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
- Economist Democracy Scores

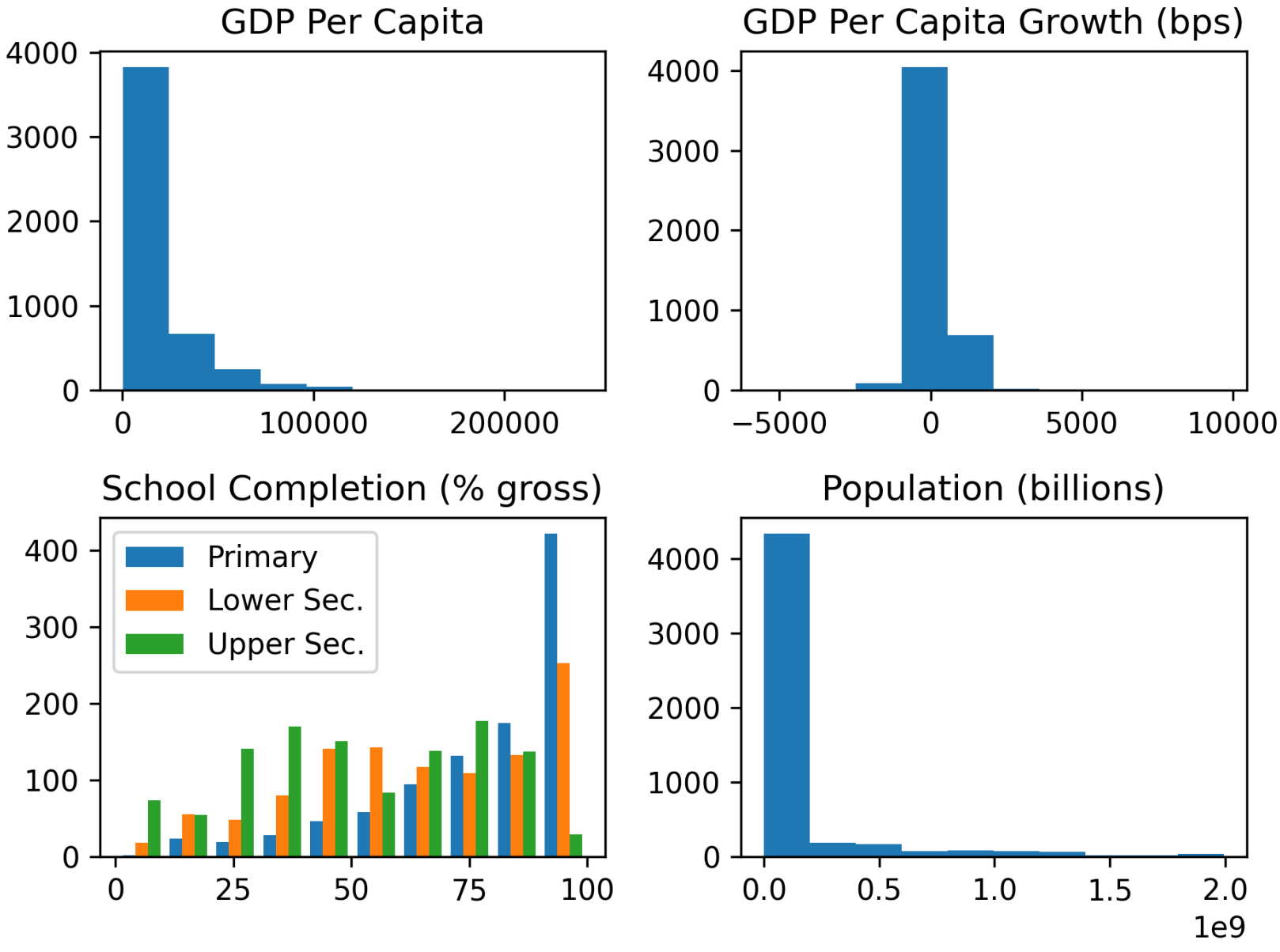
World Bank Data

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

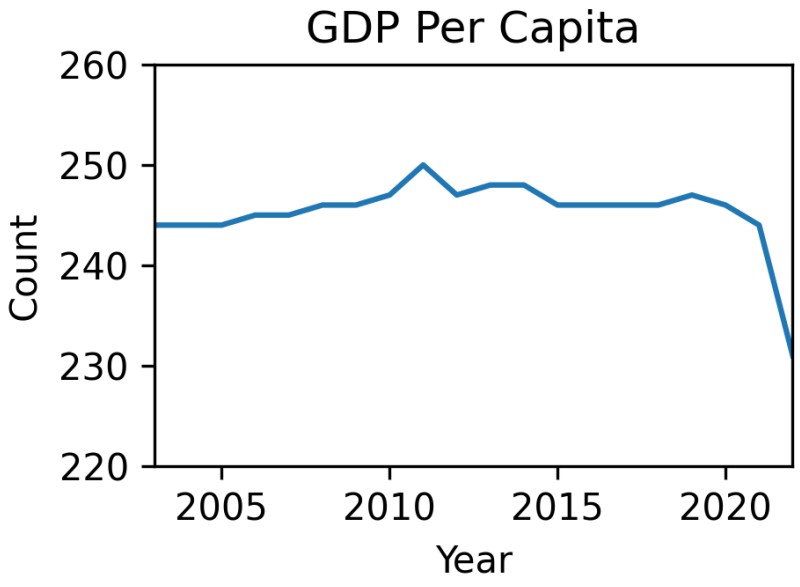
World Bank Data

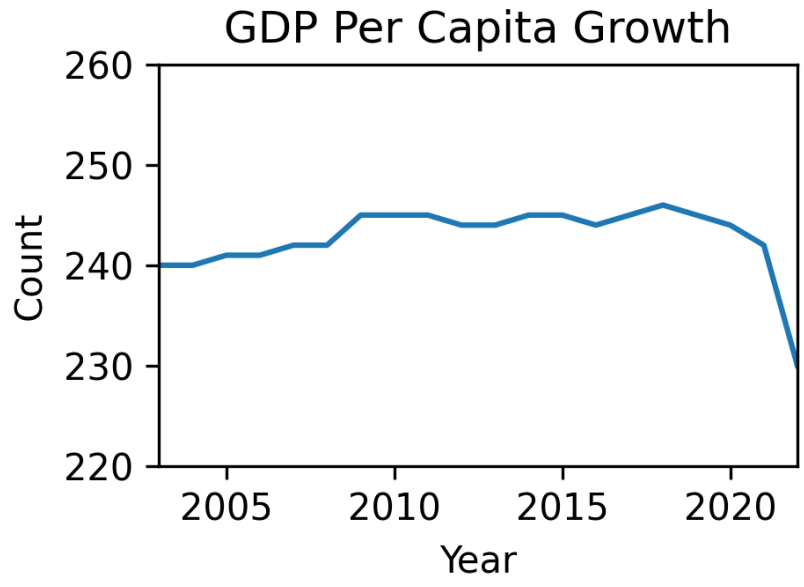
Distributions

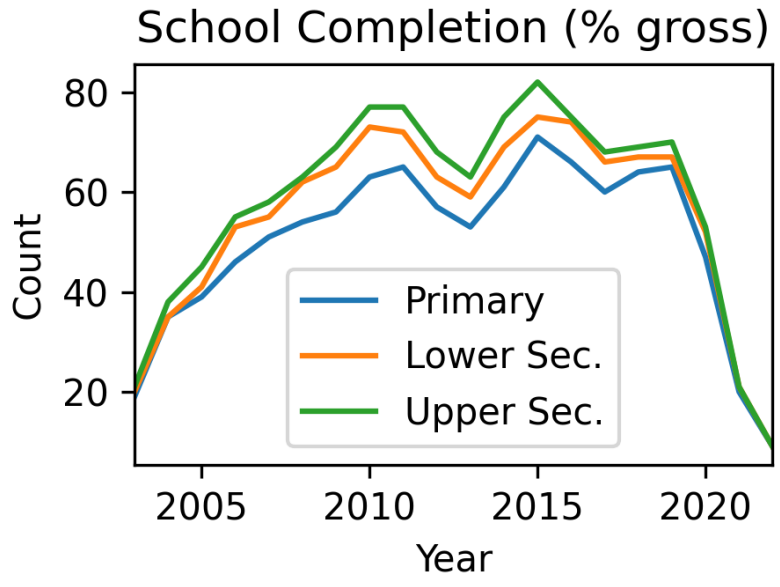


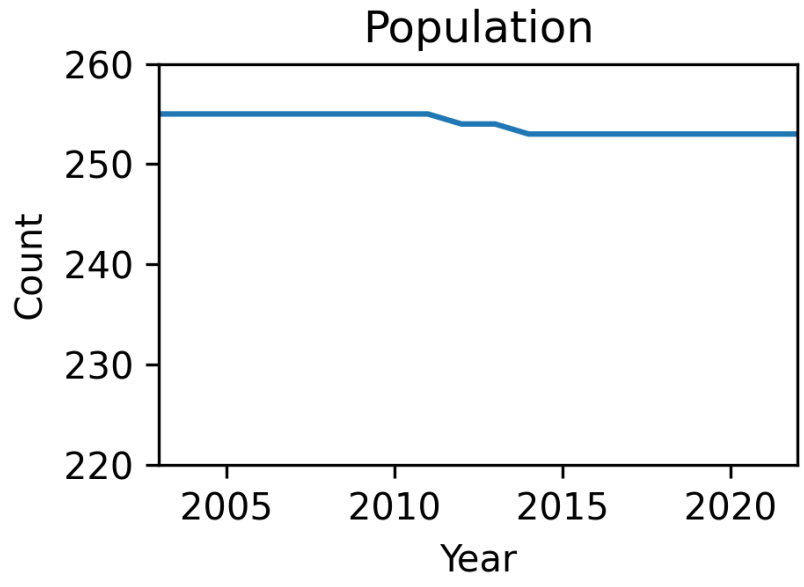
World Bank Data

Missing data









Imputing nulls

Using XGBoost for better predictions

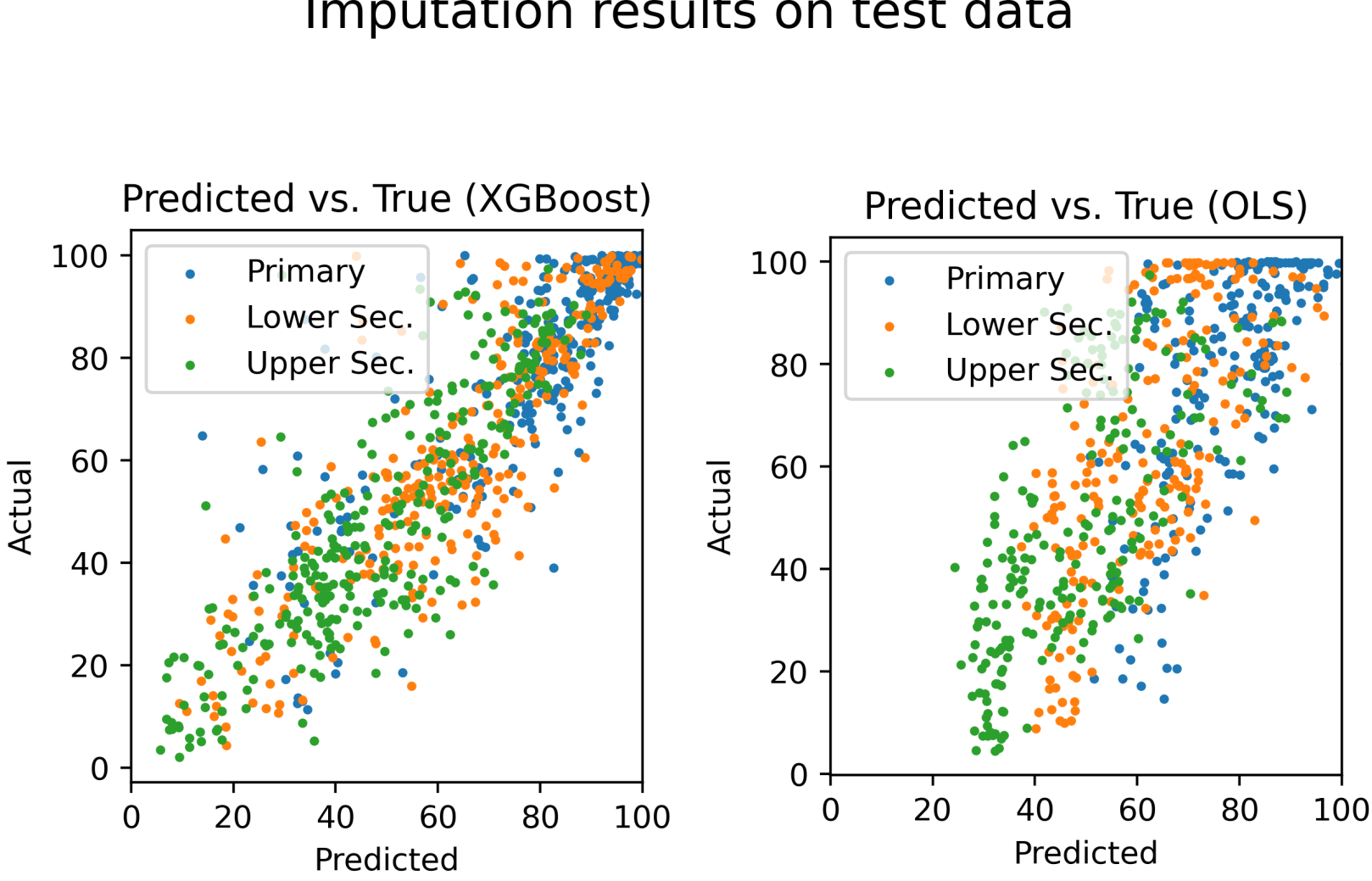
Data is not missing at random

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. Achieves significantly higher accuracy than linear regression.

Imputation results



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.

Rationale for variables

Capturing the ability of a country/region/education system to produce and identify elite talent is difficult. There are many potential omitted variables which may bias results.

Model specification

Let variables of interest be: $math99, ARWU, ARWU \times GDPpc, IMO$. For the sake of concision, let E be a 1 by 4 matrix defined as:

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

Let the coefficients of $E_{i,t}$ be a 4 by 1 matrix called λ. For control variables, $C_{i,t}$ is the matrix of variables and α is coefficients..

$$Y_{i,t} = \beta_0 + \lambda E_{i,t} + \alpha C_{i,t} + T_t + \epsilon_{i,t} \tag{1}$$

Due to missing data, consider another regression model which does not include $math99, math$:

$$Y_{i,t} = \alpha_0 + \lambda_{np} Enp_{i,t} + \alpha_{np} Cnp_{i,t} + T_t + \epsilon_{i,t} \tag{2}$$

where $Y_{i,t}$ is GDP per capita growth in basis points. Time effects are included to control for secular changes (e.g. business cycles).

PISA data regression

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

	Dependent variable: GDPpcGrowth			
	(1)	(2)	(3)	(4)
PISA Math in global P99		12.582	16.888	122.288
		(23.160)	(20.869)	(79.814)
IMO score per log population	11.744	4.247	10.055	71.462**
	(7.232)	(9.102)	(8.154)	(29.447)
ARWU insitutions	-586.307***	-559.067**	-575.550***	-295.306
	(198.985)	(240.047)	(213.365)	(559.483)
ARWU insitutions x GDP PC	0.009**	0.009*	0.008*	-0.007
	(0.004)	(0.005)	(0.004)	(0.014)
PISA Math		0.636	-0.273	-4.581
		(0.949)	(0.876)	(3.456)
GDP per capita	-0.003**	-0.006***	-0.004**	-0.007
	(0.002)	(0.002)	(0.002)	(0.012)
Primary School Completion Rate	-0.712	-2.406	-0.112	-4.624
	(3.868)	(4.849)	(4.338)	(18.411)
Lower Sec. Completion Rate	1.485	0.777	1.568	21.092
	(3.255)	(3.704)	(3.290)	(16.364)
Upper Sec. Completion Rate	1.597	1.439	1.542	-15.224
	(2.515)	(2.870)	(2.543)	(17.185)
Democracy Rating	0.940	3.972	4.167	-12.702
	(19.787)	(23.684)	(21.249)	(128.289)
Time Effects	Yes	No	Yes	Yes
Fixed Effects	No	No	No	Yes
Entities	48	48	48	48
Observations	109	109	109	109
R^2	0.397	0.212	0.402	0.753
Adjusted R^2	0.322	0.122	0.313	0.432
Residual Std. Error	197.737 (df=96)	224.993 (df=97)	199.076 (df=94)	181.047 (df=47)
F Statistic	5.275*** (df=12; 96)	2.367** (df=11; 97)	4.512*** (df=14; 94)	2.345*** (df=61; 47)

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

Interpreting Regressions

PISA regressions

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

Non-PISA data regression

	Dependent variable: GDPpcGrowth			
	Model 3 (PISA)	Model 5 (PISA years)	Model 6 (All years)	Model 7 (All years, FE)
IMO score per log population	10.055	18.160***	13.297***	10.006
	(8.154)	(6.517)	(3.993)	(10.776)
ARWU insitutions	-575.550***	-446.996**	-353.730***	523.241*
	(213.365)	(221.189)	(131.179)	(292.381)
ARWU insitutions x GDP PC	0.008*	0.008*	0.005*	-0.012**
	(0.004)	(0.004)	(0.002)	(0.006)
GDP per capita	-0.004**	-0.005***	-0.004***	0.002
	(0.002)	(0.002)	(0.001)	(0.004)
Primary School Completion Rate	-0.112	-3.530**	-1.754	-1.505
	(4.338)	(1.740)	(1.227)	(4.983)
Lower Sec. Completion Rate	1.568	5.370**	1.911	-0.147
	(3.290)	(2.445)	(1.692)	(5.035)
Upper Sec. Completion Rate	1.542	-2.365	0.081	1.981
	(2.543)	(1.946)	(1.325)	(3.776)
Democracy Rating	4.167	13.397	19.784***	87.626**
	(21.249)	(11.913)	(7.637)	(37.349)
Population	-0.000*	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Time Effects	Yes	Yes	Yes	Yes
Fixed Effects	No	No	No	Yes
Entities	48	103	137	137
Observations	109	222	746	746
R^2	0.402	0.202	0.380	0.611
Adjusted R^2	0.313	0.156	0.360	0.505
Residual Std. Error	199.076 (df=94)	240.456 (df=209)	288.864 (df=722)	253.976 (df=586)
F Statistic	4.512*** (df=14; 94)	4.417*** (df=12; 209)	19.219*** (df=23; 722)	5.785*** (df=159; 586)

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