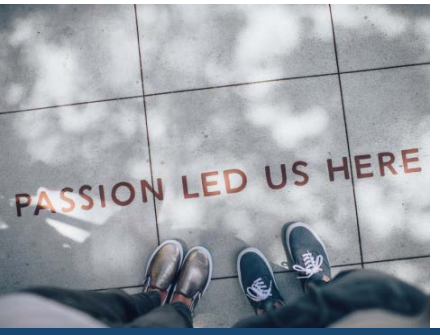

Using Big Data to Solve Economic and Social Problems

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HARVARD UNIVERSITY

OPPORTUNITY INSIGHTS

K-12 Education

K-12 Education: Background

- U.S. spends nearly $1 trillion per year on K-12 education

- Decentralized system with substantial variation across schools
  - Public schools funded by local property taxes → sharp differences in funding across areas
  - Private schools and growing presence of charter schools

K-12 Education: Overview

- Main question: how can we maximize the effectiveness of this system to produce the best outcomes for students?
  - Traditional approach to study this question: qualitative work in schools
  - More recent approach: analyzing big data to evaluate impacts

- References:

Chetty, Friedman, Hilger, Saez, Schanzenbach, Yagan. “How Does Your Kindergarten Classroom Affect Your Earnings? Evidence from Project STAR” *QJE* 2011.

Reardon, Kalogrides, Fahle, Shores. “The Geography of Racial/Ethnic Test Score Gaps.” Stanford CEPA Working Paper 2016

Fredriksson, Ockert, Oosterbeek. “Long-Term Effects of Class Size.” *QJE* 2012

Chetty, Friedman, Rockoff. “Measuring the Impacts of Teachers I and II” *AER 2014*

Using Test Score Data to Study K-12 Education

- Primary source of big data on education: standardized test scores obtained from school districts
  - Quantitative outcome recorded in existing administrative databases for virtually all students
  - Observed much more quickly than long-term outcomes like college attendance and earnings

Using Test Score Data to Evaluate Primary Education

- Common concern: are test scores a good measure of learning?
  - Do improvements in test scores reflect better test-taking ability or acquisition of skills that have value later in life?
- Chetty et al. (2011) examine this issue using data on 12,000 children who were in Kindergarten in Tennessee in 1985
  - Link school district and test score data to tax records
  - Ask whether KG test score performance predicts later outcomes

A Kindergarten Test

- I'll say a word to you. Listen for the *ending* sound.
- You circle the picture that *starts* with the same sound

"cup"

Earnings vs. Kindergarten Test Score

Average Earnings from Age 25-27

$25K
$20K
$15K
$10K

0
20
40
60
80
100

Kindergarten Test Score Percentile

Note: R^2 = 5%

Earnings vs. Kindergarten Test Score

Average Earnings from Age 25-27

$25K
$20K
$15K
$10K

Binned scatter plot: dots show *average* earnings for students in 5-percentile bins

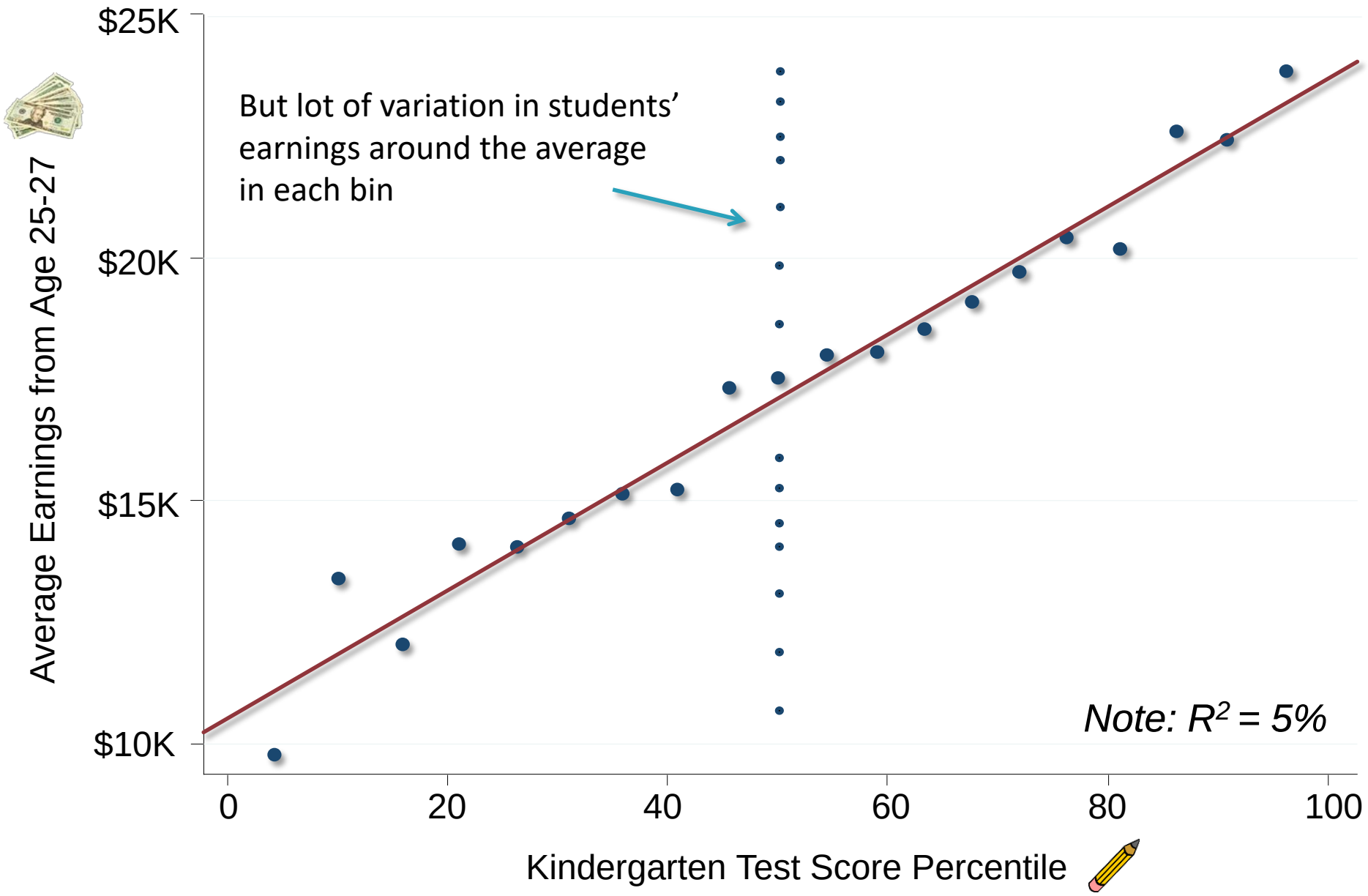
Ex: students scoring between 45-50 percentile earn about $17,000 on average

Note: R^2 = 5%

0 20 40 60 80 100

Kindergarten Test Score Percentile

Earnings vs. Kindergarten Test Score



Earnings vs. Kindergarten Test Score

Average Earnings from Age 25-27

$25K
$20K
$15K
$10K

0
20
40
60
80
100

Kindergarten Test Score Percentile

Test scores explain only 5% of the variation in earnings across students

Note: $R^2 = 5\%$

Earnings vs. Kindergarten Test Score

Lesson: KG Test scores are highly predictive of earnings…but they don't determine your fate

Note: R^2 = 5%

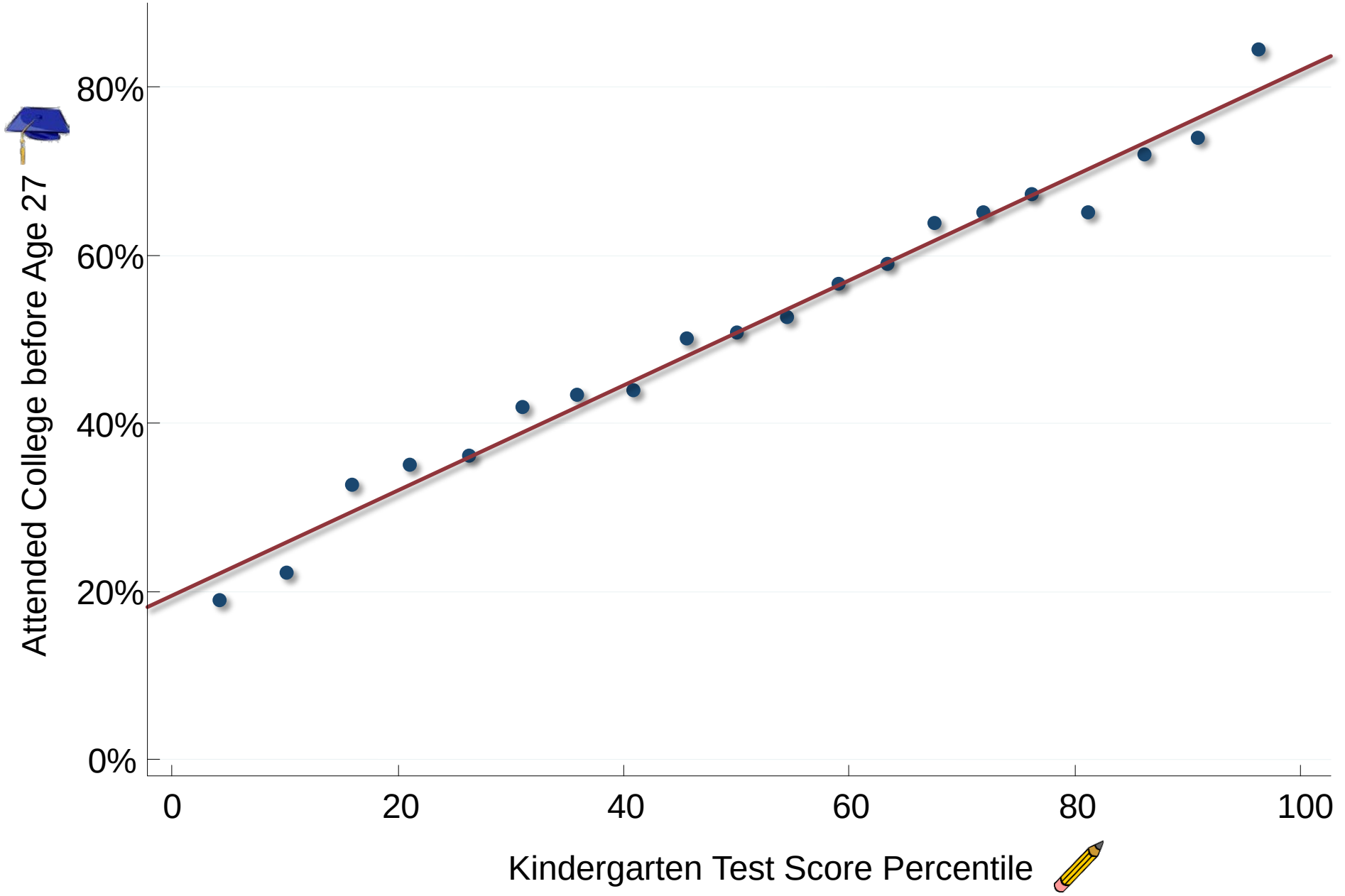
Average Earnings from Age 25-27

$25K
$20K
$15K
$10K

0
20
40
60
80
100

Kindergarten Test Score Percentile

College Attendance Rates vs. KG Test Score



Marriage by Age 27 vs. KG Test Score

Married by Age 27

55%
50%
45%
40%
35%
30%
25%

0
20
40
60
80
100

Kindergarten Test Score Percentile

Studying Differences in Test Score Outcomes

- Test scores can provide a powerful data source to compare performance across schools and subgroups (e.g., poor vs. rich)

- Problem: tests are not the same across school districts and grades → makes comparisons very difficult

- Reardon et al. (2016) solve this problem and create a standardized measure of test score performance for all schools in America

  - Use 215 million test scores for students from 11,000 school districts across the U.S. from 2009-13 in grades 3-8

Making Test Score Scales Comparable Across the U.S.

- Convert test scores to a single national scale in three steps:

1. Rank each school district's average scores in the statewide distribution (for a given grade-year-subject)

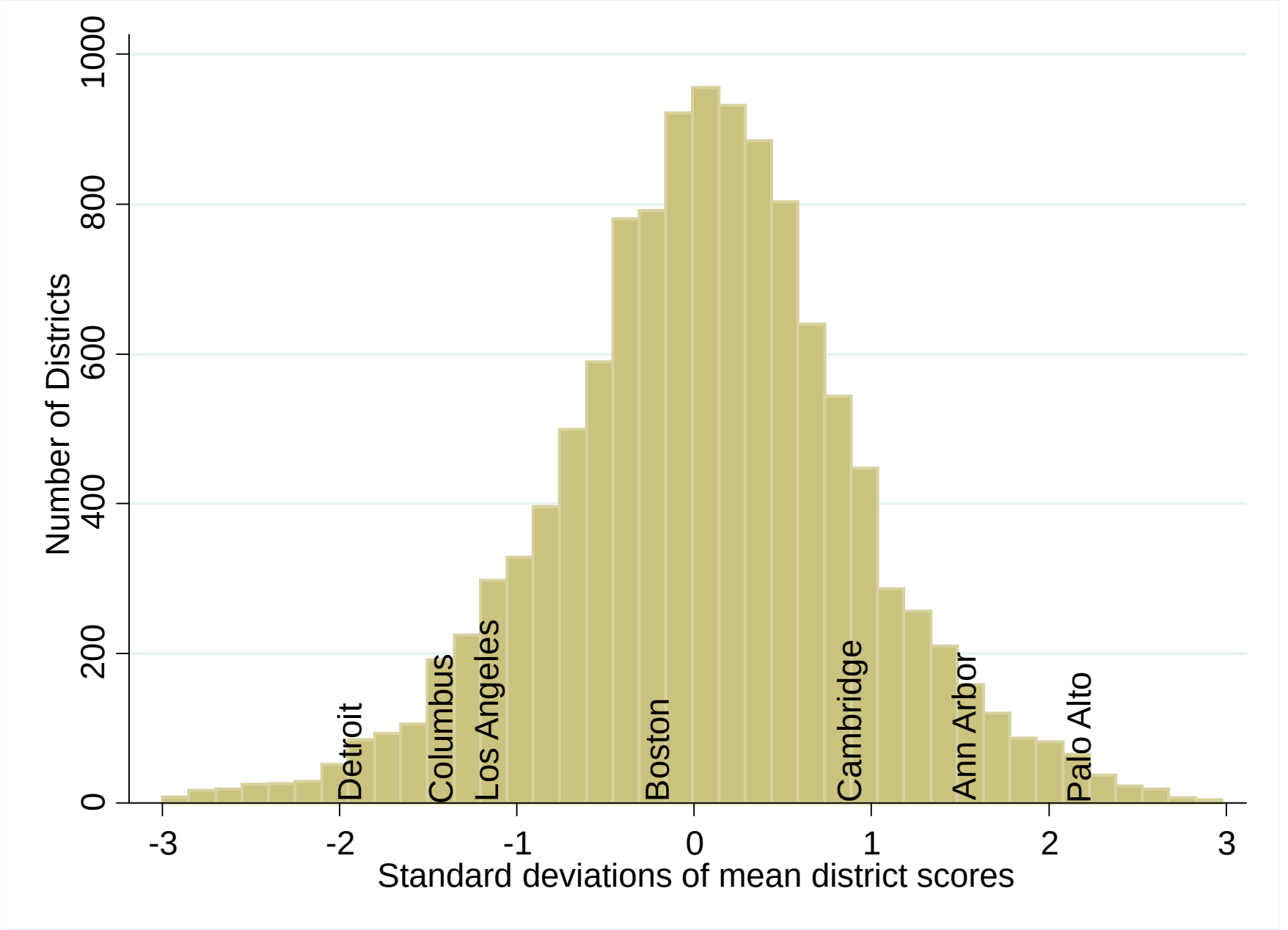
2. Use data from a national test administered to a sample of students by Dept. of Education to convert state-specific rankings to national scale

    - Ex: suppose CA students score 5 percentiles below national average

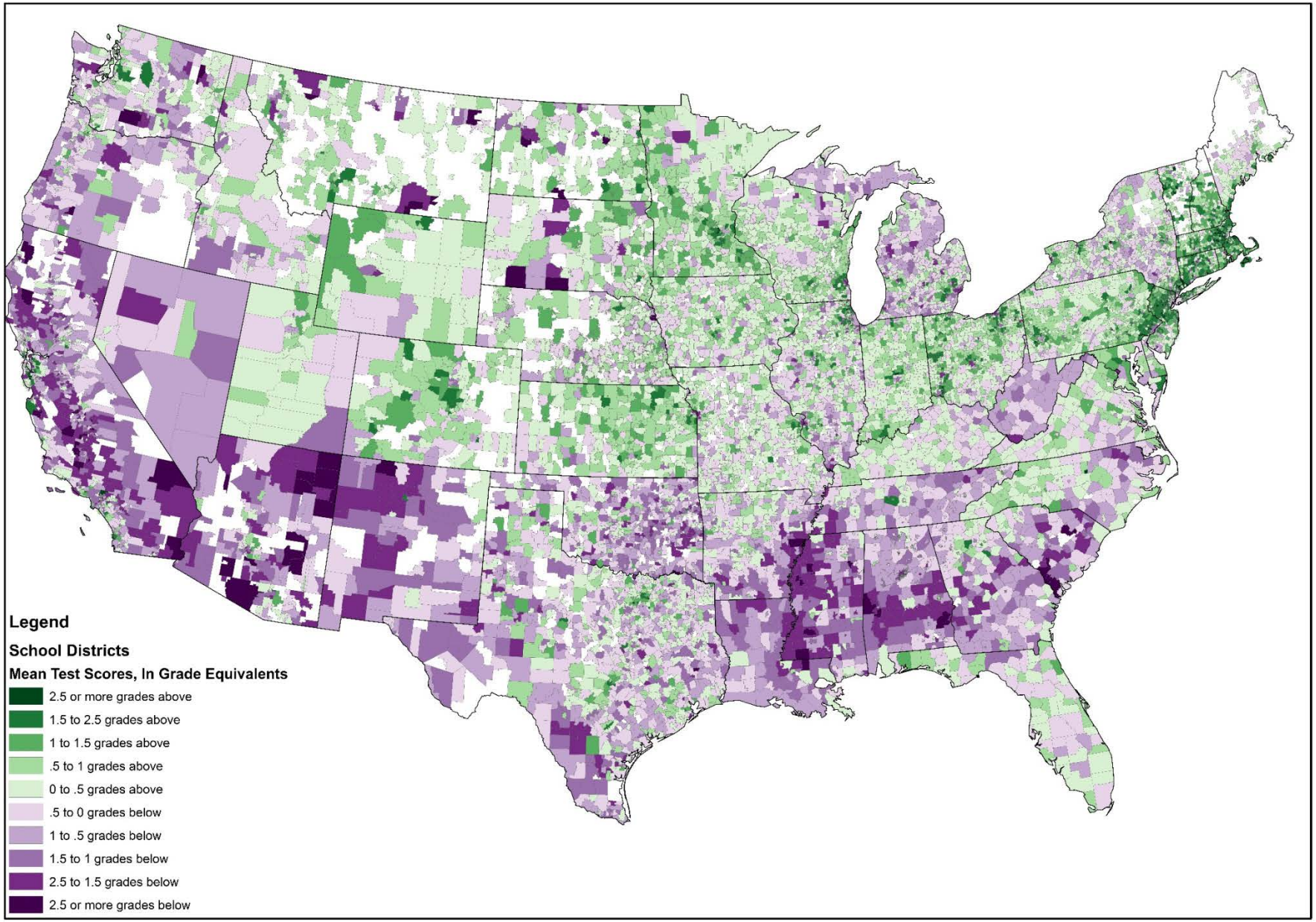
    - Then a CA school whose mean score is 10 percentiles below CA mean is 15 percentiles below national mean

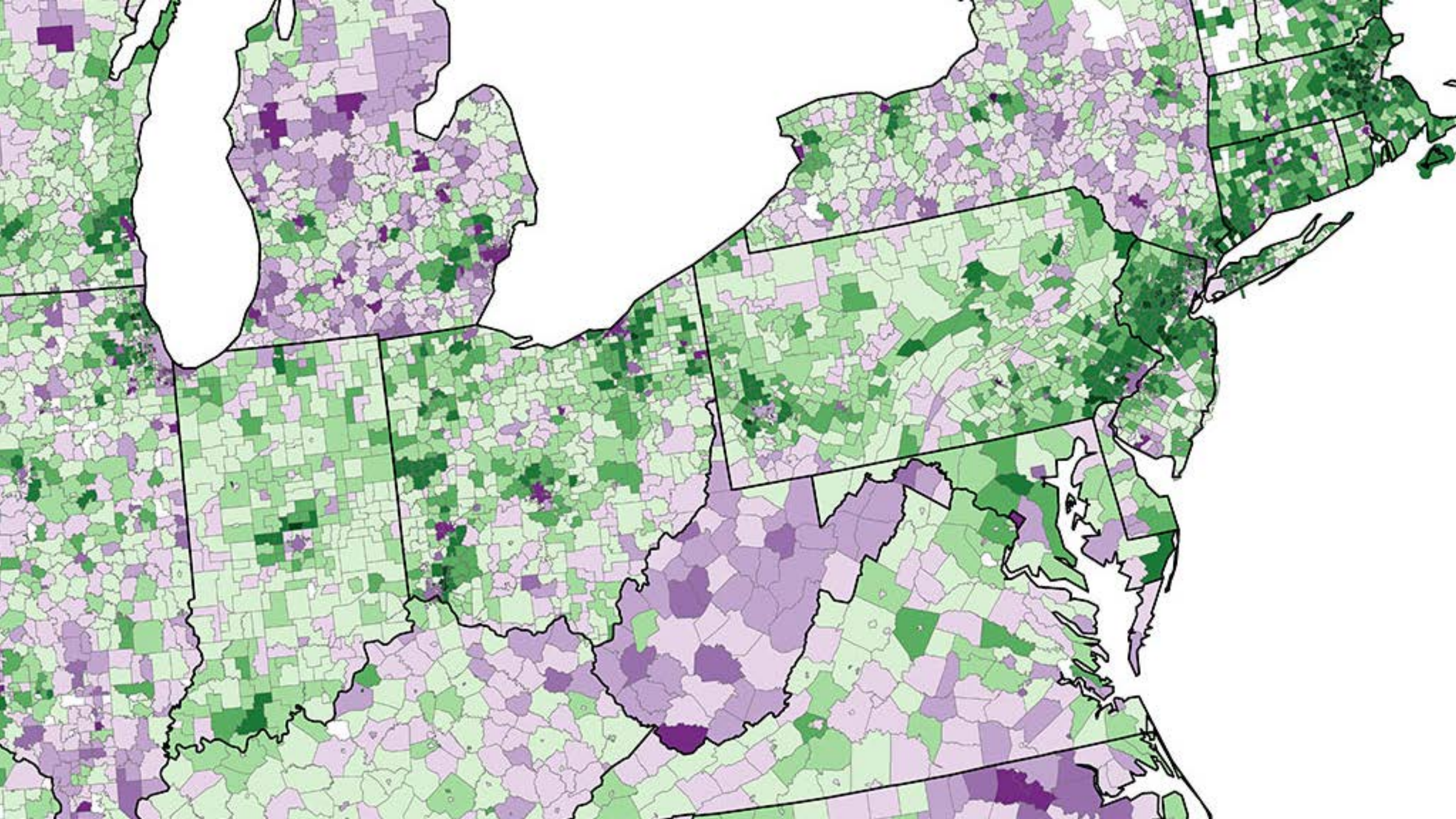
3. Convert mean test scores to "grade level" equivalents

Nationwide District Achievement Variation, 2009-2013



Average Test Scores, by School District, Grades 3-8, 2009-2013





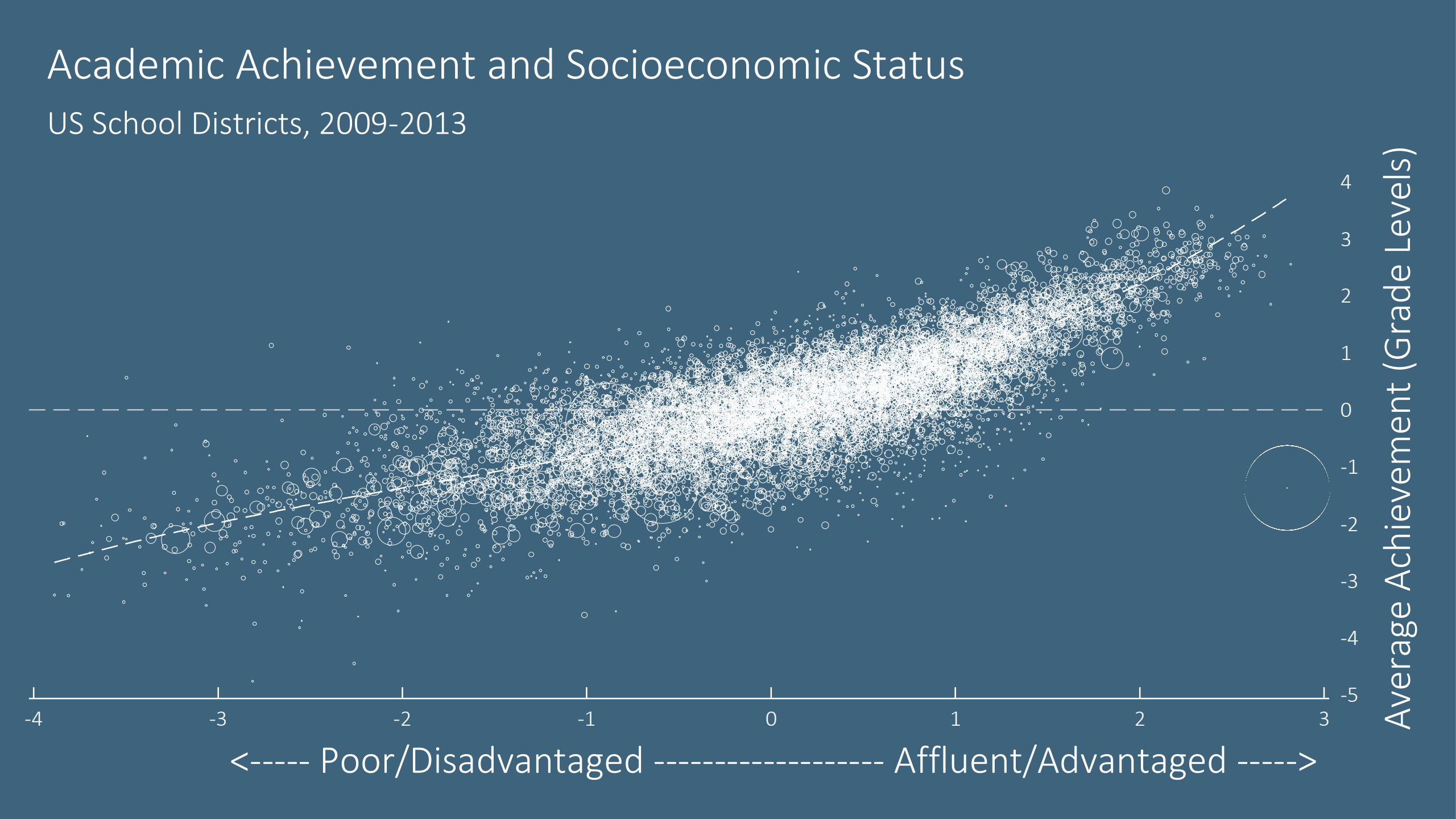
Achievement Gaps in Test Scores by Socioeconomic Status

- Next, use these data to examine how test scores vary across socioeconomic groups

- Define an index of socioeconomic status (SES) using Census data on income, fraction of college graduates, single parent rates, etc.

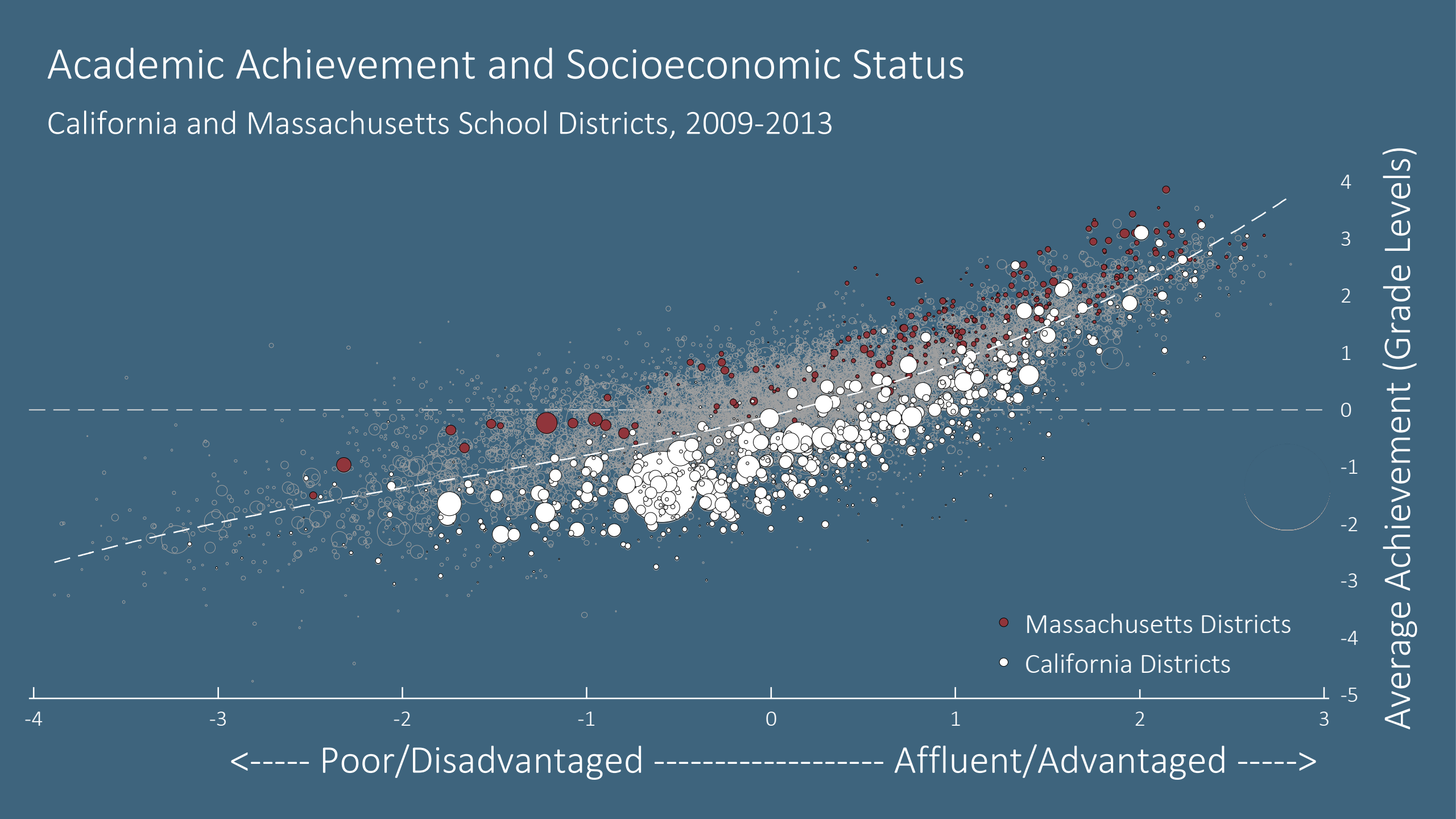
Academic Achievement and Socioeconomic Status

US School Districts, 2009-2013



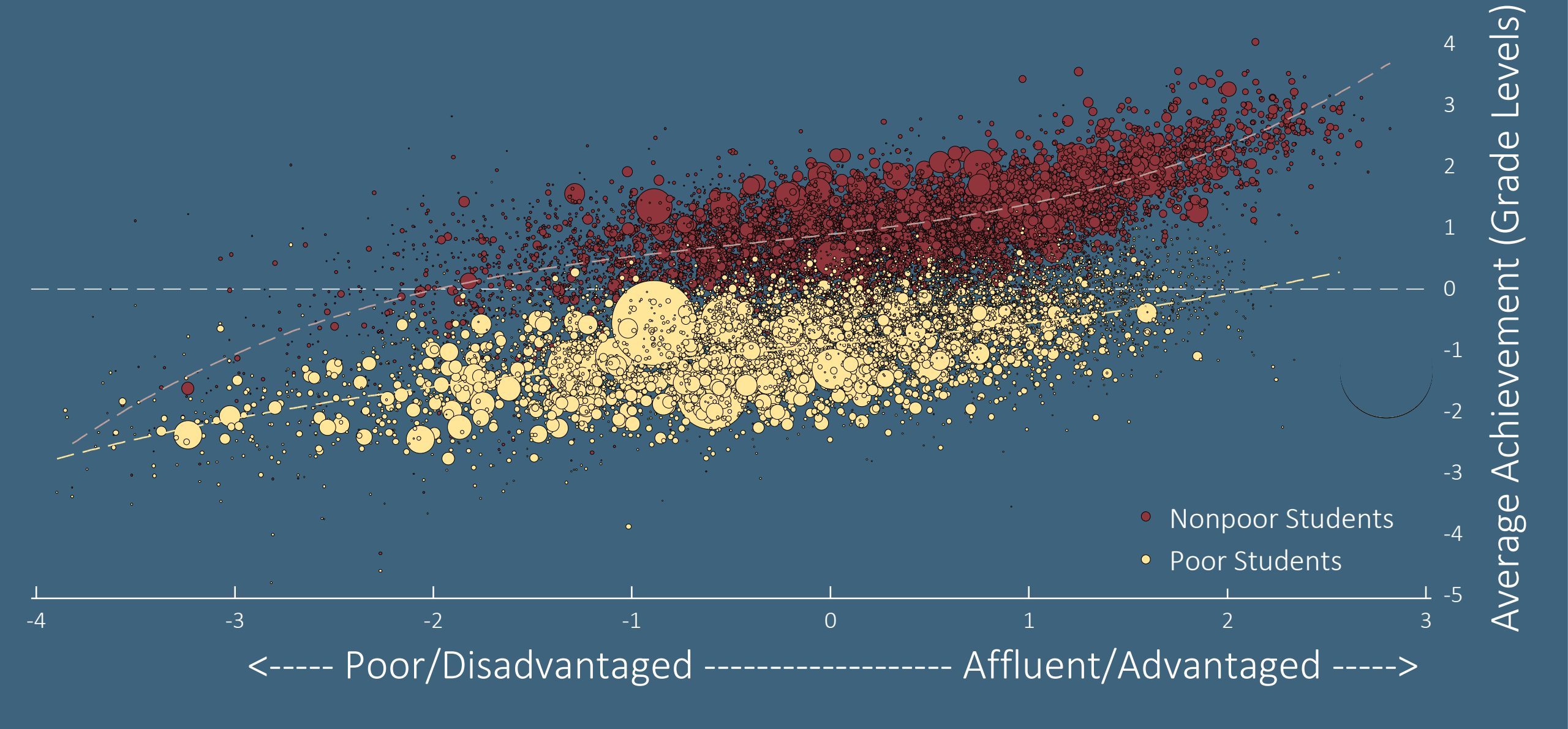
Academic Achievement and Socioeconomic Status

California and Massachusetts School Districts, 2009-2013



Academic Achievement and Socioeconomic Status, by Poverty Status

US School Districts With 20+ Students of a Given Economic Status, 2009-2013



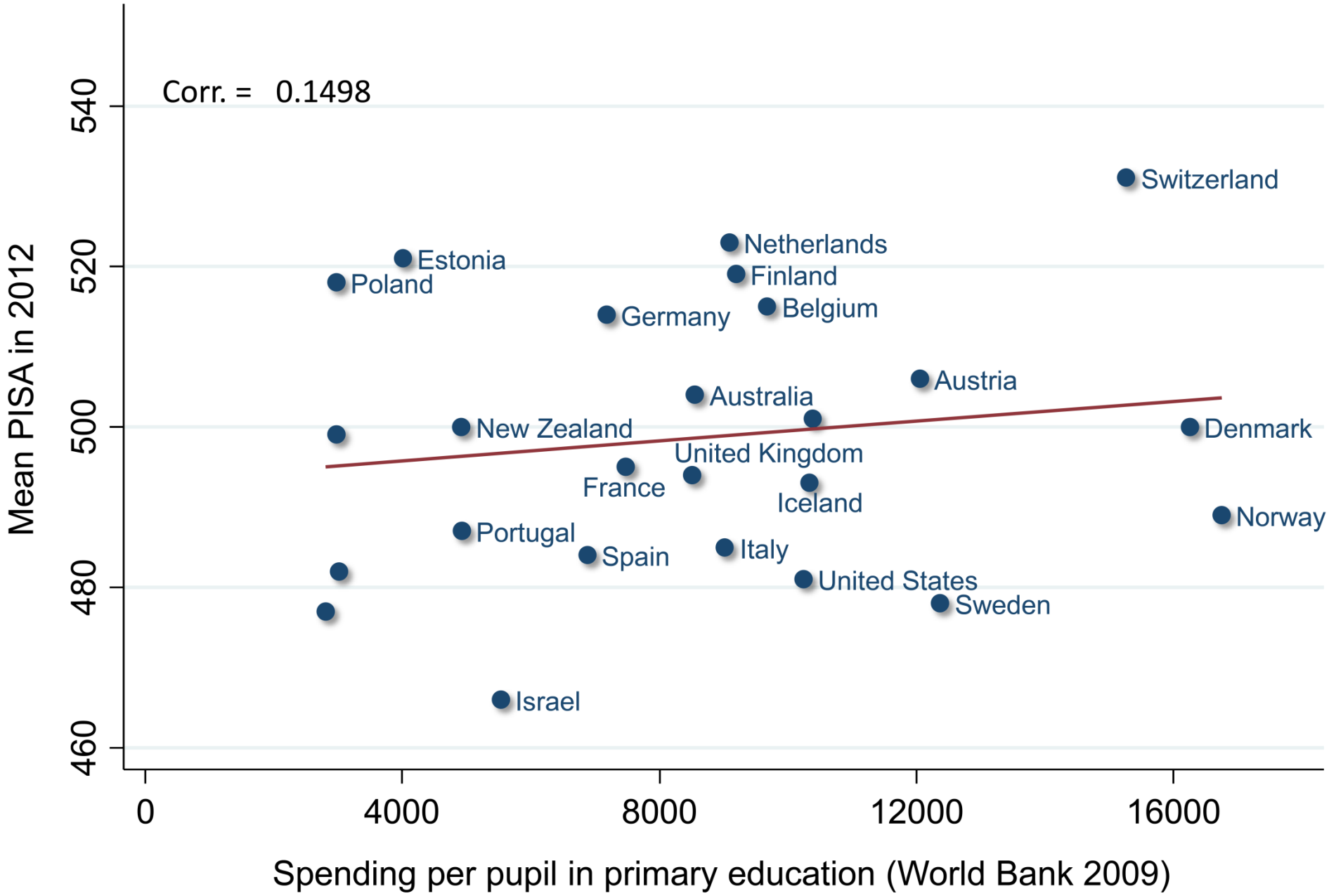
How Can We Improve Poorly Performing Schools?

- There are many school districts in America where students are two grade levels behind national average, controlling for SES

- How can we improve performance in these schools?

  - Simply spending more money on schools is not necessarily the solution…

Test Scores vs. Expenditures on Primary Education Across Countries



Two Policy Paradigms to Improve Schools

- Two distinct policy paradigms to improve schools

  1. Government-based solutions: improve public schools by reducing class size, increasing teacher quality, etc.

  2. Market-based solutions: charter schools or vouchers for private schools

- Contentious policy debate between these two approaches

  – We will consider each approach in turn

Government-Based Solutions: Improving Schools

Improving Schools: The Education Production Function

- Improving public schools requires understanding the education production function

- How should we change schools to produce better outcomes?

Better Teachers?

Smaller Classes?

Better Technology?

Effects of Class Size

- Begin by analyzing effects of class size
- Cannot simply compare outcomes across students who are in small vs. large classes
  - Students in schools with small classes will generally be from higher-income backgrounds and have other advantages
  - Therefore, this simple comparison in observational data will overstate causal effect of class size
- Need to use experimental/quasi-experimental methods instead

Effects of Class Size: Tennessee STAR Experiment

- Student/Teacher Achievement Ratio (STAR) experiment
  - Conducted from 1985 to 1989 in Tennessee
  - About 12,000 children in grades K-3 at 79 schools
- Students and teachers randomized into classrooms within schools
  - Class size differs: small (~15 students) or large (~22 students)
  - Classes also differ in teachers and peers

Effects of Class Size: Tennessee STAR Experiment

- Evaluate impacts of STAR experiment by comparing mean outcomes of students in small vs. large classes

- Report impacts using regressions of outcomes on an indicator (0-1 variable) for being in a small class [Krueger 1999, Chetty et al. 2011]

STAR Experiment: Impacts of Class Size

Dep Var:	Test Score	College Attendance	Earnings
Outcome	(1)	(2)	(3)
Small Class	4.81	2.02%	-$4
	(1.05)	(1.10%)	($327)
Observations	9,939	10,992	10,992
Mean of Dep. Var.	48.67	26.4%	$15,912

STAR Experiment: Impacts of Class Size

Dep Var:	Test Score	College Attendance	Earnings
	(1)	(2)	(3)
Small Class	4.81	2.02%	-$4
Estimated Impact	(1.05)	(1.10%)	($327)
Observations	9,939	10,992	10,992
Mean of Dep. Var.	48.67	26.4%	$15,912

Estimated impact of being in a small KG class:
4.81 percentile gain in end-of-KG test score

STAR Experiment: Impacts of Class Size

	Dep Var:	Test Score	College Attendance	Earnings
		(1)	(2)	(3)
Small Class		4.81	2.02%	-$4
		(1.05)	(1.10%)	($327)
	Standard Error			
Observations		9,939	10,992	10,992
Mean of Dep. Var.		48.67	26.4%	$15,912

95% confidence interval = estimate +/-1.96 times standard error
→ 95% CI for test score impact = 2.71 to 6.91 percentiles

If we repeat experiment 100 times, 95 of the 100 estimates will lie between 2.71 and 6.91 percentiles

STAR Experiment: Impacts of Class Size

Dep Var:	Test Score	College Attendance	Earnings
	(1)	(2)	(3)
Small Class	4.81	2.02%	-$4
	(1.05)	(1.10%)	($327)
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Mean of Dep. Var.	48.67	26.4%	$15,912

Mean Value of Outcome

STAR Experiment: Impacts of Class Size

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Mean of Dep. Var.	48.67	26.4%	$15,912

95% confidence interval: (-$645,$637)

→ *Earnings impact could be as large as **$637** (a 4% increase)*

Effects of Class Size: Quasi-Experimental Evidence

- Limitation of STAR experiment: sample is too small to estimate impacts of class size on earnings precisely

- Fredriksson et al. (2013) use administrative data from Sweden to obtain more precise estimates

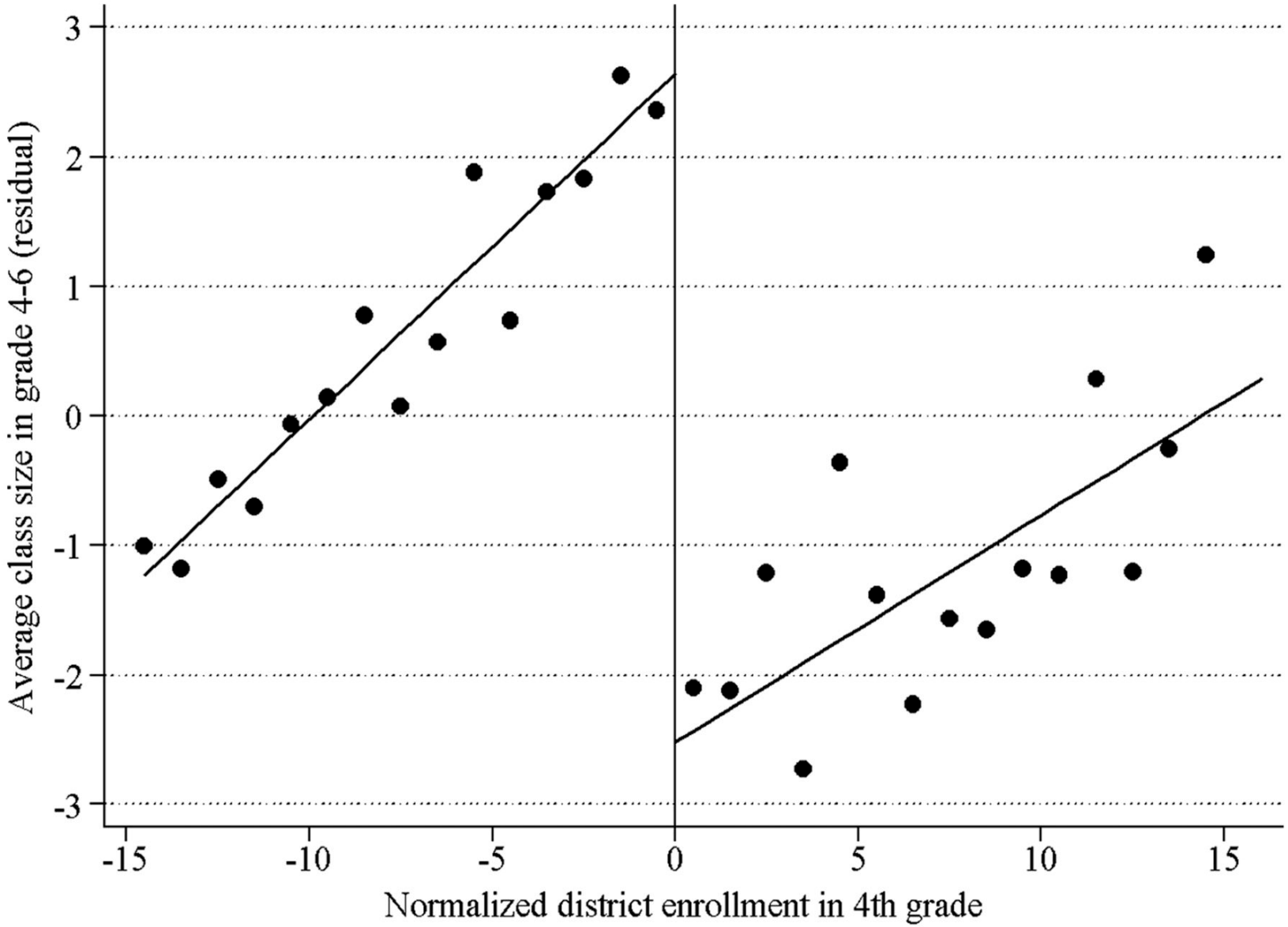
  - No experiment here; instead use a quasi-experimental method: regression discontinuity

Regression Discontinuity Using Class Size Cutoffs

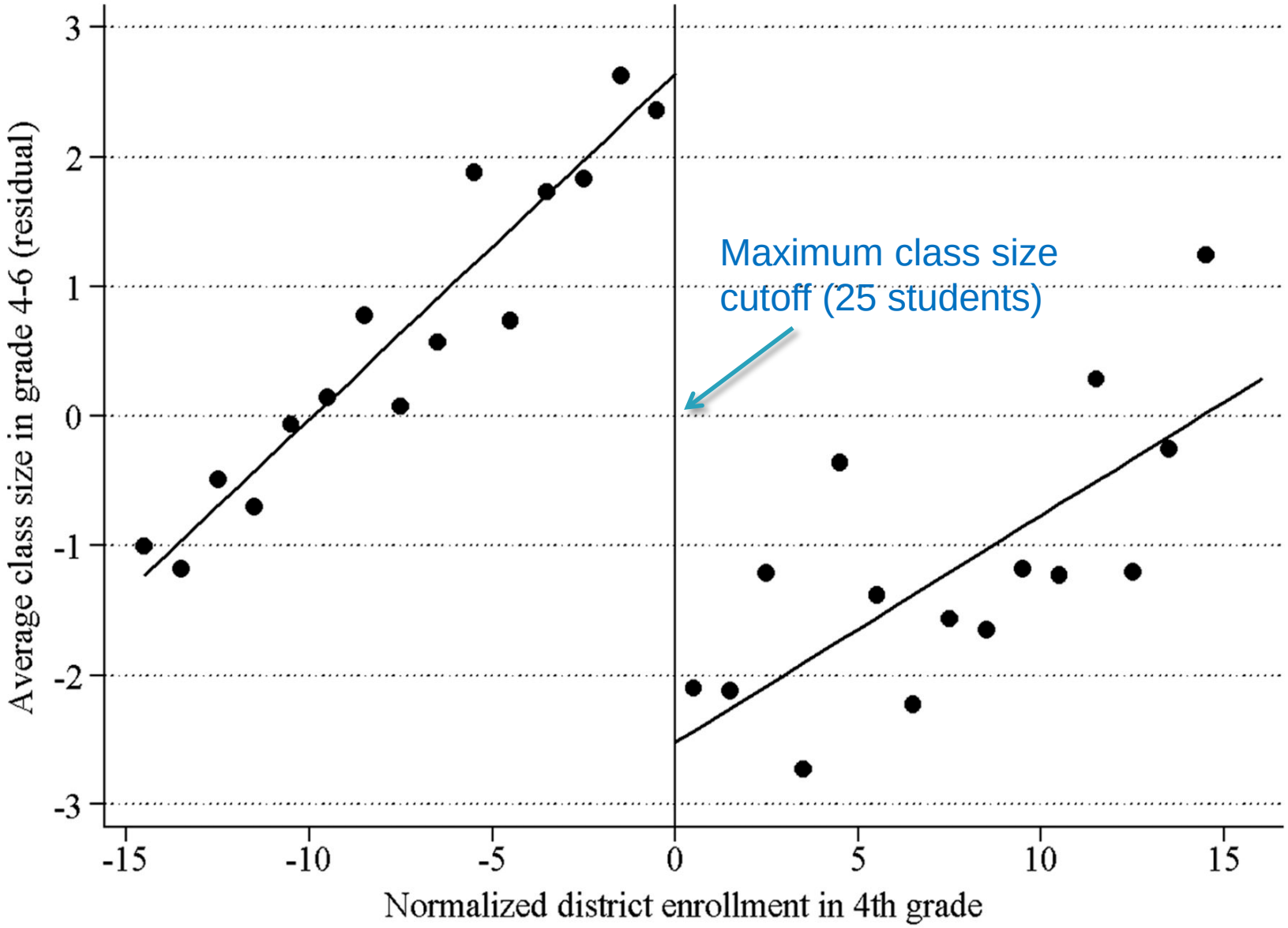
- Sweden imposes a maximum class size of 25 students
  - School that has 26 students in a given grade will therefore have two classes of 13 students each
  - School that has 25 students may have one class of 25 students
- School that have 26 students in a grade are likely to be comparable to those that have 25 students

→ Can identify causal effects of class size by comparing outcomes in schools with 26 vs. 25 students in a given grade

Discontinuities in Class Size Created by Maximum Class Size Rule



Discontinuities in Class Size Created by Maximum Class Size Rule



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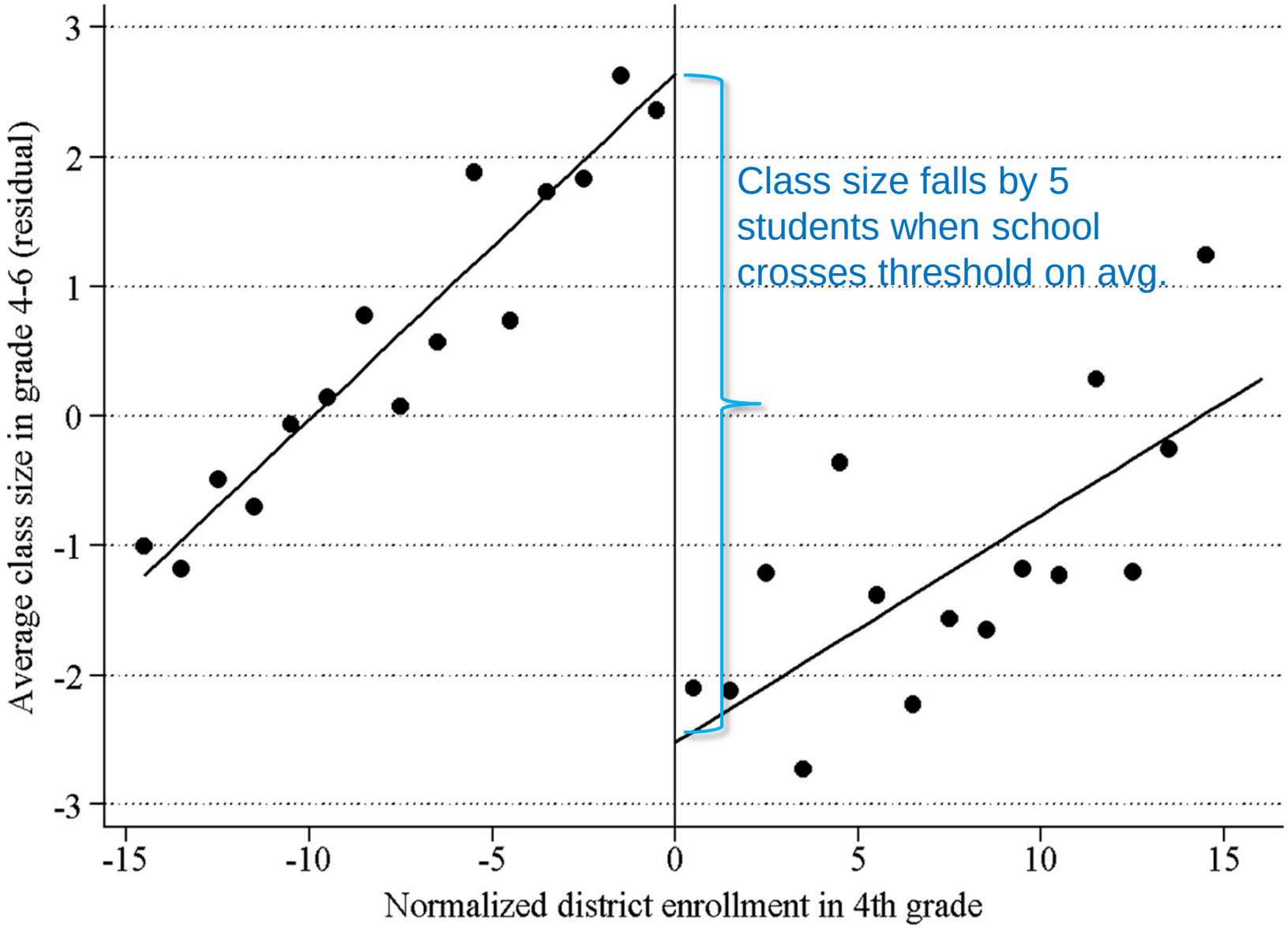
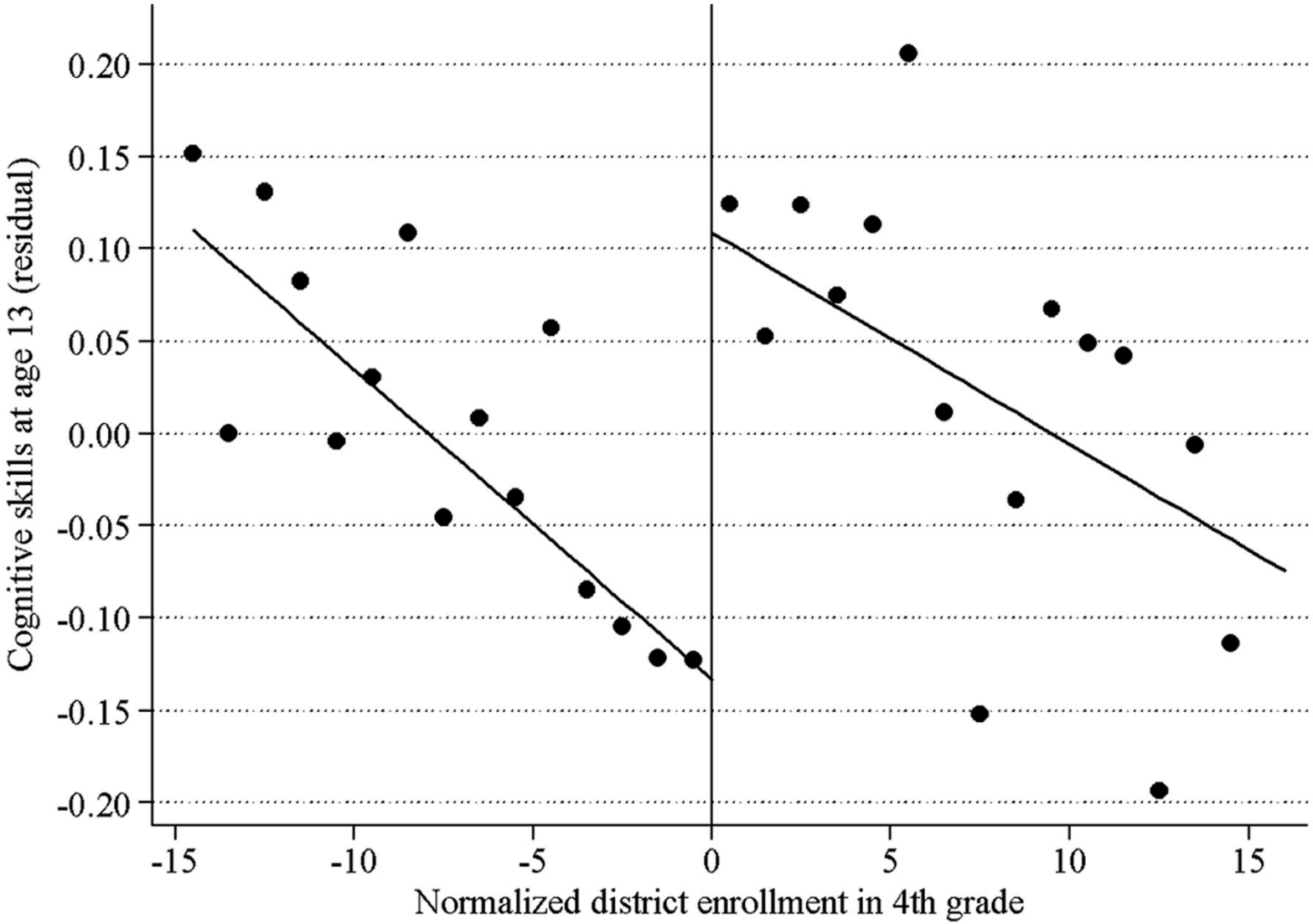
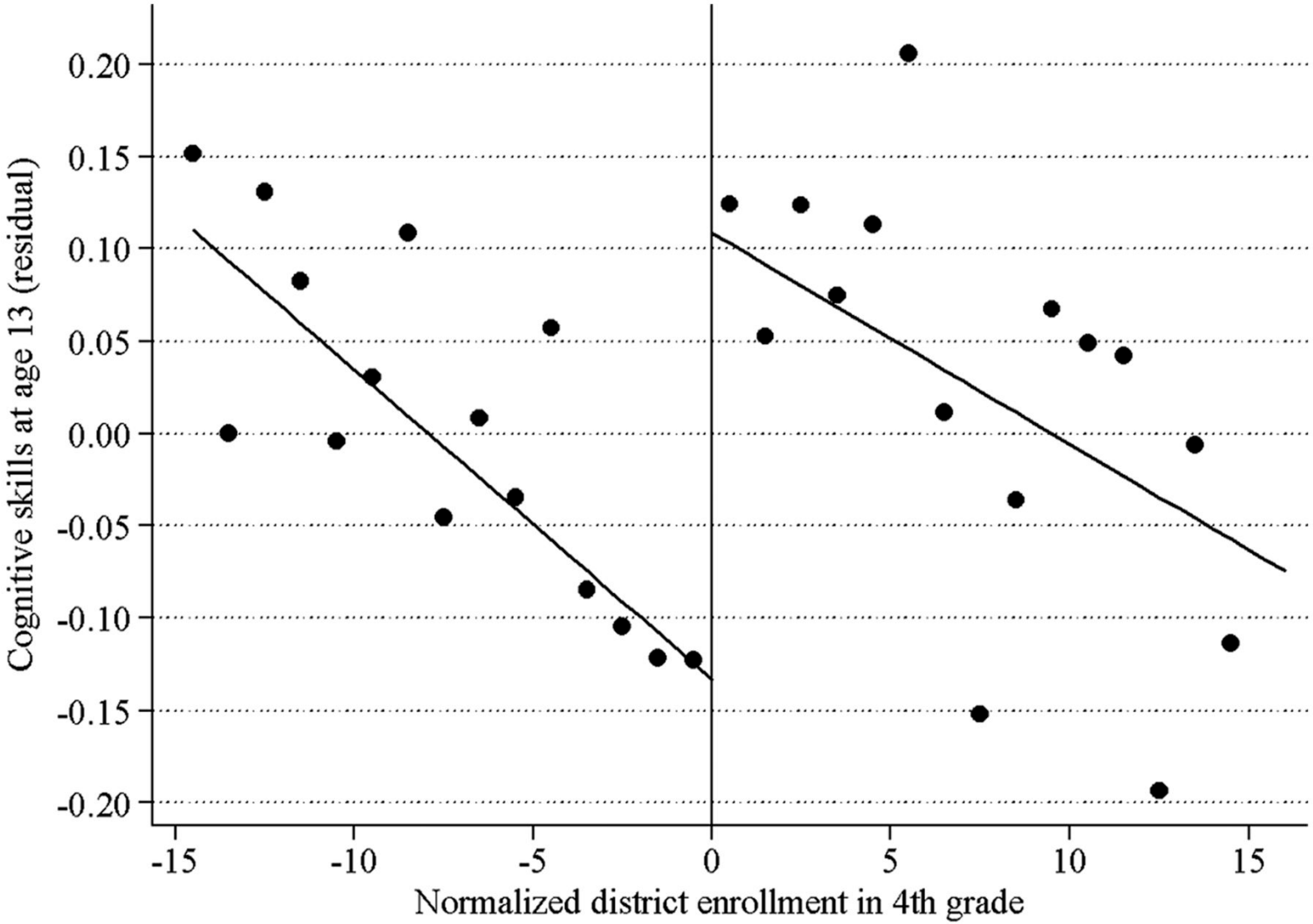


Test Score Achievement: Regression Discontinuity Estimates



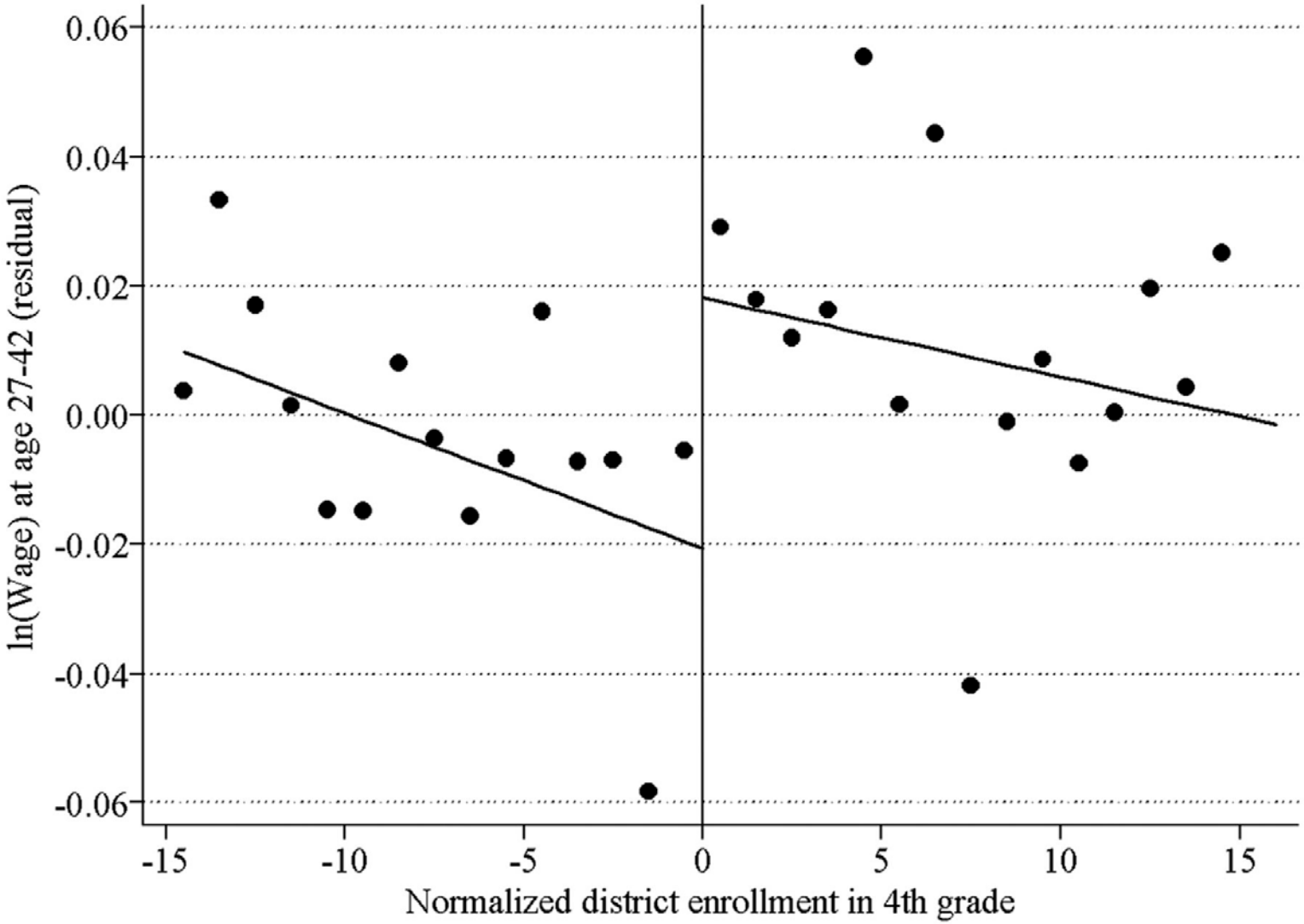
Test Score Achievement: Regression Discontinuity Estimates



Test scores jump by 0.2 standard deviations (8 percentiles) at cutoff

→ Reducing class size by 5 students causes 8 percentile increase in scores

Earnings Impacts: Regression Discontinuity Estimates



Earnings jump by 0.04 log points (4 percent) at cutoff

→ Reducing class size by 5 students causes 4% increase in earnings

Lessons on Class Size

- Reducing class sizes in primary school by hiring more teachers can have large returns
  - Present value of lifetime earnings of a child growing up in a family at 25th percentile is about $500,000 on average
  - 4% earnings gain from smaller class = $20,000
  - Dividing a class of 30 students into two would increase total earnings of students by more than $600,000
  - Costs (hiring another teacher and an additional room) likely to be well below $600,000