

The Effect of Energy Efficiency Measures on K12 Educational Performance

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Abstract

Energy efficiency measures (EEMs) frequently include measures that directly improve the learning environment. This study will use a variety of causal identification techniques to establish if the installation of EEMs results in a measurable increase in student performance as measured by standardized tests and attendance. Oregon's K12 funding structure, which levelizes funding per student across districts, and the requirements that state funding for EEMs in schools restricts be used in areas served by IOUs, assists in this identification.

History of Current Work

- Noticed this when we made SB 1149 improvements on to Parkrose Schools.
- Gave topics to John Bauer, Timothy Hulseman, Virginia Saraswati in Winter 2017 as a topic in Energy Economics.
- They learned enough econometrics and did a good enough job to present at an engineering conference.
- This takes a different approach to the same topic.

Background

- Not all jurisdictions use “participant benefits” in evaluation of cost effectiveness because they are not enjoyed by the rate payer.
- The “National Efficiency Screening Project” only gives guidance on including non-energy benefits as it explains the symmetry principal, “If you include participant benefits, include participant costs”.
- Some jurisdictions, e.g., The Energy Trust of Oregon, are reducing the technical complexity of evaluations to *reduce evaluation costs*

“Reduced Technical Complexity”

- Free ridership/drivership by survey, “Would you have done this without ETO incentives?”
 - Assume people tell the truth.
 - Economists don't believe that.
- Simpler econometrics
 - No accounting for self-selection bias.
 - No accounting for sampling bias.
 - Stops ‘futzing’

In short, the opposite of what economics is doing with program evaluation, but more inline with engineering approach, i.e., assume randomized assignment and equal probability sampling.

Why the Effect of Energy Efficiency on Education is Interesting?

- Purely facilities decision – money saved on energy.
- All Energy Efficiency Measures (EEMs) must pass cost benefit test.
- Improvements in student/staff health and the lifetime effects of academic performance dwarf the value of energy savings.
- Oregon provides almost perfect framework for Regression Discontinuity Design (RDD).

Daylighting (Sampling)

- D. A. Kleiber and others. "Environmental Illumination and Human Behavior: The Effects of Spectrum of Light Source on Human Performance in a University Setting." (1973)
 - 3 schools
 - Movement to portables.
 - 17% drop
- L. Heschong. "Daylighting in Schools: An Investigation into the Relationship between Daylighting and Human Performance. Detailed Report." (1999).
 - "Data indicate students with the most classroom daylighting progressed 20 percent faster on math tests and 26 percent on reading tests in one year than those with the least."
 - No control for self-selection
 - ~20,000 schools

- L. Heschong, R. L. Wright and S. Okura. “Daylighting impacts on human performance in school”. In: *Journal of the Illuminating Engineering Society* 31.2 (2002), pp. 101-114.
 - Positive effect. Scale is dubious.
 - Multiple school districts with various quality of daylighting.
- M. H. Nicklas and G. B. Bailey. “Analysis of the Performance of Students in Daylit Schools.” (1996).
 - “... [daylit] schools outperformed students attending artificially lighted schools by 5 to 14 percent.”

Indoor Air Quality (Sampling)

- M. J. Mendell and G. A. Heath. “Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature”. In: *Indoor air* 15.1 (2005), pp. 27-52.
 - Not all that critical (Three studies of students, x2 from 70s)
 - Summary, something is there but we don't know what it is.
- S. Moonie, D. A. Sterling, L. W. Figgs, et al. “The relationship between school absence, academic performance, and asthma status”. In: *Journal of School Health* 78.3 (2008), pp. 140-148.
 - 3K students
 - More absences, lower test scores.
 - Asthma kids have more absences but not lower scores with same absences.

- U. Haverinen-Shaughnessy, D. Moschandreas and R. Shaughnessy. “Association between substandard classroom ventilation rates and students’ academic achievement”. In: *Indoor air* 21.2 (2011), pp. 121-131.
 - Schools with less than 7.1 l/s/person, i.e., less than ASHRAE Standard 62 in 2004.
 - “... [1 l/s per person] increase in the ventilation rate within that range, the proportion of students passing standardized test (i.e., scoring satisfactory or above) is expected to increase by 2.9% (95%CI 0.9–4.8%) for math and 2.7% (0.5–4.9%) for reading.”

In Short

- Students got stuck in the 60s-70s daylighting vs air conditioning battle.
- Air quality is important but we don't know exactly what part
 - We know air exchanges, CO_2 concentrations are important, but beyond that
 - Hard to measure.
 - Allergenic mold concentrations, colony forming bodies per liter, can change by factor of 10 in a few hours.

Why Oregon Schools?

- Nice features that remove many, but not all, self-selection problems.
- Decision making cutoffs are based on energy savings, not educational outcomes.
- Still problems
 - Data shortcoming . . . as we go along.
 - Standardized tests are not standard from year-to-year.
 - Building data is not so important to departments of education.

SB 1149

- SB 1149 (1999) was Oregon's deregulation bill.
 - It was part of the implementation of FERC 888/889.
 - Established a Public Purpose Charge that funds thing like The Energy Trust of Oregon (ETO).
- The 3% Public Purpose Charge was collected by *almost* all the IOUs.
 - PacifiCorp and PGE collect, but Idaho Power in Eastern Oregon does not.
 - Used for Energy Efficiency
 - 10% must be used in schools.

Schools Program

Schools using SB 1149 public purpose funds:

- Complete energy audits of *buildings*, not districts, served by Pacificorp or PGE (with limitations);
- Audits must be completed by an approved audit company;
- Implement the approved Energy Efficiency Measures identified in the audits;
- Report Energy Use Index data in the Schools Interactive Database each year;

Key Points

- Not all districts are eligible.
- Not all schools within districts are eligible.
- Eligibility is not triggered by attendance or standardized test performance.

Makes it easier to establish a natural control group for any treated school by using ineligible ones in the district.

Educational Funding in Oregon

- 1991 Oregon establishes an Equalization Formula:
 - The legislature establishes a biennial K12 State School Fund budget
 - The State School Fund budget is distributed equally by student across the state, but adjusted for property tax collections.
 - \$1 increase in property tax collected results in \$1 less in State School Fund support.
 - Measure 5 and 50 property tax limitations put most of the power with the legislature.

School Funding

Equal, per-student, funding across the state with a few exceptions:

- Short-term, 3 year, property tax operating levies.
- Capital bonds
- A few, depends on year, school districts with few students but lots of taxable property.
- Small rural districts get more

Much smaller inter-district funding differences than other states.

School District Size

- Oregon has 197 school districts for ~500K students.
 - Washington has 296 for ~1M students
- The three largest school districts, Portland Public, Salem-Keizer, and Beaverton are about 40K each.
 - Washington has 9 over 20K
- The remainder are small.

Less opportunity for intra-district funding differences but need to watch the big three.

Key Points

- Eligibility determined by other than educational outcomes
- Equality of financial resources reduces inter-district differences.
- Smaller districts means fewer intra-district differences.

We can feel comfortable using schools out of district for controls given equal funding.

The Energy Efficiency Measures (EEMs)

Mostly what you would expect

- Building Envelope, including windows and insulation.
- HVAC Components
- HVAC Controls
- Pumps, Motors and Drives
- Domestic Hot Water
- Lighting
- Kitchen Equipment
- Other (Pool Covers ...)

What Should Strike you About the List

- Most of the items you would never notice unless you were an expert looking or listening for them.
- There are a few that could have an impact on the educational environment.
 - Double or Triple Glazed Windows (Sound, Moisture Control)
 - Cavity Insulation (Sound, Moisture Control)
 - Lighting Quality Improvements (Daylighting)

Key Points

- Treated schools may or may not have educationally impactful EEMs.
- Treated schools could have a mix.

The non-impactful EEMs can provide a placebo effect or robustness check on the effects of the impactful EEMs on educational performance.

How to Measure Educational Impact

- Some of the measures produce environmental improvements, less moisture, mold, we can look at the effect on attendance.
 - Recorded annually for each school.
 - Intermediate indicator. The more often you go to school the better you do.
- Environmental Improvements can reduce teacher absenteeism.
 - Must be acquired district-by-district and year-by-year.
- Some produce better learning environments, less distraction. We can use the annual standardized testing results.
 - Everyone in the same grade takes the same test, but the test, and the levels can be different from year-to-year.

Data Details

Schools Program Audit Requirements

- Non-educational buildings and those that are rented or will close in 5 years are ineligible.
- Energy Audits are required
 - Whole Building audits, similar to ASHRAE Level 2. Identify EEMs with 50 year payback or less.
 - Multi-component payback is allowed
 - Targeted Audits are acceptable for limited scope.
 - Target is 47/48 kBTU/SF/Year for elementary and 61/62 kBTU/SF/Year for High Schools
- Multi-competent payback calculations are allowed.

Note that some eligible schools already have the Effective EEMs, bias treatment response down.

School Program Implementation

- The maximum amount of PPC funds reimbursed will be capped at the total annual savings multiplied by the Measure Life capped at cost.
- Common for some cost to not be funded.
- Commissioning is required for:
 - All boiler or chiller measures exceeding \$100,000
 - All other HVAC measures and all HVAC controls measures exceeding \$50,000
 - All lighting control measures exceeding \$100,000
 - Other measures in which commissioning is critical for successful implementation and operation of the measure, as deemed appropriate by the auditor.

Required Annual Reporting

- Annual energy expenses by fuel type
- Square footage
- Hours of operation

Summary of Measures

Year	Installations
2010	189
2011	92
2012	119
2013	91
2014	81
2015	33
2016	17

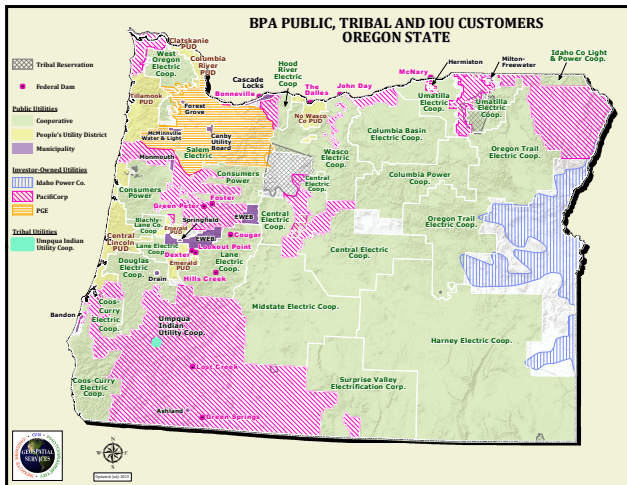
Types of Installed Measures

EEM	Installations
Boiler Equipment	121
Chiller/AC Equipment	3
Controls	44
Distribution System	44
Doors	19
Fixture Modification	100
Flow Issues	2
Heat Recovery Options	3
Insulation	38
Lamp Modification	146
Maintenance	18
Other	47
Windows	37

Comments

- Controls are frequently occupancy sensors and day-lighting controls
- Fixtures are described in detail as gym, exterior, LED Exit signs, etc.
- Each EEM was categorized as either Educationally Effective or Placebo.
 - Exterior, gym, and other non-instructional areas are all placebo.
 - Classroom lighting and controls, shell, window and ventilation improvements are all effective.
- A school can have a mix each year and can have multiple treatments over the years.
- Installations are frequently but not always during Summer or Winter break.

Electric Utilities



Oregon is a mix

- Most of population is served by IOUs
- Large tracts of COUs
- Only PacifiCorp and PGE schools are eligible.

How Many District? Schools? (2016)

- Eligible (Subset for last Test)
 - Districts: 108
 - Schools: 778
- Border (Eligible and ineligible schools in district)
 - Districts: 86
 - With treated schools: 48
- Schools in Border Districts : 934
 - Eligible untreated: 482
 - Eligible treated: 246
 - Ineligible: 206
- Schools in Border Districts with treated schools (Subset for first two Tests): 669
 - Eligible untreated: 301
 - Eligible treated: 246
 - Ineligible: 122

Test Scores

There are five tests given over the sample period, school years ending 2010 - 2016.

- English Language Arts (ELA) 2015-2016

- Writing 2010 - 2014 (High School Only)

- Reading 2010 - 2014

- Math

- Science

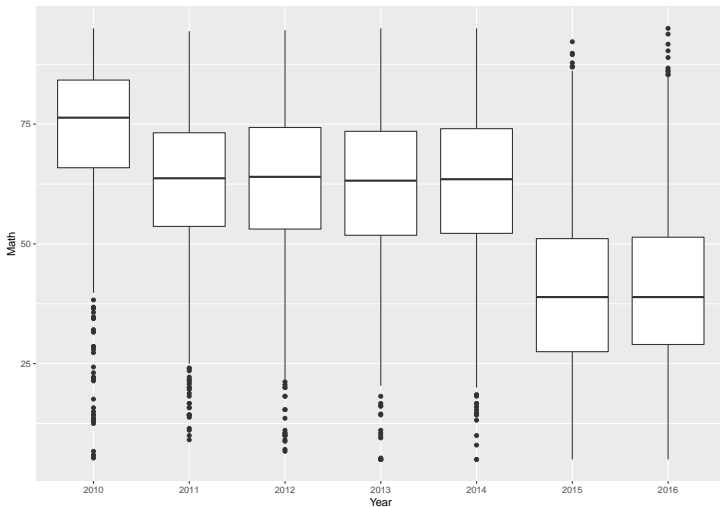
But, some elementary and middle school students will take the high school tests and some high school students need to take elementary and middle school tests.

What is Reported

What is reported is the fraction of students at each school that 'meet standards'.

- Exams can change from year-to-year.
- The cut point for passing also changes from year-to-year.
- Year is an important control variable, but will be suppressed in later tables.

Percent Passing Math By School (State)



Getting at Causality, the Identification Problem

- We don't have random assignment.
- Regression discontinuity, because of the eligibility requirements, is very close.
- Room for improving the match of observable differences across treated and untreated schools.

How Different are Treated, Untreated and Ineligible schools?

Ideally, there should be no *observable* difference – the ignorability assumption. As close as you can get to random assignment.

- Dimensions:

- Current Student Population, free and reduced rate, ethnicity, etc.
- Prior Test scores (Parallel movement)
- Facility characteristics

The problems start with facility characteristics.

Problems with Facilities Data

- Oregon Department of Education (ODE) discontinued the School Facilities Report in 2002. Only have built and remodel dates before 2001.
- Current facilities characteristics are *only available for audited buildings in schools*.
 - Schools are collections of buildings, not one, very common to have multiple buildings with a variety of vintages.
 - Elementary near my house has 4 buildings but looks like only 2 .

We can't use building characteristics but we can use student characteristics to model treatment process.

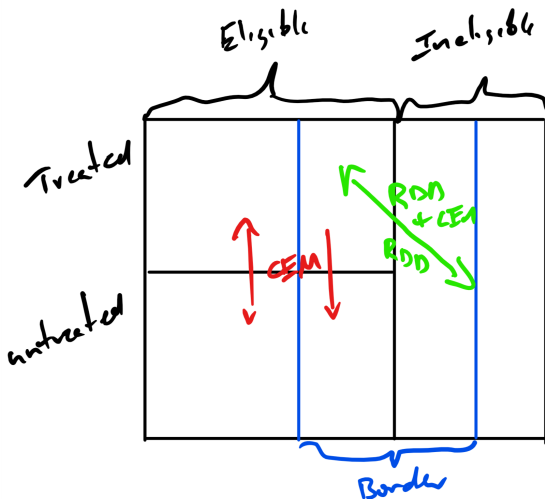
Approaches

- Ineligible schools in border districts as control
 - *Regression Discontinuity Design* (RDD) with student population controls.
 - Refine with a matching method, *Coarsened Exact Matching* (CEM).
- Eligible but untreated schools in *all eligible districts* as controls
 - CEM

Methods

- Regression Discontinuity Design (RDD)
 - Old... 1960
 - Arbitrary line cutting eligible and not.
 - “As good as Randomized Control Design (RCD)” with many caveats.
 - Can be sensitive to specification bias.
- Coarsened exact matching (CEM)
 - Iacus, King, and Porro (2012)
 - Define what you mean by close enough in multiple dimensions
 - Find the close enough match on observable dimensions
 - Reduces sensitivity to specification bias.

Cover Many Different Assumptions about Endogeneity



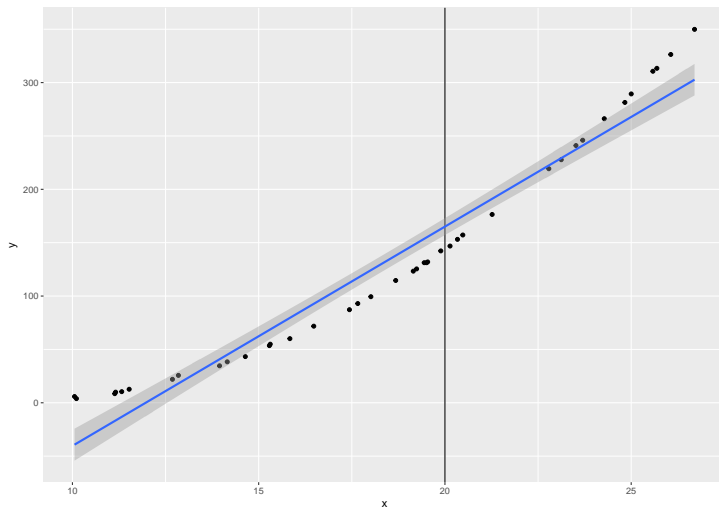
Simple Regression Discontinuity Design (RDD)

- Units with very similar characteristics should have similar responses.
- An arbitrary line simulates random assignments to units close to the line.
 - Two units that would normally be treated but one is outside the line.
 - Works even if the line is in domain that is correlated with treatment.
- Depends on correct specification.

Example RDD Failure

- Intend to Treat all values of $x > 20$.
- No true treatment effect.
- Misspecified as linear model when actually quadratic.
- Shows treatment effect

Example RDD Failure



RDD Requirements for Us

- Strong prior that treatment, installing EEMs, is unrelated to student characteristics.
 - Good, or bad, test performance does not trigger EEMs.
 - Based solely on energy cost benefit evaluation.
- In this context, RDD requires at least parallel movement in response, test scores in this case, similar to Differences-In-Differences (DID).

Parallel Movement Test

$$\ln \left(\frac{p}{1-p} \right) = \beta_0 X_0 + \beta_1 X_1$$

- p : Fraction of students meeting standards for each test
- X_0 : Ever Treated and Year interacted
- X_1 : Control variables, race/ethnicity and Free and Reduced Lunch, Year
- Simple F-test of $\beta_0 = \vec{0}$.

Comments on Demographic Controls

For those that don't work with education data.

- Male: Correlated with lower pass rates.
- African-American: Correlated with lower pass rates.
- Free Reduced: Correlated with lower pass rates.
- Suppressed throughout.

P-Value of F-Test for Parallel Movement

School Type	Math	Science	ELA	Reading	Writing
High	0.357	0.535	NA	0.258	0.172
Middle	0.862	0.128	NA	0.643	
Elementary	0.878	0.145	0.543	0.825	

- Blanks for non-required tests
- ELA started in 2015 so test not applicable.
- Slight concern with Middle and Elementary Science test.

RDD Model

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 X_0 + \beta_1 X_1$$

- Only districts with both eligible and ineligible schools with at least one treated school
- p : Fraction of students meeting standards for each test
- X_0 : Placebo and Effective EEMs installed in past.
- X_1 : Control variables, Eligibility, race/ethnicity, and Free and Reduced Lunch, Year

RDD Summary Results (Significant at 10% Level)

School Type	EEMs	Math	Sci	ELA	Read	Write	Attend
Elementary	Effective	-					
	Placebo	+			+		
	Joint	Yes			Yes		
Middle	Effective	+	+		+		
	Placebo			-			
	Joint	Yes	Yes	Yes	Yes		
High	Effective						
	Placebo				+		
	Joint				Yes		

Not much evidence.

RDD Model Results (Math)

	Elementary	MathLogit Middle	High
Placebo	0.090*** (0.032)	-0.053 (0.041)	0.043 (0.596)
Effective	-0.073** (0.034)	0.098** (0.049)	0.341 (0.900)
Observations	1,686	896	203
R ²	0.718	0.681	0.540
Adjusted R ²	0.715	0.675	0.503
Residual Std. Error	0.495 (df = 1670)	0.495 (df = 880)	0.848 (df = 187)
F Statistic	282.780*** (df = 15; 1670)	125.166*** (df = 15; 880)	14.630*** (df = 15; 187)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

RDD Model Results (Science)

	Elementary	ScienceLogit Middle	High
Placebo	0.074* (0.042)	-0.019 (0.048)	-0.256 (0.421)
Effective	0.018 (0.045)	0.193*** (0.057)	0.995 (0.635)
Observations	1,590	866	203
R ²	0.529	0.536	0.416
Adjusted R ²	0.524	0.527	0.369
Residual Std. Error	0.651 (df = 1574)	0.558 (df = 850)	0.599 (df = 187)
F Statistic	117.844*** (df = 15; 1574)	65.371*** (df = 15; 850)	8.892*** (df = 15; 187)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

RDD Model Results (ELA)

	Elementary	ELALogit Middle	High
Placebo	0.028 (0.047)	-0.127** (0.062)	0.074 (1.160)
Effective	-0.037 (0.050)	0.105 (0.067)	
Observations	480	260	58
R ²	0.667	0.644	0.426
Adjusted R ²	0.660	0.629	0.318
Residual Std. Error	0.418 (df = 469)	0.399 (df = 249)	0.855 (df = 48)
F Statistic	94.118*** (df = 10; 469)	45.001*** (df = 10; 249)	3.951*** (df = 9; 48)

Notes:

***Significant at the 1 percent level.

** Significant at the 5 percent level.

*Significant at the 10 percent level.

RDD Model Results (Reading)

	ReadingLogit		
	Elementary	Middle	High
Placebo	0.102*** (0.036)	-0.031 (0.041)	0.244*** (0.080)
Effective	-0.033 (0.039)	0.097* (0.050)	-0.001 (0.091)
Observations	1,169	634	361
R ²	0.663	0.612	0.606
Adjusted R ²	0.659	0.604	0.591
Residual Std. Error	0.450 (df = 1155)	0.407 (df = 620)	0.507 (df = 347)
F Statistic	174.413*** (df = 13; 1155)	75.180*** (df = 13; 620)	40.982*** (df = 13; 347)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

RDD Model Results (Writing)

	Elementary	WritingLogit Middle	High
Placebo	0.123 (0.086)	-0.143 (0.089)	-0.155 (0.610)
Effective	0.048 (0.082)	-0.063 (0.113)	0.444 (0.601)
Observations	484	279	142
R ²	0.522	0.542	0.510
Adjusted R ²	0.509	0.520	0.461
Residual Std. Error	0.549 (df = 470)	0.510 (df = 265)	0.559 (df = 128)
F Statistic	39.556*** (df = 13; 470)	24.153*** (df = 13; 265)	10.261*** (df = 13; 128)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

RDD Model Results (Attendance)

	AttendanceLogit		
	Elementary	Middle	High
Placebo	0.002 (0.016)	-0.037 (0.029)	0.102 (0.434)
Effective	-0.021 (0.018)	-0.000 (0.032)	
Observations	727	391	90
R ²	0.370	0.246	0.432
Adjusted R ²	0.360	0.224	0.360
Residual Std. Error	0.176 (df = 715)	0.231 (df = 379)	0.436 (df = 79)
F Statistic	38.141*** (df = 11; 715)	11.253*** (df = 11; 379)	6.014*** (df = 10; 79)

Notes:

*** Significant at the 1 percent level.

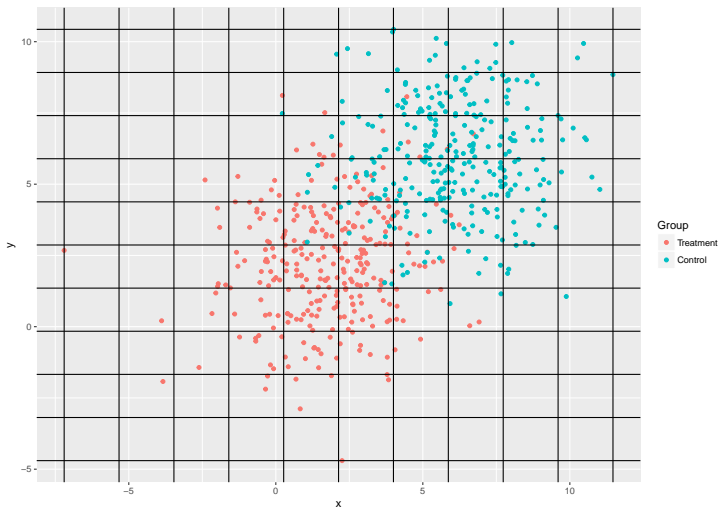
** Significant at the 5 percent level.

* Significant at the 10 percent level.

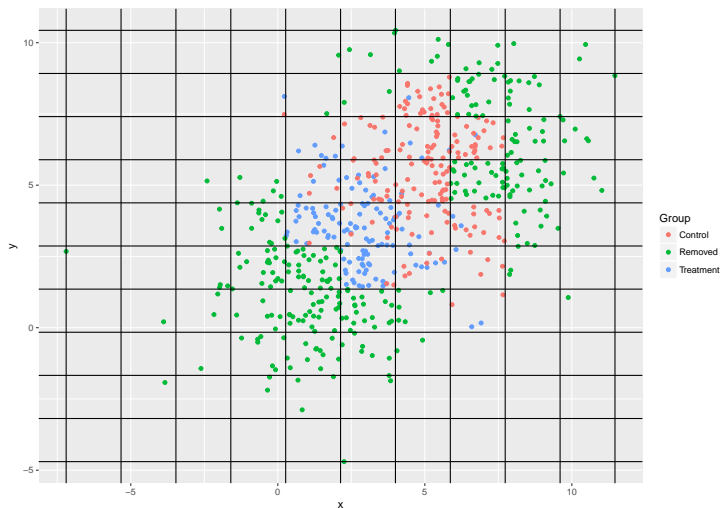
Coarsened Exact Matching

- RDD is sensitive to specification errors.
 - Example: Assuming increases in proportion male have the same effect at all proportions, i.e., linear effect, when there is an increasing effect.
 - If treated groups are more likely to be male, then treatment effects are biased.
- Coarsened Exact Matching (CEM) reduces this problem.
 - Break RHS variables into histograms.
 - Multivariate histograms
 - Remove observations that do not have a treatment and a control observation.
 - Remove influence of observations not in joint support.
 - Balance the cells for treated and not treated.

Hypothetical Data



With Unmatched Observations Removed



RDD+CEM Summary Results (Significant at 10% Level)

School Type	EEMs	Math	Sci	ELA	Read	Write	Attend
Elementary	Effective	-					
	Placebo	+		+	+	+	
	Joint	Yes		Yes			
Middle	Effective	+	+		+		
	Placebo				-	-	-
	Joint	Yes	Yes		Yes	Yes	Yes
High	Effective	+	+	NA			NA
	Placebo			NA	+		NA
	Joint	Yes	Yes	NA	Yes		NA

Recall, Writing was required for HS only and ELA only has two years of data.

RDD+CEM Model Results (Math)

	Elementary	MathLogit Middle	High
Placebo	0.079** (0.035)	-0.059 (0.049)	-0.067 (0.923)
Effective	-0.120*** (0.036)	0.121** (0.055)	1.506** (0.649)
Observations	1,686	896	203
R ²	0.659	0.611	0.741
Adjusted R ²	0.655	0.602	0.660
Residual Std. Error	0.504 (df = 1433)	0.492 (df = 656)	0.552 (df = 48)
F Statistic	184.562*** (df = 15; 1433)	68.568*** (df = 15; 656)	9.159*** (df = 15; 48)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

RDD+CEM Model Results (Science)

	Elementary	ScienceLogit Middle	High
Placebo	0.029 (0.047)	-0.037 (0.055)	-0.206 (0.783)
Effective	0.063 (0.048)	0.138** (0.063)	1.805*** (0.551)
Observations	1,590	866	203
R ²	0.396	0.355	0.701
Adjusted R ²	0.389	0.340	0.608
Residual Std. Error	0.657 (df = 1324)	0.536 (df = 631)	0.469 (df = 48)
F Statistic	57.784*** (df = 15; 1324)	23.154*** (df = 15; 631)	7.519*** (df = 15; 48)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

RDD+CEM Model Results (ELA)

	ELALogit	
	Elementary	Middle
Placebo	0.121** (0.056)	-0.092 (0.087)
Effective	0.066 (0.059)	-0.076 (0.085)
Observations	480	260
R ²	0.554	0.493
Adjusted R ²	0.542	0.461
Residual Std. Error	0.423 (df = 353)	0.393 (df = 157)
F Statistic	43.882*** (df = 10; 353)	15.258*** (df = 10; 157)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

RDD+CEM Model Results (Reading)

	Elementary	ReadingLogit Middle	High
Placebo	0.076* (0.043)	-0.091* (0.050)	0.317*** (0.102)
Effective	-0.028 (0.043)	0.103* (0.056)	0.110 (0.104)
Observations	1,169	634	361
R ²	0.551	0.484	0.547
Adjusted R ²	0.544	0.468	0.522
Residual Std. Error	0.466 (df = 918)	0.381 (df = 415)	0.496 (df = 232)
F Statistic	86.557*** (df = 13; 918)	29.906*** (df = 13; 415)	21.570*** (df = 13; 232)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

RDD+CEM Model Results (Writing)

	Elementary	WritingLogit Middle	High
Placebo	0.180* (0.095)	-0.329** (0.127)	0.003 (0.899)
Effective	-0.051 (0.083)	-0.105 (0.145)	0.663 (0.546)
Observations	484	279	142
R ²	0.468	0.418	0.672
Adjusted R ²	0.447	0.368	0.525
Residual Std. Error	0.518 (df = 324)	0.523 (df = 152)	0.444 (df = 29)
F Statistic	21.925*** (df = 13; 324)	8.401*** (df = 13; 152)	4.576*** (df = 13; 29)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

RDD+CEM Model Results (Attendance)

	AttendanceLogit	
	Elementary	Middle
Placebo	-0.010 (0.019)	-0.078** (0.034)
Effective	-0.001 (0.020)	-0.014 (0.037)
Observations	727	391
R ²	0.348	0.251
Adjusted R ²	0.336	0.218
Residual Std. Error	0.179 (df = 575)	0.216 (df = 253)
F Statistic	27.960*** (df = 11; 575)	7.697*** (df = 11; 253)

Notes:

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Only Eligible

Different Identification technique.

- Use all eligible schools with eligible but untreated schools as controls.
 - Not just the border districts
 - Not just border districts with treated schools.
- CEM used as a substitute for IV style identification.

CEM Model Summary Results (Significant at 10% Level)

School Type	EEMs	Math	Sci	ELA	Read	Write	Attend
Elementary	Effective		+	+			-
	Placebo	+	+		+	+	-
	Joint	Yes	Yes	Yes	Yes		Yes
Middle	Effective	+	+		+		
	Placebo	-	-	-	-	-	
	Joint	Yes	Yes		Yes		
High	Effective	+	+	NA			NA
	Placebo	-	-		+		
	Joint	Yes	Yes	NA			NA

CEM Model Results (Math)

	Elementary	MathLogit Middle	High
Placebo	0.083*** (0.026)	-0.075** (0.035)	-0.831** (0.335)
Effective	-0.020 (0.027)	0.275*** (0.040)	1.136*** (0.424)
Observations	3,204	1,553	1,084
R ²	0.708	0.673	0.785
Adjusted R ²	0.707	0.670	0.750
Residual Std. Error	0.484 (df = 3086)	0.498 (df = 1407)	0.529 (df = 85)
F Statistic	534.081*** (df = 14; 3086)	207.208*** (df = 14; 1407)	22.202*** (df = 14; 85)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

CEM Model Results (Science)

	Elementary	ScienceLogit Middle	High
Placebo	0.069** (0.034)	-0.069* (0.039)	-1.027*** (0.372)
Effective	0.072** (0.035)	0.295*** (0.046)	1.763*** (0.481)
Observations	3,031	1,517	1,059
R ²	0.534	0.501	0.627
Adjusted R ²	0.532	0.496	0.558
Residual Std. Error	0.624 (df = 2916)	0.563 (df = 1367)	0.588 (df = 75)
F Statistic	238.464*** (df = 14; 2916)	98.149*** (df = 14; 1367)	9.017*** (df = 14; 75)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

CEM Model Results (ELA)

	Elementary	ELALogit Middle	High
Placebo	0.079** (0.033)	-0.090* (0.047)	-0.049 (0.778)
Effective	0.036 (0.037)	-0.003 (0.057)	
Observations	921	454	318
R ²	0.716	0.580	0.609
Adjusted R ²	0.713	0.569	0.467
Residual Std. Error	0.374 (df = 833)	0.380 (df = 363)	0.520 (df = 22)
F Statistic	233.119*** (df = 9; 833)	55.595*** (df = 9; 363)	4.285*** (df = 8; 22)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

CEM Model Results (Reading)

	ReadingLogit		
	Elementary	Middle	High
Placebo	0.087*** (0.030)	-0.110*** (0.035)	0.317*** (0.102)
Effective	0.049 (0.030)	0.195*** (0.039)	0.110 (0.104)
Observations	2,209	1,094	361
R ²	0.647	0.574	0.547
Adjusted R ²	0.645	0.569	0.522
Residual Std. Error	0.436 (df = 2083)	0.395 (df = 952)	0.496 (df = 232)
F Statistic	318.564*** (df = 12; 2083)	107.011*** (df = 12; 952)	21.570*** (df = 13; 232)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

CEM Model Results (Writing)

	Elementary	WritingLogit Middle	High
Placebo	0.139* (0.076)	-0.168* (0.086)	-0.816 (0.593)
Effective	0.082 (0.067)	-0.005 (0.096)	0.511 (0.732)
Observations	930	534	761
R ²	0.438	0.401	0.525
Adjusted R ²	0.430	0.383	0.402
Residual Std. Error	0.562 (df = 836)	0.547 (df = 406)	0.643 (df = 46)
F Statistic	54.204*** (df = 12; 836)	22.642*** (df = 12; 406)	4.244*** (df = 12; 46)

Notes:

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

CEM Model Results (Attendance)

	Elementary	AttendanceLogit	
		Middle	High
Placebo	-0.032*** (0.011)	0.012 (0.023)	0.047 (0.347)
Effective	-0.025** (0.013)	-0.003 (0.026)	
Observations	1,384	679	475
R ²	0.470	0.296	0.429
Adjusted R ²	0.466	0.283	0.322
Residual Std. Error	0.155 (df = 1301)	0.222 (df = 580)	0.318 (df = 48)
F Statistic	115.457*** (df = 10; 1301)	24.336*** (df = 10; 580)	4.009*** (df = 9; 48)

Notes:

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Discussion

ETO guy was right, economists do futz with models.

- Students were right - there is a there there.
- I found there is a there there but I don't where it is.
- RDD alone is insufficient – changes with CEM are too great to not have a specification error.
- Joint tests of treatment effects are almost all significant.
- “Placebos” often have real effects.
 - Collinearity of treatment effects
 - Effective and Placebo often take place at the same time.
- Attendance is a dud – probably a heterogeneous effect on students.

Where Next?

- Expand the variability in EEM measurement
- Include Scale of EEMs
 - Expenditures in each broad category, windows, controls, etc. crossed with Effective/Placebo.
 - Not two treatment variables but 12.
 - Allow the measures to degrade according to the measure life.
- ODE started using a new attendance measure in the final two years.