In re Delaware Public Schools Litigation

C.A. No. 2018-0029-VCL
State Track

Expert Report

Dr. Jesse Rothstein

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I. Qualifications

I am a labor economist, appointed as Professor in the Goldman School of Public Policy and the Department of Economics at the University of California, Berkeley. At Berkeley, I am also the Director of the Institute for Research on Labor and Employment and the California Policy Lab, and Co-Director of the Opportunity Lab, where I lead the Education and Child Development Initiative. I am also a Research Associate of the National Bureau of Economic Research and a Fellow of the National Education Policy Center at the University of Colorado, Boulder; of the CESifo Research Network; and of the IZA Institute of Labor Economics. I serve on the editorial boards of the *American Economic Review*, *Education Finance and Policy*, *Industrial Relations,* and the *Review of Economics and Statistics*. My curriculum vitae is attached as **Exhibit 1**.

Much of my research concerns education policy. I have written papers on educational finance published in the top-ranked peer reviewed journal in economics, the *Quarterly Journal of Economics,* and in the *American Economic Journal: Applied Economics*. I have also written a number of papers on teacher effectiveness and teacher evaluation, school choice, segregation, educational measurement, and college and university admissions, among other topics. Outside of education, I have published papers on the impact of the Earned Income Tax Credit on recipients' wages and on the incentive effects of Unemployment Insurance extensions. My work has been published in many of the leading peer-reviewed journals in economics, education, and public policy, including the *American Economic Review*, the *Quarterly Journal of Economics*, *Education Finance and Policy*, the *Journal of Human Resources*, and the *Journal of Public Economics*, as well as in other prestigious outlets such as the *Brookings Papers on Economic Activity*, *Kappan*, and the *Chicago Law Review*.

I am recognized within my profession as a leading expert on the economics of education, and on labor economics and causal inference more broadly. My expertise has been recognized in a number of ways. In 2009-2010, I served as Senior Economist for labor and education at the White House Council of Economic Advisers, and in 2010 I served as Chief Economist at the U.S. Department of Labor. I have served on technical advisory panels

for the National Center for Education Statistics and the Bureau of Labor Statistics. I was one of six economists invited to teach continuing education courses at the 2013 annual meetings of the American Economic Association, where I co-taught a course in labor and education economics.

I have filed expert reports in several cases in state and federal courts regarding teacher evaluation, teacher workforce policies, and educational finance. I testified as an expert witness in the *Vergara v. California* case[1] in the California Superior Court in 2014 and in the *Martinez v. New Mexico* case[2] in the First Judicial District of the State of New Mexico in 2017. Most recently, I submitted an expert rebuttal report in the *Glendale Elementary School District v. State of Arizona* case[3] in Arizona in October 2019. A complete list of cases in which I have submitted expert reports or testified as an expert in the last five years is attached as **Exhibit 2**.

II. Assignment

I was retained by the law firm of Arnold & Porter Kaye Scholer LLP, and the American Civil Liberties Union (ACLU) Foundation of Delaware, Inc., attorneys for Delawareans for Educational Opportunity (DEO) and the NAACP Delaware State Conference of Branches (NAACP-DE), on August 23, 2019. Counsel has asked me to offer my professional expert opinion on two topics:

1) The empirical association between school demographics and teacher quality in Delaware, and
2) What the research literature shows about the value of additional school resources in general, and of specific inputs, for student achievement and other student outcomes.

A statement for my services to date is attached as **Exhibit 2**.

As part of my engagement, I have reviewed and analyzed several data sets provided by the State, cited below. I have also reviewed relevant reports and academic publications in the economics, education, and public policy literatures, with which I am very familiar and which I teach in graduate-level classes. I have also reviewed material and data provided to me by Plaintiffs' counsel and obtained from websites maintained by the Delaware Department of Education. I have relied on many of these documents and the data contained therein in conducting my analysis as described in this report. Below, I indicate the specific articles and documents that form the basis of my opinions.

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[1] *Beatriz Vergara, et al., vs. State of California, et al. and California Teachers Association, et al.*, Hon. Rolf M. Treu, presiding, case number BC484642.

[2] *Louise Martinez, et al,. v. State of New Mexico, et al.*, D-101-CV-2014-00793, consolidated with *Wilhelmina Yazzie, et al., v. State of New Mexico, et al.,* D-101-CV-2014-02224.

[3] *Glendale Elementary School District, et al., v. State of Arizona, et al.,* no. CV 2017-006975.

III. Summary of Opinions

Based upon my review of the above sources, I have reached the following conclusions:

a) There are substantial disparities in teacher quality between Delaware schools. Schools serving higher proportions of low-income students have fewer teachers with masters' degrees and more inexperienced teachers, two commonly used measures of teacher quality, than do schools serving more advantaged student populations. The schools serving low-income students also have higher proportions of teachers who receive low summative evaluation ratings under the Delaware Performance Appraisal System (DPAS), Delaware's teacher performance assessment system.

b) The research literature makes clear that it is challenging to identify the causal effects of school resources, in general or in particular, on student achievement in observational data. Inferring these effects requires a research design that credibly distinguishes causal effects from other factors that may confound them. Studies that merely examine the association between school resources and student outcomes, in the absence of such a research design, do not provide credible evidence regarding the causal effects of school resources.

c) Researchers in a range of settings have identified natural experiments, and in some cases actual randomized control trials, that do credibly identify the causal effects of school resources. These studies generally indicate that transferring additional resources to low-income schools and districts, such as sometimes occurs when state courts order reforms of state school finance formulas, causes higher achievement in those schools and districts. Studies that identify the causal effects of particular types of resources are less common. I discuss evidence regarding several specific types of resources; it indicates that providing students with access to high-quality pre-school, to smaller classes, to high quality teachers, and to improved school facilities has positive effects on student achievement.

IV. The Distribution of Teacher Quality in Delaware

As part of my research for this case, I analyzed data on teacher characteristics and evaluations in Delaware. I focused on the question of whether schools that serve high proportions of low-income students are as likely to have high-quality teachers as are schools that serve more advantaged students.

There are two common ways to measure the distribution of teacher quality. The most common and simplest is to examine teacher characteristics that are indicative of teacher quality. For example, in most states, including Delaware, teachers with master's degrees are paid more than teachers without, in recognition of the extra knowledge that a master's degree provides and the presumption that these teachers are better trained for their roles. Similarly, teachers with more experience garner higher pay, and the evidence indicates that more experienced teachers are more effective. This is particularly true at the early stages

of the career, and extensive evidence indicates that new teachers are less effective than more experienced teachers.[4]

The second common way to measure teacher quality is to use teacher appraisals. These reflect the state or district's own assessment of the teacher's performance, and can capture whether a teacher in fact performs well or poorly, regardless of his or her credentials. In Delaware, the state lays out a detailed review process that incorporates a wide variety of information into the DPAS score. I use the summative DPAS assessment score, representing the overall DPAS assessment of a teacher's performance and incorporating all of the different components of the state's assessment system. Teachers are given one of four scores: Highly Effective, Effective, Needs Improvement, and Ineffective.

To examine the association between school composition and teacher quality, as defined above, I combined several sources. First, I used a dataset providing student counts in various demographic categories at each school in Delaware in 2015-2019.[5] By comparing the count of students classified as low income to the total number of students at each school I compute the fraction of students who are low income at each school in each year.[6]

Second, I used a list of schools that was provided to me by counsel.[7] This indicates schools that have different characteristics from most K-12 schools, such that it would not be appropriate to compare them – for example, it includes several early childhood learning centers, the Delaware School for the Deaf, some adult education schools, and the Dover Air Base Middle School. I exclude the schools indicated on this list from my analysis.

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[4] See, for example, John P. Papay and Matthew A. Kraft (2015), "Productivity returns to experience in the teacher labor market: Methodological challenges and new evidence on long-term career improvement." *Journal of Public Economics*, *130*, 105-119. The evidence regarding teachers with master's degrees and those without is much less clear, and many studies find that teachers with master's degrees are no more effective than those without. Nevertheless, Delaware clearly recognizes master's degrees as an indication of teacher quality; on average, teachers with MAs are paid about 18% more than teachers with similar experience who do not have MAs (my analysis of "SD_0012441 (1).csv").

[5] Downloaded from https://data.delaware.gov/Education/Student-Enrollment/6i7v-xnmf on March 4, 2020.

[6] This measure is highly stable across years. A given school's fraction low income is correlated 0.91 between 2015 and 2019. In a few cases where a school's fraction is not available for a particular year, I impute the fraction by using the average across other years for which it is available. This allows me to conduct a more complete analysis, without excluding schools that are missing for just one or two years.

[7] Letter from Karen Lantz, March 5, 2020, listing schools with special characteristics to exclude from analysis.

Third, I used two listings of Delaware school staff.[8] The first provides district and school IDs, position codes, full-time-equivalent shares, salaries, and codes indicating both the education level and the number of years of experience. The second provides district and school IDs and evaluation results from the Delaware Performance Appraisal System (DPAS). In each list, I restrict attention to individuals with teacher positions, excluding librarians, nurses, counselors, administrators, and other personnel. I use the first listing to count the share of teachers at the school with master's degrees and the share in the lowest experience category (with no more than four years of experience).[9] In the second listing, I count the share of teachers who receive Needs Improvement and Ineffective scores, the two lowest categories, excluding teachers who are not rated.

Exhibit 4 shows the relationship between the fraction of students at each school who are low income and the fraction of teachers with masters degrees in 2018. I present several graphs of this type, known as "binscatter" plots, and I explain this one in some detail. I begin by dividing schools into twenty equally sized groups based on the fraction low income. The graph shows means of the two variables for each of these twenty groups, as well as a linear relationship fit to the underlying data. The rightmost point in the graph, for example, represents the 5 percent of schools with the highest fraction of low income students; its position indicates that the average fraction at low income at these schools is nearly 80 percent, and that just over 55 percent of the teachers at these schools have master's degrees. In the schools with the lowest shares of low-income students, represented by the points on the upper left of the graph, the share of teachers with master's degrees is between 64 and 69 percent.

Overall, there is a clear negative relationship between a school's low income share and the fraction of teachers with master's degrees. Although there are exceptions, the more low-income students there are at a school, the smaller the share of teachers with master's degrees. The correlation between the two, shown in the upper right of the graph, is -0.22. This is a strong association for observational data like this, where there are many other factors at play – I rarely see correlations of this magnitude between two variables in my work.[10]

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[8] These files are called "SD_0012441 (1).xlsx" and "SD_0012431.xlsx." I received them from counsel on October 4, 2019.

[9] These shares are weighted – a teacher with a 0.5 FTE appointment is counted half as much as a 1.0 FTE teacher.

[10] In fields where conditions are more controlled, a correlation of -0.2 might be considered weak. For example, in lab sciences where all influences other than a treatment of interest are carefully controlled, one might see much larger correlations, either positive or negative. However, in observational data in social sciences, there are many other factors that influence the variables. For example, the fraction of teachers at a school with master's degrees might be influenced by the school's proximity to a teacher training institution or by patterns of turnover and retirement among past teachers, in addition to the fraction of students at the school who are low income. In these contexts, correlations tend to be closer to zero, and in my judgment -0.2 represents a fairly strong relationship.

Exhibit 5 is formatted similarly, but shows the association between the school low income share and the fraction of teachers with four or fewer years of experience, the lowest category tabulated in the state's reporting. Extensive research (see for example Papay and Kraft 2015, cited earlier) shows that inexperienced teachers are less effective, on average. Here, we see that the lowest income schools have roughly three times the share of inexperienced teachers as are seen at the highest income schools. The correlation between the fraction of students who are low income and the fraction of teachers with low experience is 0.28, quite large by observational data standards. Each of the four lowest-income groups, representing one-fifth of schools, have more than 30 percent inexperienced teachers, while none of the groups with higher-income students have that many inexperienced teachers.

One contributor to low experience levels at low-income schools is high rates of turnover, with many teachers starting their careers at these schools but moving over time to less disadvantaged schools. The state's data indicate that in 2018-19, 9.7 percent of teachers at high-need schools moved to non-high-need schools, with very little movement in the other direction. Moreover, 8.4 percent of teachers at high-need schools left teaching altogether, much more than the 5.9 percent exit rate at non-high-need schools.[11]

Exhibit 6 examines the relationship between the fraction of students at each school who are low income and teacher performance appraisal scores. As in many other locations, the distribution of Delaware teacher evaluations is very much skewed toward the upper end of the scale.[12] In 2018, only 4 teachers received Ineffective ratings, and only 66 received Needs Improvement, while over 1,000 received Highly Effective scores.[13] Nevertheless, Exhibit 5 shows that the few poorly rated teachers are more likely to be in low-income schools, with a correlation of 0.19.

These gaps in teacher education, experience, and appraisals between low-income and non-low-income schools are supported by the state's own evidence. The Delaware Department of Education, for the state's Plan to Ensure Equitable Access to Excellent Educators for All Students[14], tabulated the gap between the quarter of schools with the most low-income

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[11] SD_0148945.

[12] There is similar skew for administrator evaluations: In 2018-19, only 1% received Needs Improvement scores, and 0% received Ineffective scores. SD_0149336.

[13] In his deposition, Delaware Associate Secretary of Education for Educator Support Jonathan D. Neubauer suggests that too many teachers receive high ratings relative to what a consistently applied rubric would generate. "…I think what we're seeing is that there is more of a tendency for those evaluators, the LEA [Local Education Agency] evaluators to rate folks perhaps higher than where they really should be." Deposition of Jonathan D. Neubauer, p. 53.

[14] Downloaded on March 4, 2020 from https://www.doe.k12.de.us/cms/lib09/DE01922744/Centricity/Domain/390/Delaware%20Excellent%20Educators%20for%20All%20Plan%20Body.pdf.

students and the quarter of schools with the least low-income students in a range of teacher quality measures. An updated version of this analysis indicates that the lowest-income schools have 13.6 percentage points more early-career teachers than the highest-income schools, 2.5 percentage points more teachers with ineffective or needs improvements ratings, and teacher turnover rates that are 14.9 percentage points higher.[15]

V. The value of additional school resources

The second topic on which I was asked to offer my expert opinion is the evidence regarding the effects of school resources, in general and in particular, on student achievement.

A. Correlation vs. causation

The major challenge in studying the effect of school resources is the well-known difficulty of distinguishing correlation from causation. It is relatively straightforward to measure differences in resources across schools, and to compute the correlation between resources and student outcomes. But this correlation reflects a number of unmeasured factors that may influence both resources and outcomes. Beginning in the late 1980s, the expert literature in economics and education has come to recognize the difficulty of inferring causation from observational data in which the key variable (in this case, school resources) is not randomly assigned.

Observational analyses – that is, studies based on data collected from natural settings in which there is no particular reason to think that the resource measures are uncorrelated with other, unmeasured determinants of student outcomes – are no longer considered to provide credible evidence regarding causal effects. The modern view is that causal inference requires a source of credibly random variation in resources, such as in a true randomized experiment (sometimes called a "randomized controlled trial," or "RCT").[16] When RCTs are not feasible, researchers often turn to so-called "natural experiments" or "quasi-experiments," in which the way that resources are assigned in a natural setting have a specific, identifiable random component that can be isolated. Valid natural and quasi-experiments are not always available, but when they are they also provide credible evidence of causal effects.

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[15] SD_0150211. Neither the original report nor the updated tabulation includes information about the share of teachers with Masters degrees.

[16] In an influential article reviewing modern empirical methods, Joshua Angrist and Alan Krueger write, "because it is typically impossible to control for all relevant variables, it is often desirable to seek situations where it is reasonable to presume that the omitted variables are uncorrelated with the variables of interest. Such situations can arise if the researcher can use random assignment, or if the forces of nature or human institutions provide something close to random assignment." Joshua D. Angrist and Alan B. Krueger (1999), "Chapter 23 - Empirical strategies in labor economics," in Orley C. Ashenfelter and David Card, Editors, *Handbook of Labor Economics*, Volume 3A, Elsevier, 1281.

The reason that simple regressions do not provide credible evidence regarding causal effects is that there are many factors that affect student outcomes that are not readily measured or controlled and that may affect or be associated with student resources. For example, much of the variation in school resources is compensatory, with additional resources directed to students with higher needs. These students may do better than they would have without the additional resources, but even with the benefit of these resources they are unlikely to do as well as do students who did not have such high needs in the first place. This will lead the correlation between resources and student outcomes to understate the causal effect of resources on outcomes, and may even lead to a negative correlation despite a positive causal effect of resources. An observational estimate could then indicate that resources have a negative effect on outcomes, as the analyst is unlikely to observe all of the factors that influence resource allocations.

This problem is widely recognized in the literature. Indeed, a widely used graduate textbook in econometrics uses it as a leading example of the value of RCTs:

> Many studies of education production using nonexperimental data suggest there is little or no link between class size and student learning. So perhaps school systems can save money by hiring fewer teachers, with no consequent reduction in achievement. The observed relation between class size and student achievement should not be taken at face value, however, since weaker students are often deliberately grouped into smaller classes. A randomized trial overcomes this problem by ensuring that we are comparing apples to apples, that is, that students assigned to classes of different sizes are otherwise comparable.[17]

B. Modern approaches to identifying the causal effect of resources

To obtain credible evidence regarding the effect of school resources, economists today typically look to settings where resources are randomly assigned, or where "the forces of nature or human institutions provide something close to random assignment" (Angrist and Krueger, cited above, p. 1281).

In a few, relatively rare cases, it is possible to use actual randomized experiments to examine the effects of school resources. In a true randomized experiment, schools or students would be randomly assigned to receive access either to greater or lesser resources. This random assignment ensures that resources are uncorrelated with other determinants of student outcomes, so any correlation observed can be interpreted as reflecting the causal effects of the resources.

But randomized experiments are very difficult to conduct in education, and there are few such studies in the literature. Much of what we know about the effects of school resources derives instead from what are known as "natural experiments." These are cases where the

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[17] Joshua D. Angrist and Jörn-Steffen Pischke (2008), *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton University Press, 17.

researcher is able to isolate variation in exposure to school resources that is not explicitly randomly assigned but is nearly as good as random, unrelated to other determinants of student outcomes. Often these natural experiments take advantage of arbitrariness in policies that generates variation in resources. Other studies use the implementation of new policies, such as new funding formulas. The states and districts that adopt these policies are likely different in many ways from those that do not, but the exact timing of the new policies is often arbitrary, so that students just before and just after the new policy adoption are likely to be similar in all ways except for the differing levels of resources to which they are exposed.

The most credible evidence regarding the effect of school resources derives from randomized experiments and from carefully chosen and analyzed natural experiments. In both cases, researchers conduct a range of validity tests designed to identify potential deviations from random assignment that could bias the results, and only studies that pass these checks can support strong causal interpretations of their results. It is studies of this form that I rely upon in forming my opinions regarding the impacts of school resources.

C. The value of resources in general

I begin by reviewing studies that examine the effect of additional funding to schools and districts. These studies generally examine policies that change the overall allocation of funding but do not necessarily tightly constrain the way that districts spend their resources. Thus, the additional resources might be spent on smaller classes, upgraded facilities, better student support services, transportation services, or textbooks. It will generally be up to the school and district leadership how to allocate their resources; thus, if these leaders do not make wise resource allocation decisions then one might not observe impacts on student outcomes. In other words, these studies identify the effect of resources as actually used, not some idealized effect in a hypothetical world where they are used perfectly; in principle, they could show small or zero effects of resources even when resources used more wisely would have larger effects.

In some cases, the funding examined in these studies may be earmarked for certain categories of expenses, as in funding deriving from court rulings in many states regarding inadequate school facilities, though districts may nevertheless have discretion about how to allocate it within those categories. In these cases, the effects that are identified are the effects of additional resources earmarked for those categories.

There is a long older literature that examines the correlation between resources and student outcomes.[18] For the reasons discussed above, I do not believe that that literature provides useful estimates of the effect of additional resources. More recently, a series of studies have used school finance reforms as natural experiments, using the fact that states often make changes in their funding systems all at a sudden, often at arbitrary times that have more to do with court calendars than student needs. Other factors that influence student

[18] For a review of much of this literature, see Eric A. Hanushek (2003), "The failure of input-based schooling policies," *The Economic Journal*, 113, no. 485: F64-F98.

achievement are not likely to change so suddenly or at the particular time that the funding systems change, making it possible to distinguish the effects of funding.

One important such study was conducted by Kirabo Jackson, Rucker Johnson, and Claudia Persico.[19] This study examined early school finance reforms, implemented mostly in the 1980s, when many states, often acting under court orders, changed their school finance systems to more equitably distribute funding. Jackson et al. examine the impact of these reforms on children's eventual education and adult wages, contrasting the outcomes of children whose districts saw larger and smaller increases in funding under the reforms. They find substantial effects of the reforms: Children who are exposed as children to higher levels of funding due to school finance reforms obtain more years of education and earn higher wages as adults.

A second such study is one that I conducted, with Julien Lafortune and Diane Schanzenbach.[20] We compared the evolution of school spending and student test scores in districts serving high- and low-income students, both in states that implemented school finance reforms since 1990 and states that didn't. Our strategy took advantage of the fact that the timing of reforms is largely random, and unlikely to respond to short-run trends in student achievement. We found that when states implemented school finance reforms, this led to higher funding in low-income school districts, and in turn to achievement gains in these districts.

A number of other studies examine the impacts of individual school finance reforms carried out in particular states, with similar results.[21] Overall, the literature examining the effect of school resources on student outcomes by exploiting quasi-random variation in resources in natural experimental research designs points to positive effects of resources on student outcomes, particularly for disadvantaged students. This contrasts with older estimates that rely on observational comparisons across settings with different levels of resources, without a strong claim on causality, which generally point to smaller effects.

As noted above, these school finance reform studies identify the effect of additional resources as actually used when courts or legislatures direct more resources to low-income or under-resourced districts. One might be concerned that these reforms operate with broad strokes, and that districts do not use the additional resources efficiently. If that were the

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[19] C. Kirabo Jackson, Rucker C. Johnson, and Claudia Persico (2016), "The effects of school spending on educational and economic outcomes: Evidence from school finance reforms," *Quarterly Journal of Economics* 131, no. 1 (February): 157-218.

[20] Julien Lafortune, Jesse Rothstein, and Diane W. Schanzenbach (2018), "School finance reform and the distribution of student achievement," *American Economic Journal: Applied Economics* 10, no. 2 (April): 1-26.

[21] See, for example, Joshua Hyman (2017), "Does money matter in the long run? Effects of school spending on educational attainment" *American Economic Journal: Economic Policy* 9, no. 4: 256-80, and Melissa A. Clark (2003), *Education reform, redistribution, and student achievement: Evidence from the Kentucky Education Reform Act*, PhD diss. Princeton University.

case, we would see small effects of resources in the school finance reform studies, even if an optimal allocation of resources would generate larger effects. We do not see this, which indicates that districts given additional resources by broad-stroke reforms use them effectively to improve student outcomes.

D. The value of specific school inputs

There have also been studies examining specific variation in some of the individual inputs that schools use to educate students. I review some of them here.

Class size

The more teachers a school has, the smaller the classes that can be offered. But more teachers are expensive, so can only be justified if small classes contribute to greater student learning. As discussed above, observational comparisons of outcomes in small and large classes are not useful guides to the causal effect of class size: Often, students needing extra attention or resources are systematically assigned to smaller classes, so the observational comparison confounds any class size effect with differences between these students and their peers in larger classes.

Class size was the subject of one of the few true randomized experiments that has been conducted in education, the STAR experiment in Tennessee in the mid-1980s. In this study, children in Kindergarten through 3rd grade were randomly assigned either to regular sized or to small classes. Random assignment ensures that the students in small classes were comparable to those in large classes, and thus that the comparison between them identifies the causal effect of class size unconfounded by the effects of unobserved differences among students.

Most professional opinion views this experiment as providing the best available evidence regarding the causal effect of class size.[22] A widely used econometrics textbook – a

[22] This view is not universal; some scholars continue to see the evidence as pointing to small or zero effects of class size reductions. See, for example, Eric A. Hanushek 1999. "Some findings from an independent investigation of the Tennessee STAR experiment and from other investigations of class size effects." *Educational Evaluation and Policy Analysis* 21, no. 2 (Summer): 143-163. Hanushek rejects the STAR experiment in favor of nonexperimental evidence. As discussed above, in my view the nonexperimental evidence does not provide credible evidence regarding causal effects, and is not persuasive. As Alan Krueger stated it, "One well-designed experiment should trump a phalanx of poorly controlled, imprecise observational studies based on uncertain statistical specifications." Alan B. Krueger (1999), "Experimental estimates of education production functions." *Quarterly Journal of Economics*, 114, 528.

different textbook than the one cited earlier – says, "[t]he results of this experiment have strongly influenced our understanding of the effect of class size reductions."[23]

In the STAR study, students assigned to small classes earned higher test scores in the early grades.[24] They also outperformed their peers who had been randomly assigned to larger classes in the early grades on a number of later outcomes – they were more likely to take college entrance exams; experienced lower teen pregnancy rates; attended and graduated college at higher rates; and were more likely to major in higher-earning fields such as the sciences, business, and economics.[25] All of these differences can be interpreted as the causal effect of smaller classes, given the random assignment of students to classes.

Capital spending and school facilities

Although there have not been randomized experimental evaluations of the impact of school capital investments and school facility quality on student outcomes, there have been a number of natural experimental evaluations. These come in two types, one more successful than the other.

The first, less successful type compares districts where bond referenda just pass with those where similar referenda just fail. The idea here is that extremely close elections create natural experiments: While communities that overwhelmingly support additional school spending differ in many ways from those that do not, when one limits the comparison to districts where elections on school bonds are very close, random factors determine which districts just pass and which just reject the bond issue, ensuring that the two groups are likely to be similar in observed and unobserved ways.[26] Based on this, any subsequent

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[23] James S. Stock and Mark W. Watson (2007), *Introduction to Econometrics* (2 ed.). p. 486.

[24] Alan B. Krueger (1999), "Experimental estimates of education production functions." *Quarterly Journal of Economics*, 114, 497–532.

[25] Alan B. Krueger and Diane M. Whitmore (2001), "The effect of attending a small class in the early grades on college-test taking and middle school test results: Evidence from Project STAR." *Economic Journal*, 111, 1–28. Diane W. Schanzenbach (2006), "What have researchers learned from Project STAR?" *Brookings Papers on Education Policy*, 2006, 205–228. Susan Dynarski, Joshua Hyman, and Diane W. Schanzenbach (2013), "Experimental evidence on the effect of childhood investments on postsecondary attainment and degree completion." *Journal of Policy Analysis and Management*, 32: 692–717.

[26] Similar research designs exploiting close elections have been used to study the effects of incumbency and unionization. See David S. Lee (2008), "Randomized experiments from non-random selection in U.S. House elections." *Journal of Econometrics* 142, 675-697, and David S. Lee and John DiNardo (2004), "Economic impacts of new unionization on private sector employers: 1984-2001." *Quarterly Journal of Economics* 119, no. 4, 1383-1441. This claim that close elections create effective randomization is not pure speculation. Studies are typically able to assess it by showing that, prior to the election, the communities where the referendum would go on to just pass are observably quite similar to those that

differences in later student achievement can be attributed to the effect of bond-financed capital expenditures in the former districts. I introduced this research design in a 2010 paper[27] (with Stephanie Cellini and Fernando Ferreira) that examined the effect of capital expenditures in California school districts on property values, finding that homebuyers value school capital investments more than they do the additional property taxes needed to finance them. Subsequent papers have extended the strategy to other settings.[28]

There are two shortcomings, however, in attempting to use this research design to study the effect of capital spending on student achievement. First, the estimates are quite imprecise. This reflects several factors: There are not many close referenda, the amount of additional funding per pupil is typically relatively small, the investments take several years to complete, and benefits from new facilities are often not spread evenly across a district but concentrated in a small area (such as the neighborhood where a new school is built). All of these make it difficult to detect effects on student achievement.[29] As a consequence, the estimates from bond referenda studies are generally consistent both with zero effects and with large effects of capital investments on achievement and thus are largely uninformative about whether capital investments raise achievement. These studies do consistently indicate that bond-financed capital expenditures raise local property values, a market test that suggests that homebuyers perceive educational benefits.

A second shortcoming is that the districts that have close votes on referenda are not representative. The evidence that bond referenda studies yield about the effects of capital

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will go on to just fail a referendum. For more discussion, see Stephanie Riegg Cellini, Fernando Ferreira, and Jesse Rothstein (2010), "The value of school facility investments: Evidence from a dynamic regression discontinuity design." *The Quarterly Journal of Economics* 125, no. 1, 215-261. The congressional incumbency application has been criticized on the basis of evidence that near winners of congressional elections differ from near losers prior to the election, suggesting that even among close elections the outcome is not random. See Devin Caughey and Jasjeet S. Sekhon (2011), "Elections and the regression discontinuity design: Lessons from close U.S. House races, 1942-2008." *Political Analysis* 19, no. 4, 385-408. Caughey and Sekhon note that an advantage of this research design is that it allows simple tests of the assumption of as-good-as-random assignment. No evidence against this assumption has been found in any of the school facility referenda studies.

[27] Stephanie Riegg Cellini, Fernando Ferreira, and Jesse Rothstein (2010), "The value of school facility investments: Evidence from a dynamic regression discontinuity design." *The Quarterly Journal of Economics* 125, no. 1, 215-261.

[28] For example, Paco Martorell, Kevin Stange, and Isaac McFarlin Jr. (2016), "Investing in schools: capital spending, facility conditions, and student achievement." *Journal of Public Economics* 140, 13-29. Another example is Kai Hong and Ron Zimmer (2016), "Does investing in school capital infrastructure improve student achievement?" *Economics of Education Review* 53, 143-158.

[29] Martorell et al. (2016) write that "typical capital campaigns deliver only modest facility improvements for the average student" so it is "unsurprising that overall achievement effects are also small" (p. 14).

spending is specific to the types of districts that have close referenda. In the California setting that I studied, the close elections were disproportionately in relatively well-off districts. Thus, the estimates say little about the effect of capital investments in chronically under-resourced districts or in those that have persistently had trouble funding capital investments, where facility quality is likely to be the worst and where we might expect the beneficial impact of improved facilities to be greatest.

The second type of natural experimental study of school capital investments focuses on within-district variation in exposure to large district-level school construction and rehabilitation programs. It is typically not feasible to implement a large school construction campaign all at once; rather, schools are built gradually, with the order determined by logistical considerations. This makes it possible to identify the causal effect of facility quality by comparing students attending new or rehabilitated schools to others in the same district who attend schools that have not yet been rehabilitated. Because these studies leverage large differences in facility quality between renovated or new and non-renovated schools in the same districts, they have much more statistical power to detect effects of facility quality than do the district comparisons used in the bond referenda studies.

One study of this type examined a school construction, reconstruction, and renovation project in New Haven, Connecticut.[30] It finds that, "[b]y the sixth year following building occupancy, student scores rise by 0.15 standard deviations above their levels in the year prior to building occupancy."[31] This is a very large effect; few interventions that have been studied yield sustained impacts on test scores as large as 0.15 standard deviations, and it would be worth a large amount of money to raise test scores by this much. The black-white test score gap is usually estimated to be around. 0.8 – 1.0 standard deviations, so a 0.15 standard deviation increase for black students would close 15-19% of the gap. As another point of comparison, 0.15 standard deviations is two-thirds as large as the effect of reducing class size by one-third in grades Kindergarten to three, a much more expensive intervention, in the Project STAR experiment discussed above. The implied benefit-cost ratio for the New Haven facilities investment is thus very high.

More recently, Lafortune and Schönholzer[32] have applied a strategy similar to that used by Nielson and Zimmerman to an enormous school construction campaign in the Los Angeles

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[30] Christopher A. Neilson and Seth D. Zimmerman (2014), "The effect of school construction on test scores, school enrollment, and home prices." *Journal of Public Economics* 120, 18-31.

[31] Neilson and Zimmerman (2014), p. 18.

[32] Julien Lafortune and David Schönholzer. "Measuring the efficacy and efficiency of school facility expenditures." Working paper, August 2019. Retrieved from https://www.dropbox.com/s/lh2i104uqigg0vj/lafortune_schonholzer_lausd.pdf?dl=0 on September 28, 2019. Lafortune and Schönholzer measure the effect of newly built schools and do not include major renovations or expansions. This contrasts with the Neilson and Zimmerman study above, which examined the effect of attending a new or renovated school and does not distinguish between them. The Los Angeles project was motivated by overcrowding; a primary aim was to add new capacity, and many wholly new schools were

Unified School District, in which over 150 new schools were built and hundreds more were renovated. Like the New Haven study, this study finds large positive effects of attending a newly built school on student attendance and test scores, and concludes that the benefits of investing in improved schools greatly exceed the costs.

Facilities investments are directed at a range of school outputs – student safety, for example – not captured by standardized test scores. Nevertheless, both the Nielson and Zimmerman and Lafortune and Schönholzer studies, each excellent and compelling, find that improved facilities dramatically increase student achievement. The achievement effects alone are more than enough in each case to justify the cost of the investment. Moreover, the evidence is quite clear that facilities investments lead to increases in local housing prices, implying that the set of outputs produced by facilities investments is valued by parents and other homebuyers.

Teacher quality

Teachers vary in their effectiveness – some teachers raise student achievement more than do others.[33] Researchers have long debated how best to measure teacher effectiveness, and the literature is not yet settled on this.[34] However, there is good evidence that effective teachers make a difference to student achievement. A large scale randomized trial known as the Talent Transfer Initiative tested this experimentally: Teachers who had been identified as unusually effective were offered large bonuses to transfer to a randomly-chosen group of high-need schools, while a control group of similar schools was not given access to these teachers.[35] While not all teachers took up this option, enough did to study their impacts on student achievement at the receiving schools.[36] Student test scores in

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added. In New Haven, enrollment was shrinking, so even newly build schools were intended only as replacements for older schools.

[33] See, e.g., Steven G. Rivkin, Eric A. Hanushek, and John F. Kain (2005), "Teachers, schools, and academic achievement," *Econometrica* 73, no. 2: 417-458.

[34] Two recent entries in the debate are Raj Chetty, John N. Friedman, and Jonah E. Rockoff (2014), "Measuring the impacts of teachers I: Evaluating bias in teacher value-added estimates," *American Economic Review* 104, no. 9: 2593-2632, and Jesse Rothstein (2017), "Measuring the impacts of teachers: Comment," *American Economic Review* 107, no. 6: 1656-84.

[35] Steven Glazerman, Ali Protik, Bing-ru Teh, Julie Bruch, and Jeffrey Max (2013), *Transfer Incentives for High- Performing Teachers: Final Results from a Multisite Experiment* (NCEE 2014-4003), Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education.

[36] The TTP study demonstrates that teacher quality impacts student achievement, but is largely negative on the potential for incentive pay to address teacher quality gaps, because very few teachers took up the incentives when offered. Although TTP did not investigate the impact of incentives on individual teachers' productivity, other studies do, and indicate small or zero effects. See Matthew G. Springer, et al. (2010), *Teacher Pay for*

treated elementary schools rose significantly, demonstrating that the bonus payments, and the high-quality teachers who they attracted, contributed to student achievement.

Preschool

Both experimental and quasi-experimental evidence points to positive effects of access to high-quality pre-schools on children's later academic and life outcomes. A famous experimental study was conducted in Ypsilanti, Michigan, starting in 1962. A group of disadvantaged children were randomly assigned either to a control condition or to receive access to an intensive preschool program, accompanied by home visits. Those who received access to the program completed more education and, notably, committed less crime than those who did not.[37]

The evidence on the Ypsilanti program (known as the Perry Preschool program) is complemented by quasi-experimental evidence in a variety of settings, typically examining less intensive programs than Perry. One study examined universal public preschool programs in Oklahoma and Georgia, and found that the introduction of these programs raised the achievement of children from low-income families.[38] Other studies have examined the federal Head Start program for low-income children, finding positive effects of attending Head Start relative to not attending preschool.[39]

Performance: Experimental Evidence from the Project on Incentives in Teaching, National Center on Performance Incentives, Vanderbilt University.

[37] James J. Heckman, Seong Hyeok Moon, Rodrigo Pinto, Peter A. Savelyev, and Adam Yavitz (2010), "The rate of return to the HighScope Perry Preschool Program." *Journal of public Economics* 94, no. 1-2, 114-128.

[38] Elizabeth U. Cascio and Diane Whitmore Schanzenbach (2013), "The impacts of expanding access to high-quality preschool education," *Brookings papers on economic activity* 2: 1-54.

[39] David Deming (2009), "Early childhood intervention and life-cycle skill development: Evidence from Head Start," *American Economic Journal: Applied Economics* 1, no. 3: 111-34. In some studies the positive effects are obscured because Head Start students are compared to non-Head Start students who attend alternative preschools of similar quality, who obtain similar outcomes. When the comparisons are adjusted to identify the effect of Head Start relative to no preschool, effects are much larger. See, e.g., Avi Feller, Todd Grindal, Luke Miratrix, and Lindsay C. Page (2016), "Compared to what? Variation in the impacts of early childhood education by alternative care type," *The Annals of Applied Statistics* 10, no. 3: 1245-1285, and Patrick Kline and Christopher R. Walters (2016), "Evaluating public programs with close substitutes: The case of Head Start," *The Quarterly Journal of Economics* 131, no. 4: 1795-1848.

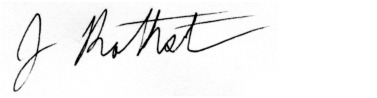
VI. Conclusion

Persuasive evidence shows that increased student resources have a systematic, positive, causal effect on student outcomes. This is true whether one examines the effects of resources in general, as in studies of school finance reforms, or of specific types of school inputs, such as class sizes, school facilities, preschools, or high quality teachers.

A review of data from Delaware shows that schools serving low-income students in Delaware have systematically lower quality teachers, whether this is measured by their education, their experience, or their performance ratings from the Delaware teacher evaluation system, than do schools with fewer low-income students. By any of the available measures, Delaware is not ensuring that students in schools with high shares of low-income students have the same access to high-quality teachers as their peers in more advantaged schools.

Although I am aware of no experiment or natural experiment in Delaware that would allow me to measure directly the effect of school resources, in general or in specific, on the outcomes of students in Delaware low-income schools, the national evidence strongly suggests that Delaware's practice of providing lower quality teachers in lower income schools reduces achievement in those schools relative to what could be obtained were teacher quality more equitably distributed.

Signed on March 10, 2020.



Jesse Rothstein

Exhibit 1: Current CV

JESSE ROTHSTEIN

Professor of Public Policy & Economics
Director, Institute for Research on Labor and Employment
Director, California Policy Lab
University of California, Berkeley

CURRICULUM VITAE

CONTACT

Address: Institute for Research on Labor and Employment
University of California, Berkeley
2521 Channing Way #5555
Berkeley, California 94720-5555
Phone: (510) 495-0646
Email: rothstein@berkeley.edu
Homepage: http://eml.berkeley.edu/~jrothst

EDUCATION

1998 - 2003 Ph.D., Economics, University of California, Berkeley
1998 - 2003 M.P.P., University of California, Berkeley
1991 - 1995 A.B., Mathematics, *magna cum laude*, Harvard University

EMPLOYMENT

2009 - University of California, Berkeley:
Professor of Public Policy and Economics (2015-)
Goldman School of Public Policy and Department of Economics
Director, Institute for Research on Labor and Employment (2015-)
Founding Director, California Policy Lab, Berkeley (2017-)
Founding Co-Director, Opportunity Lab (2016-)
Past:
Associate Professor of Public Policy (2009-2015)
Associate Professor of Economics (2010-2015)
Associate Director (2014-5); Acting Director (2013), Institute for Research on Labor and Employment

2010 U.S. Department of Labor: Chief Economist
2009 - 2010 Council of Economic Advisers: Senior Economist
2003 - 2009 Princeton University: Assistant Professor of Economics and Public Affairs
1997 - 1998 Economic Policy Institute: Researcher

AFFILIATIONS

2004 - National Bureau of Economic Research: Faculty Research Fellow (2004-2009); Research Associate (2010-)
2013 - National Education Policy Center, University of Colorado: Fellow
2014 - CESifo Research Network: Fellow

2014 - Forschungsinstitut zur Zukunft der Arbeit GmbH (IZA): Research Fellow
2016 - Learning Policy Institute: Senior Research Fellow

SCHOLARLY PUBLICATIONS

"Universal Basic Income in the U.S. and other Advanced Countries" (with Hilary Hoynes). Annual Review of Economics 11, 2019: 929-958.

"Inequality of Educational Opportunity? Schools as Mediators of the Intergenerational Transmission of Income." *Journal of Labor Economics* 37(S1), January 2019: S85-S123.

"School Finance Reform and the Distribution of Student Achievement" (with Julien Lafortune and Diane Schanzenbach). *American Economic Journal: Applied Economics* 10(2), April 2018: 1-26.

"Making Work Pay Better Through an Expanded Earned Income Tax Credit" (with Hilary Hoynes and Krista Ruffini). In *The 51%: Driving Growth through Women's Economic Participation* (Diane Whitmore Schanzenbach and Ryan Nunn, eds.). Brookings Institution, 2017.

"Scraping By: Income and Program Participation After the Loss of Extended Unemployment Benefits" (with Robert G. Valletta). *Journal of Policy Analysis and Management* 36 (4), Fall 2017: 880-908.

"Measuring the Impact of Teachers: Comment." *American Economic Review* 107(6), June 2017: 1656-1684.

"Social Experiments in the Labor Market" (with Till von Wachter). In *Handbook of Field Experiments, vol. 2*. (Abhijit Banerjee & Esther Duflo, eds.). North Holland, 2017.

"Tax Policy Toward Low-Income Families" (with Hilary Hoynes). In *The Economics of Tax Policy* (Alan Auerbach & Kent Smetters, eds.). Oxford University Press, 2017.

"The Great Recession and its Aftermath: What Role for Structural Changes?" *The Russell Sage Foundation Journal of the Social Sciences* 3(3), April 2017: 22-49.

"The Earned Income Tax Credit" (with Austin Nichols). In *Economics of Means-Tested Transfer Programs in the United States (volume 1)*, Robert A. Moffit, ed. Chicago: University of Chicago Press, 2016.

"The Measurement of Student Ability in Modern Assessment Systems" (with Brian Jacob). *Journal of Economic Perspectives* 30(3), Summer 2016: 85-108.

"Unemployment Insurance and Disability Insurance in the Great Recession" (with Andreas Mueller and Till von Wachter). *Journal of Labor Economics* 34(S1, pt 2), January 2016: S445-S475.

"The Effect of Extended Unemployment Insurance Benefits: Evidence from the 2012-2014 Phase-Out" (with Henry S. Farber and Robert G. Valletta). *American Economic Review: Papers & Proceedings* 105(5), May 2015.

"Teacher Quality Policy When Supply Matters." *American Economic Review* 105(1), January 2015: 100-130.

"Permanent Income and the Black-White Test Score Gap" (with Nathan Wozny). *Journal of Human Resources* 48(3), Summer 2013: 510-544.

"The Labor Market Four Years into the Crisis: Assessing Structural Explanations." *Industrial and Labor Relations Review* 65(3), June 2012: 467-500.

"Unemployment Insurance and Job Search in the Great Recession." *Brookings Papers on Economic Activity*, Fall 2011: 143-210.

"Constrained After College: Student Loans and Early Career Occupational Choices" (with Cecilia Rouse). *Journal of Public Economics* 95(1-2), February 2011: 149-163.

"Are Mixed Neighborhoods Always Unstable? Two-Sided and One-Sided Tipping" (with David Card and Alexandre Mas). In Harriet Newburger, Eugenie Birch, and Susan Wachter, editors, Neighborhood and Life Chances: How Place Matters in Modern America. 2011. Philadelphia: University of Pennsylvania Press.

"Is the EITC as Good as an NIT? Conditional Cash Transfers and Tax Incidence." *American Economic Journal: Economic Policy* 2(1), February 2010: 177-208.

"Teacher Quality in Educational Production: Tracking, Decay, and Student Achievement." *Quarterly Journal of Economics* 125(1), February 2010: 175-214.

"The Value of School Facilities: Evidence from a Dynamic Regression Discontinuity Design" (with Stephanie Cellini and Fernando Ferreira). *Quarterly Journal of Economics* 125(1), February 2010: 215-261.

Republished: *The Economics of Evaluation in Public Programs* (Albert N. Link and John T. Scott, editors, 2011). International Library of Critical Writings in Economics, 258. Cheltenham: Edward Elgar.

"Student Sorting and Bias in Value Added Estimation: Selection on Observables and Unobservables." *Education Finance and Policy* 4(4), Fall 2009: 537-571.

"Selection Bias in College Admissions Test Scores" (with Melissa Clark and Diane Whitmore Schanzenbach). *Economics of Education Review* 28(3), June 2009: 295-307.

"Affirmative Action in Law School Admissions: What Do Racial Preferences Do?" (with Albert Yoon). *University of Chicago Law Review* 75(2), Spring 2008: 649-714.

"Tipping and the Dynamics of Segregation" (with David Card and Alexandre Mas). *Quarterly Journal of Economics* 123(1), February 2008: 177-218.

"Does Competition Among Public Schools Benefit Students and Taxpayers? A Comment on Hoxby (2000)." *American Economic Review* 97(5), December 2007: 2026-2037.

"Racial Segregation and the Black-White Test Score Gap" (with David Card). *Journal of Public Economics* 91(11-12), December 2007: 2158-2184.

"Good Principals or Good Peers? Parental Valuations of School Characteristics, Tiebout Equilibrium, and the Incentive Effects of Competition among Jurisdictions." *American Economic Review* 96(4), September 2006: 1333-1350.

"Was Justice O'Connor Right? Race and Highly Selective College Admissions in 25 Years" (with Alan Krueger and Sarah Turner). In Michael McPherson and Morton

Schapiro, editors, College Access: Opportunity or Privilege. 2006. New York: The College Board.

"Race, Income, and College in 25 Years" (with Alan Krueger and Sarah Turner). *American Law and Economics Review* 8(2), Summer 2006: 282-311.

"College Performance Predictions and the SAT." *Journal of Econometrics* 121(1-2), July-August 2004: 297-317.

WORKING PAPERS

"Synthetic Controls and Weighted Event Studies with Staggered Adoption" (with Eli Ben-Michael and Avi Feller). December 2019

"The Lost Generation? Scarring After the Great Recession." May 2019.

"The Augmented Synthetic Control Method" (with Eli Ben-Michael and Avi Feller). November 2019.

"The Unintended Consequences of Encouraging Work: Tax Incidence and the EITC." May 2008.

"Mismatch in Law School" (with Albert Yoon). August 2008.

CALIFORNIA POLICY LAB REPORTS

"The 'Gig Economy' and Independent Contracting: Evidence from California Tax Data" (with Annette Bernhardt and Allen Prohofsky). August 2019.

"Making California Data More Useful for Educational Improvement (with Meredith Philips and Sarah Reber). Published by Getting Down To Facts II, Stanford University / Policy Analysis for California Education, September 2018

"Linking Administrative Data: Strategies and Methods" (with Elsa Augustine and Vikash Reddy). White paper, December 19, 2018.

"Increasing the Take Up of Cal Grants" (with Elizabeth Linos and Vikash Reddy). In *Designing Financial Aid for California's Future*. The Institute for College Access And Success, November 2018.

"The Impact of Letters of Recommendation on UC Berkeley Admissions in the 2016-17 Cycle." June 2017.

REPORTS, OPINION, AND OTHER WRITING

"An Expanded View of Government's Role in Providing Social Insurance and Investing in Children" (with Sandra Black). In Suresh Naidu, Dani Rodrik, and Gabriel Zucman, eds., *Economics for Inclusive Prosperity: An Introduction*, January 2019.

"What Does the Seattle Experience Teach Us About Minimum Wages?" (with Diane Schanzenbach). EconoFact, Tufts University, August 2017.

"Do Minimum Wages Really Kill Jobs?" (with Michael Reich). EconoFact, Tufts University, April 2017.

"Social Security Benefits: When Do You Plan to Retire?" EconoFact, Tufts University, February 2017.

"Expand Social Security." Washington Center for Equitable Growth, October 31, 2016.

"UC Berkeley Admissions in 2015 and 2016: An Analysis of the Role of Letters of Recommendation and Augmented Review." Report to the UC Berkeley faculty committee on Admissions, Enrollment, and Preparatory Education, July 2016.

"Taking on Teacher Tenure Backfires." Op-ed, *The New York Times*, June 13, 2014.

"Effects of Value-Added Policies." *Focus* (University of Wisconsin Institute for Research on Poverty) 29(2), Fall/Winter 2012-13, 23-24.

"Review of Two Culminating Reports from the MET Project" (with William J. Mathis). Published online in Think Tank Review, National Education Policy Center, Boulder Colorado, http://nepc.colorado.edu/thinktank/review-MET-final-2013, January 31, 2013.

"Evaluating Teacher Evaluation" (with Linda Darling-Hammond, Audrey Beardsley, and Edward Haertel). *Phi Delta Kappan* 93(6), March 2012: 8-15.

"Let's Not Rush into Value-Added Evaluations." In *Room for Debate* feature, http://www.nytimes.com, January 16, 2012.

"Using Housing Markets to Estimate the Value of School Infrastructure Investments" (with Stephanie Riegg Cellini and Fernando Ferreira). *Wharton Real Estate Review* 15 (2), Fall 2011.

"Review of 'Learning About Teaching: Initial Findings from the Measures of Effective Teaching Project.'" Published online in Think Tank Review, National Education Policy Center, Boulder Colorado, http://nepc.colorado.edu/thinktank/review-learning-about-teaching, January 13, 2011.

"Assessing a Teacher's Value: More Harm Than Good." In *Room for Debate* feature, http://www.nytimes.com, Sept. 6, 2010.

"Conversation: Merit, Testing, and Opportunity" (with Richard Rothstein). *The American Prospect* 11 (21), Sept. 25-Oct. 9, 2000, pp. 19-20.

"Taxes and the Internet: Updating Tax Structures for a Wired World" (with Traci Gleason Wright). *State Tax Notes* 17 (9), August 23, 1999.

POLICY & ISSUE BRIEFS

"There Is More to Equal Access To A Good Education Than Sound School Budgets." Policy Brief, Washington Center for Equitable Growth, August 2017.

"Can Value-Added Models Identify Teachers' Impacts?" Policy Brief, UC Berkeley Institute for Research on Labor and Employment, December 2016.

"Can School Finance Reforms Improve Student Achievement?" (with Julien Lafortune and Diane Schanzenbach). Policy Brief, UC Berkeley Institute for Research on Labor and Employment, March 2016.

"The New California Earned Income Tax Credit" (with Claire Montialoux). Policy Brief, UC Berkeley Institute for Research on Labor and Employment, December 2015.

"The Earned Income Tax Credit" Issue Brief, Washington Center for Equitable Growth, December 2015.

"The Great Recession and Its Aftermath: What Role Do Structural Changes Play?" Issue Brief, Washington Center for Equitable Growth, June 2015.

"Extended Unemployment Insurance Remains Critical." Issue Brief, Washington Center for Equitable Growth, May 25, 2014.

HONORS AND FELLOWSHIPS

2011 John T. Dunlop Outstanding Scholar, Labor and Employment Relations Association
2006 - 2007 Nicholas Fellow, Center for Economic Policy Studies, Princeton University
2006 - 2009 Jacob Viner University Preceptorship, Princeton University
2003 Public Policy Research Prize, Department of Economics, UC Berkeley
2000 - 2003 Graduate Research Fellowship, National Science Foundation
2002 - 2003 Graduate Fellowship, Fisher Center for Real Estate and Urban Economics, UC Berkeley
1998 - 1999 Departmental Fellowship, Goldman School of Public Policy, UC Berkeley

PROFESSIONAL ACTIVITIES

2019 - Board of Editors, *Education Finance and Policy*
2019 - Associate Editor, *Review of Economics and Statistics*
2011 - Board of Editors, *American Economic Review*
2012 - Associate Editor, *Industrial Relations*
2016 - Advisory Board, *Capital & Main* (online newspaper)
2015 - Research Advisory Board, Washington Center for Equitable Growth
2010 - Review Panel, College & Beyond (Mellon Foundation)
2012 - 2018 Technical Review Committee, National Longitudinal Surveys
2016 - 2018 Technical Working Group on Adequacy of Unemployment Insurance Benefits, U.S. Department of Labor
2016 Testimony, U.S. Civil Rights Commission hearing on school finance.
2014 - 2016 Member (2014) and Chair (2016), H. Gregg Lewis Prize Committee (Society of Labor Economists)
2012 - 2016 Executive Committee, UC Berkeley / UC San Francisco Robert Wood Johnson Foundation (RWJF) Scholars in Health Policy Research Program.
2011 - 2015 Expert Panel, Interagency Working Group on Expanded Measures of Enrollment and Attainment (National Center for Education Statistics)
2010 - 2015 Advisory Council, Tipping Point Foundation
2010 - 2013 Technical Review Panel, High School Longitudinal Study of 2009
2009 - 2011 External Advisory Council, Chicago Public Education Fund

CONFERENCE ORGANIZATION

2020 Trans-Pacific Labor Studies conference, UC Berkeley
2019 Convening on Income Support Policies, Russell Sage Foundation
2019 Convening on Higher Education Financing, Russell Sage Foundation

2016 Conference on the Causes of Wage Stagnation, UC Berkeley
2016,7,8 Program Committee, Labor and Employment Relations Association (LERA) Annual Meetings
2012,3,6,7 Program Committee, Society of Labor Economists Annual Meetings
2015 Program Committee, Econometric Society World Congress
2011,4 Program Committee (2011) and Co-Organizer (2014), All-California Labor Economics Conference

EXTERNAL GRANTS

2020 – 2022 Laura and John Arnold Foundation, "The California Policy Lab – Berkeley" (PI; $2,689,129)
2019 – 2020 University of California Office of the President, "California Policy Lab: Studying Inequality and Homelessness" (Lead PI, with Michal Kurlaender, Margot Kushel, Emily Owens, and Till von Wachter; $1,249,963)
2018 – 2021 Ewing Marion Kauffman Foundation, "Gig Economy" (Co-PI, with Annette Bernhardt; $409,980)
2018 – 2020 James Irvine Foundation, "California Policy Lab" (PI; $575,000)
2018 – 2020 Jameel Poverty Action Lab, "Increasing the Take-Up of Cal Grant Awards Through Improved Notification Letters" (PI; $99,232)
2018 – 2020 Alfred P. Sloan Foundation, "The 'Gig Economy' and Independent Contracting: Evidence from California Tax Data on Prevalence, Industry Concentration, Incomes, and Use by Older Workers" (Co-PI, with Annette Bernhardt; $219,875)
2018 – 2019 Jameel Poverty Action Lab, "Using Tax Information to Reduce Poverty and Increase Tax Compliance in California" (Co-PI, with Julie Moreno; $98,768)
2018 – 2019 U.S. Department of Labor / Avar Consulting, "The 'Gig Economy' and Independent Contracting: Evidence from California Tax Data" (PI; $49,880)
2018 – 2019 Laura and John Arnold Foundation, "The California Policy Lab – Berkeley" (PI; $2,675,000)
2018 – 2019 Tipping Point Community, "EITC Outreach Campaign Evaluation" (PI; $110,000)
2017 Laura and John Arnold Foundation, "The California Policy Lab – Berkeley (Pilot Year Proposal)" (Co-PI, with Justin McCrary; $931,629)
2016 – 2018 Russell Sage Foundation, "The Role of Education in the Intergenerational Transmission of Inequality: Using Spatial Differences in Developmental Trajectories to Identify Channels" (PI; $142,821)
2014 - 2016 Washington Center for Equitable Growth, "School Finance Reform and Educational Equity" (PI; $60,000)
2014 - 2016 Spencer Foundation, "School Finance Reform and the Distribution of Student Achievement" (co-PI, with Diane Schanzenbach; $305,469)
2012 - 2013 Russell Sage Foundation, "The Labor Market in the Great Recession: What Role for the Supply Side?" (PI; $156,270)
2008 - 2011 Institute for Education Sciences, "Value Added Models and the Measurement of Teacher Quality" (R305A080560, PI; $294,295)
2005 - 2007 Mellon Foundation, "Affirmative Action and Law School Admissions: The Mismatch Hypothesis and Minority Student Performance" (co-PI, with Albert Yoon)
2004 - 2005 UCLA Center on Education Policy and Evaluation, "Race, Income and College in 25 Years" (co-PI, with Alan Krueger and Sarah Turner; $50,000).

TEACHING

University of California, Berkeley:
Quantitative Methods for Public Policy (masters level)
Intermediate Microeconomics (undergraduate)
Economics of Education Policy (doctoral & masters level)
Statistics for Program Evaluation (masters level)
Introduction to Policy Analysis (masters level)
Princeton University:
Econometrics and Public Policy: Advanced (masters level)
Public Economics (Ph.D. level)
Nominated twice for Princeton University Graduate Mentoring Award.
Other:
Short course in Labor Economics (with Lowell Taylor). Delivered at:
American Economic Association continuing education program, January 2013.
Canadian Labour Market and Skills Research Network summer school, June 2013.

PROFESSIONAL ASSOCIATIONS

American Economic Association, Association for Education Finance and Policy, Association for Public Policy Analysis and Management, Econometric Society, Labor and Employment Relations Association, Society of Labor Economists.

Exhibit 2: Statement of services to date

For legal services from August 25, 2019 through March 10, 2020, 25 hours at $350 per hour, for a total of $8,750.

Exhibit 3: Expert witness work

Glendale Elementary School District, et al. vs. State of Arizona, Superior Court of the State of Arizona (Maricopa County). No. CV2017-006975. 2019.
Plaintiffs' expert. Report. Case is ongoing.

Martinez v. State of New Mexico, et al. First Judicial District, County of Santa Fe, State of New Mexico. No. D-101-CV-2014-00793. 2016.
Plaintiffs' expert. Report, deposition, & trial testimony.

Houston Federation of Teachers vs. Houston Independent School District. U.S. District Court, Southern District of Texas. 4:14-cv-01189. 2016.
Plaintiffs' expert. Report & deposition.

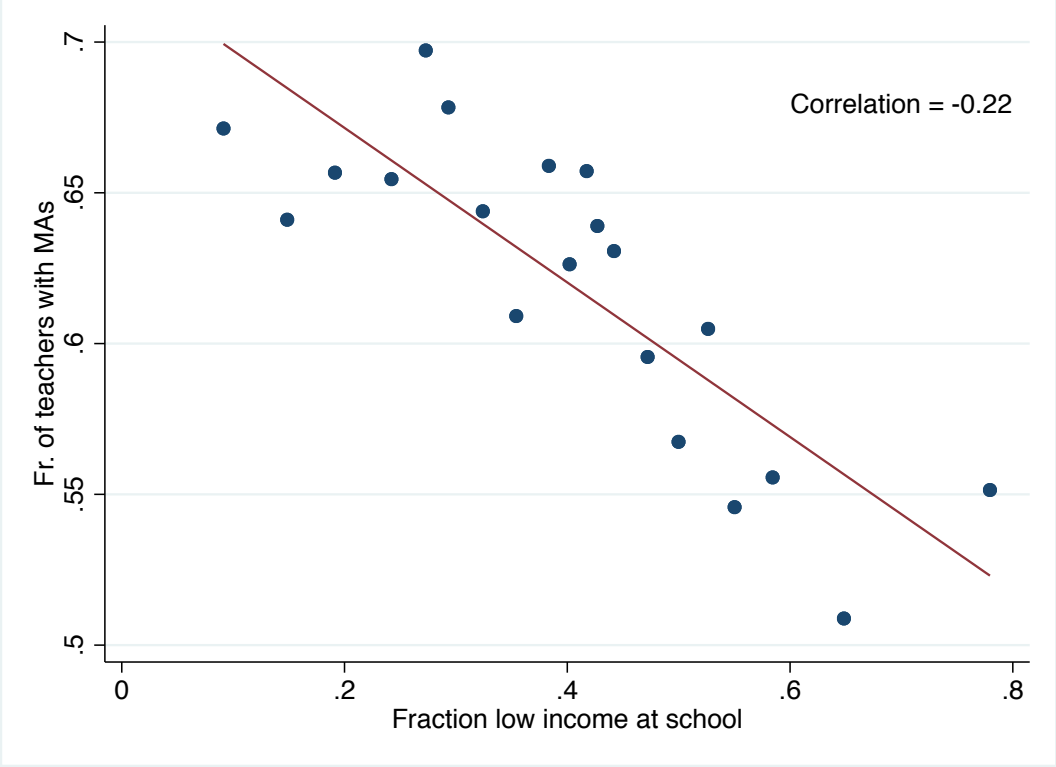
North Carolina Association of Educators, et al., v. State of North Carolina. North Carolina Superior Court, Wake County. No. 13 CVS 16240. 2016.
Plaintiffs' expert. Report.

Trout v. Knox County Board of Education; Taylor v. Haslam, Huffman, and Knox County Board of Education. U.S. District Court, Eastern District of Tennessee. No. 3:14-CV-49 and 3:14-CV-113. 2016.
Plaintiffs' expert. Report & deposition.

Vergara v. California, Los Angeles County Superior Court. No BC484642.
Intervenors' expert. Deposition & trial testimony.

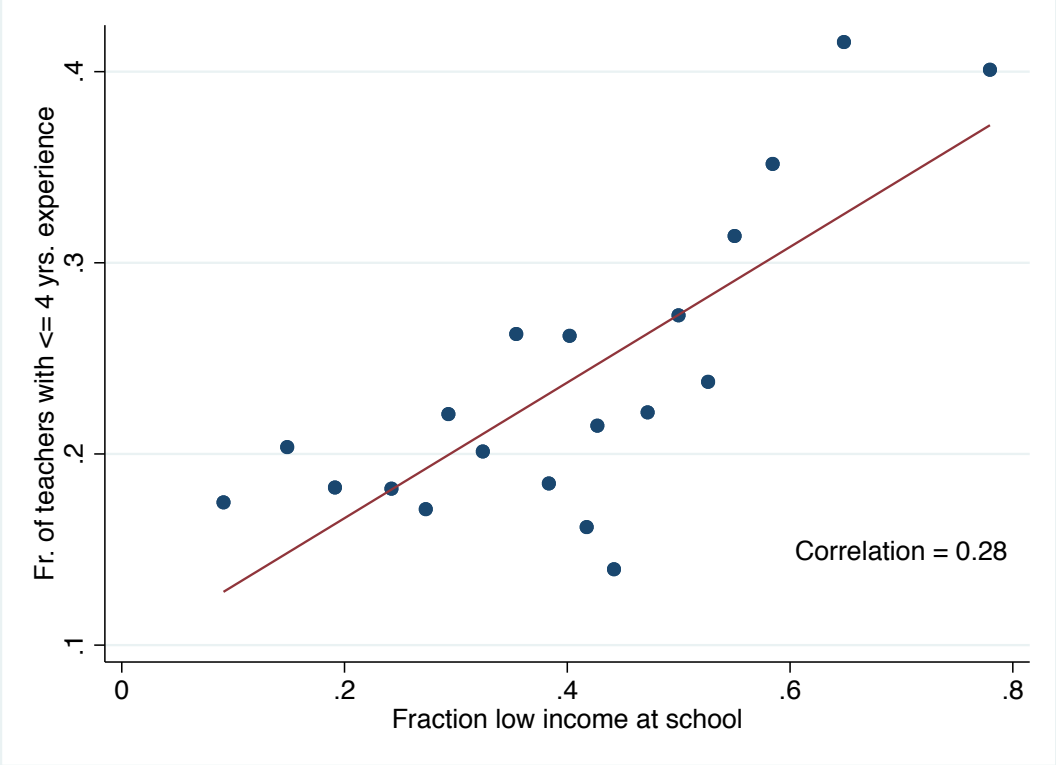
Los Angeles Times Communications, LLC v. Los Angeles Unified School District (Los Angeles Superior Court. No. BS139828. 2013.
Intervenor-respondent's expert. Report.

Exhibit 4: Low income schools in Delaware have fewer teachers with masters degrees



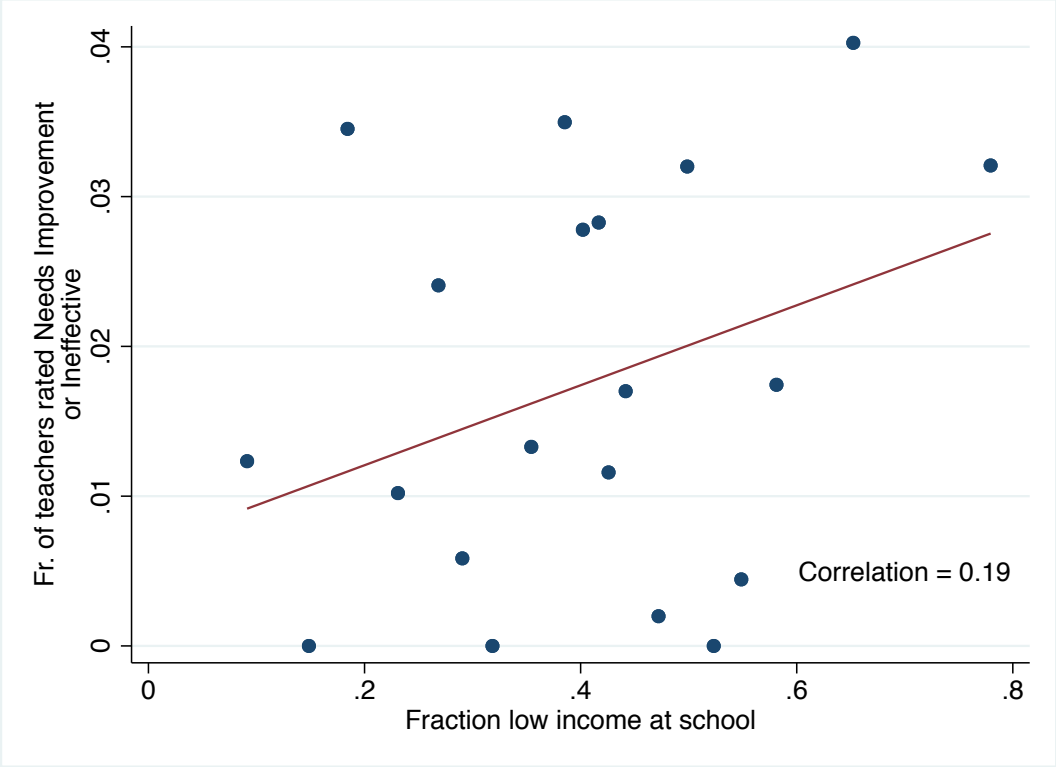
Notes: Each dot represents 5% of schools in Delaware in 2018, sorted by the fraction of low-income students in the school. The leftmost dot represents the 5% of schools with the smallest low-income shares, the next dot the next 5%, and so on. The position of the dot indicates the average fraction low income and the average fraction of teachers with masters degrees among schools in the group. The correlation between the fraction low-income and the fraction of teachers with masters degrees is -0.22; the straight line represents the linear relationship.

Exhibit 5: Low income schools in Delaware have more inexperienced teachers



Notes: Each dot represents 5% of schools in Delaware in 2018, sorted by the fraction of low-income students in the school. The leftmost dot represents the 5% of schools with the smallest low-income shares, the next dot the next 5%, and so on. The position of the dot indicates the average fraction low income and the average fraction of teachers with four or fewer years of experience among schools in the group. The correlation between the fraction low-income and the fraction of inexperienced teachers is 0.28; the straight line represents the linear relationship.

Exhibit 6: Low income schools in Delaware have more teachers with Needs Improvement or Ineffective ratings



Notes: Each dot represents 5% of schools in Delaware in 2018, sorted by the fraction of low-income students in the school. The leftmost dot represents the 5% of schools with the smallest low-income shares, the next dot the next 5%, and so on. The position of the dot indicates the average fraction low income and the average fraction of teachers whose DPAS summative assessments were Needs Improvement or Ineffective. Teachers who did not receive DPAS ratings are excluded. The correlation between the fraction low-income and the fraction of poorly assessed teachers is 0.19; the straight line represents the linear relationship.