# The Effect of Energy Efficiency Measures on K12 Educational Performance

# Abstract

This is early work. Still much to do.

# Background

- Cost effectiveness evaluation requires an evaluation of *all* costs and *all* benefits.
- 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.

# Why the Effect of Energy Efficency on Education is Interesting

- Decisions to improve structures is a financial decision – money saved on energy.
- No financial gain, not allowed to participate.

Improvements in student/staff health and the lifetime effects of academic performance dwarf the value of energy savings.

# 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 air conditioning daylighting vs air conditioning battle.
- Air quality is important but we don't know exactly what part
  - Keep in mind that allergenic mold concentrations, colony forming bodies, can change by factor of 10 in a few hours.
  - Hard to measure.

# Why Oregon Schools?

- Nice features that remove many, but not all, self-selection problems.
- Decison 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.

Now, on to the data . . .

# SB 1149

- SB 1149 (1999) was Oregon's deregulation bill.
  - It was part of the implementation of FERC 888.
  - Established a public purpose charge that funds thing like The Energy Trust of Oregon.
- 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.

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

# Educational Funding in Oregon

Oregon Educational Funding has key provisions that makes using schools in other district more attractive than other states.

- 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.
- Result, 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.

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

- Management and salary levels may be different across districts
- There are fewer haves and have nots within and between districts than other states.

We can feel more 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 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 aquired 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.

# Key Points

- Test scores are the main indicator but for some EEMs, absenteeism and attendance may be good predictors.
- We have some candidates for instruments if we wish to take that route.

# 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.

# School Program Implementation

- The maximum amount of PPC funds reimbursed will be capped at the total annual savings multiplied by the Measure Life caped 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 |

Note spikes in installation.

# 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 later as gym, exterior, etc.

# Electric Utilities

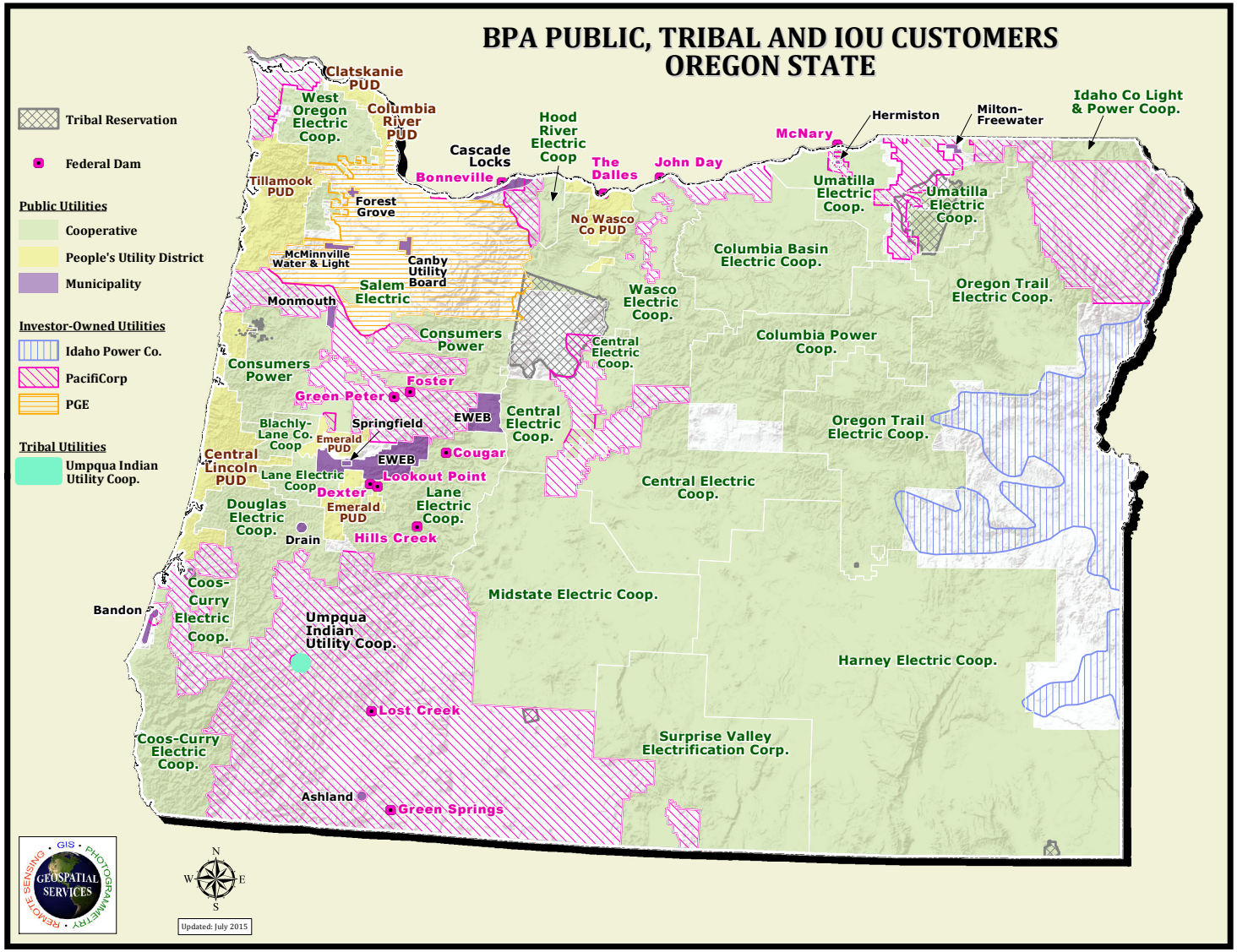
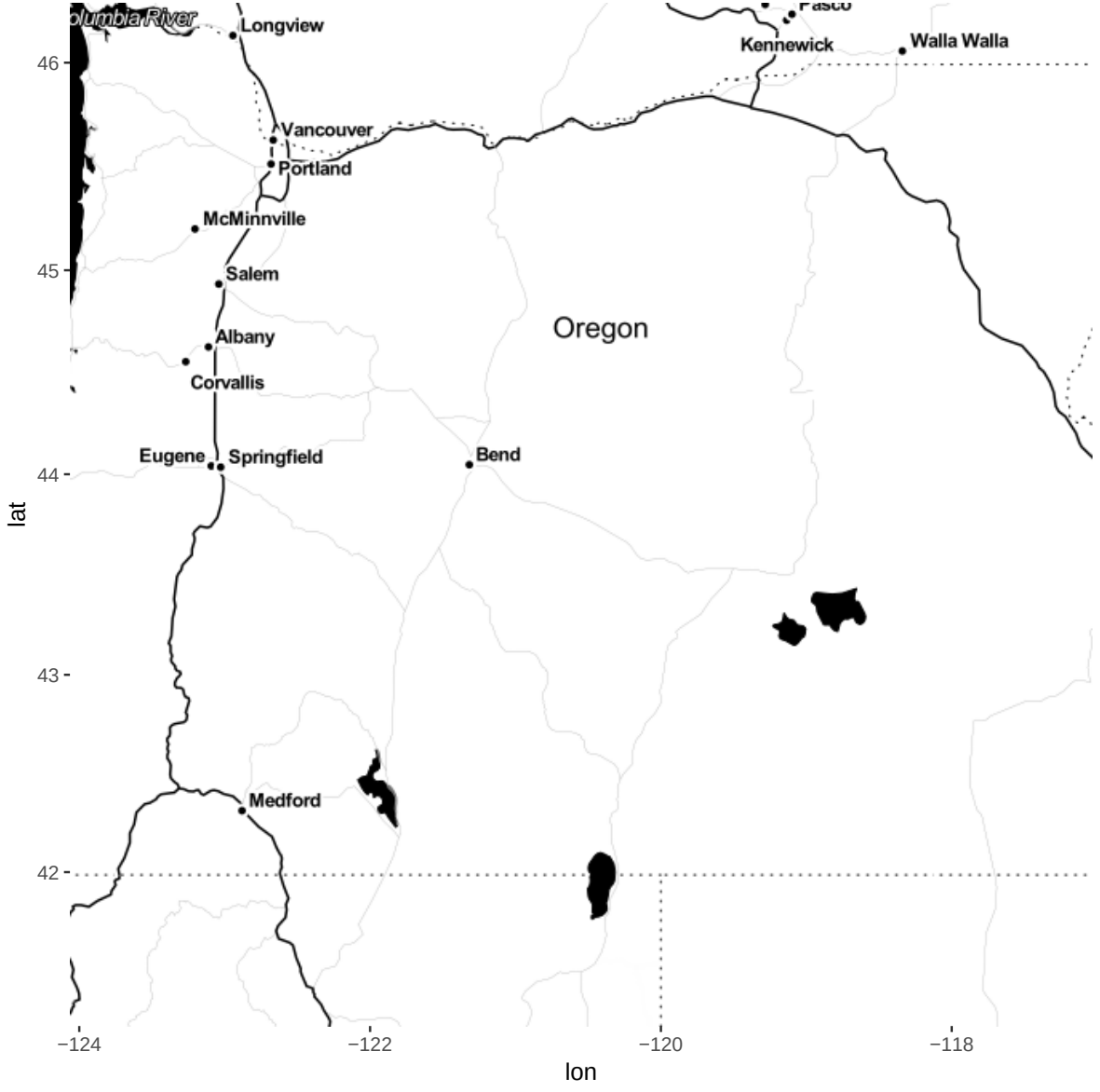



Figure 1: BPA 2015

# Oregon is a mix

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

# Districts with Eligible Schools



# How Many District? Schools?

- Eligible
  - 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 : 669
  - Eligible untreated: 301
  - Eligible treated: 246
  - Ineligible: 122

# Test Scores

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

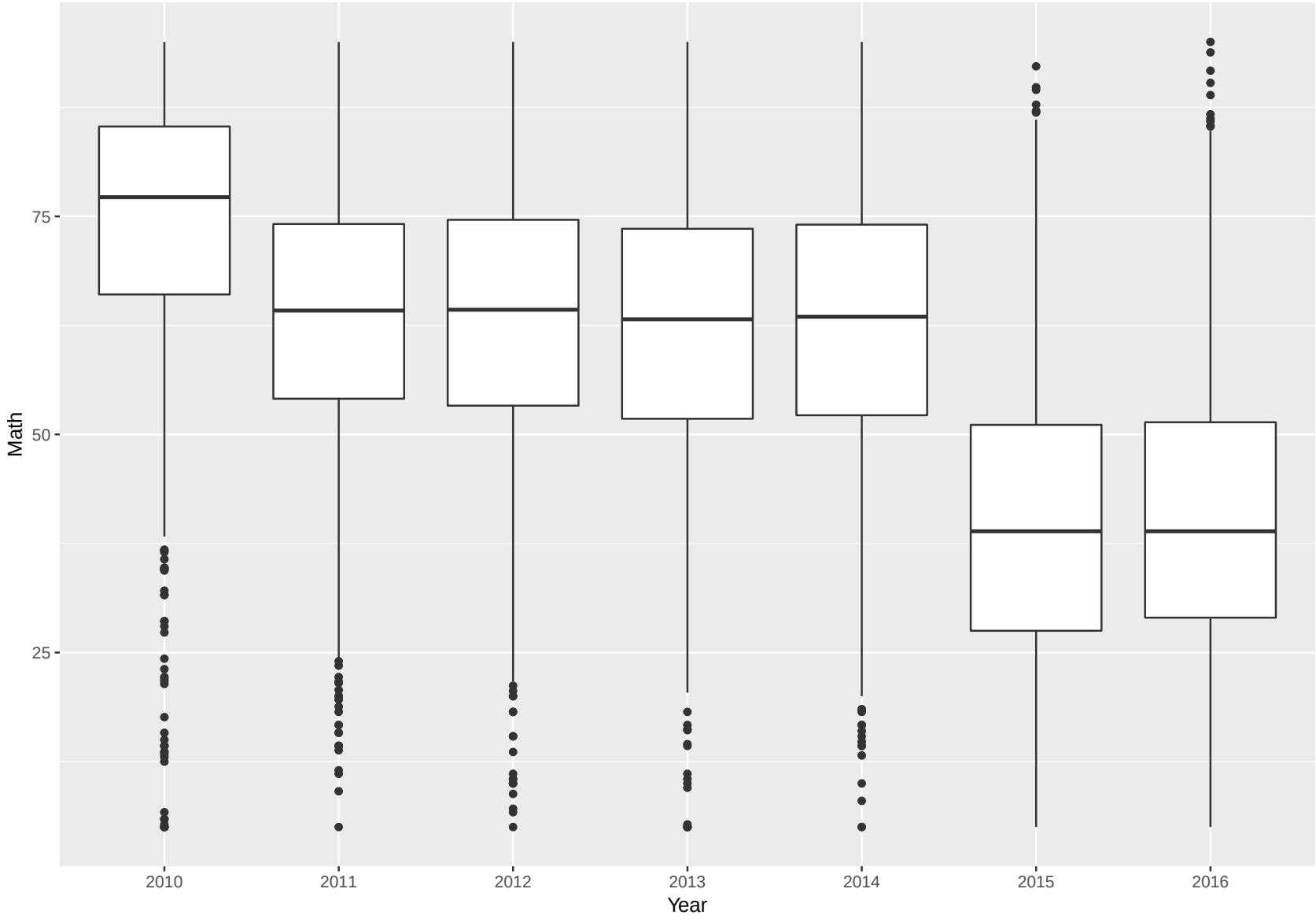
- English Language Arts 2015-2016
  - Writting 2010 - 2014
  - Reading 2010-2014
- Math
- Science

# What is Reported

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

- That standard changes from year-to-year
- Year is an important control variable

# Percent Passing Math By School (State)



# Getting at Causality, the Identification Problem

# How Different are Treated, Untreated and Ineligible schools?

Ideally, there should be no *obserable* difference. As close as you can get to random assignment.

- Dimensions:
  - Current Student Population, free and reduced rate, ethnicity, etc.
  - Prior Test scores
  - Facility characteristics
- Problems:
  - Oregon Department of Education 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 .

In short, we can't use building characteristics but we can use

# Approaches

- Only looking at schools in districts that have both eligible and ineligible schools
  - Helps control for teacher salaries
  - Other district policies
- Ineligible schools as control
  - Simple regression with student population controls.
  - Refine with a matching method later.
- Eligible but untreated schools as controls
  - Must start with matching.

# Is there a there there?

Two Views:

- Fraction of students passing each of the tests
- Student Attendance

Note:

- No contols for student population
- Only ineligible schools and schools eventually treated.
- Separate Results for elementary, middle and high schools.
- Year controls

# Elementary

Table 3

| | *Dependent* | |
|---|---|---|
| | ELA | Math |
| | (1) | (2) |
| EverTreated | | |
| Treated | 23.258 | 2.227* |
| | (17.389) | (1.215) |
| Constant | 31.100* | 80.083*** |
| | (17.342) | (1.304) |
| Observations | 369 | 1,308 |

# Methods

- Corsened exact matching
  - Iacus, King, and Porro (2012)
  - Define what you mean by close enough in multiple dimensions
  - Find the close enough match on observable dimensions
  - Excluded treated with no match
- Synthetic control method
  - Card, D. and A. Krueger (1994)
  - Mix of differences in differences and matching
  - Weights basket of controls to achieve better results