How do socio-economic indicators relate to state-level test scores?

US Department of Education

30 May 2022

Problem Statement

How do socio-economic indicators relate to state-level test scores?

Context:

- Recent concerns that the SAT and ACT are biased towards various socio-economic factors.

- The US Department of Education will conduct a preliminary analysis of how Human Development Index (HDI), Racial Diversity and Population Density affect state-level test scores.

- This preliminary analysis would inform further studies at an individual student-level.

Overview of both tests:
As test participation increases, test score decreases

Scores vs Participation Rates by State
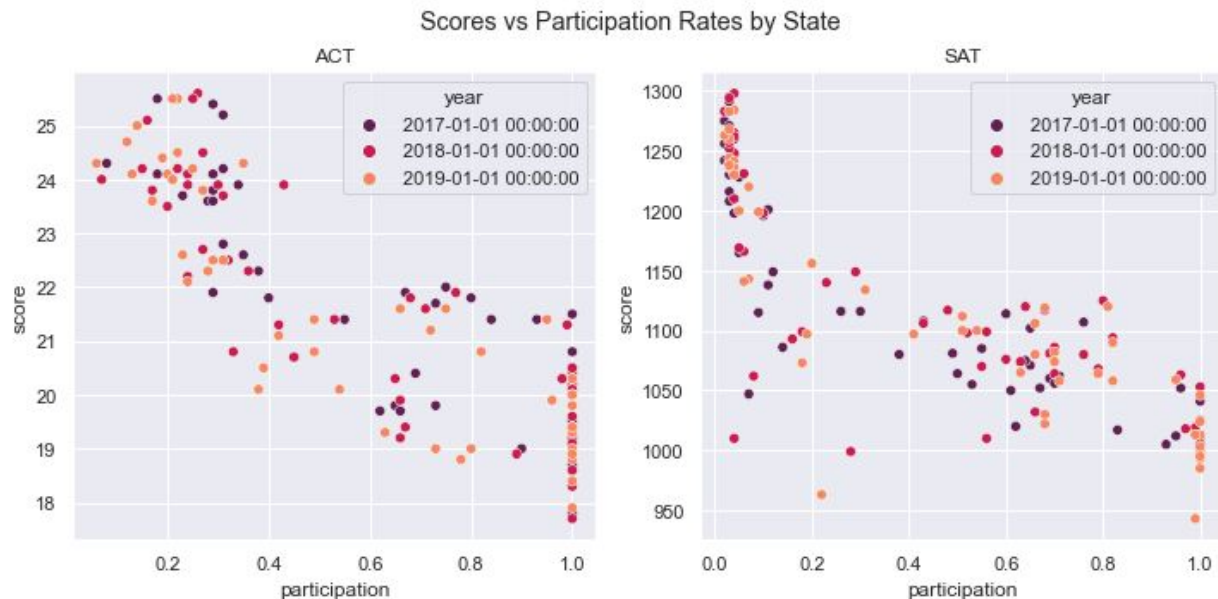
- Scores are inversely related to participation rates, and this holds true for both ACT and SAT groups.

- In states with optional testing, we surmise that strong students would be more inclined to pay and participate in the tests, leading to higher average scores within the state.

- In states with compulsory testing, or close to 100% participation, the entire eligible population is tested, leading to lower average scores.

Feature Engineering - Racial Concentration

$$Concentration = P_1{}^2 + P_2{}^2 + ... + P_n{}^2$$

$$Concentration = 0.4^2 + 0.35^2 + 0.25^2$$

The Average Racial Diversity metric across the 50 states is 0.633
The range of the HDI index is from 0.278 to 0.890

The 3 most racially diverse States are Hawaii, Maryland and California

The 3 least racially diverse States are West Virginia, Vermont and Maine

Racial concentration - No significant correlation with scores

Scores vs Racial Concentration by State
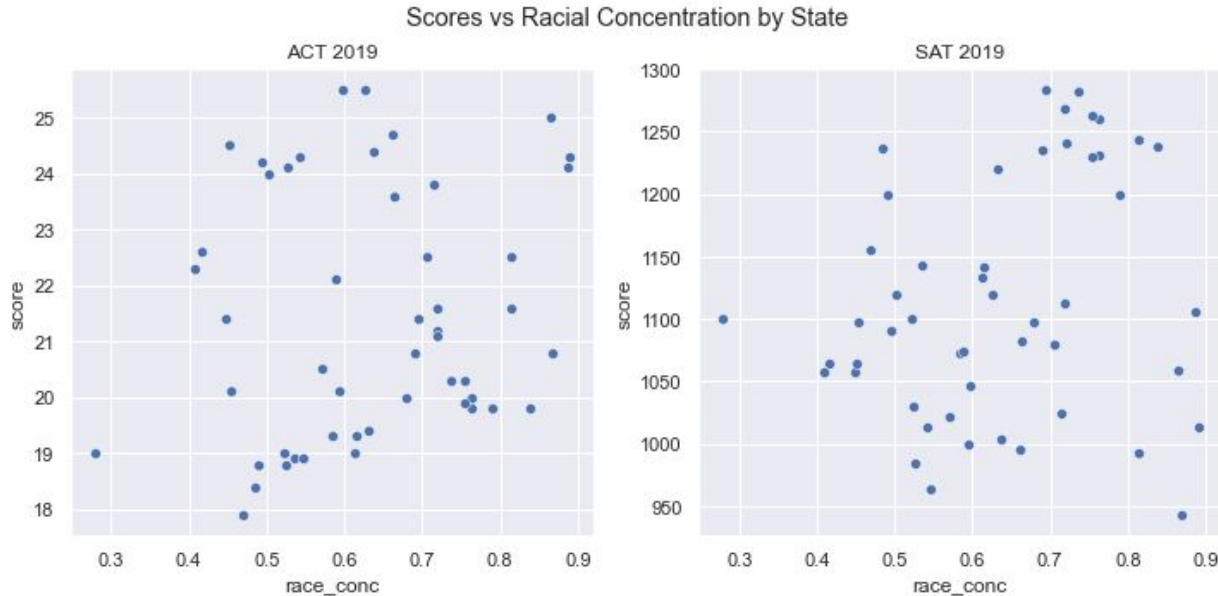
- For the ACT group, racial concentration doesn't seem to correlate with scores.

- For the SAT group, racial concentration is weakly positively correlated (Pearson's r = 0.22) with scores. However, the p-value of the correlation is 0.13 and not statistically significant at a 5% alpha.

Human Development Index (HDI)

Distribution of HDI Index Across the States

- Average HDI: 0.92
- Range of the HDI: 0.87 to 0.95
- Most states have a HDI of higher than 0.9
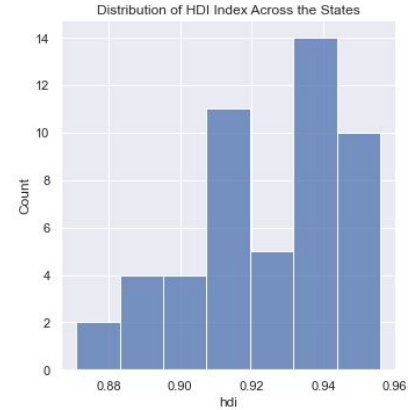
- The top 3 states are Minnesota, Connecticut and Massachusetts with a HDI of above 0.95.
- The bottom 3 states are Mississippi, West Virginia and Alabama with a HDI of around 0.87 to 0.88.

HDI: Positive Correlation with ACT but no relation with SAT

Scores vs HDI by State

- For the ACT group, there is a strong positive correlation between HDI and the ACT scores (Pearson's r = 0.61). It is statistically significant at 5% level

- For the SAT group, there does not seem to be any relation between HDI and SAT scores (Pearson's r = 0.03)

Population Density

Scores vs Population density by State
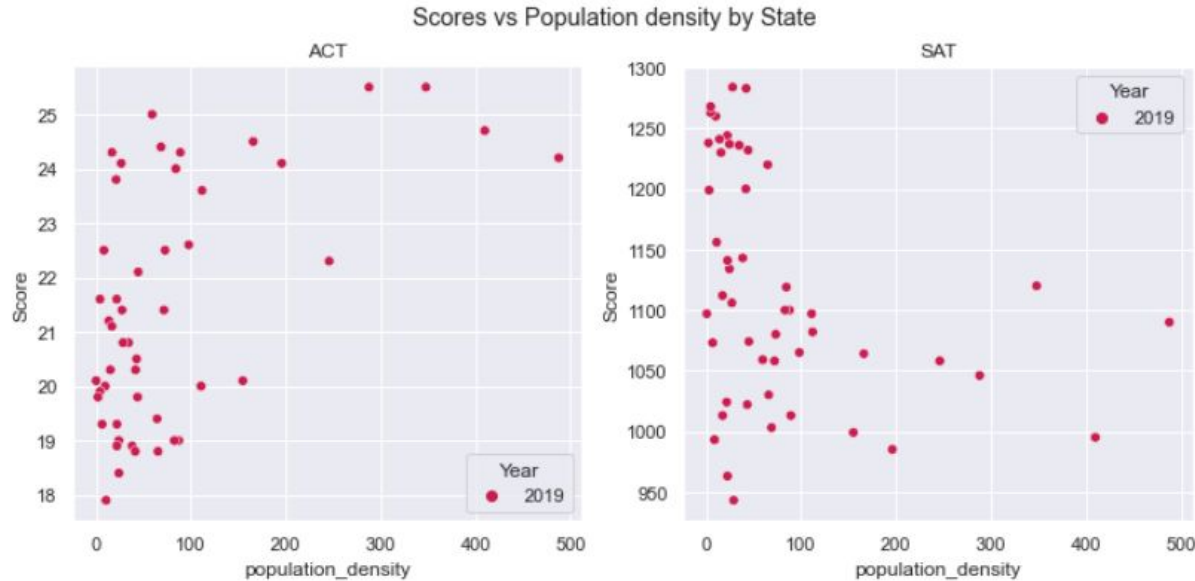
- For the ACT group, an increase in population density does indicate a positive correlation in ACT scores. This corresponds with a moderate value (0.55) on the heatmap.

- For the SAT group, population density is weakly negatively correlated (Pearson's r = -0.33) with scores.

- Both correlation coefficients are statistically significant at a 5% alpha.

Feature	Effect on ACT Scores	Effect on SAT Scores
Participation Rate	Strong negative correlation	Strong negative correlation
Racial Concentration	No correlation	No correlation
Population Density	Moderate positive correlation	Weak negative correlation
HDI	Moderate positive correlation	No correlation

Conclusion

- States test scores are correlated with select socio-economic indicators
- Of note is that some of correlations are in "opposite" directions (e.g. Population Density)
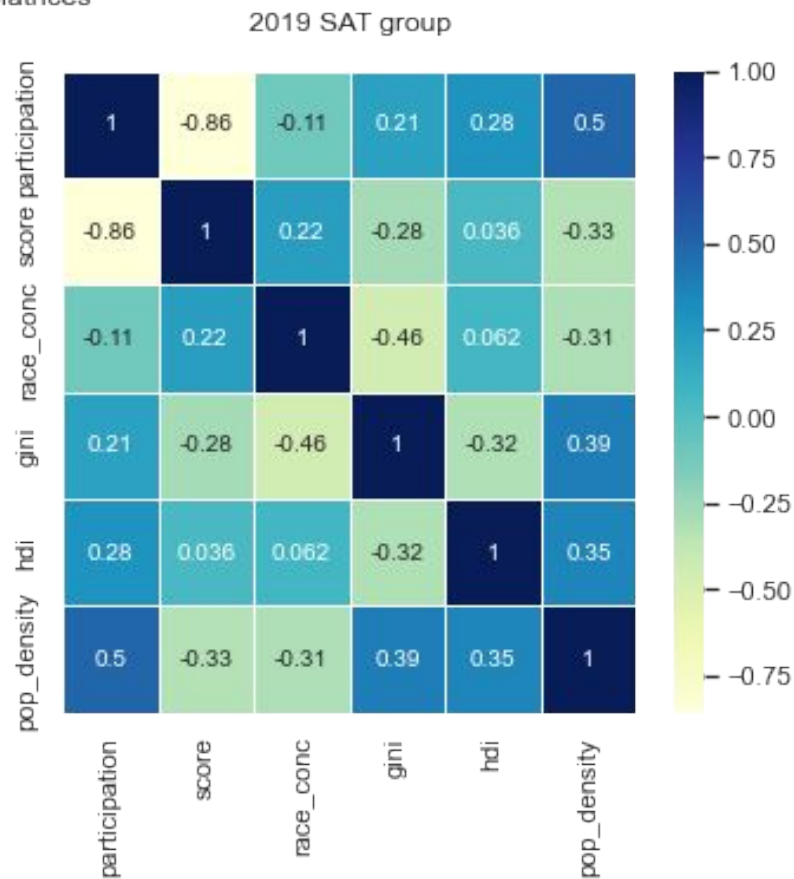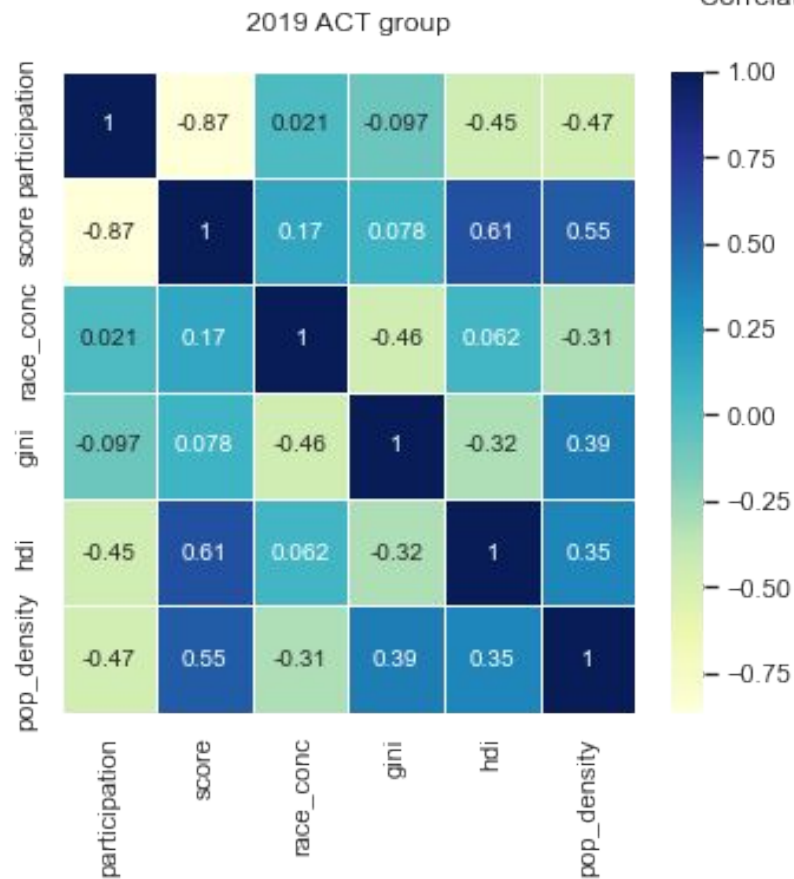- Strong evidence that features are not independent and are affecting each other

Recommendation

This line of inquiry is deserving of a more in-depth study by the Department with:

- Increased no. of feature
- More careful feature selection
- Longitudinal studies
- Individual student-level analysis

Annex

Correlation Matrices

Annex

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Pearson's r p-values for the ACT correlation matrix
                participation    score race_conc     gini       hdi pop_density
participation            0.0      0.0    0.8871   0.5039     0.001      0.0006
score                    0.0      0.0    0.2477   0.5915       0.0         0.0
race_conc             0.8871   0.2477       0.0   0.0009    0.6693      0.0273
gini                  0.5039   0.5915    0.0009      0.0    0.0246      0.0052
hdi                    0.001      0.0    0.6693   0.0246       0.0      0.0135
pop_density           0.0006      0.0    0.0273   0.0052    0.0135         0.0


Pearson's r p-values for the SAT correlation matrix
                participation    score race_conc     gini       hdi pop_density
participation            0.0      0.0    0.4615   0.1456    0.0449      0.0002
score                    0.0      0.0    0.1309   0.0466    0.8042      0.0179
race_conc             0.4615   0.1309       0.0   0.0009    0.6693      0.0273
gini                  0.1456   0.0466    0.0009      0.0    0.0246      0.0052
hdi                   0.0449   0.8042    0.6693   0.0246       0.0      0.0135
pop_density           0.0002   0.0179    0.0273   0.0052    0.0135         0.0
```

2019 ACT Group
Regress score on select features

OLS Regression Results

Dep. Variable:	score	R-squared:	0.874
Model:	OLS	Adj. R-squared:	0.863
Method:	Least Squares	F-statistic:	78.13
Date:	Mon, 30 May 2022	Prob (F-statistic):	1.16e-19
Time:	10:49:10	Log-Likelihood:	-57.989
No. Observations:	50	AIC:	126.0
Df Residuals:	45	BIC:	135.5
Df Model:	4		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	-27.3232	8.848	-3.088	0.003	-45.143	-9.503
participation	-4.3350	0.394	-11.002	0.000	-5.129	-3.541
race_conc	4.2094	0.926	4.546	0.000	2.344	6.074
hdi	37.7045	6.878	5.482	0.000	23.852	51.557
gini	29.7492	7.818	3.805	0.000	14.003	45.495

Omnibus:	4.134	Durbin-Watson:	2.274
Prob(Omnibus):	0.127	Jarque-Bera (JB):	3.796
Skew:	-0.672	Prob(JB):	0.150
Kurtosis:	2.865	Cond. No.	181.

2019 SAT Group
Regress score on select features

OLS Regression Results

Dep. Variable:	score	R-squared:	0.835
Model:	OLS	Adj. R-squared:	0.820
Method:	Least Squares	F-statistic:	56.78
Date:	Mon, 30 May 2022	Prob (F-statistic):	5.15e-17
Time:	10:49:10	Log-Likelihood:	-253.75
No. Observations:	50	AIC:	517.5
Df Residuals:	45	BIC:	527.1
Df Model:	4		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	-392.7149	410.479	-0.957	0.344	-1219.462	434.032
participation	-237.2499	16.688	-14.217	0.000	-270.862	-203.638
race_conc	88.5446	46.268	1.914	0.062	-4.644	181.733
gini	410.8474	393.832	1.043	0.302	-382.372	1204.066
hdi	1489.4546	318.903	4.671	0.000	847.151	2131.758

Omnibus:	37.351	Durbin-Watson:	1.325
Prob(Omnibus):	0.000	Jarque-Bera (JB):	144.046
Skew:	-1.856	Prob(JB):	5.26e-32
Kurtosis:	10.441	Cond. No.	168.