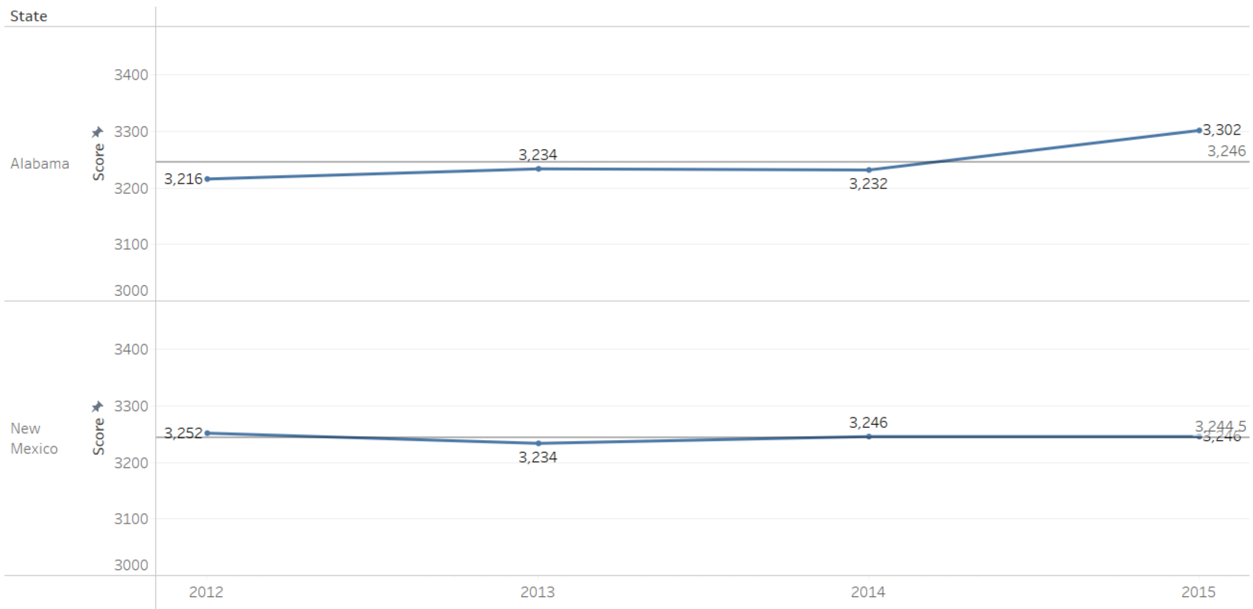
Looking at the school with the highest predicted graduation rate and the lowest predicted graduation rate, I plotted the average ACT scores of those two states over the years:



Despite the wide difference in graduation rate, New Mexico boasts a slightly higher average score on the ACT exam.

Looking at the old SAT score data (because the rubric changed in 2016), we see a similar comparison:

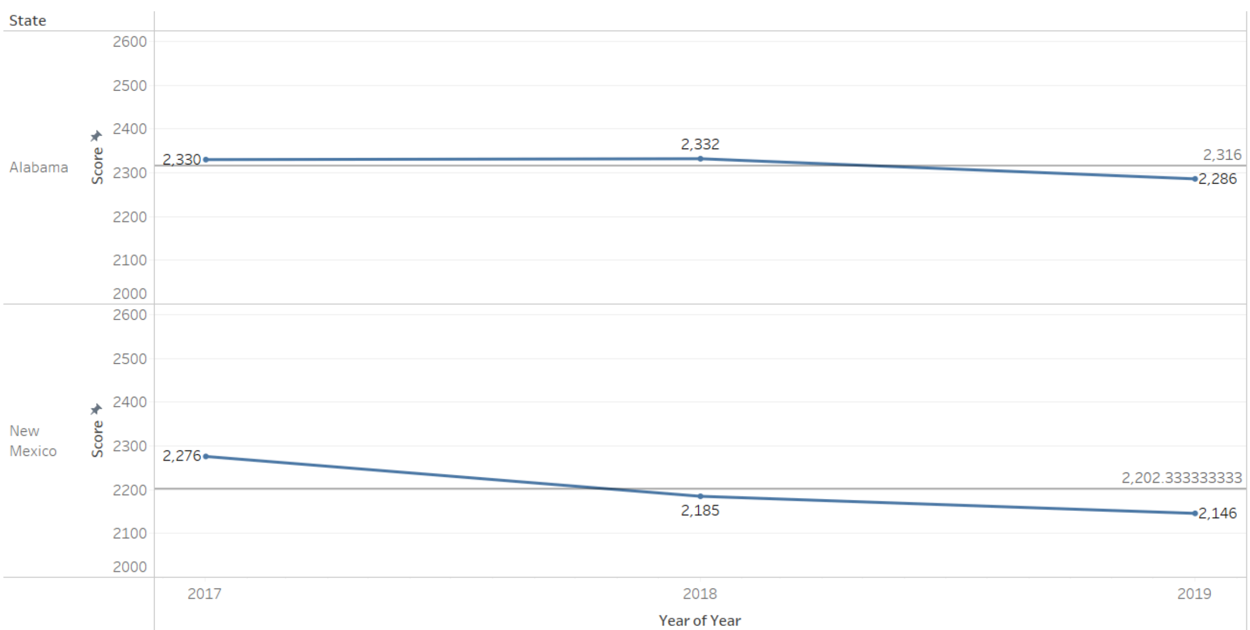
Average Old SAT Score for Highest & Lowest Graduation States



The average SAT score for the state with the highest graduation and lowest graduation rates is almost exactly the same.

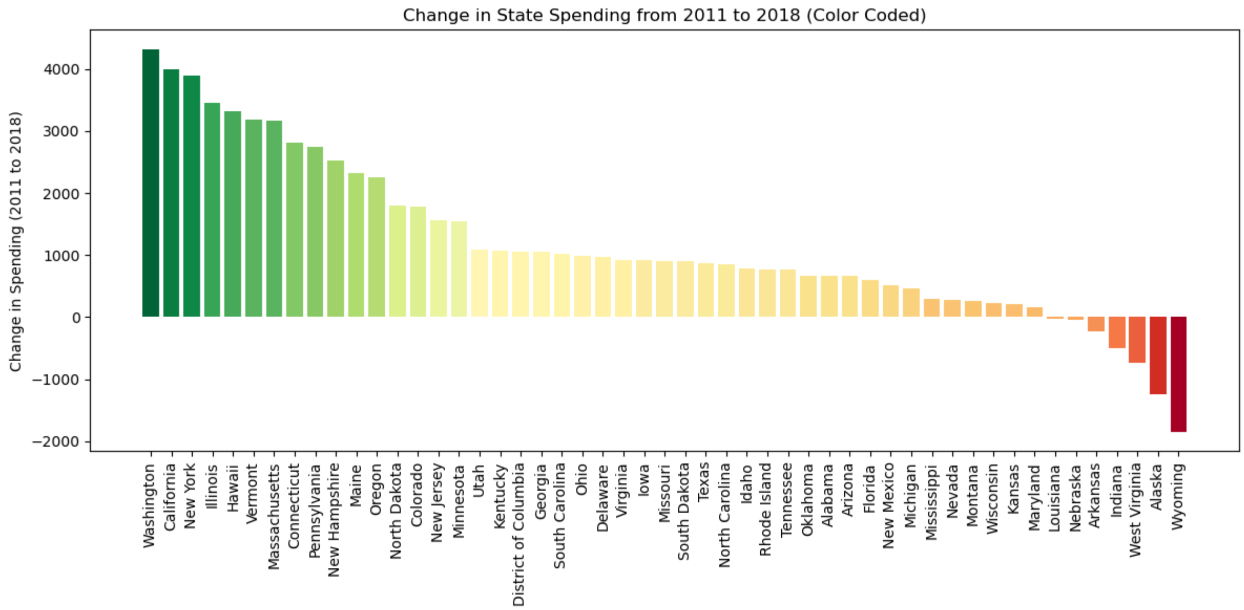
The newer data shows something similar.

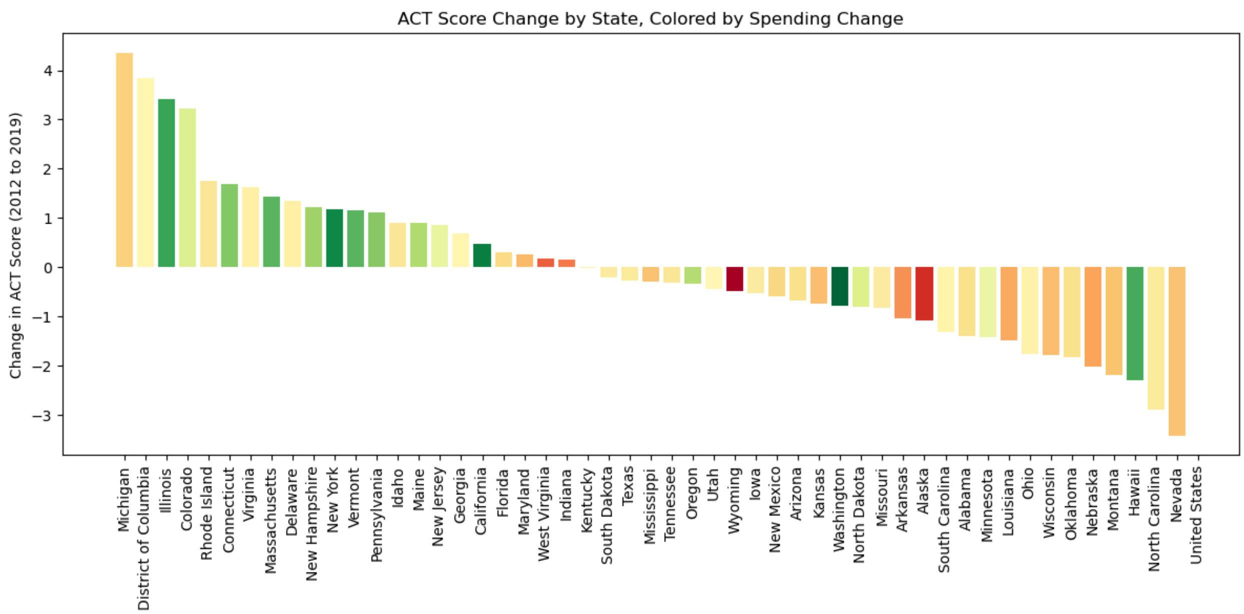
Average New SAT Score for Highest & Lowest Graduation States

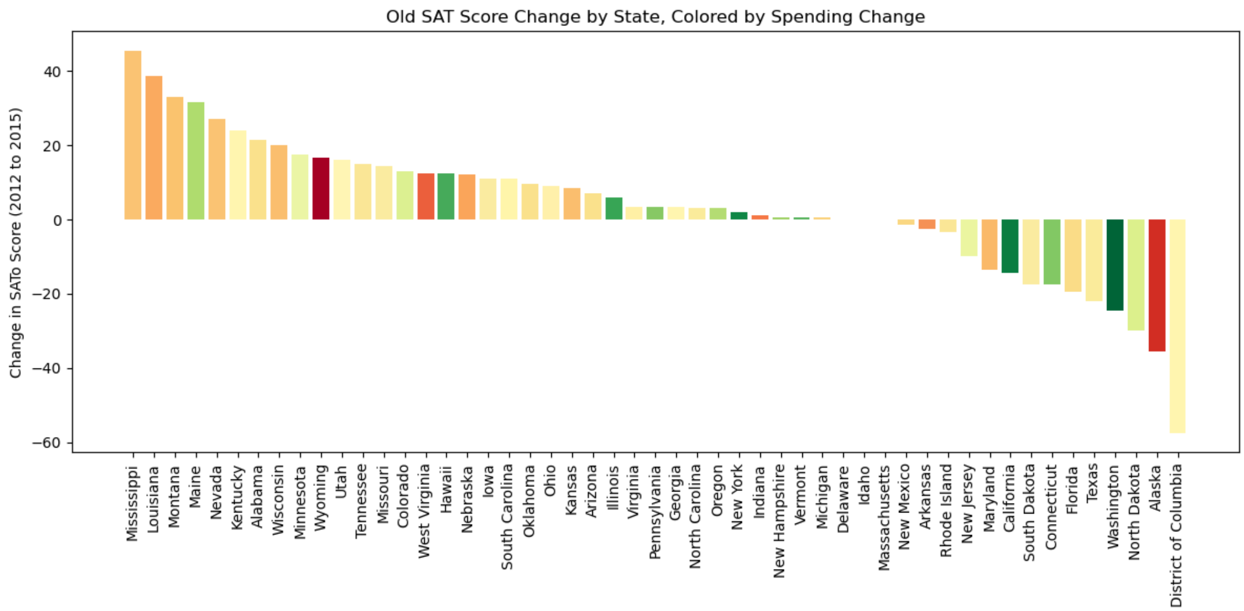


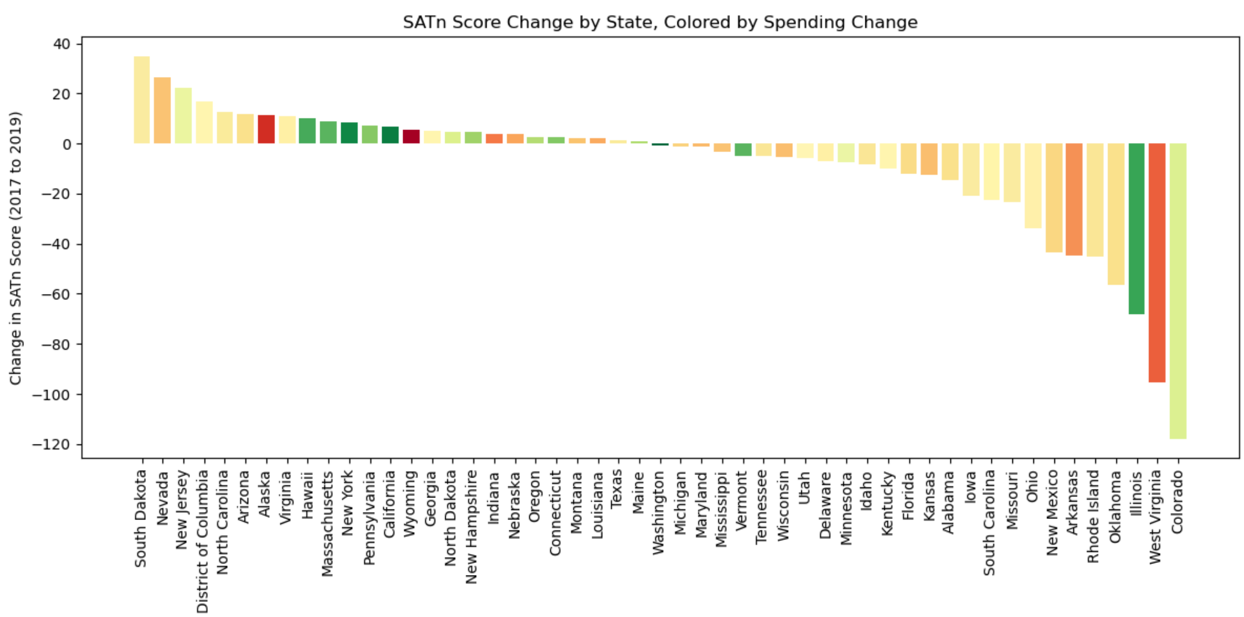
The newer SAT scores show a similar average, a difference of only 114 between the highest-graduating state and the lowest-graduating state.

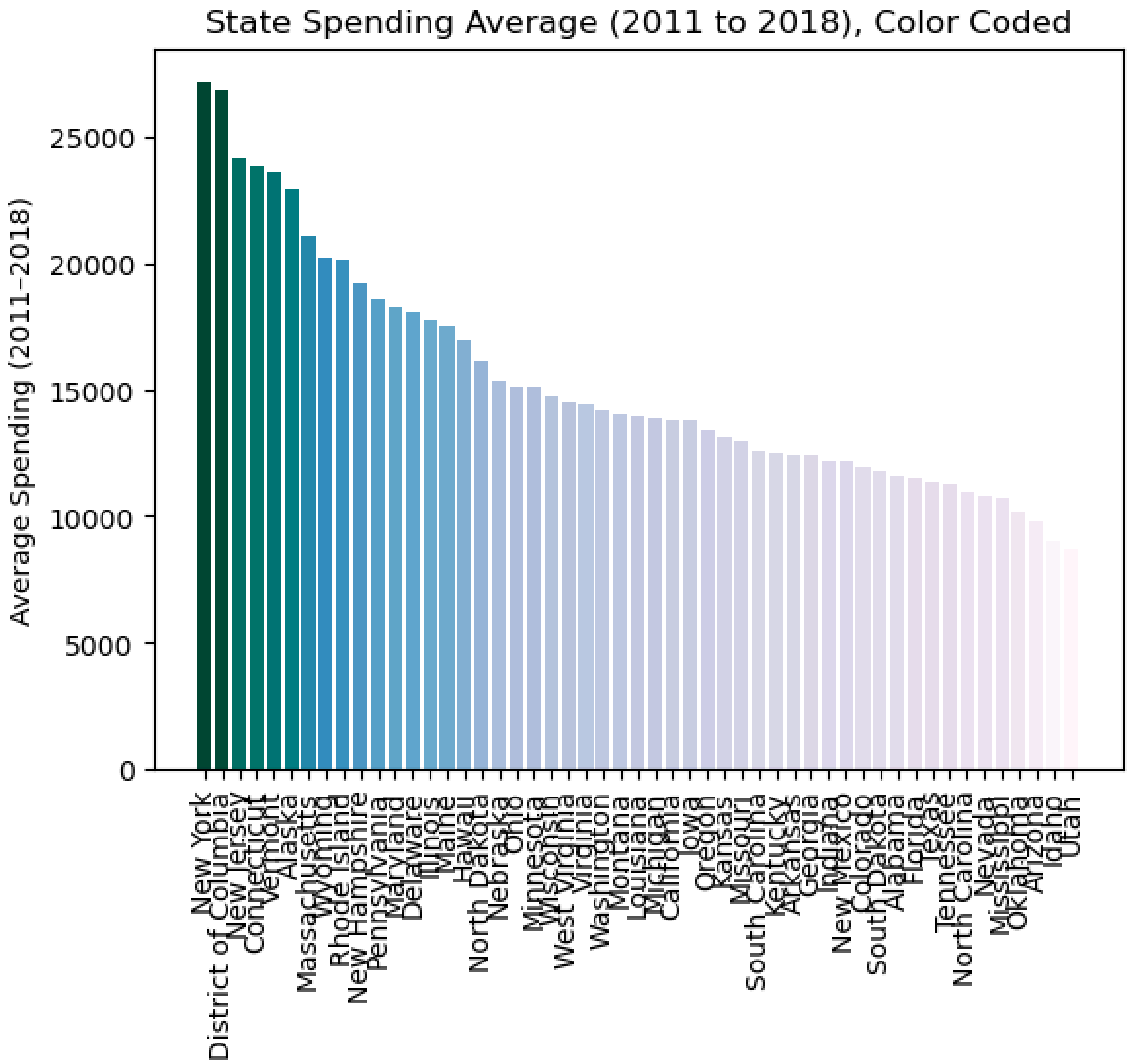
To be as certain as possible, I plotted the changes in spending as well as absolute dollar spending and how it relates to the ACT, old SAT, and new SAT scores. The results were similar:

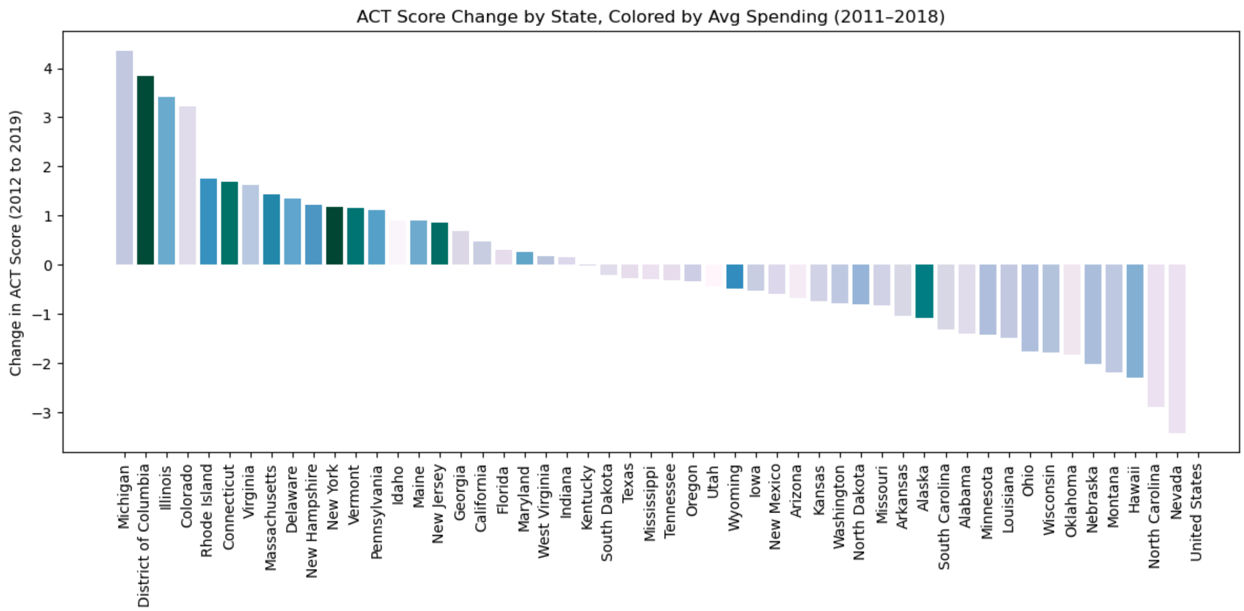




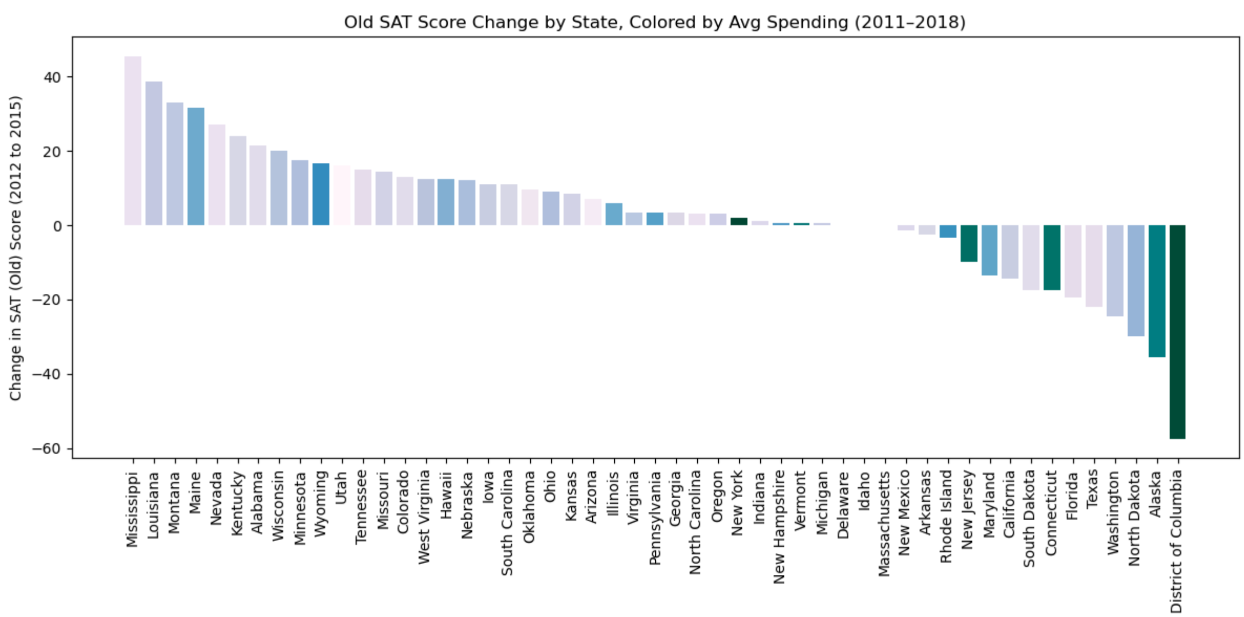

Old SAT Score Change by State, Colored by Spending Change
Change in SATo Score (2012 to 2015)
40
20
0
−20
−40
−60
Mississippi
Louisiana
Montana
Maine
Nevada
Kentucky
Alabama
Wisconsin
Minnesota
Wyoming
Utah
Tennessee
Missouri
Colorado
West Virginia
Hawaii
Nebraska
Iowa
South Carolina
Oklahoma
Ohio
Kansas
Arizona
Illinois
Virginia
Pennsylvania
Georgia
North Carolina
Oregon
New York
Indiana
New Hampshire
Vermont
Michigan
Delaware
Idaho
Massachusetts
New Mexico
Arkansas
Rhode Island
New Jersey
Maryland
California
South Dakota
Connecticut
Florida
Texas
Washington
North Dakota
Alaska
District of Columbia


SATn Score Change by State, Colored by Spending Change
Change in SATn Score (2017 to 2019)
40
20
0
−20
−40
−60
−80
−100
−120
South Dakota
Nevada
New Jersey
District of Columbia
North Carolina
Arizona
Alaska
Virginia
Hawaii
Massachusetts
New York
Pennsylvania
California
Wyoming
Georgia
North Dakota
New Hampshire
Indiana
Nebraska
Oregon
Connecticut
Montana
Louisiana
Texas
Maine
Washington
Michigan
Maryland
Mississippi
Vermont
Tennessee
Wisconsin
Utah
Delaware
Minnesota
Idaho
Kentucky
Florida
Kansas
Alabama
Iowa
South Carolina
Missouri
Ohio
New Mexico
Arkansas
Rhode Island
Oklahoma
Illinois
West Virginia
Colorado

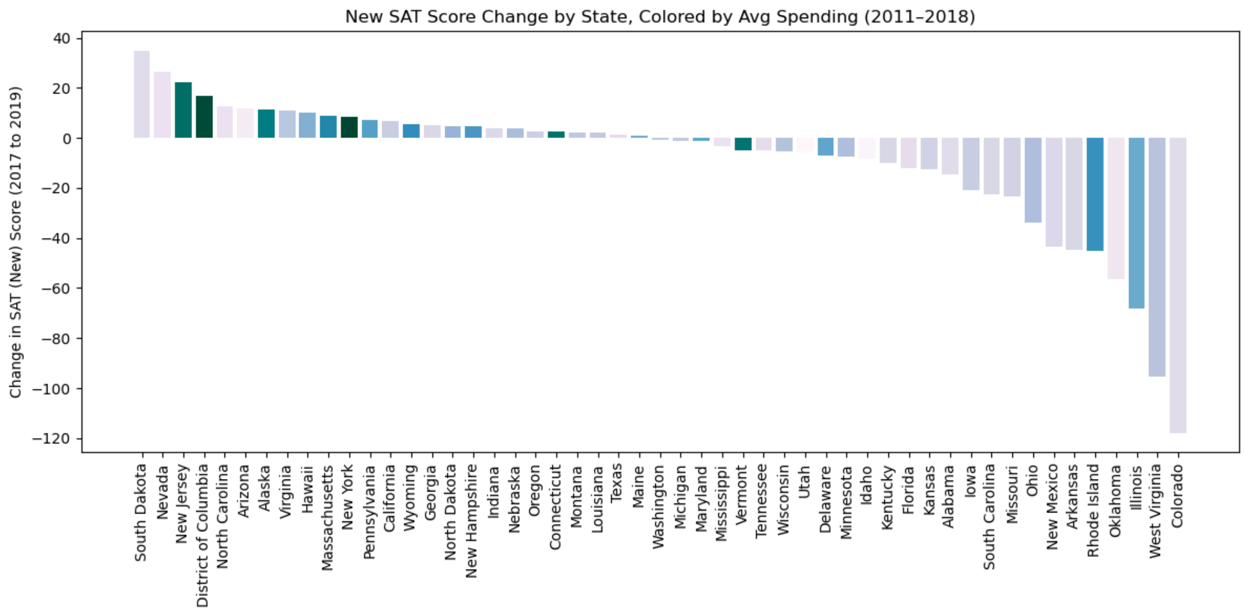

State Spending Average (2011 to 2018), Color Coded
Average Spending (2011–2018)
0
5000
10000
15000
20000
25000
New York
District of Columbia
New Jersey
Connecticut
Vermont
Alaska
Massachusetts
Wyoming
Rhode Island
New Hampshire
Pennsylvania
Maryland
Delaware
Illinois
Maine
Hawaii
North Dakota
Nebraska
Ohio
Minnesota
Wisconsin
West Virginia
Virginia
Washington
Montana
Louisiana
Michigan
California
Iowa
Oregon
Kansas
Missouri
South Carolina
Kentucky
Arkansas
Georgia
Indiana
New Mexico
Colorado
South Dakota
Alabama
Florida
Texas
Tennessee
North Carolina
Nevada
Mississippi
Oklahoma
Arizona
Idaho
Utah



ACT Score Change by State, Colored by Avg Spending (2011–2018)
Change in ACT Score (2012 to 2019)
4
3
2
1
0
−1
−2
−3
Michigan
District of Columbia
Illinois
Colorado
Rhode Island
Connecticut
Virginia
Massachusetts
Delaware
New Hampshire
New York
Vermont
Pennsylvania
Idaho
Maine
New Jersey
Georgia
California
Florida
Maryland
West Virginia
Indiana
Kentucky
South Dakota
Texas
Mississippi
Tennessee
Oregon
Utah
Wyoming
Iowa
New Mexico
Arizona
Kansas
Washington
North Dakota
Missouri
Arkansas
Alaska
South Carolina
Alabama
Minnesota
Louisiana
Ohio
Wisconsin
Oklahoma
Nebraska
Montana
Hawaii
North Carolina
Nevada
United States

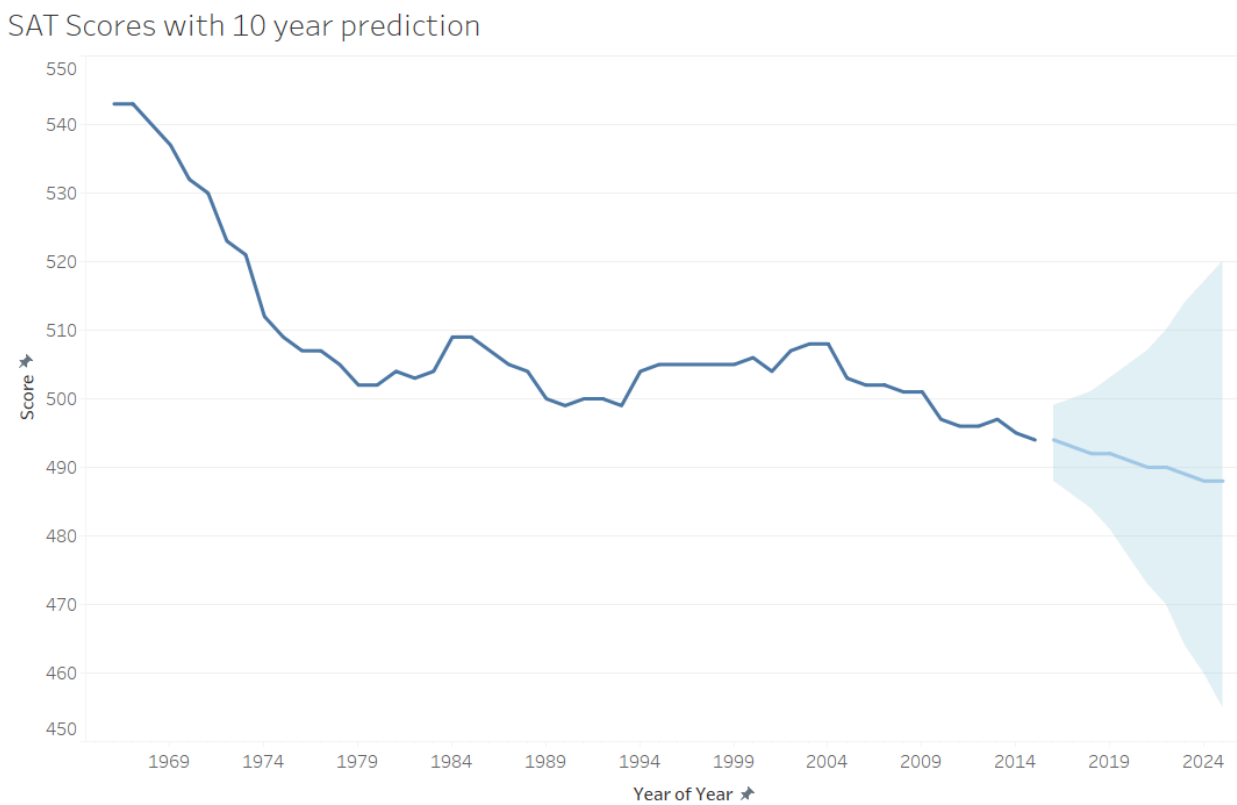


Old SAT Score Change by State, Colored by Avg Spending (2011–2018)
Change in SAT (Old) Score (2012 to 2015)
40
20
0
−20
−40
−60
Mississippi
Louisiana
Montana
Maine
Nevada
Kentucky
Alabama
Wisconsin
Minnesota
Wyoming
Utah
Tennessee
Missouri
Colorado
West Virginia
Hawaii
Nebraska
Iowa
South Carolina
Oklahoma
Ohio
Kansas
Arizona
Illinois
Virginia
Pennsylvania
Georgia
North Carolina
Oregon
New York
Indiana
New Hampshire
Vermont
Michigan
Delaware
Idaho
Massachusetts
New Mexico
Arkansas
Rhode Island
New Jersey
Maryland
California
South Dakota
Connecticut
Florida
Texas
Washington
North Dakota
Alaska
District of Columbia



The conclusion drawn from this, then, is that the rate of high school graduation does not reflect secondary-school aptitude, as measured by the SAT and ACT exams. And, as spending has no bearing on these numbers either, a well-intentioned desire to improve educational outcomes will not be accomplished through spending alone.

SAT scores are declining and predicted to continue declining over the next 10 years. I collected the entire available history of SAT scores for this prediction (leaving out the data after the 2016 change).



Based on this information, it would not be my recommendation to increase funding or spending in any state in order to prove academic performance, neither for standardized testing nor for graduation rates. Whatever relationship exists between the variables, increasing spending will not prove to be a sufficient solution.

In order to combat the decline in standardized testing, additional information will need to be gathered in order to determine what factors differentiate states that perform well from those that do not. Given that the states that perform well on the standardized tests are primarily located in the midwest, additional information about the culture would be helpful.

Another recommendation would be to analyze the actual line item breakdown of budgets and compare them between states. It is possible that funds are spent on non-curricular needs, such as facilities, maintenance, or discipline that other states do not experience, thus redirecting funds that would show a more correlative impact on higher educational outcomes.