Elite individuals, insitutions, and economic growth accounting

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Research Question

What is the relationship between elite students, academic institutions, and economic growth?

- Are there outsized returns to economic growth when there are more academic elites?
- How can we measure academic competition and education quality beyond means?

Method

Through this paper, I investigate the relationship between the number of top-ranked universities, share of top math students, IMO scores, and GDP per capita growth to analyze these questions.

Data Sources

- World Bank: World Development Indicators
- International Math Olympiad
- ARWU University Rankings
- PISA Math Scores
- Economist Democracy Scores

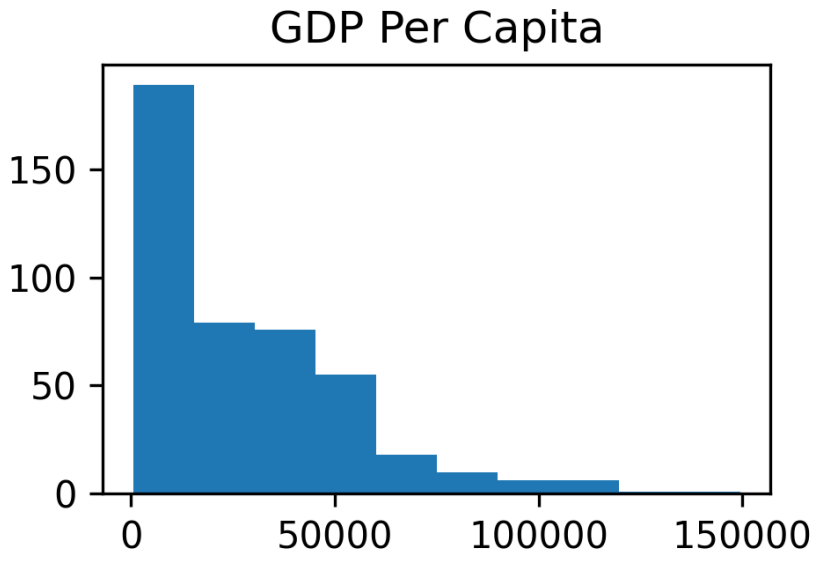
World Bank Data

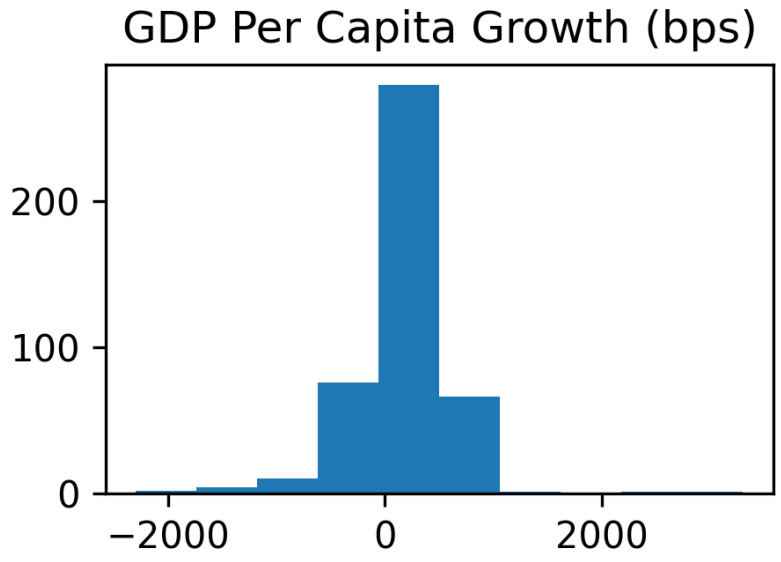
The World Bank collects and publishes development indicators for most countries/economies in the world. In this paper, I use the following variables:

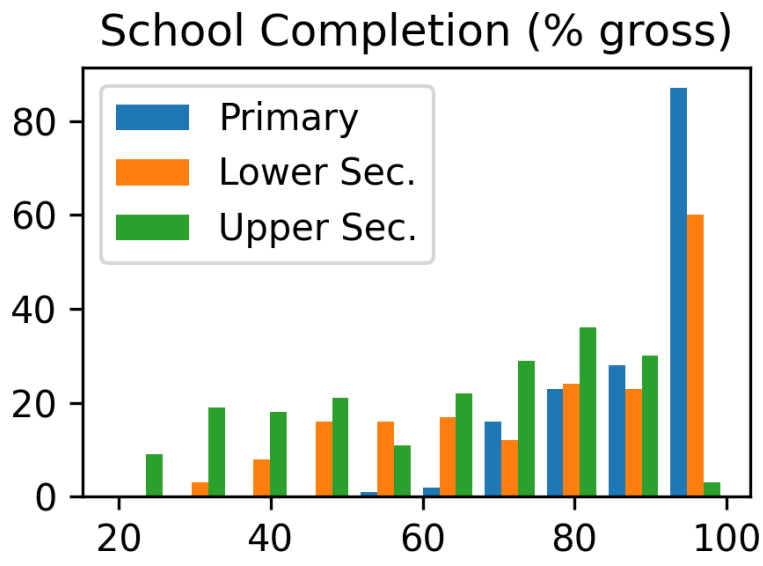
- GDP Per Capita Growth: % growth in constant 2015 $USD
- GDP Per Capita: current $USD
- School Completion Rates: % gross of relevant age group
  - "What % of primary-school-aged population is enrolled in primary school?"
  - This number can be greater than 100%
  - Not available for all years and all countries $\rightarrow$ missing data problem
- Population: all residents of a country/territory

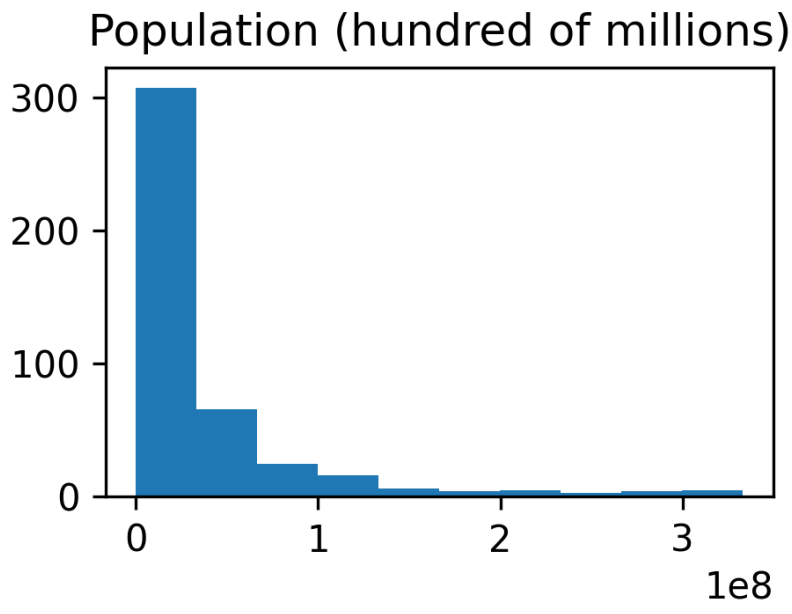
World Bank Data

Distributions



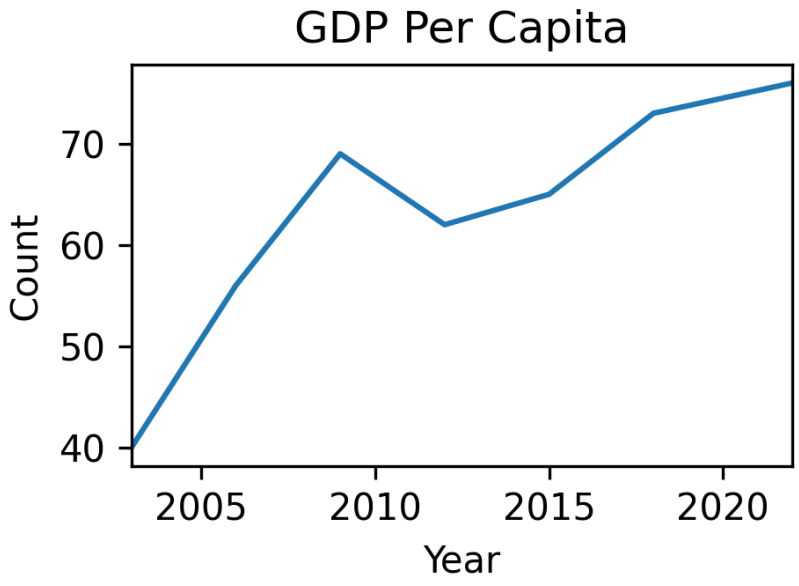


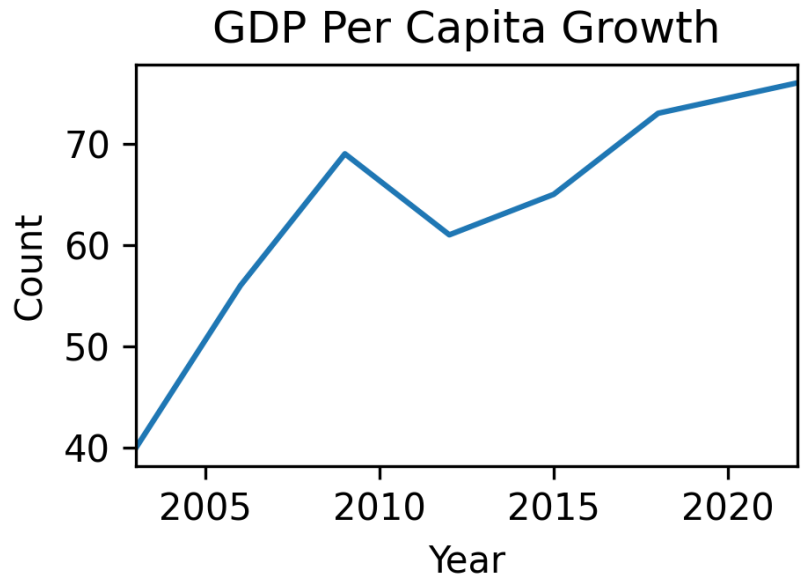


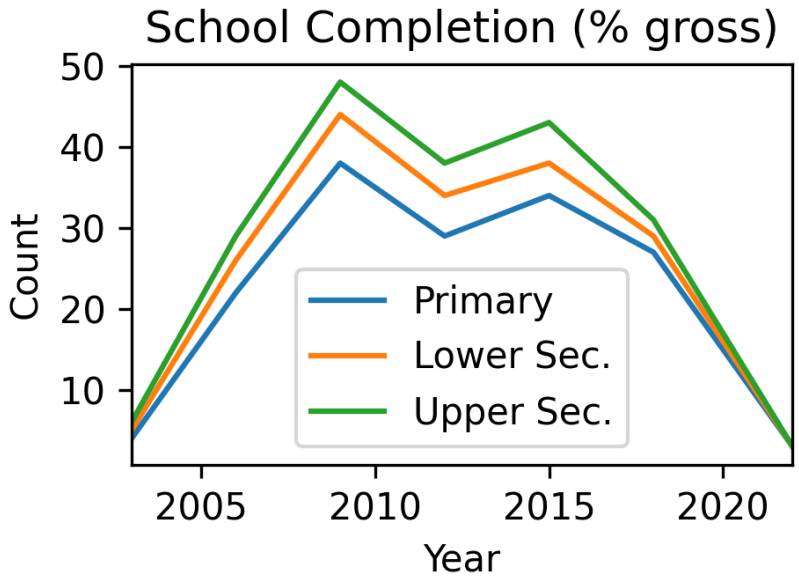


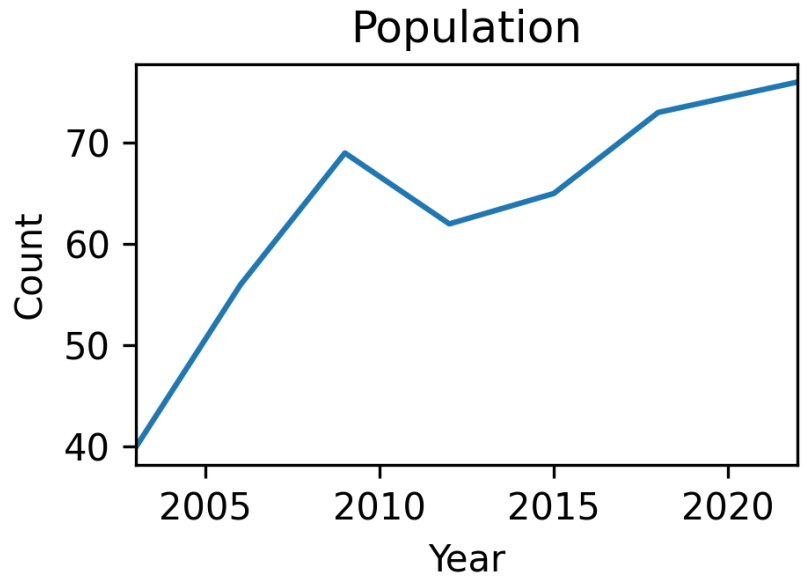
World Bank Data

Missing data









Imputing nulls

Using XGBoost for better predictions

Data is not missing at random

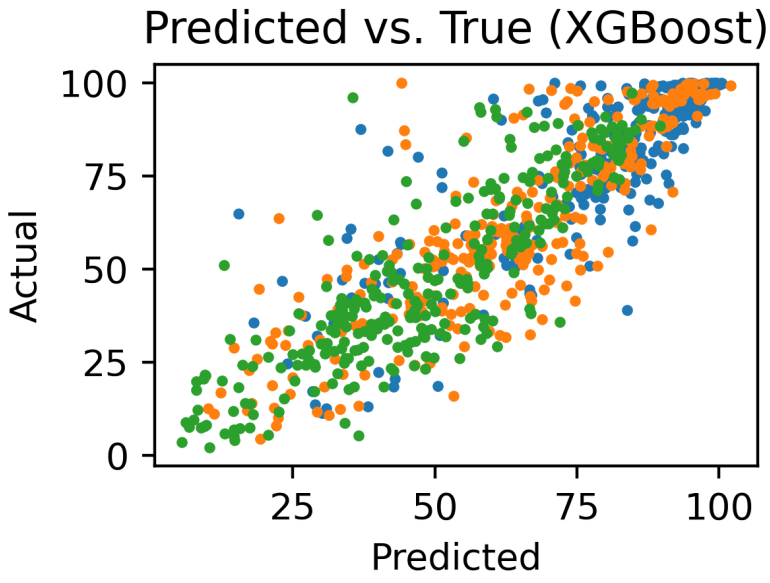
School completion data is only available for a maximum of 80 countries per year and has high variance in this availablility. This is the most limiting factor in the analysis.

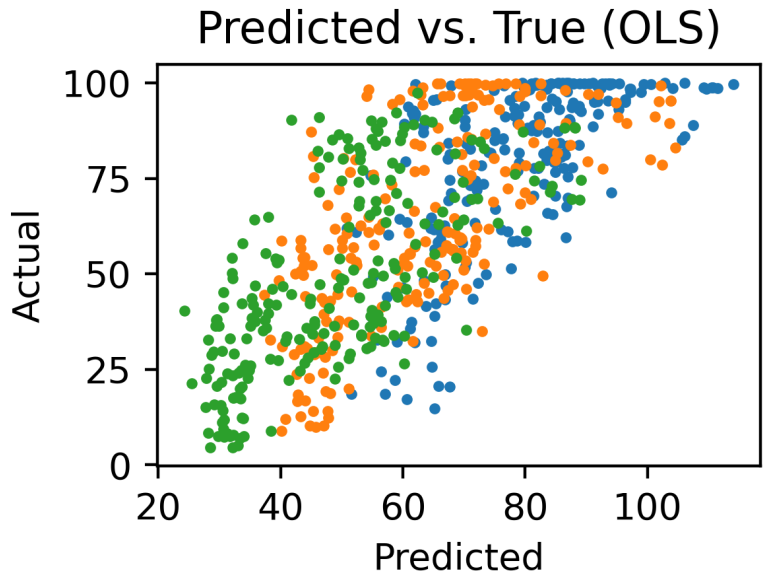
Predicting missing values

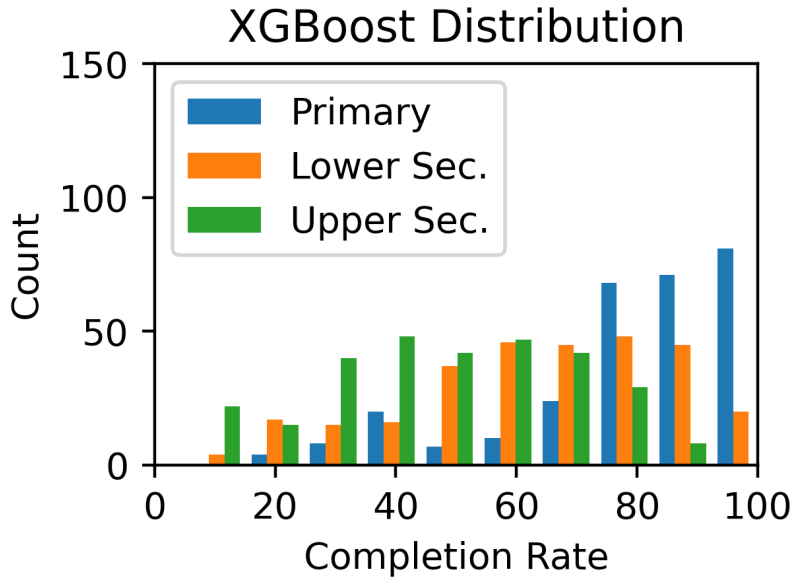
XGBoost is a tree-based model that has built-in null handling. I use the remaining variables to predict school completion rates and EIU democracy scores. Achieves significantly higher accuracy than linear regression.

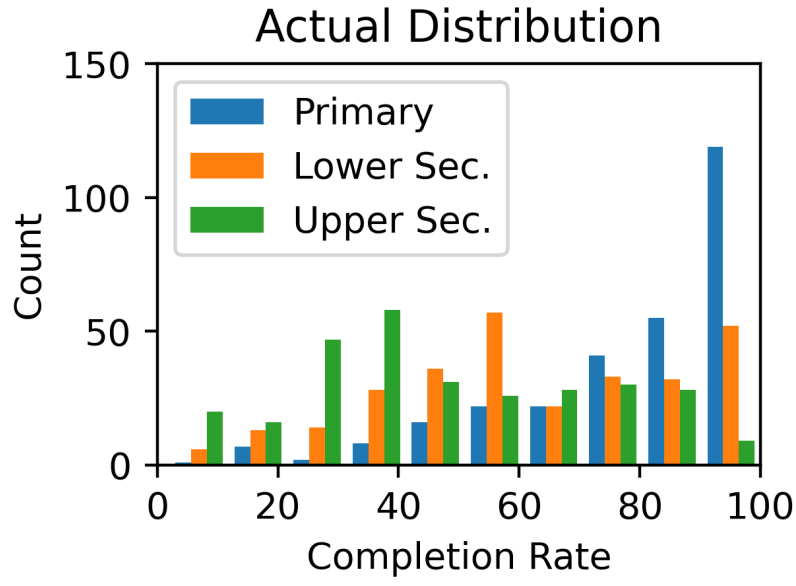
Imputation results

School completion rates



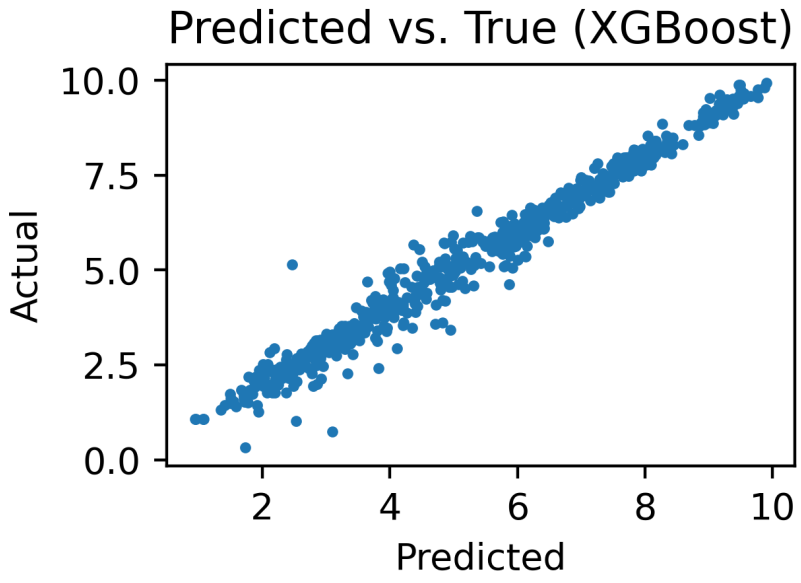


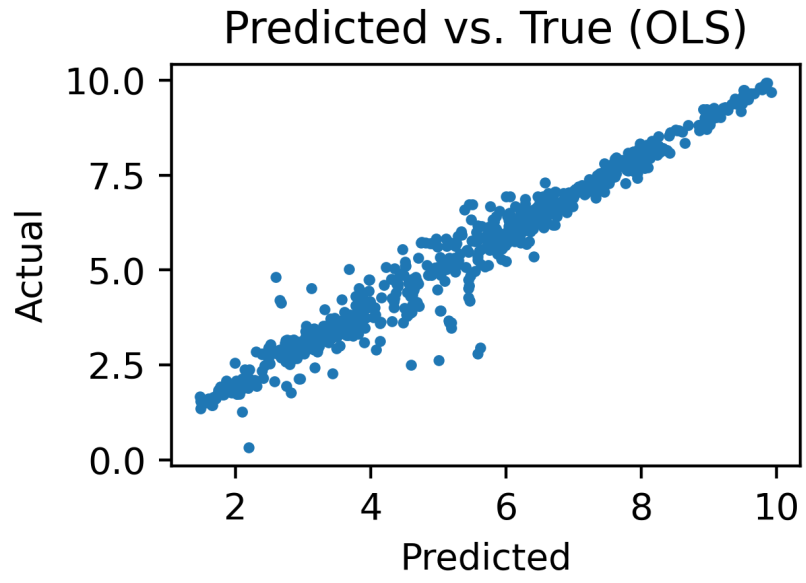


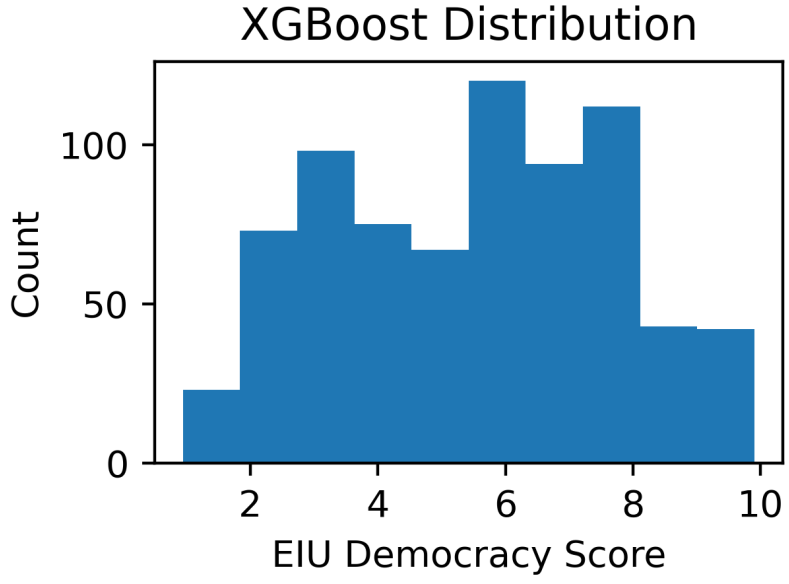


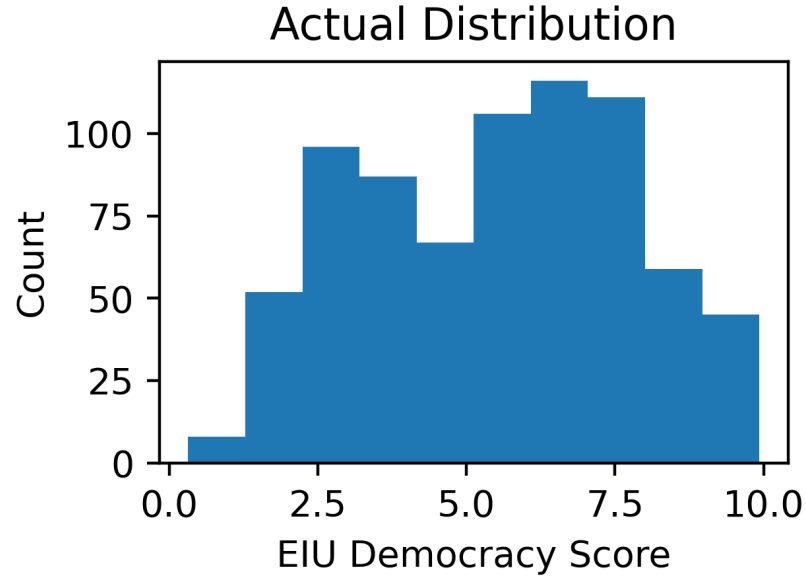
Imputation results

EIU Democracy Score









IMO Scores

The IMO is an international mathematics contest for high school students

Table: Top 10 countries by IMO score.

Region	IMO Score	GDPpc	GDPpc Growth
KOR	10.2026	26060.9203	293.8552
CHN	9.8296	6424.4972	786.8171
USA	9.6196	54346.5078	125.7613
RUS	9.0800	10432.8366	277.0704
SGP	9.0642	51652.4651	348.0543
BGR	8.8821	7556.3933	417.7564
ROU	8.7367	9432.6698	439.7522
HUN	8.7153	13979.7009	262.9650
VNM	8.5029	2159.2583	527.6404
UKR	8.3941	3079.8378	131.9303

- Scores collected from 2003 to 2022
- Scores are transformed by $t(s) = \frac{s}{\log P}$ where s is the country's raw score and P is population.
  - Team size of 6 means that larger countries have an advantage due to "genius odds"
  - Score is capped, so dividing by $\log P$ will correct for theoretical ceiling of performance

ARWU Rankings

Description and Usage

ARWU (Academic Ranking of World Universities) is a set of university rankings based primarily on research output.

- Rankings are produced annually and are available from 2003
- From 2003 to 2016, 500 top universities were ranked; after 2017, 1000 were ranked.

Per-Capita Scaling

Larger countries naturally have an advantage, so a more fair metric is

$$ARWU_{i,t} = \frac{arwuCount_{i,t}}{P_{i,t}} \cdot 10^6$$

Instead, looking at ARWU insitutions per million population indicates the relative quantity of elite insitutions in a country/region.

Summary Statistics

Hello

Rationale for variables

IMO Scores

Indicator for a country's (and region's) ability to develop/identify pinncale STEM talent at high school level.

ARWU Rankings

Indicator for a country's (and region's) ability to produce exellence in research output.

Percent in PISA 99th percentile

When controlling for average PISA math scores, this is a partial indicator for whether general excellence in academics is encouraged/necessary.

Model specification

Let elite indicators be: $math99, ARWU, IMO$. For the sake of concision, let $E_{i,t}$ be a 1 by 4 matrix defined as:

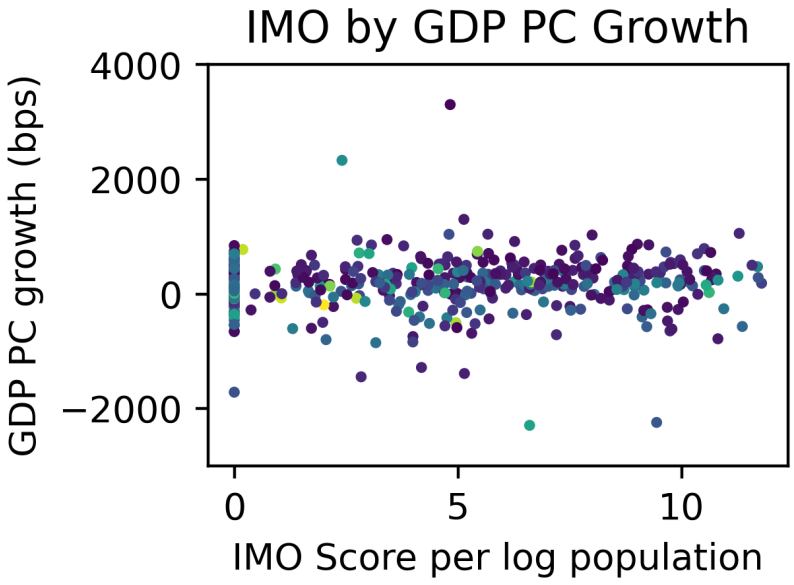
$$E_{i,t} = \begin{bmatrix} math99_{i,t} & ARWU_{i,t} & ARWU_{i,t} \times GDPpc_{i,t} & IMO_{i,t} \end{bmatrix}$$

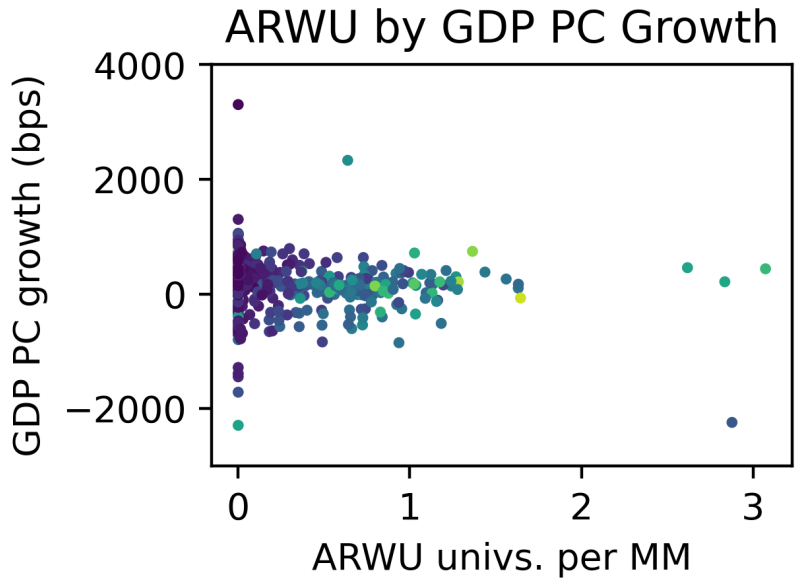
for country/region i in year t. Let the coefficients of $E_{i,t}$ be a 4 by 1 matrix called λ. For control variables, $I_{i,t}$ is the matrix of variables and α is coefficients.

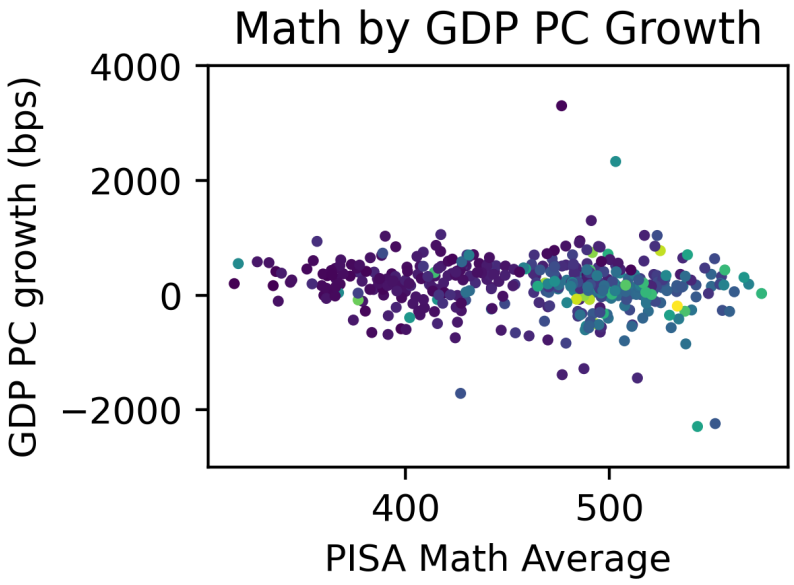
$$Y_{i,t} = \beta_0 + \lambda E_{i,t} + \delta GDPpc \times E_{i,t} + \alpha I_{i,t} + T_t + C_i + \epsilon_{i,t} \qquad (1)$$

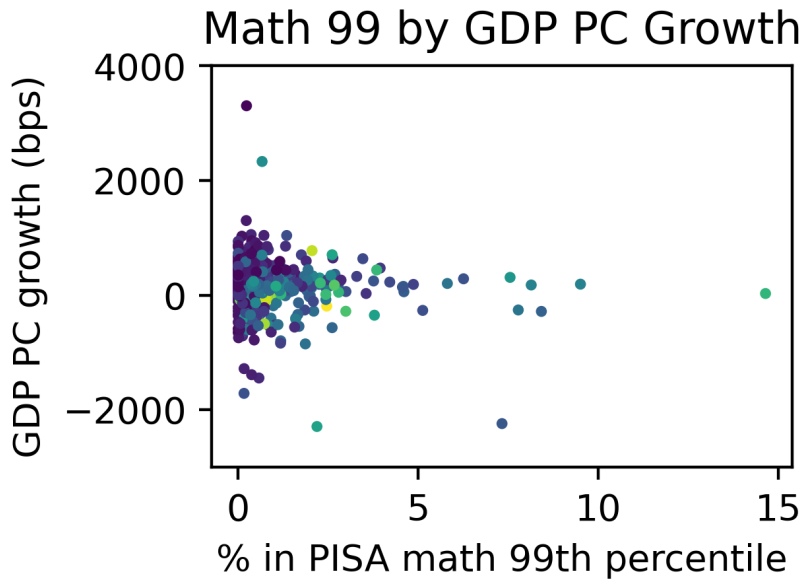
where T, C represent time and entity dummies respectively and $Y_{i,t}$ be the GDP per capita growth in basis points for a country/region i and year t.

Relationships









PISA panel regression

Highly dependent on model specification due to rich country bias and limited variation

	Dependent variable: GDP Per Capita Growth (bps)			
	Model 1 (base)	Model 2	Model 3 (Time FE)	Model 4 (Time + Entity FE)
PISA Math in global P99		-43.491	-40.291	-126.152*
		(48.245)	(40.349)	(64.627)
PISA Math 99 x GDP PC		0.000	0.000	0.001
		(0.001)	(0.001)	(0.001)
IMO score per log population	6.604	3.629	4.581	20.285
	(8.473)	(10.582)	(8.833)	(21.169)
IMO score x GDP pc	-0.000	0.000	-0.000	-0.001*
	(0.000)	(0.000)	(0.000)	(0.000)
ARWU insitutions	-588.767***	-538.997***	-580.030***	-764.617***
	(135.656)	(178.746)	(149.452)	(250.804)
ARWU insitutions x GDP PC	0.009***	0.008**	0.009***	0.011***
	(0.003)	(0.003)	(0.003)	(0.004)
PISA Math		1.150	0.908	0.495
		(0.792)	(0.732)	(1.761)
GDP per capita	-0.003**	-0.003*	-0.003**	0.000
	(0.001)	(0.002)	(0.001)	(0.005)
Primary School Completion Rate	-3.554	-11.911***	-5.387	-4.028
	(3.345)	(4.157)	(3.602)	(4.947)
Lower Sec. Completion Rate	-1.475	-0.571	-1.291	-0.446
	(2.945)	(3.540)	(2.948)	(4.443)
Upper Sec. Completion Rate	5.643**	6.665**	5.385**	3.364
	(2.343)	(2.835)	(2.354)	(3.692)
Democracy Rating	-1.606	2.270	-7.429	36.204
	(13.894)	(17.254)	(14.431)	(61.854)
Time Effects	Yes	No	Yes	Yes
Fixed Effects	No	No	No	Yes
Entities	89	89	89	89
Observations	440	440	440	440
R^2	0.388	0.092	0.392	0.567
Adjusted R^2	0.364	0.064	0.364	0.428
Residual Std. Error	360.908 (df=423)	437.923 (df=426)	360.976 (df=420)	342.461 (df=332)
F Statistic	16.727*** (df=16; 423)	3.314*** (df=13; 426)	14.230*** (df=19; 420)	4.066*** (df=107; 332)

Note: *p<0.1; **p<0.05; ***p<0.01

PISA yearly regression

	Dependent variable: GDP Per Capita Growth (bps)							
	2003	2006	2009	2012	2015	2018	2022	Panel FE
PISA Math in global P99	-36.263	-323.594**	128.012	-57.807	466.275**	-13.249	-185.929**	-126.152*
	(92.257)	(138.527)	(134.080)	(93.739)	(198.856)	(80.330)	(75.932)	(64.627)
PISA Math 99 x GDP PC	-0.000	0.004	0.001	0.001	-0.009**	0.000	0.002	0.001
	(0.002)	(0.003)	(0.003)	(0.002)	(0.004)	(0.001)	(0.001)	(0.001)
IMO score per log population	5.787	13.706	7.250	9.955	27.849	2.586	-10.574	20.285
	(24.329)	(28.793)	(25.375)	(20.089)	(37.305)	(10.918)	(18.736)	(21.169)
IMO score x GDP pc	-0.000	-0.001	0.000	0.000	-0.001	-0.000	0.000	-0.001*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
ARWU insitutions	-461.941	-374.847	298.772	-746.052**	-1132.300	-365.119	-1310.810***	-764.617***
	(443.713)	(420.235)	(453.763)	(292.719)	(718.477)	(288.492)	(455.353)	(250.804)
ARWU insitutions x GDP PC	0.004	0.001	-0.004	0.008	0.030**	0.006	0.013	0.011***
	(0.011)	(0.009)	(0.009)	(0.005)	(0.014)	(0.004)	(0.008)	(0.004)
PISA Math	0.436	6.935***	-6.860***	0.324	-1.519	1.177	2.807	0.495
	(1.552)	(1.906)	(2.386)	(1.489)	(2.828)	(1.002)	(2.056)	(1.761)
GDP per capita	-0.006	-0.005	-0.000	-0.003	0.002	-0.007***	-0.003	0.000
	(0.005)	(0.005)	(0.006)	(0.002)	(0.005)	(0.002)	(0.004)	(0.005)
Primary School Completion Rate	7.306	-11.680	4.589	-15.665	-4.820	-8.787	4.752	-4.028
	(4.789)	(10.409)	(13.405)	(9.658)	(14.437)	(5.579)	(9.745)	(4.947)
Lower Sec. Completion Rate	4.652	7.506	-0.454	2.430	-1.228	6.617*	-13.439	-0.446
	(6.867)	(8.157)	(8.302)	(5.785)	(10.676)	(3.951)	(8.396)	(4.443)
Upper Sec. Completion Rate	4.916	3.930	-2.992	5.781	4.631	0.908	10.924*	3.364
	(7.172)	(6.850)	(7.450)	(4.375)	(8.029)	(3.174)	(6.081)	(3.692)
Democracy Rating	-91.681**	-148.435**	59.739	36.375	25.423	15.183	-5.316	36.204
	(39.476)	(56.849)	(46.067)	(30.648)	(51.072)	(16.370)	(28.766)	(61.854)
Observations	40	56	69	61	65	73	76	440
R^2	0.677	0.536	0.268	0.363	0.267	0.343	0.477	0.567
Adjusted R^2	0.516	0.392	0.095	0.187	0.081	0.198	0.368	0.428
Residual Std. Error	188.826 (df=26)	363.704 (df=42)	411.759 (df=55)	250.551 (df=47)	455.710 (df=51)	178.763 (df=59)	325.047 (df=62)	342.461 (df=332)
F Statistic	4.193*** (df=13; 26)	3.732*** (df=13; 42)	1.547 (df=13; 55)	2.060** (df=13; 47)	1.432 (df=13; 51)	2.365** (df=13; 59)	4.353*** (df=13; 62)	4.066*** (df=107; 332)

Note: *p<0.1; **p<0.05; ***p<0.01

Interpretation

IMO Scores

- Mostly indicates positive main relationship with GDP per capita growth, but negative interaction with GDP per capita.
- Suggests that lower income countries may see more benefit to what IMO scores are a proxy of (non-causal)

PISA math 99 percentile share

- Very sensitive to model specification and changes between years
- Negative main effect but positive interaction effect

ARWU insitutions per million

- Consistent negative main effect, but positive interaction effect with GDP per capita
- Can interpret as OVB, or that higher income countries may see more use from high-ranking institutions

Limitations: data sample problems

Regression results do not present a clear picture of the existence of a statistical relationship between elite indicators and economic growth.

Little variation in data

- Countries and regions with PISA test scores tend to be wealthier, more developed economies
- Low variance within countries over time and between countries as a result

Model specification matters

- Including entity fixed effects makes the most significant difference versus time effects (likely due to above)
- Magnitudes of $math99$ is 10x larger when entity fixed effects are included; similar for IMO
- $ARWU$ and interaction terms reversed in sign compared to not including fixed effects
  - Possibly due to omitted variable bias that is captured by fixed effects

Limitations: Yearly vs. Panel

Significant year-to-year variation

Unstable panel vs. yearly results

The panel methods mask some of the year-to-year changes in relationships. Some indicators are more stable than others, but $math99$ in particular alternates from positive to negative coefficient with large swings.

Omitted Variable Bias

Large changes in relationship magnitude and direction suggests that omitted variable bias is a big problem.