Do Low-Income Students Have Equal Access to Effective Teachers? Evidence from 26 Districts

October 2016

NATIONAL CENTER FOR EDUCATION EVALUATION AND REGIONAL ASSISTANCE
Institute of Education Sciences

U.S. Department of Education

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Inequity in educational outcomes is substantial and persistent in the United States. Students from high-income families outperform those from low-income families on achievement tests and educational attainment (Reardon 2011; Chetty et al. 2014a; U.S. Department of Education 2014). Recent policy initiatives to address these gaps have emphasized teachers' contributions to student achievement. These policy efforts are supported by evidence showing that teachers vary a great deal in their effectiveness (Rockoff 2004; Rivkin et al. 2005; Kane et al. 2008; Aaronson et al. 2007; Koedel and Betts 2009).

A key question for policymakers is whether inequality in educational outcomes is caused by differences in students' access to effective teachers. Are students from low-income families taught by less effective teachers than students from high-income families? Would a more equitable distribution of effective teachers narrow the gap in achievement between high- and low-income students?

In this report, we examine whether low-income students are taught by less effective teachers than high-income students, and if so, whether reducing this inequity would close the student achievement gap. We also describe how the hiring of teachers and their subsequent movement into and out of schools could affect low-income students' access to effective teachers. To measure teacher effectiveness, we used a value-added model, a statistical approach to measure a teacher's contribution to student learning, based on students' performance on achievement tests. The study includes fourth- to eighth-grade teachers over five school years (2008-2009 to 2012-2013) in 26 school districts across the country.

The main findings are:

- **There are small differences in the effectiveness of teachers of high- and low-income students in the average study district.** In both subjects, differences in the effectiveness of teachers of high- and low-income students are one percentile point, on average. The average teacher of a low-income student is just below the 50th percentile, while the average teacher of a high-income student is at the 51st percentile. As a result, providing low-income students with at least equally effective teachers typically would not substantively reduce the student achievement gap. In addition, high- and low-income students have similar chances of being taught by the most effective teachers and the least effective teachers. In ELA, for example, 10 percent of both high- and low-income students are taught by one of the top 10 percent of teachers in a district, while 9 percent of high-income students and 10 percent of low-income students are taught by one of the bottom 10 percent of teachers.
- **Teacher hiring patterns are consistent with small differences in the effectiveness of teachers of high- and low-income students.** The teachers hired into high-poverty schools are equally effective as those hired into low-poverty schools. These new hires are less effective than the average teacher, with value added at the 39th percentile on average (-0.05 standard deviations of student achievement). High-poverty schools have more new hires than low-poverty schools, but this difference is likely to have only a small influence on equity because (1) the difference itself is small (11 percent of teachers in high-poverty schools are new hires compared to 5 percent in low-poverty schools), and (2) new hire

performance improves quickly. On average, new hires become as effective as the average teacher after one year.

- **Teacher transfer patterns are also consistent with small differences in the effectiveness of teachers of high- and low-income students.** On average, teachers who transfer to schools in a lower poverty category within a district—such as from high- to medium- or low-poverty schools—are nearly as effective as the average district teacher (with value added at the 48th percentile). Teachers who transfer to schools in a higher poverty category are significantly less effective than the average district teacher (43rd percentile). These differences are likely to have a small influence on equity since just under 4 percent of all teachers transfer to a school in a higher or lower poverty category (a little less than 2 percent from higher- to lower-poverty and less than 2 percent from lower- to higher-poverty). A little more than 4 percent of all teachers move between schools with similar poverty rates.
- **Teacher attrition patterns do not contribute to differences in the effectiveness of teachers of high- and low-income students.** The teachers who leave a district from both high- and low-poverty schools are less effective than the average district teacher. The average leaver from high-poverty schools is at the 43rd percentile and the average leaver from low-poverty schools is at the 46th percentile, but this difference is not statistically significant. More of these teachers leave high-poverty schools than low-poverty schools (10 versus 7 percent). This attrition likely does not lead to greater inequity in access to effective teachers because the teachers leaving high- and low-poverty schools are equally effective.
- **In a small subset of study districts, there is meaningful inequity in access to effective teachers in math.** In 3 of 26 study districts in math, providing high- and low-income students with equally effective teachers from grade four to eight would reduce the student achievement gap by at least a tenth of a standard deviation of student achievement, the equivalent of about 4 percentile points over a five year period. In these districts, differences between teachers of high- and low-income students are large enough to meaningfully contribute to the existing student achievement gap. We also examined the correlation of district-level measures of inequity with patterns of hiring, transfer, and attrition in a district. We found that inequity in access to effective teachers is greater in study districts where new hires in high-poverty schools are less effective than those in low-poverty schools.

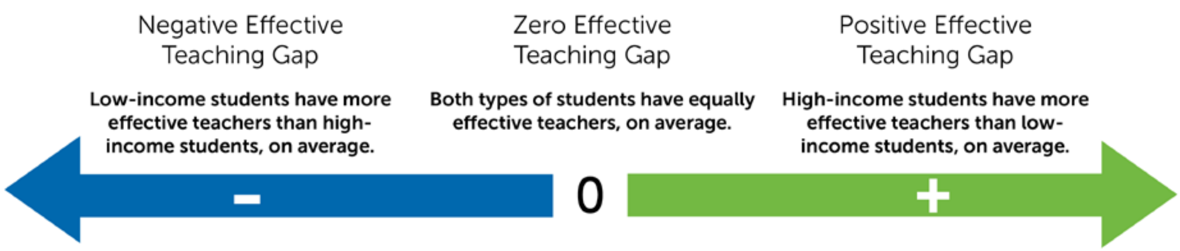
Research questions and study design

The U.S. Department of Education's Institute of Education Sciences (IES) contracted with Mathematica Policy Research to examine low-income students' access to effective teachers in a set of diverse school districts. The study addresses the following research questions:

1. Are low-income students taught by less effective teachers than high-income students? If so, to what extent would providing equal access to effective teachers reduce the student achievement gap?
2. Are there differences between high- and low-poverty schools in teacher hiring, transfer, and attrition? If so, are they consistent with inequitable access to effective teachers for low-income students?

To determine whether low-income students have equal access to effective teachers, we compare the average effectiveness of teachers of high- and low-income students, a difference known as the Effective Teaching Gap. It describes whether high-income students have more effective teachers than low-income students (a positive Effective Teaching Gap), low-income students have more effective teachers than high-income students (a negative Effective Teaching Gap), or the two types of students have equally effective teachers (a zero Effective Teaching Gap) (Figure ES.1). We defined students who are eligible for a free or reduced-price school lunch as low-income; all other students were defined as high-income. We did not compare the average characteristics or credentials of teachers of high- and low-income students because research has shown that they are not consistently related to teacher effectiveness—with the exception of teacher experience (Hanushek and Rivkin 2006; Kane et al. 2008; Constantine et al. 2009; Harris and Sass 2011). Instead, we measure teacher effectiveness using a value-added model, as described below.

Figure ES.1. Interpreting the Effective Teaching Gap



To better understand the factors that influence the Effective Teaching Gap, the study team measured the number and effectiveness of teachers (1) hired into high- and low-poverty schools, (2) transferring between high- and low-poverty schools, and (3) leaving the district from each type of school.

Study Design

Sample. We examined access to effective teachers in English/language arts (ELA) and math among students in 26 study districts, with grades four to eight in 12 districts and—due to data limitations—grades six to eight in the remaining 14 districts. We report results from the 2008–2009 through 2012–2013 school years for 21 districts, and results from the 2007–2008 through 2009–2010 school years for the other 5 districts.

Measuring Teacher Effectiveness. To measure teacher effectiveness, we used a value-added model, a statistical approach to isolate a teacher's contribution to student achievement. It measures the achievement levels of a teacher's students after accounting for students' prior achievement levels and other characteristics, as well as the characteristics of other students in the classroom. A value-added model predicts the test score each student would have achieved with the average teacher in the district, and then compares the average actual performance of a given teacher's students to the average of these students' predicted scores. The difference between the two scores is the teacher's value-added estimate. One limitation of value added is that if students in different classrooms differ on unmeasured characteristics, and those characteristics are related to student learning, that may lead to bias in the value-added estimates. The value-added scores are converted into teacher percentiles, which rank teachers from least effective (1st percentile) to most effective (99th percentile), with the average teacher at the 50th percentile.

Data. We collected standardized student test scores from state assessments in grades three to eight, a set of student characteristics (free or reduced-price lunch status, limited English proficiency, special education status, gender, race, and ethnicity), school enrollment data for students, and teacher-student-course links indicating the teacher responsible for teaching ELA and/or math to each student. We also collected information on district policies through interviews with senior district officials and staff.

Measuring Access to Effective Teaching. We measured access to effective teachers within each district using four steps to calculate the Effective Teaching Gap:

Step 1: Measure the effectiveness of each teacher in the district using a value-added model.

Step 2: Assign each student in the district the value added of his or her teacher in the relevant subject. This value-added estimate represents the effectiveness of each student's teacher for a given subject.

Step 3: Calculate average teacher value added for low-income students and for high-income students, identifying low-income students as those who are eligible for a free or reduced-price lunch.

Step 4: Subtract the average value added for low-income students from the average value added for high-income students in the district. This difference is the Effective Teaching Gap.

Measuring Patterns of Teacher Hiring, Development, Transfer, and Attrition. We defined teachers who enter a district as ***new hires***, those who move between schools as ***transfers***, and those who leave a district as ***leavers***. Teachers who do not move at all between school years are ***stayers***. We measured the percentage of teachers in each of these categories and their effectiveness, comparing patterns in schools with many low-income students (high-poverty schools) and those with fewer low-income students (medium- or low-poverty schools). For this analysis, low-poverty schools are those with less than 60 percent of students eligible for a free or reduced-price lunch, medium-poverty schools have 60 to 90 percent of students who are eligible, and high-poverty schools have more than 90 percent of students who are eligible.

District context

Although we did not use a nationally representative sample of districts, the study districts were chosen to be geographically diverse, with at least three districts from each of the four U.S. Census regions. The districts are similar to the 100 largest U.S. districts, on average. Median district enrollment is approximately 70,000 students, and there are more low-income and minority students than the typical U.S. district. In study districts, 63 percent of the students are eligible for free or reduced-price lunch, 29 percent are black, and 42 percent are Hispanic. Overall, achievement levels of students in study districts lag behind the average achievement levels of other students in their respective states by about 4 to 5 percentile points.

In two key ways, the study districts reflect national patterns. First, student achievement gaps in study districts mirror those at the national level. Among 8th grade students, the typical low-income student in the study districts performs 26 to 27 percentile points lower on state achievement tests than the typical high-income student. This achievement gap is similar to the national achievement gap on the National Assessment of Educational Progress (NAEP). Second, there is substantial variation in teacher effectiveness.

Detailed summary of findings

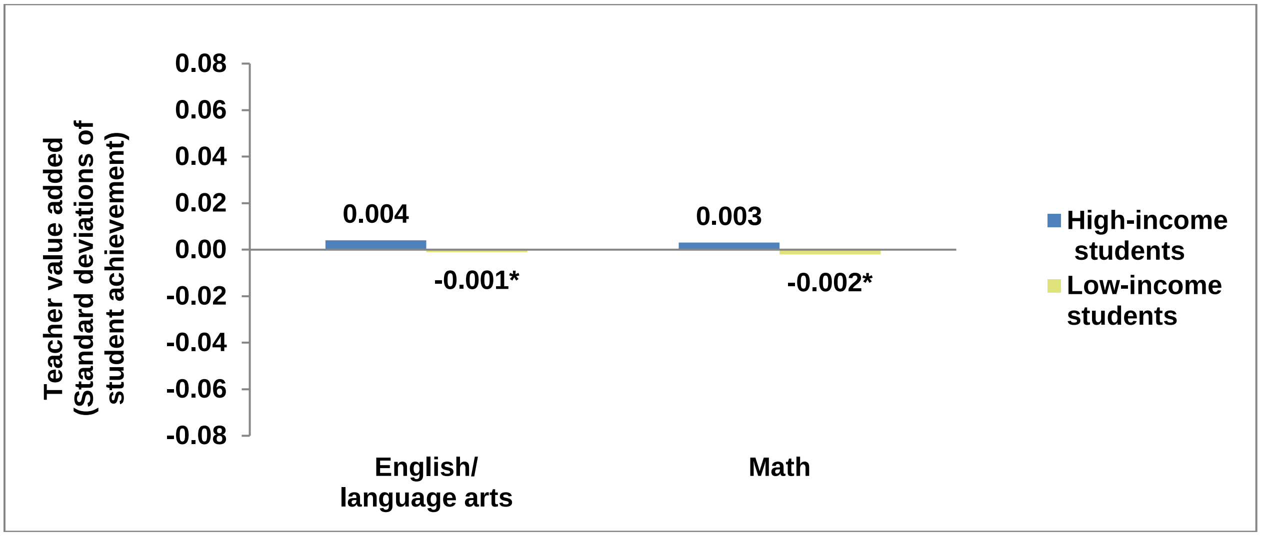
Are low-income students taught by less effective teachers than high-income students? To what extent could providing equal access to effective teachers reduce the student achievement gap?

We describe low-income students' access to effective teachers in 26 school districts for five years, from 2008–2009 to 2012–2013. We report results for the average study district to characterize the overall pattern across the 26 districts in our sample in a relatively straightforward way. Moreover, as we show below, the results for most study districts are similar to the results for the average study district. Consequently, the sample-wide average meaningfully captures low-income students' access to effective teachers in most of the districts we studied. However, because the patterns differ from the overall average in a few study districts, we also discuss low-income students' access to effective teachers for individual districts.

There are small differences in the effectiveness of teachers of high- and low-income students in the average study district

On average across study districts, high-income students have more effective teachers than low-income students, but the differences are small. In English/Language Arts (ELA), average teacher value added is 0.004 standard deviations of student achievement for high-income students and -0.001 for low-income students. This results in a statistically significant difference of 0.005—the Effective Teaching Gap in ELA (Figure ES.2). In math, the Effective Teaching Gap is 0.004 and is also statistically significant. In both subjects, the average teacher of a low-income student is just below the 50th percentile, while the average teacher of a high-income student is at the 51st percentile, indicating nearly equitable access to effective teaching in most study districts. The Effective Teaching Gap in both subjects has remained stable over time.

Figure ES.2. Average teacher effectiveness for low-income and high-income students (standard deviations of student achievement)

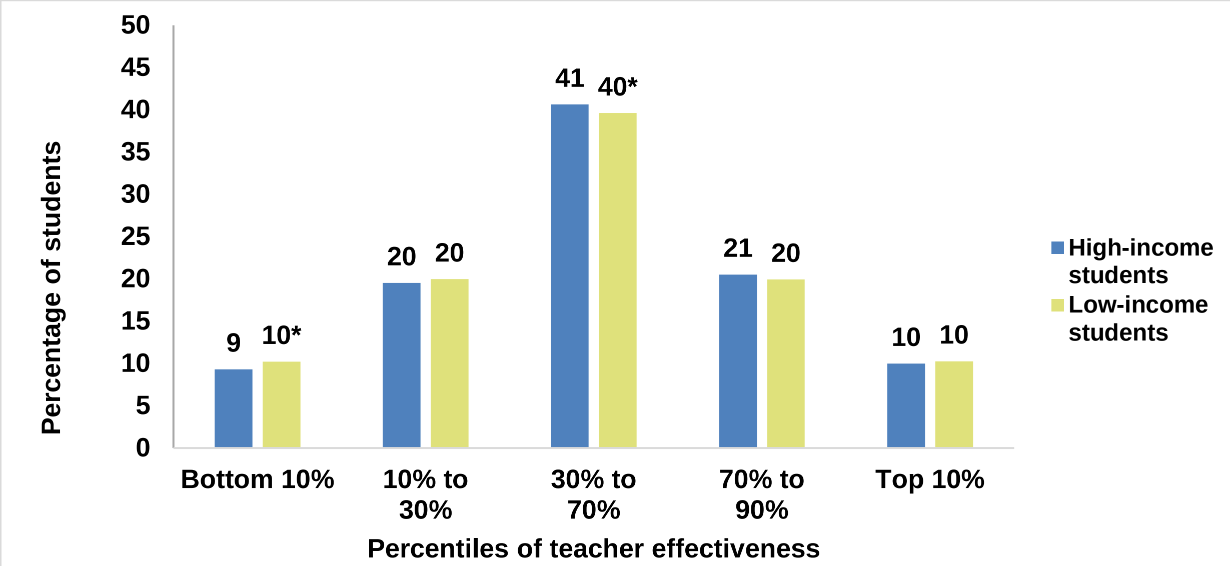


Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.
* Differences in the value added of the teachers of high-income and low-income students are statistically significant at the 0.05 level, two-tailed test.

High- and low-income students have similar chances of having one of the most effective teachers or one of the least effective teachers within study districts. We examined the likelihood that high- and low-income students are taught by teachers with value added in the top or bottom 10 percent of district teachers. In both subjects, 10 percent of high- and low-income students have one of the most effective teachers, on average (Figures ES.3 and ES.4). In ELA, 10 percent of low-income students have one of the least effective teachers compared with 9 percent of high-income students (this difference is statistically significant, but less than one percentage point). In math, among both groups of students, 10 percent have one of the least effective teachers. Thus, the small Effective Teaching Gap does not appear to be concealing larger differences in students' chances of having the most effective or least effective teachers in the district.

Figure ES.3. Percentage of low-income and high-income students taught by teachers at different levels of effectiveness, English/language arts

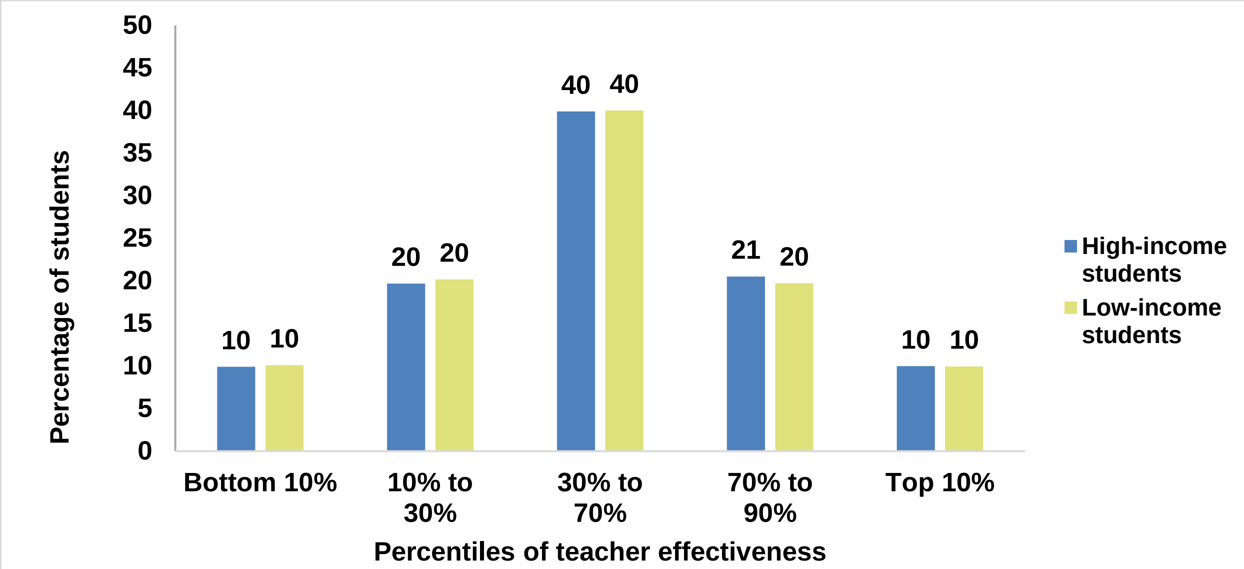


Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

* Differences in the percentage of low-income and high-income students are statistically significant at the 0.05 level, two-tailed test.

Figure ES.4. Percentage of low-income and high-income students taught by teachers at different levels of effectiveness, math



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

* Differences in the percentage of low-income and high-income students are statistically significant at the 0.05 level, two-tailed test.

If low-income students had teachers at least as effective as those of high-income students, this would not substantially reduce the student achievement gap. In the average district in ELA, a typical high-income student has achievement at the 61st percentile and the typical low-income student is at the 35th percentile—a student achievement gap of 25.1 percentile points. The gap in math is 24.5 points. Providing low-income students with teachers at least as effective as those of high-income students every year from 4th through 8th grade would have relatively little effect on the student achievement gap in the average study district. We found that this would reduce the student achievement gap in 8th grade in the average district from 25.1 to 24.2 percentile points in ELA and from 24.5 to 22.3 percentile points in math.

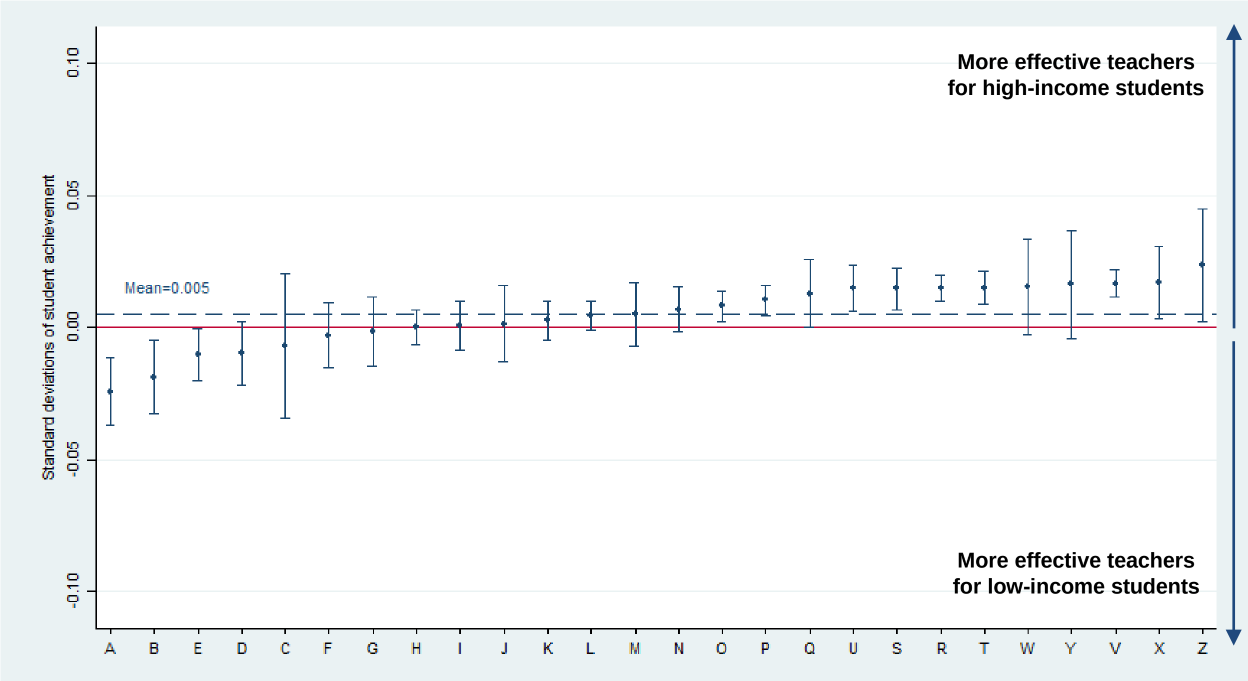
In a small subset of study districts, there is meaningful inequity in access to effective teachers in math

We characterized study districts as having meaningful inequity in access to effective teaching if eliminating this inequity for five consecutive years would reduce the student achievement gap between high- and low-income students by a tenth of a standard deviation of student achievement, or about 4 percentile points (this threshold is equivalent to an Effective Teaching Gap of 0.034 in ELA and 0.028 in math).[1] The Effective Teaching Gaps for each study district are shown in Figures ES.5 and ES.6 below.

[1] We defined a threshold for this analysis because the statistical significance of the Effective Teaching Gap is not a useful indicator of practical significance or importance of the difference between the effectiveness of teachers of

There is evidence of meaningful inequity in a few study districts in math, with low-income students receiving less effective teachers than high-income students. In a few study districts, differences between teachers of high- and low-income students are large enough to meaningfully contribute to the student achievement gap. Eliminating inequity for five consecutive years would reduce the student achievement gap by 4 or more percentile points in no study districts in ELA and 3 of the 26 districts in math. In the district with the greatest inequity among math teachers, eliminating this inequity for five consecutive years would reduce the student achievement gap by 5 percentile points.

Figure ES.5. Average Effective Teaching Gap in English/language arts, by district

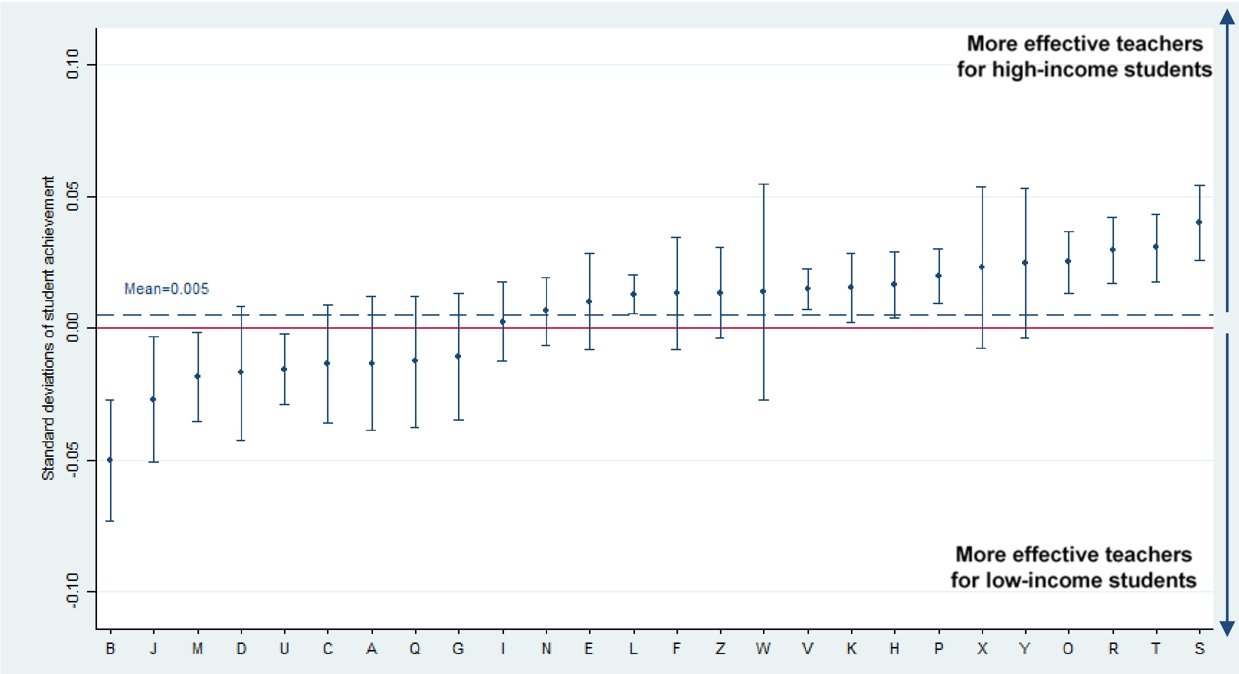


Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). Effective Teaching Gaps are computed within each district-grade-year combination and averaged with equal weight across years within each district. The points represent the district-level Effective Teaching Gaps and the vertical lines show the 95-percent confidence intervals around each point. The cross-district average of 0.005 standard deviations is shown by the dashed horizontal line. To reduce the risk that districts, particularly those with relatively few teachers and students, will receive a very high or very low Effective Teaching Gaps by chance, we applied an empirical Bayes shrinkage procedure to the estimates.

high- and low-income students. In particular, the analysis relies on very large samples that yield statistically significant estimates even when they are close to zero. We did not have a specific guideline or precedent for setting a threshold for meaningful inequity, so we chose a somewhat conservative standard: a threshold effect size that corresponds to the target minimal detectable effect size of 0.10 often used in studies of education interventions.

Figure ES.6. Average Effective Teaching Gap in math, by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). Effective Teaching Gaps are computed within each district-grade-year combination and averaged with equal weight across years within each district. The points represent the district-level Effective Teaching Gaps and the vertical lines show the 95-percent confidence intervals around each point. The cross-district average of 0.004 standard deviations is shown by the dashed horizontal line. To reduce the risk that districts, particularly those with relatively few teachers and students, will receive a very high or very low Effective Teaching Gaps by chance, we applied an empirical Bayes shrinkage procedure to the estimates.

Are there differences between high- and low-poverty schools in teacher hiring, transfer, and attrition? Are these differences consistent with inequitable access to effective teachers for low-income students?

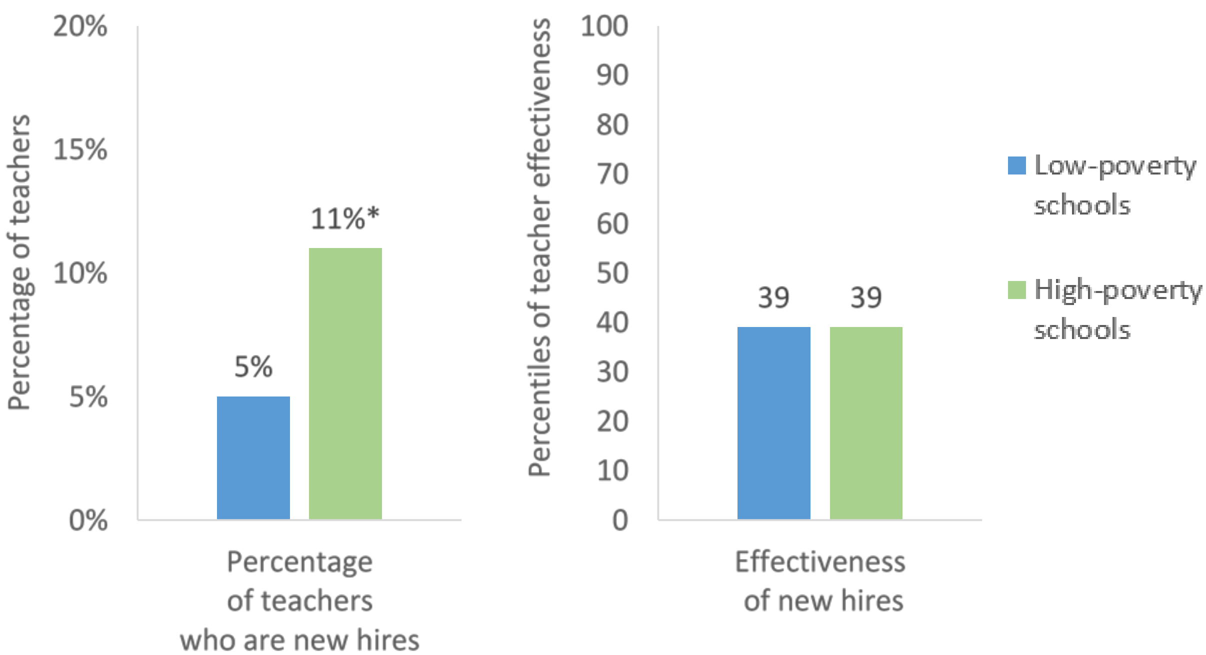
To understand how teacher hiring, transfer, and attrition patterns might contribute to inequitable access for low-income students, we measured average differences between high- and low-poverty schools in (1) the percentage of teachers who experience each type of career transition, and (2) the effectiveness of these teachers. Both of these factors may influence teacher equity. We first focus on average patterns across the full sample. These average patterns reflect hiring, transfer, and attrition in most study districts. We then examine whether district-specific patterns of hiring, transfer, and attrition are related to inequity in access to effective teachers at the district level. In particular, we present the results from a correlational analysis examining whether certain hiring, transfer, or attrition patterns tend to occur in districts with greater (or lesser) inequity in access to effective teachers.

Hiring patterns are consistent with small differences in the effectiveness of teachers of high- and low-income students

High- and low-poverty schools hire teachers who are similarly effective in their first year in study districts. These new hires (defined as novice or experienced teachers who are new to a district) are less effective than the average teacher, with value added at the 39th percentile on average (-0.05 standard deviations of student achievement) in both high- and low-poverty schools (Figure ES.7).

The presence of more new hires in high-poverty schools is consistent with a small amount of inequity for two reasons. First, although high-poverty schools have more new hires than low-poverty schools, the difference is small (11 percent of teachers in high-poverty schools are new hires compared to 5 percent in low-poverty schools). In addition, most teachers in both high- and low-poverty schools in study districts (89 and 95 percent, respectively) are not new hires. Second, while new hires tend to be less effective than the average district teacher in their first year, they improve substantially by their second year, when they are nearly as effective as the average teacher. New hires at high- and low-poverty schools improve at similar rates in study districts, on average.

Figure ES.7. Percentage and effectiveness of new hires for low- and high-poverty schools



Source: Authors' calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 2 through 5.

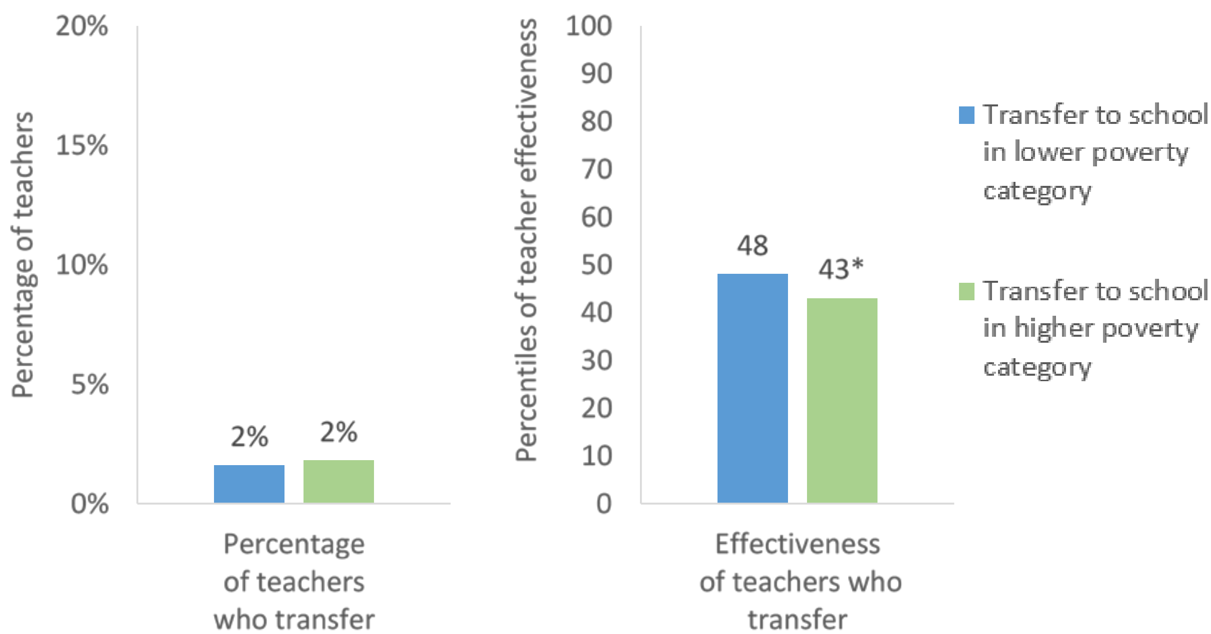
* Differences between low- and high-poverty schools are statistically significant at the 0.05 level, two-tailed test.

Teachers' transfer patterns are consistent with small differences in the effectiveness of teachers of high- and low-income students

Teachers who transfer to schools in a lower poverty category are more effective than those who transfer to a higher poverty category. On average, teachers who transfer to schools in a lower poverty category within a district have value added at the 48th percentile. Teachers who transfer to schools in a higher poverty category have value added at the 43rd percentile, on average (Figure ES.8).

Overall, transfer patterns are consistent with a small amount of inequity because a small percentage of teachers transfer to schools with poverty levels different from their former schools. Although teachers transferring to schools in lower poverty categories are more effective than those transferring to schools in higher poverty categories, this difference is likely to have a small influence on inequity. This is because just under 4 percent of teachers transfer to a school in a higher or lower poverty category (a little less than 2 percent from higher- to lower-poverty and less than 2 percent from lower- to higher-poverty). A little more than 4 percent of teachers move between schools with similar poverty rates.

Figure ES.8. Percentage and effectiveness of teachers transferring to schools in lower and higher poverty categories



Source: Authors' calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 1 through 4.

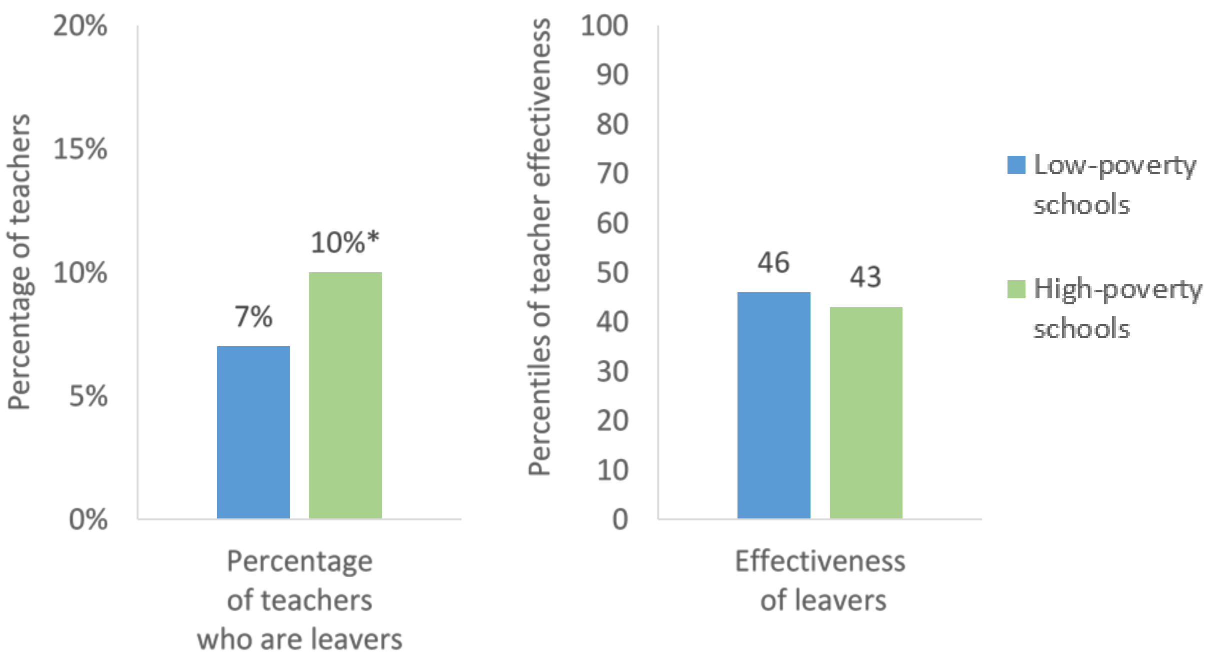
* Differences between teachers who transfer to schools in a lower poverty category and those who transfer to schools in a higher poverty category are statistically significant at the 0.05 level, two-tailed test.

Teacher attrition patterns do not contribute to low-income students having less effective teachers than high-income students, on average

Teachers in high-poverty schools are more likely than those in low-poverty schools to leave study districts. On average, 10 percent of teachers in high-poverty schools and 7 percent of teachers in low-poverty schools leave study districts at the end of a school year to teach in another district or leave the profession (Figure ES.9).

Leavers are less effective than stayers in both high- and low-poverty schools. Teacher attrition could either benefit or harm students, because schools may lose their more or less effective teachers. In study districts, teachers who leave the district are less effective than those who stay, on average. This is true in both high- and low-poverty schools, as the average leaver from a high-poverty school is at the 43rd percentile of effectiveness and the average leaver from a low-poverty school is at the 46th percentile. This difference in the effectiveness of leavers at high- and low-poverty schools is not statistically significant.

Figure ES.9. Percentage and effectiveness of leavers from low- and high-poverty schools



Source: Authors' calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 1 through 4.

* Differences between low- and high-poverty schools are statistically significant at the 0.05 level,

Hiring patterns in individual study districts are correlated with low-income students' access to effective teachers in those districts

Districts where high-poverty schools hire less effective teachers than low-poverty schools tend to have greater inequity. Just as some districts have greater inequity than the average district, some have patterns of teacher hiring, development, transfer, and attrition that differ from the average district. Thus, we examined patterns of hiring, transfer, and attrition in individual districts and measured the relationships between these patterns and the districts' measures of low-income students' access to effective teachers. We found that district-level patterns of teacher hiring are associated with greater inequity in study districts. In particular, districts tend to have greater inequity (a larger Effective Teaching Gap) when high-poverty schools hire less effective teachers than low-poverty schools; that is, when new hires in high-poverty schools are less effective than new hires in low-poverty school. By contrast, district-level teacher transfer or attrition patterns are not associated with greater inequity. Nor are differences in the prevalence of new hires, transfers, or leavers related to greater inequity.

I. INTRODUCTION

Inequality in educational outcomes is substantial and persistent in the United States. Recent evidence suggests that students from high-income families outperform those from low-income families on achievement tests by considerable amounts, and that this achievement gap has widened over the past 30 years (Reardon 2011). Inequality persists in longer-term educational outcomes as well, with high-income students more likely to attend college (Chetty et al. 2014a) and obtain college degrees (U.S. Department of Education 2014).

Recent policy initiatives to address these gaps have emphasized teachers' contributions to student achievement. These policy efforts are supported by evidence showing that teachers vary a great deal in their effectiveness (Rockoff 2004; Rivkin et al. 2005; Kane et al. 2008; Aaronson et al. 2007; Koedel and Betts 2009). In addition, students taught by the best teachers not only achieve higher test scores but also have better outcomes in the long run, including greater likelihood of college attendance and higher wages (Chetty et al. 2014b).

A key question for policymakers is whether the growing inequality in educational outcomes is caused by differences in students' access to effective teachers. Are students from low-income families taught by less effective teachers than students from high-income families? Would a more equitable distribution of effective teachers narrow the gap in achievement between high- and low-income students?

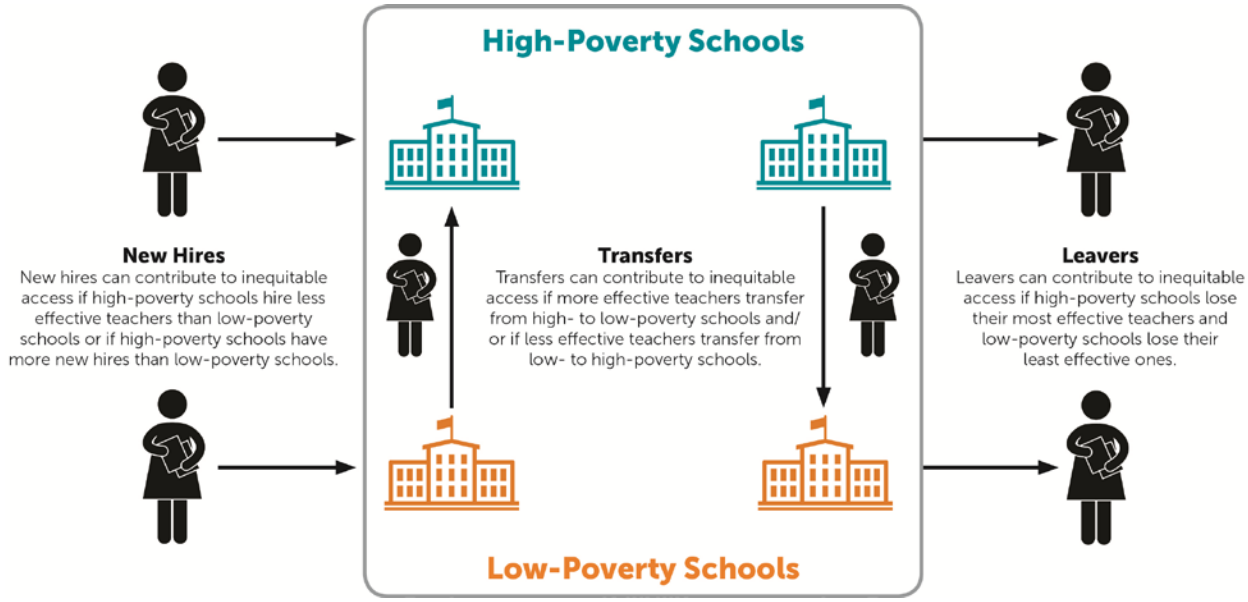
In this report, we use one measure of teacher effectiveness—based on a value-added model—to examine whether low-income students are taught by less effective teachers than high-income students, and whether any such inequity could contribute to the achievement gap. We also describe how the hiring of teachers and their subsequent movement into and out of schools could affect low-income students' access to effective teachers. The study includes fourth- to eighth-grade teachers over five school years (2008–2009 to 2012–2013) in 26 school districts across the country.

What determines low-income students' access to effective teachers?

Many factors influence students' access to effective teachers—where their families live, which schools they attend, which teachers they are assigned to within those schools, and how teachers are matched to schools. Understanding teachers' career transitions, including their hiring, development over time, and movement within and out of the district can inform the design of policies to improve low-income students' access to effective teachers. Figure I.1 shows how these career transitions could lead to inequitable access to effective teachers for low-income students.

Hiring. Each year, districts hire new teachers to replace the ones who leave or to respond to growth in student enrollment. Differences in the effectiveness of these new hires at high- and low-poverty schools may influence a student's access to effective teachers. The number of teachers hired into high- and low-poverty schools may also play a role. For example, if high-poverty schools repeatedly hire less effective teachers than low-poverty schools, this would eventually lead to high-poverty schools having less effective teachers. However, if high- and low-poverty schools hire a similar number of new teachers and hire teachers who are similarly effective, teacher hiring will not contribute to inequitable access to effective teachers.

Figure I.1. How hiring, transfer, and attrition affect access to effective teachers



Development. Teachers typically become more effective as they gain experience, especially in the early years (Clotfelter et al. 2007b, Boyd et al. 2008a, Kane et al. 2008, Kraft and Papay 2014, Ladd and Sorenson 2014, Xu et al. 2015). If teachers in high- and low-poverty schools improve their effectiveness at different rates, this could contribute to inequitable access. For example, if high-poverty schools have fewer opportunities for professional development, or if the environments in these schools are less conducive to teacher growth, the development of teachers in these schools might lag the development of teachers in low-poverty schools. A persistent difference in how quickly teachers develop could lead to less effective teachers at high-poverty schools.

Transfer. Transfers between schools within a district typically occur at the end of a school year, when teachers change schools voluntarily or involuntarily. The influence of these transfers on a student's access to effective teachers depends on three factors: (1) how many teachers transfer, (2) the types of schools (high- or low-poverty) that transfers leave and move into, and (3) the effectiveness of the teachers who transfer. If many effective teachers transfer from high- to low-poverty schools, the students in high-poverty schools will get less effective teaching as a result. But if the number of transfers is small or those who transfer move between similar types of schools, transfers will have little influence on low-income students' access to effective teachers.

Attrition. Teachers may leave a district because they retire, change careers, move to a different district, or lose their jobs. The influence of this attrition on a student's access to effective teachers depends on the effectiveness of teachers who leave relative to the effectiveness of those who stay, and whether this differs between high- and low-poverty schools. If high-poverty schools lose their most effective teachers and low-poverty schools lose their least effective ones, attrition can significantly influence low-income students' access to effective teachers. On the other hand, if attrition is low, or if high- and low-poverty schools are both losing the same types of teachers, attrition will have little influence.

What do we know from past research?

Several past studies have focused on whether low-income students are assigned to less qualified teachers than high-income students (DeAngelis et al. 2005; Clotfelter et al. 2006; Boyd et al. 2008b; Education Trust 2008; Almy and Theokas 2010; Schultz 2014). Although the studies found that low-income students generally have less qualified teachers than high-income students—based on measures such as years of teaching experience, teacher test scores, certification status, and educational attainment—this does not necessarily imply that they also have substantially less effective teachers. Most research has found no consistent link between teachers' effectiveness in increasing student learning and these types of qualifications, except for teaching experience (Hanushek and Rivkin 2006; Kane et al. 2008; Constantine et al. 2009; Harris and Sass 2011).

More recent studies have compared the effectiveness of high- and low-income students' teachers based on value-added estimates using several different approaches (Glazerman and Max 2011; Sass et al. 2012; Steele et al. 2014; Chetty et al. 2014c; Mansfield 2015; Goldhaber et al. 2015; Lauen and Henry 2015). One approach involves comparing the effectiveness of the average teacher of high- versus low-income students. Another focuses on whether low-income students are more likely to have a highly ineffective teacher or are less likely to have a highly effective teacher. Still other studies have focused on how teachers are distributed across schools, comparing the effectiveness of the average teacher at high- versus low-poverty schools or examining whether the highest poverty schools are most likely to have the least effective teachers (see Appendix A for more details about this research).

While informative, most of these studies have not taken the next step of examining how inequities in students' access to effective teachers relate to inequities in student outcomes. While most studies have found that low-income students receive somewhat less effective teaching, they do not show how these inequities relate to meaningful policy goals, such as closing the student achievement gap. In particular, the studies do not give a sense of the *magnitude* of any inequities in students' access to effective teachers.

Past studies have also examined patterns of teacher hiring, transfer, and attrition, and how these differ between high- and low-poverty schools (for example, Clotfelter et al. 2007a; Boyd et al. 2008b; Hanushek and Rivkin 2010; Goldhaber et al. 2011; Sass et al. 2012; Kalogrides and Loeb 2013). Some of these studies compare the amount of teacher hiring and mobility that occurs in high- and low-poverty schools. Others compare high- and low-poverty schools in terms of the effectiveness of the teachers being hired, transferring, or leaving the district. But most of these studies do not explicitly examine whether these patterns are consistent with inequitable access to effective teachers for low-income students. Even where patterns of teachers' transitions seem to favor low-poverty schools, these differences still may not contribute in a meaningful way to inequitable access to effective teachers. For example, more teachers transferring out of high-poverty schools than out of low-poverty schools would have little effect on low-income students' access to effective teachers if teachers from high-poverty schools tend to transfer into other high-poverty schools.

Contributions of this study

The U.S. Department of Education's Institute of Education Sciences (IES) contracted with Mathematica Policy Research to examine low-income students' access to effective teachers in a set of diverse school districts. The study is designed to fill gaps in the prior literature, which has not explicitly connected teachers' career transitions, low-income students' access to effective teaching, and the student achievement gap. The study addresses the following research questions:

1. Are low-income students taught by less effective teachers than high-income students? If so, to what extent would providing equal access to effective teachers reduce the student achievement gap?
2. Are there differences between high- and low-poverty schools in teacher hiring, transfer, and attrition? If so, are they consistent with inequitable access to effective teachers for low-income students?

In an earlier report from this study (Isenberg et al. 2013), we answered the first question using three years of data (2008–2009 to 2010–2011) on teachers of English/language arts (ELA) and math in grades 4 to 8. The data covered 29 districts in 16 different states. The study team measured teacher effectiveness using value added, and compared the average effectiveness of teachers of high- and low-income students. Across study districts, on average, the low-income students' ELA teachers were at the 47th percentile and their math teachers were at the 48th percentile. In a situation of perfect equity, the average teacher of a low-income student would be at the 50th percentile of all teachers. The findings were in line with similar literature that measured teacher effectiveness using value added.

This study adds to the literature on access to effective teachers and teachers' career transitions in three main ways:

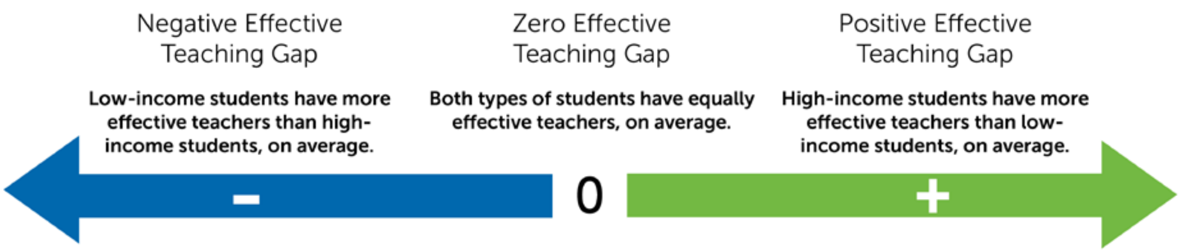
- It examines access in a large number of geographically dispersed school districts over a five-year period (2008–2009 to 2012–2013). While past studies in this literature have typically focused on teachers in a single district or single state, we use data on teachers in 26 districts located in 15 states in all four Census regions, using data from five school years.
- It examines how current inequities in access to effective teachers relate to the student achievement gap. A key challenge for policymakers is interpreting the magnitude of any differences between high- and low-income students in their access to effective teachers for policy. In this report, we look at the likely influence of these inequities by measuring how much the student achievement gap could be reduced by providing equally effective teachers.
- It measures how teachers' career transitions could contribute to low-income students' access to effective teachers. The report describes patterns of teacher hiring, transfer, and attrition in high- and low-poverty schools and assesses how these patterns could affect low-income students' access to effective teachers.

The analyses in this report are designed to (1) measure low-income students' access to effective teachers and (2) examine patterns of teacher hiring, development, and mobility that could affect that access. In this chapter, we describe our approach to these two study goals and the data we used in the analysis.

Measuring low-income students' access to effective teachers

To determine whether low-income students are taught by less effective teachers than high-income students, we created a measure we call the Effective Teaching Gap. This measure describes whether high-income students have more effective teachers than low-income students (a positive Effective Teaching Gap), low-income students have more effective teachers than high-income students (a negative Effective Teaching Gap), or the two types of students have equally effective teachers (a zero Effective Teaching Gap) (Figure II.1).

Figure II.1. Interpreting the Effective Teaching Gap



We calculated the Effective Teaching Gap in each district using the four steps shown in the following box.

Calculating the Effective Teaching Gap for a District

Step 1: Measure the effectiveness of each teacher in the district using a value-added model. Value added is a statistical analysis that uses data on students' test scores and other characteristics to isolate a teacher's contribution to student achievement.

Step 2: Assign each student in the district the value added of his or her teacher in the relevant subject. This value-added estimate represents the effectiveness of each student's teacher for a given subject.

Step 3: Calculate average teacher value added for low-income students and for high-income students, identifying low-income students as those who are eligible for a free or reduced-price lunch.

Step 4: Subtract the average value added for low-income students from the average value added for high-income students in the district. This difference is the Effective Teaching Gap.

We did not compare the average characteristics or credentials of teachers of high- and low-income students because research has shown that they are not consistently related to teacher effectiveness—with the exception of teacher experience (Hanushek and Rivkin 2006; Kane et al. 2008; Constantine et al. 2009; Harris and Sass 2011). Instead, we use one possible approach for measuring a teacher's effectiveness, a value-added model, as described below.

The remainder of this section includes more details about our approach for measuring whether low-income students are taught by less effective teachers than high-income students. We begin by describing the value-added model used to measure teacher effectiveness (Step 1). We then describe the calculations we made using these value-added estimates to produce each district's Effective Teaching Gap (Steps 2 through 4).

Step 1: Estimating teacher value added

Our value-added model measures the effectiveness of English/language arts (ELA) and math teachers in grades 4 to 8 in the study districts. We designed a model that would measure teacher effectiveness for the purpose of subsequently measuring the Effective Teaching Gap and comparing it across districts and years. Thus, we used the same data and methods in each district even when more data were available in certain districts.

Using Value Added To Measure Teachers' Effectiveness

States and districts are increasingly evaluating teachers based on multiple measures of performance, and these evaluation systems often combine classroom observations with measures based on student achievement growth.

A value-added model attempts to isolate a teacher's contribution to student achievement using statistical methods. It measures the achievement levels of a teacher's students after accounting for the students' previous achievement levels and other characteristics, such as special education or English language learner (ELL) status that may be related to student achievement during the year. A value-added model predicts the test score each student would have achieved if taught by the average teacher in a district or state, and then compares the actual performance of a teacher's students to those predicted scores. The average difference between the two scores is the estimate of the teacher's value added. Although value added does not measure every aspect of effective teaching, it is positively related to other measures of teachers' effectiveness (Kane et al. 2012).

A value-added model assumes that if two classrooms have students with the same measured background characteristics (such as previous achievement levels, eligibility for free and reduced-price lunch, and ELL status), those students will not systematically differ in other unmeasured ways that could affect their achievement, such as their motivation to learn or the stability of their home environment. If students in the two classrooms differ on unmeasured characteristics, and those characteristics are related to student learning, that may lead to bias in the value-added estimates. Some recent evidence suggests that these differences in unmeasured characteristics do not play a large role in determining teachers' value-added scores (Kane and Staiger 2008; Kane et al. 2013; Chetty et al. 2014c).

Another issue is whether a value-added estimate isolates the effectiveness of each teacher—based on his or her knowledge, ability, and skills—or whether it also captures the effect of other school-based factors beyond the teacher's control. Although we estimate a value-added model that accounts for one school-based factor that may be beyond the teacher's control—the composition of students in the classroom—the model does not account for other school-based factors such as the quality of a principal's leadership or the effect of the school's policies.

We estimated a value-added model that (1) includes an indicator for a student's teacher, (2) accounts for a common set of student characteristics in each study district, and (3) accounts for the characteristics of other students in each student's classroom (that is, classroom characteristics). The indicator for each teacher represents a teacher fixed effect, and implies that the influence of a teacher is constant across the teacher's students.[1] The student characteristics included in the model are gender; race; ethnicity; eligibility for a free or reduced-price lunch; limited English proficiency status; special education status; an indicator of whether a student transferred schools during the year; and test scores in math and ELA from the previous year. At the classroom level, the model includes the average achievement of other students in the classroom, the variability of the achievement of other students, and the proportion of students eligible for a free or reduced-price lunch.

This report differs from the first report from this study (Isenberg et al. 2013) in that the primary value-added model from the first report excluded classroom characteristics. As a result, this report is based on fewer districts than our first report. In this report, our main analysis includes 26 districts, with grades 4 to 8 covered in 12 districts and—due to data limitations—grades 6 to 8 covered in the remaining 14 districts. Isenberg et al. (2013) included grades 4 to 8 in all districts (including 3 additional districts for a total of 29) over 3 years.

In this report, our primary value-added model includes classroom characteristics, the most important of which is the average prior achievement of other students in the classroom. We do so because recent evidence suggests that estimates of teacher effectiveness can be substantially influenced by whether value-added models include classroom characteristics, and models with classroom characteristics have been shown to produce unbiased estimates of teacher effectiveness.[2] For example, Guarino et al. (2015) emphasize the importance of classroom characteristics, Chetty et al. (2014c) produce evidence that a value-added model that includes classroom characteristics yields estimates of teacher effectiveness with no statistically significant forecast bias, and Bacher-Hicks et al. (2014) and Rothstein (2015) have replicated these results with different samples of teachers.

Because some early work on value added had suggested that including classroom characteristics may cause a value-added model to become unstable and produce different estimates based on different model specifications (Ballou et al. 2004), we tested our results using a variety of approaches to incorporating classroom characteristics. In three separate value-added model specifications, we (1) used a single classroom characteristic (prior performance of

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[1] In other words, this assumption implies that a given teacher is equally effective for high- and low-income students, as well as for other student subgroups. Studies that have examined the relative effectiveness of teachers for different subgroups of students have found that teachers who are effective for one group of students (relative to the average teacher of that group of students) also tend to be effective for other groups of students (relative to the average teacher of that group of students). See Loeb and Candelaria (2012) for a review of the early literature, as well as more recent studies by Condie et al. (2014) and Fox (2014).

[2] A secondary reason for using a value-added model that includes classroom characteristics in this report is that we now have five years of data for most study districts, while the first report covered only three years. With additional years of data for individual teachers, we now have more variation in classroom characteristics for the teachers in our sample. Since the model relies on within-teacher variation in classroom characteristics, the additional data help us identify the effects of classroom characteristics more precisely.

classmates), (2) used a different way of measuring the variation in the prior performance of classmates, and (3) adjusted our approach to allow for the effect of other students in the classroom to be measured using differences that arose both within classrooms of the same teacher and between different teachers. In each case, our estimates of low-income students' access to effective teaching were similar to those obtained using our primary value-added model. This reduced our concerns about the instability of estimates from the classroom characteristics models, and gave us greater confidence in the model. However, to allow for comparisons between this report and the first report, we also include results based on a value-added model that excludes classroom characteristics.

Our value-added model measures the effectiveness of a teacher relative to other teachers in the same district, grade, and subject. A teacher with a positive value-added estimate is more effective than the average teacher while a teacher with a negative value-added estimate is less effective than the average teacher. Teachers with value-added estimates equal to zero are as effective as the average teacher.

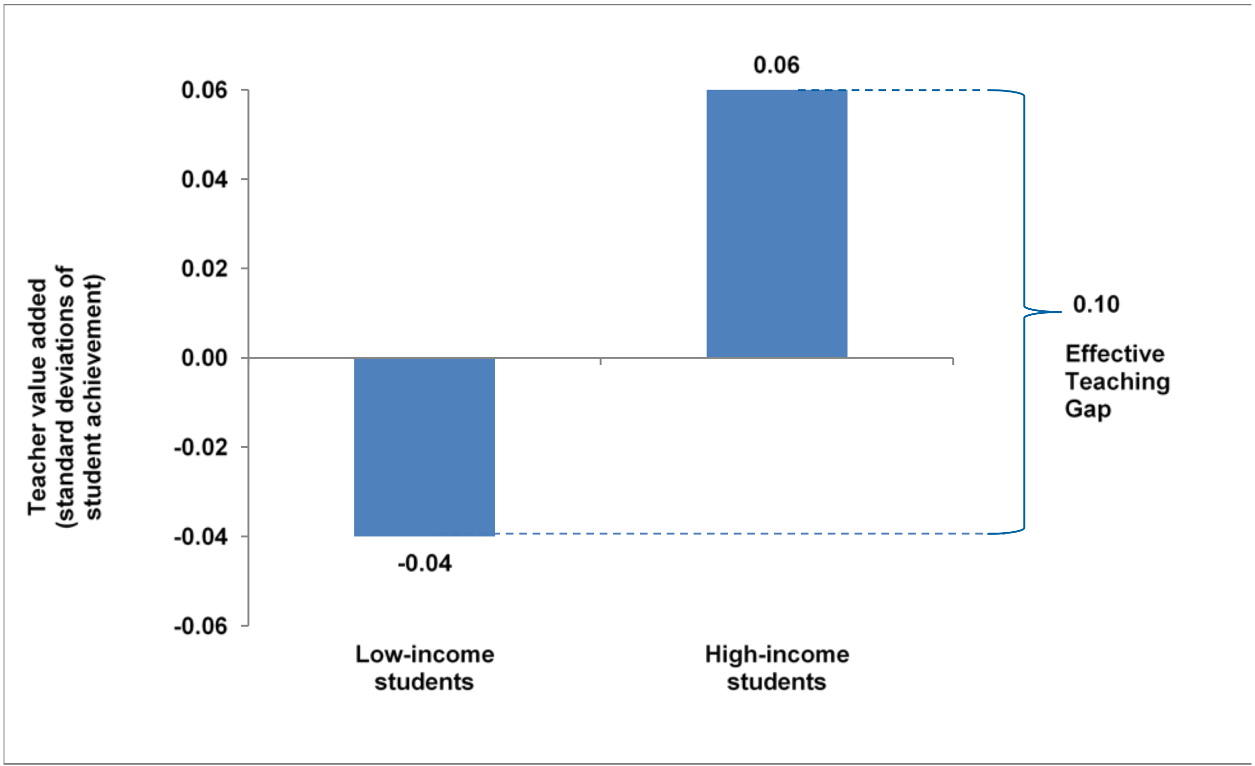
Steps 2-4: Measuring Effective Teaching Gaps

After generating a value-added estimate for each teacher, we linked each student to his or her teacher's value-added estimate. We then calculated a district's Effective Teaching Gap as follows:

- **We calculated average value added among teachers of low-income students.** In this average, we weighted each teacher by the number of low-income students that he or she taught. For example, a teacher with 20 low-income students would be weighted twice as heavily as a teacher with 10 low-income students. This weighted average represents the value added we would expect for the teacher of a typical low-income student in the district.
- **We calculated average value added among teachers of high-income students.** We used the same approach to calculate average value added for high-income students that we used for low-income students. The weighted average represents the value added we would expect for the teacher of a typical high-income student in the district. Many teachers have both low-income and high-income students in their classroom and are thus included in both calculations.
- **We calculated the Effective Teaching Gap.** We calculated the Effective Teaching Gap by subtracting the average teacher's value added for low-income students from the average teacher's value added for high-income students. This measure describes the extent to which high-income students are taught by more or less effective teachers than low-income students. If high-income students are taught by more effective teachers than low-income students, the gap will be positive. If high-income students are taught by less effective teachers than low-income students, the gap will be negative. An Effective Teaching Gap of zero means that high-income and low-income students are taught by equally effective teachers on average.

We provide a hypothetical example in Figure II.2. In this case, teachers of high-income students are relatively effective, with an average value added of 0.06. This indicates that the typical high-income student gets a boost of 0.06 standard deviations in test scores because of his or her teacher. Teachers of low-income students in this example tend to be below average, with an average value added of -0.04. As a result, this hypothetical district's Effective Teaching Gap is 0.10, indicating that low-income students have less effective teachers than high-income students, on average. In this hypothetical, low-income students have test scores that are 0.10 standard deviations lower than they would be if they had the same teachers as high-income students. After calculating the Effective Teaching Gap for each district, we averaged results across districts by weighting each district equally. The resulting estimate characterizes inequity in the distribution of teachers in the typical study district, rather than for the typical student in one of those districts. When comparing the Effective Teaching Gap across individual districts, we adjust the estimates to reduce the risk that districts with fewer teachers and students will receive very high or very low measures of the Effective Teaching Gap by chance. See Section B of Appendix B for details.

Figure II.2. Hypothetical example of the Effective Teaching Gap when low-income students have less effective teachers than high-income students



Identifying low-income students. We defined students who are eligible for a free or reduced-price school lunch as low-income; all other students were defined as high-income. Students are eligible for a free lunch if they live in households with incomes that are at or below 130 percent of the official poverty line, and eligible for a reduced-price lunch if their household income is between 131 and 185 percent of the official poverty line. Free or reduced-price lunch status is commonly used in studies as an indicator of students' socioeconomic status, because it is generally available in a district's administrative data.

Although free and reduced-price lunch status offers a way to distinguish between low-income and high-income students, it is an imperfect measure of family income. It is not always accurate, as some eligible students do not apply for or are incorrectly denied the benefit, and some ineligible students receive it. In addition, household income can vary within the group of students eligible for a free or reduced-price lunch and within the group that is ineligible.

Because of these limitations, we used two approaches to test the sensitivity of our results. First, we used a statistical technique that accounted for potential inaccuracies in students' free and reduced-price lunch status. Second, in our analyses we excluded those students who were eligible for a reduced-price lunch and focused only on differences in the effectiveness of the teachers of students not eligible for either a free or reduced-price lunch versus teachers of students eligible for a free lunch. In other words, we compared results for students with household incomes above 185 percent of the poverty line with results for those whose household incomes were no more than 130 percent of the poverty line. We found that the Effective Teaching Gap did not substantially change in either analysis. See Section H of Appendix C for details.

Measuring patterns of teacher hiring, transfer, and attrition

The Effective Teaching Gap is a summary measure of low-income students' access to effective teachers. To better understand the patterns underlying any inequity, the study team measured the number and effectiveness of teachers (1) hired into high- and low-poverty schools, (2) transferring between high- and low-poverty schools, and (3) leaving the district from each type of school. We also compared how quickly teachers in high- and low-poverty schools improve their effectiveness over time.

In this section, we describe the approach we used to define and measure these patterns of hiring, development, transfer, and attrition. We focus on differences in these patterns between high- and low-poverty schools to isolate how each career transition could contribute to inequity.

This description of our approach is covered in five sub-sections. First, we define terms that capture different types of career transitions. Second, we explain how we classified schools into high-, medium-, and low-poverty categories. Third, we describe our measures of teacher hiring, transfer, and leaving. Fourth, we describe our analysis of teacher development over time. Finally, we note how we aggregated results across districts. See Section B of Appendix B for additional details about our approach.

Defining new hires, transfers, and leavers

We looked at four types of teacher transitions, defining them from the perspective of the district:

1. **Hiring:** Entry of newly hired teachers into the district, including novice and experienced teachers new to the district
2. **Development:** Year-to-year changes in effectiveness as teachers gain experience
3. **Transfer:** Movement of teachers from one school to another in the district
4. **Attrition:** When teachers no longer teach in the district

We labeled all teachers as new hires, transfers, stayers, or leavers depending on these transitions. We define teachers who enter a district as ***new hires***, those who move between schools as ***transfers***, and those who leave a district as ***leavers***. Teachers who do not move at all between school years are ***stayers***. Teachers who remain at the same school but no longer teach ELA and/or math in grades 4 to 8 (and so do not have a value-added estimate the next year) are still considered stayers. We consider teachers who move into administrative roles to be leavers because they are no longer teaching in the district (this differs from stayers who continue teaching in the same district and school, just in a different subject or grade).[3]

Defining school poverty categories

To understand how teacher hiring, development, transfer, and attrition patterns influence low-income students' access to effective teachers, we measured how the patterns differed for schools with many low-income students (high-poverty schools) and those with fewer low-income students (medium- or low-poverty schools). For this analysis, we grouped schools into three poverty categories based on the percentage of students eligible for a free or reduced-price lunch:

- **Low-poverty schools:** fewer than 60 percent of the students are eligible for free or reduced-price lunch
- **Medium-poverty schools:** 60 to 90 percent of the students are eligible for free or reduced-price lunch
- **High-poverty schools:** more than 90 percent of the students are eligible for free or reduced-price lunch

We selected these cutoffs to ensure we had a sufficient sample of teachers in each school poverty category. Prior studies use a variety of different cutoffs to group schools into poverty categories. For example, Sass et al. (2012) distinguish two groups of schools using a threshold of 70 percent eligible for a free or reduced-price lunch; and Keigher (2010) defines high- and low-poverty schools based on those below 34 percent of students for a free or reduced-price lunch

[3] Some districts provided personnel data that tracked teachers when they moved into administrative roles, but others did not (so teachers who moved into administrative roles would disappear from the data). To ensure we treated teachers who moved into administrative roles consistently across districts, we treated these teachers as leavers in all study districts.

and those above 75 percent. To test the sensitivity of the results to our approach of classifying schools into poverty categories, we examined how patterns of career transitions are related to a continuous (rather than categorical) measure of school poverty. The results of the analysis are similar whether we use school poverty categories or a continuous measure of school poverty. See Section G of Appendix D for details.

We defined high-, medium-, and low-poverty using these cutoff values consistently across all study districts rather than setting different cutoffs for each district for two reasons. First, we wanted to ensure that the difference between high- and low-poverty schools reflects a meaningful difference in the characteristics of students across the school groupings. Differences in hiring, transfer, and attrition patterns across high- and low-poverty schools will affect low-income students' access to effective teaching minimally if there are small differences in the poverty levels of these school poverty categories. For example, if we grouped a district's schools into three poverty categories with equal numbers of schools in each category, there could be relatively small differences in the poverty levels of high- and low-poverty schools. Second, the school poverty categories would be difficult to interpret if they were defined differently for each district. For example, a given school might be classified as a high-poverty school in one district and a low-poverty school in a different district.

Measuring differences in hiring, transfer, and attrition of teachers by school poverty level

Comparing hiring, transfer, and attrition patterns across different types of schools is key to understanding how the patterns might influence the effectiveness of teachers of low-income students. The study team examined *how many teachers* were hired, transferred, or left the district and the *effectiveness of these teachers*. Specifically, we:

1. Measured the percentage of teachers in a given year that are newly hired, transfer between schools, or leave the district
2. Measured the average effectiveness of new hires, transfers, and leavers based on a value-added model of teacher effectiveness
3. Compared the estimates of prevalence and teacher effectiveness in low-, medium-, and high-poverty schools

In comparing the prevalence and effectiveness of teachers in low-, medium-, and high-poverty schools, we used regression analysis to account for teachers' district, grade span (elementary versus middle school), and subject. See Section D of Appendix B for details about this analysis, and see Section H of Appendix D for results presented separately by grade span and subject.

Measuring differences in teacher development by school poverty level

To compare the rates of teacher development in high- versus low-poverty schools, the study team examined changes in teacher value added as teachers gain experience. The analysis took advantage of multiple years of value-added estimates for each teacher by measuring changes in each teacher's effectiveness as he or she gains an additional year of experience. For example, we measure the change in teacher effectiveness between the fourth and fifth year of teaching based on all teachers who completed their fourth and fifth years of teaching during the study years. We do not measure development by comparing the effectiveness of different teachers—those with more and less experience—because that approach would capture both (1) teacher development, and (2) differences between teachers who remain in teaching for longer periods of time versus those who leave the profession sooner. For example, if more effective teachers remain in teaching longer than other teachers, more experienced teachers will appear more effective than less experienced teachers even aside from any gains in effectiveness due to development over time.

Combining the results across all the districts

When combining results across all of the districts to analyze patterns in teacher hiring, development, transfer, and attrition, we gave greater weight to the teachers with more students and to districts with more teachers. In other words, the averages we report reflect career transitions and development for teachers of the average student across the study districts. For example, suppose that two teachers are new hires, but the first one teaches twice as many students as the second. Thus, the first teacher has twice as much influence as the second on access to effective teachers for low-income students. So, in calculating the average effectiveness of new hires, our approach gives twice the weight to the value added of the first teacher relative to the second.

Data

The districts in our study provided data on their ELA and math teachers in grades 4 through 8 and their students. We collected data to measure access to effective teachers over a five-year period: the 2008–2009 through 2012–2013 school years for 21 districts, and the 2007–2008 through 2011–2012 school years for 5 districts. Throughout this report, we refer to years 1 through 5 rather than referring to the actual school years.

We collected the following types of data from districts:

- **Standardized test scores**. We obtained students' scores on state assessments in ELA and math for grades 3 through 8 for six consecutive school years. Because a value-added model accounts for previous student achievement, the first year of data (usually the 2007–2008 school year) served as the pre-test for the first year that we measured teacher value added (usually the 2008–2009 school year). The student test score data for 3rd grade students provided a pre-test score for measuring teacher value added in 4th grade.
- **Student demographic characteristics**. Districts provided background data on the following student characteristics: gender, race, and ethnicity; eligibility for a free or reduced-price lunch; limited English proficiency status; and special education status.
- **Teacher/student-course links**. A value-added model requires data that link each student to the teacher responsible for teaching him or her ELA and/or math. Districts provided teacher/student linked data that identified students' ELA and/or math teachers and their classes.
- **School assignment data**. Districts provided data for each year on the school where each teacher taught, including data for teachers of grades and subjects that were not part of our analysis. We used these data to determine whether a teacher stayed at the same school or

transferred schools from one year to the next. With school assignment data for all teachers, we could distinguish teachers who changed schools from those who moved to a grade or subject within the same school that was not part of our study.

- **Teacher experience.** For analyses that required data on teachers' experience, we used information on teachers' total teaching experience, not just their experience in the district.
- **District policies**. To collect information about the policies implemented during the study period, we conducted telephone interviews with district staff who were knowledgeable about policies (for example, assistant superintendents, human resources directors, professional development coordinators, and teacher recruiters). The first round of interviews was conducted between September 2011 and January 2012, and the second round between March 2013 and August 2013.

As shown in Table II.1, in all of the analyses we used data on student test scores and demographic characteristics as well as data linking teachers to their students. For the analysis of teacher hiring, development, and mobility, we required two types of additional data: information on school assignments for all teachers, and information on each teacher's years of teaching experience.

Table II.1. Data collected for each type of analysis

	Value-added model	Access to effective teaching	Teacher hiring, development, transfer, and attrition patterns
Standardized test scores	✓	✓	✓
Student demographic characteristics	✓	✓	✓
Teacher-student course links	✓	✓	✓
Teachers' school assignments (for all teachers)			✓
Years of teaching service/experience			✓

We excluded districts from an analysis when they could not provide key data, as shown in Table II.2. The main results are based on 26 districts where we could estimate a value-added model that included classroom characteristics. We report on three additional districts when we describe results based on the value-added model that excludes classroom characteristics. We excluded an additional district from the analysis of teacher hiring and mobility because that district lacked school assignment data for all teachers, and we excluded seven districts from the teacher development analysis because they did not have data on teachers' entire experience. See Section D of Appendix B for details.

Table II.2. Number of districts in each analysis

	Number of districts		
	Upper elementary grades	Middle school grades	Total districts (any grades)
Districts in analysis of access to effective teaching	12	26	26

No school assignment data for all teachers	0	1	1
Districts in teacher hiring and mobility analysis	12	25	25
No data on total teaching experience	2	7	7
Districts in teacher development analysis	10	18	18

Data for the analysis of teachers' career transitions covered the same years as data used in the analysis of low-income students' access to effective teachers. However, because of the nature of the different types of transitions we examined, the individual analyses presented in this report were based on somewhat different time periods:

- The analysis of teacher transfer and attrition was based on four transitions that occurred after years 1 through 4 (2008–2009 through 2011–2012). Transfer and attrition patterns in year 5 were not examined, because we did not have data on where the teachers were working in the following year.
- The analysis of new hires was based on years 2 through 5 (2009–2010 through 2012–2013). Year 1 was not used for the new hire analysis, because it was not possible to determine whether teachers had taught in the district in the previous year.

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III. DISTRICT CONTEXT

We measure low-income students' access to effective teachers in a geographically diverse set of 26 districts. This chapter provides context for the findings by describing the characteristics of students in these districts, the economic climate during the study period, and the implementation of policies that could influence access to effective teachers. The last two sections of the chapter present evidence from study districts on student achievement gaps and variation in teacher effectiveness, two of the key motivations for measuring low-income students' access to effective teachers.

A diverse set of districts, similar to the 100 largest districts in the nation

We purposely selected 30 medium to large districts from across the country to participate in the study. We recruited districts with a mix of low- and high-income students, as we planned to measure differences in teacher effectiveness between these two groups. We also targeted districts with data linking teachers to the students they taught. After obtaining data from 30 districts, we excluded one district that was unable to provide data that reliably distinguished low- from high-income students based on free or reduced-price lunch status. We also excluded districts that could not provide sufficient data (as described in Chapter II), so the main analysis in this report includes 26 districts.

Although we did not use a nationally representative sample of districts, the districts were chosen to be geographically diverse, with at least three districts from each of the four U.S. Census regions. The districts are large—with a median enrollment of approximately 70,000 students—and have high percentages of low-income and minority students (Table III.1). In these study districts, 63 percent of the students are eligible for free or reduced-price lunch, 29 percent are black, and 42 percent are Hispanic. These characteristics distinguish study districts from the typical district nationally. The median U.S. district has an enrollment of about 1,000 students. Nationally, 44 percent of students are eligible for free or reduced-price lunch, 17 percent are black, and 22 percent are Hispanic. The study districts are similar on most measures to the 100 largest U.S. districts, a group that includes many of the study districts. For example, the largest U.S. districts have the same median enrollment as the study districts (approximately 70,000 students) and the percentage of black and ELL students differs by no more than five percentage points from the study districts.

Study districts differ from the 100 largest U.S. districts in two main ways. First, study districts are more urban—69 percent of the students live in large cities compared with 46 percent in the 100 largest districts—and have more low-income students, with 63 percent eligible for a free or reduced-price lunch compared with 53 percent in the 100 largest districts. Second, study districts agreed to participate in the study and could provide the data needed to estimate value-added models. At the time of district recruitment in spring 2011, districts that could provide such data tended to have more sophisticated and well-organized data systems. As a result, the findings described in this report are specific to the districts included in the study sample.

Table III.1. Comparison of study districts to all U.S. districts and the 100 largest

	All U.S. districts	100 largest U.S. districts	Study districts
District enrollment (district median)	1,000	70,000	70,000
Percentage of students in large city	14%	46%	69%
Percentage of students eligible for free or reduced-price lunch	44%	53%	63%
Student race and ethnicity (percentages)			
White	55%	30%	23%
Black	17%	27%	29%
Hispanic	22%	34%	42%
Percentage English language learner students	9%	14%	19%
Average student achievement (percentiles)			
English/language arts	N/A	N/A	45
Math	N/A	N/A	46
Number of districts	13,406	100	26

Source: 2008–2009 Common Core of Data.

Note: District enrollment is based on the size of the median district; the other characteristics are based on student-weighted averages for all districts. District enrollment is rounded to the nearest 10,000 to maintain confidentiality.

N/A = not available.

The percentage of high-, medium-, and low-poverty schools ranged considerably across districts. In many of the districts, most teachers are concentrated in two of the three school poverty categories, typically in low- and medium-poverty schools (Figure III.1). Overall, 38 percent of the teachers teach in low-poverty schools, 39 percent in medium-poverty schools, and 23 percent in high-poverty schools.

Figure III.1. Percentage of teachers in low-, medium-, and high-poverty schools, by district

Source: Author's calculations based on districts' administrative data.

Note: Results are for teachers of grades 6 through 8 in 25 districts and grades 4 through 5 in 12 of these districts, for years 2 through 5. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap) and are consistent across figures. District J is excluded because the figure includes only the 25 districts (out of 26 total study districts) with the data necessary to analyze teacher hiring and mobility. Low-poverty schools are defined as those with 60 percent of students eligible for free or reduced-price lunch. Medium-poverty schools have 60 to 90 percent of students eligible for free or reduced-price lunch. High-poverty schools have 90 percent or more students eligible for free or reduced-price lunch. Districts are ordered from highest to lowest by the percentage of teachers in low-poverty schools.

Overall, the achievement levels of students in the study districts lag behind the average achievement levels of other students in their respective states. For each district, the 50th percentile represents the average achievement level in the state. Students in the study's districts, on average, are lower performing than their peers in their respective states, with performance levels of the average student in our sample at the 45th percentile in ELA and at the 46th percentile in math.

Period of high unemployment, staff layoffs

The 2008–2009 to 2012–2013 study years were marked by a severe economic recession followed by a gradual recovery, with high unemployment by historical standards. Study districts had an average unemployment rate of 8.2 percent during this period, which matched the national average (U.S. Bureau of Labor Statistics 2016). The average unemployment rate in study districts increased sharply from 5.9 percent in 2008 to 9.7 percent by 2010—a consequence of the economic downturn—and then decreased to 7.4 percent in 2013. Amid these poor economic conditions, which existed in tandem with tight state and local government budgets, 19 of the 26 districts laid off teachers during the study years, usually based on seniority (based on study interviews with district staff). Although layoffs during the study period increased involuntary attrition, high levels of unemployment may have discouraged teachers from leaving their positions voluntarily to seek another teaching position or a job in another field. Overall, however, it is not clear how this context may have influenced low-income students' access to effective teachers, particularly because it is not known whether more effective or less effective teachers were more strongly affected by these trends.

Study districts implemented policies to address inequitable access

To provide more context on the policy environment in study districts, we collected information on a set of 11 policies that could have improved the effectiveness of teachers in high-poverty schools relative to low-poverty schools (Table III.2). Although there is minimal evidence on the impact of most of these policies, we focused on policies that have been supported by federal and state initiatives to address inequity.[4] Details on the definition of each of these policies are in Section G of Appendix B.

Table III.2. Policies designed to improve the effectiveness of teachers in high-poverty schools relative to other schools

Policy type	Policy
Teacher compensation policies	1. Bonuses for teaching in high-need schools[a] 2. Performance pay in high-need schools
Teacher recruitment and hiring policies (other than compensation)	3. Teacher recruitment activities targeted to high-need schools[b] 4. Highly selective alternate routes to teaching 5. Early teacher hiring timelines for high-need schools
Teacher transfer and retention policies (other than compensation)	6. Performance-based tenure decisions 7. Mutual consent for teacher transfers in high-need schools 8. Performance-based teacher layoffs
Teacher development	9. Comprehensive teacher induction 10. Teacher professional development in high-need schools
School improvement	11. School improvement activities in chronically low-performing schools

[a] We asked district staff about teacher policies that targeted a specific set of high-need schools rather than focusing solely on one type of high-need school (e.g. high-poverty schools, low achieving schools).

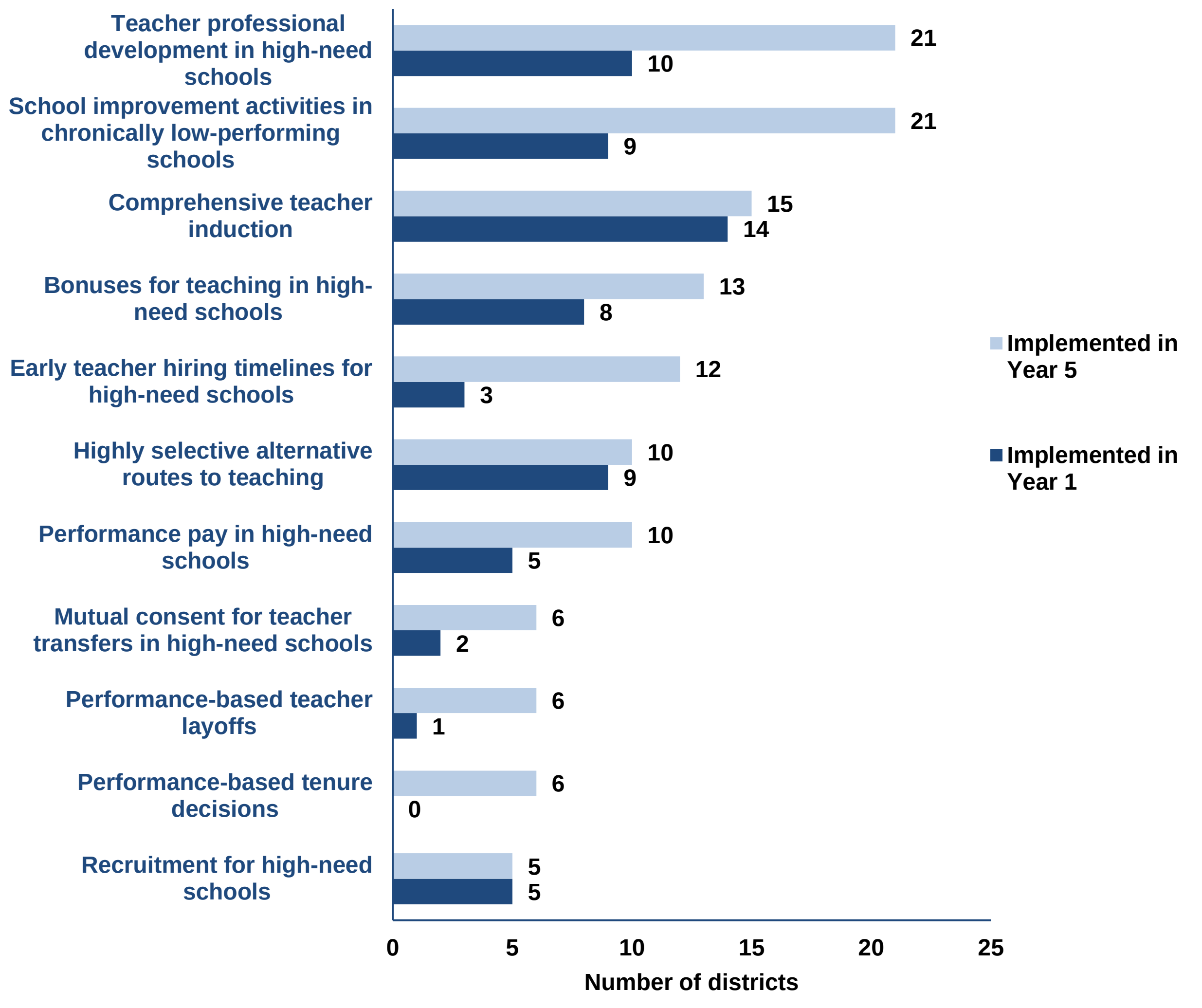
[b] Any recruitment activities related to compensation—such as signing bonuses or performance bonuses—are categorized as teacher compensation policies. Examples of recruitment activities include holding job fairs specifically for high-need schools, developing marketing materials to recruit candidates into high-need schools, and providing additional recruiters to identify candidates for high-need schools.

Study districts reported implementing multiple policies during the study period that could potentially address any inequitable distribution of teachers. For example, in the last year of the study period, the typical district implemented 5 of the 11 policies we examined. Moreover, districts became increasingly likely to implement these policies over the course of the study period. For example, the average district went from implementing just two or three of the

[4] For example, the federal Teacher Incentive Fund grants support performance pay and bonuses for teaching in high-need schools; Race to the Top grants support state and district policies that address teacher recruitment and hiring; states can use Title I funds to support professional development in high-need schools; and School Improvement Grants fund school turnaround activities in chronically low-performing schools.

policies in the first year of the study period to implementing five policies by the last year. In this last study year, 10 districts were implementing 6 or more of the policies, compared to just 2 such districts in the first year. Figure III.2 shows the number of districts implementing each of the 11 policies in the first and last study year.

Figure III.2. Number of districts implementing selected policies, years 1 and 5



Source: Telephone interviews with district staff.

Note: The following number of districts implemented a policy in year 1 but were no longer implementing the policy in year 5: 4 districts for comprehensive induction and recruitment activities for high-need schools; 2 districts for mutual consent for teacher transfers in high-need schools and performance pay in high-need schools; and 1 district for early hiring timelines for high-need schools, professional development targeted to high-need schools, and school improvement activities in chronically low-performing schools.

By the end of the study period, 21 districts (81 percent) had implemented each of the two most common policies: school improvement activities in high-poverty schools (often funded by federal School Improvement Grants) and teacher professional development targeted to high-need schools; 15 districts had implemented comprehensive induction, which we defined as instructionally focused mentoring by trained mentors during a teacher's first year of teaching. Additional changes in policy implementation included the following:

- There was a sharp increase in the number of districts allowing high-poverty schools to hire teachers on an earlier timeline than other schools, from 3 to 12 districts over the study period. This policy is designed to improve the effectiveness of new hires in high-poverty schools by improving the quality of teacher candidates and giving high-poverty schools early access to these new hires (Levin and Quinn 2003; Levin et al. 2005).
- Another 13 districts offered bonuses to attract or retain teachers in high-need schools. These districts provided bonuses to teachers who were hired into or transferred into high-need schools, and/or to teachers already in these schools who remained.
- A growing number of districts used teacher performance to make decisions about teacher tenure (six districts) and layoffs (six districts) by the last year of the study.
- Although the number of districts implementing each policy remained the same or increased, some districts that were implementing the policies in year 1 stopped implementing these policies by year 5 (see footnote to Figure III.2). No more than two districts dropped most of the policies, but four districts no longer implemented comprehensive induction and recruitment activities for high-need schools.

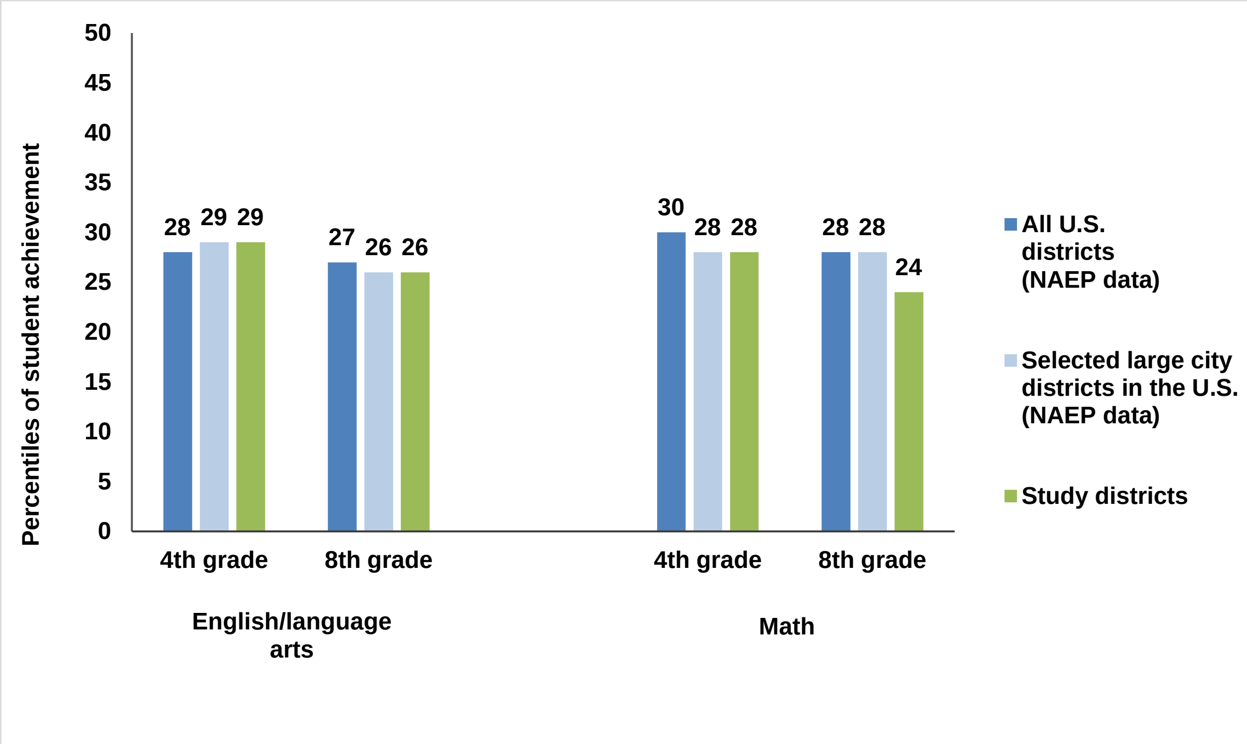
Substantial variation in teachers' effectiveness

In general, the greater the variation in teachers' effectiveness, the greater the potential for inequitable access—if all teachers are equally effective, there can be no difference in the access of low-income and high-income students to an effective teacher. One way to describe how much teachers matter is to compare how much better typical students would do if they had one of the most effective teachers (one at the 90th percentile of teacher effectiveness) than if they had one of the least effective teachers (one at the 10th percentile). For the typical student in our study, having one of the most effective rather than least effective teachers would move him or her up in the distribution of students by 13 percentile points in ELA and 19 percentile points in math. This suggests substantial variation in teacher effectiveness that is consistent with the existing research on value added (Nye et al. 2004; Rockoff 2004; Rivkin et al. 2005; Kane et al. 2008; Aaronson et al. 2007; Koedel and Betts 2009).

Large student achievement gaps that mirror national averages

Student achievement gaps in the study districts mirror those at the national level. Among 8th grade students in study districts, the typical low-income student performs at the 36th percentile on ELA state achievement tests, whereas the typical high-income student is at the 63rd percentile, Thus, there is a gap of 26 percentile points between low-income and high-income students (difference due to rounding). The achievement gap in math is 24 percentile points in study districts. The 8th grade student achievement gap, based on the National Assessment of Educational Progress (NAEP), is similar, whether measured based on a national sample or a select group of large U.S. cities (Figure III.3). The achievement gap in 8th grade is 27 to 28 percentile points for all U.S. districts, and 26 to 28 percentile points in selected large city districts in the U.S. In 4th grade, the student achievement gap is slightly larger than in 8th grade, at 28 to 29 percentile points in study districts and 28 to 30 percentile points in the national sample.[5]

Figure III.3. Average student achievement gap by poverty status in 4th and 8th grades: All U.S., selected large U.S. cities, and study districts



Source: Author's calculations based on the 2009 National Assessment of Education Progress (NAEP) for all U.S. districts and for large city districts in NAEP's Urban District Assessment; and district administrative data for all 26 study districts in 2009.

Notes: The achievement gap is the difference in student achievement between students who are eligible for a free or reduced-price lunch and students who are ineligible for this benefit.

[5] An alternative approach to examining the achievement gap is to measure the difference between the average achievement levels of high- and low-income students after accounting for their test scores in the prior year. This is a measure of differences in student learning in a given year. We examined this difference in student learning in a regression framework, and found that after accounting for prior test scores, high-income students have significantly higher achievement levels than low-income students, with a difference of 0.076 standard deviations in ELA and 0.070 in math. See Section J of Appendix C for more details.

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IV. ARE LOW-INCOME STUDENTS TAUGHT BY LESS EFFECTIVE TEACHERS THAN HIGH-INCOME STUDENTS?

In this chapter, we describe low-income students' access to effective teachers in 26 school districts for five years, from 2008–2009 to 2012–2013. We compare the effectiveness of the average teacher of a high-income student to that of the average teacher of a low-income student (the Effective Teaching Gap). We also measure how much the achievement gap between high- and low-income students could be reduced over a five-year period if the two groups were taught by equally effective teachers.

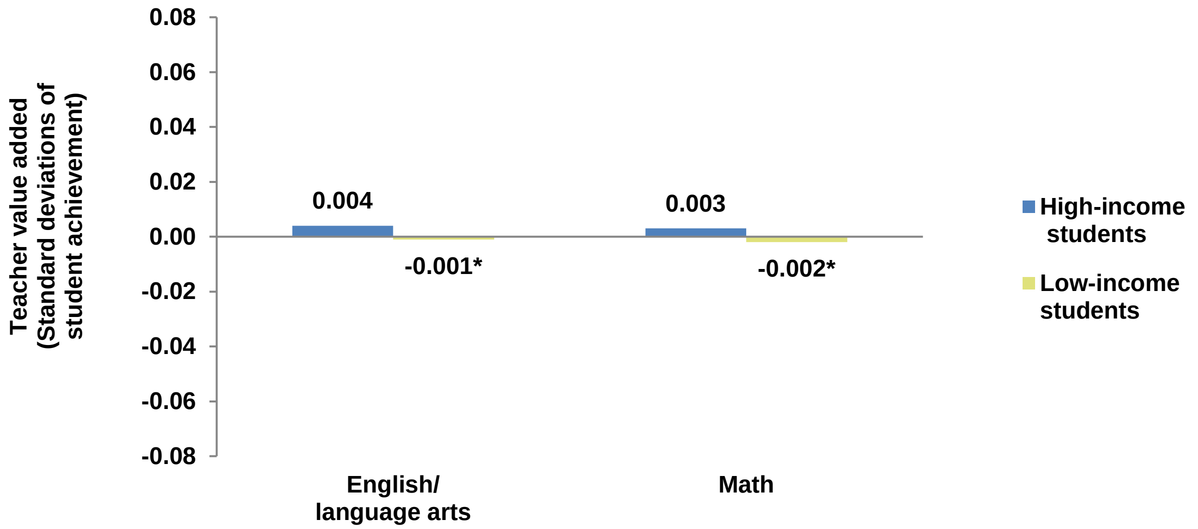
There are small differences in the effectiveness of teachers of high- and low-income students in the average study district

Reporting results for the average study district characterizes the overall pattern across the 26 districts in our sample in a relatively straightforward way. Moreover, as we show below, the results for most study districts are similar to the results for the average study district. Consequently, the sample-wide average meaningfully captures low-income students' access to effective teachers in most of the districts we studied. However, in a few study districts the patterns differ from the overall average. We discuss low-income students' access to effective teachers for individual districts in the second section of the chapter.

The Effective Teaching Gap is small and stable over time, on average

On average across study districts, high-income students have more effective teachers than low-income students, but the differences are small (Figure IV.1). In ELA, average teacher value added is 0.004 standard deviations of student achievement for high-income students and -0.001 for teachers of low-income students. This results in a statistically significant difference of 0.005—the Effective Teaching Gap in ELA. This implies that the typical high-income student has a teacher who increases student achievement by 0.005 standard deviations more than the typical low-income student's teacher. In math, the Effective Teaching Gap is 0.004 and is also statistically significant.

Figure IV.1. Average teacher effectiveness for low-income and high-income students (standard deviations of student achievement)



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. The Effective Teaching Gap in math is 0.004. The difference between the average teacher value added for high- and low-income students in math is 0.005 in the figure due to rounding.

* Differences in the value added of the teachers of high-income and low-income students (the Effective Teaching Gaps) are statistically significant at the 0.05 level, two-tailed test.

One way to interpret the Effective Teaching Gap is to compare where the average teacher of high- and low-income students falls in the overall distribution of teachers. In both subjects, the average teacher of a low-income student is just below the 50th percentile, while the average teacher of a high-income student is at the 51st percentile. Thus, the distribution of teachers in the average study district is almost perfectly equitable, where perfect equity would mean that the average teacher for both groups of students is at the 50th percentile. We also compared the Effective Teaching Gap in the average study district to a scenario in which high-income students have the most effective teachers and low-income students have the least effective teachers. Examined this way, the actual Effective Teaching Gap is substantially less than it could be—much lower than the maximum potential gaps of 0.204 standard deviations in ELA and 0.253 in math. See Section A of Appendix C for more details.[6]

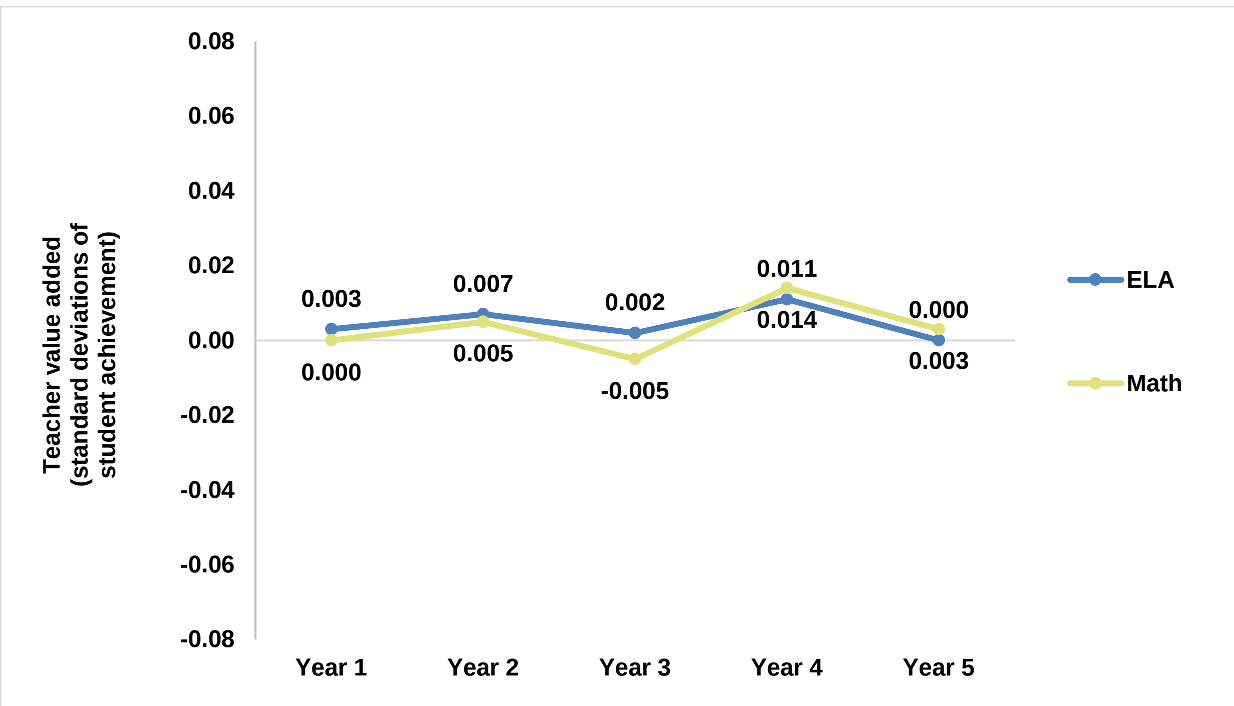
[6] We also examined whether low-income students' access to effective teachers differed between schools and within schools. In other words, we measured whether low-income students attended schools with less effective teachers, and whether low-income students were assigned to less effective teachers within schools. We found that the Effective Teaching Gap is small both between and within schools. See Section E of Appendix C for more details.

Are There Inequities in Access by Race/Ethnicity?

Just as there are large differences in student achievement between students from different economic backgrounds, there are also substantial achievement gaps between students of different races and ethnic groups. To examine whether differences in these groups' teachers might play a role in contributing to student achievement gaps, we measured access to effective teachers for black, Hispanic, and English Language Learner (ELL) students using the same approach we used to measure low-income students' access to effective teachers. On average, black students have math teachers who are less effective than those who teach white students, but this difference is small (at 0.010 standard deviations of student achievement). In ELA, black and white students have teachers who are similarly effective, as the difference between the two groups is not statistically significantly. In both subjects, there are no significant differences between teachers of Hispanic and white students, or between teachers of ELL students and non-ELL students. These results are described in greater detail in Section F of Appendix C.

The Effective Teaching Gap has remained stable over time. In the 21 districts with data for all five years of the study, the Effective Teaching Gap in ELA varies from year to year by 0.01 standard deviations of student achievement or less, with no clear trend over time (Figure IV.2). In math, the gap varies by less than 0.02 standard deviations across the five years.

Figure IV.2. Average Effective Teaching Gap, by year and subject



Source: Author's calculations based on district administrative data.

Note: Results are based on 14 districts for grades 6 to 8 and 12 districts for grades 4 to 8, for years 1 to 5. District-level results are weighted across grades by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

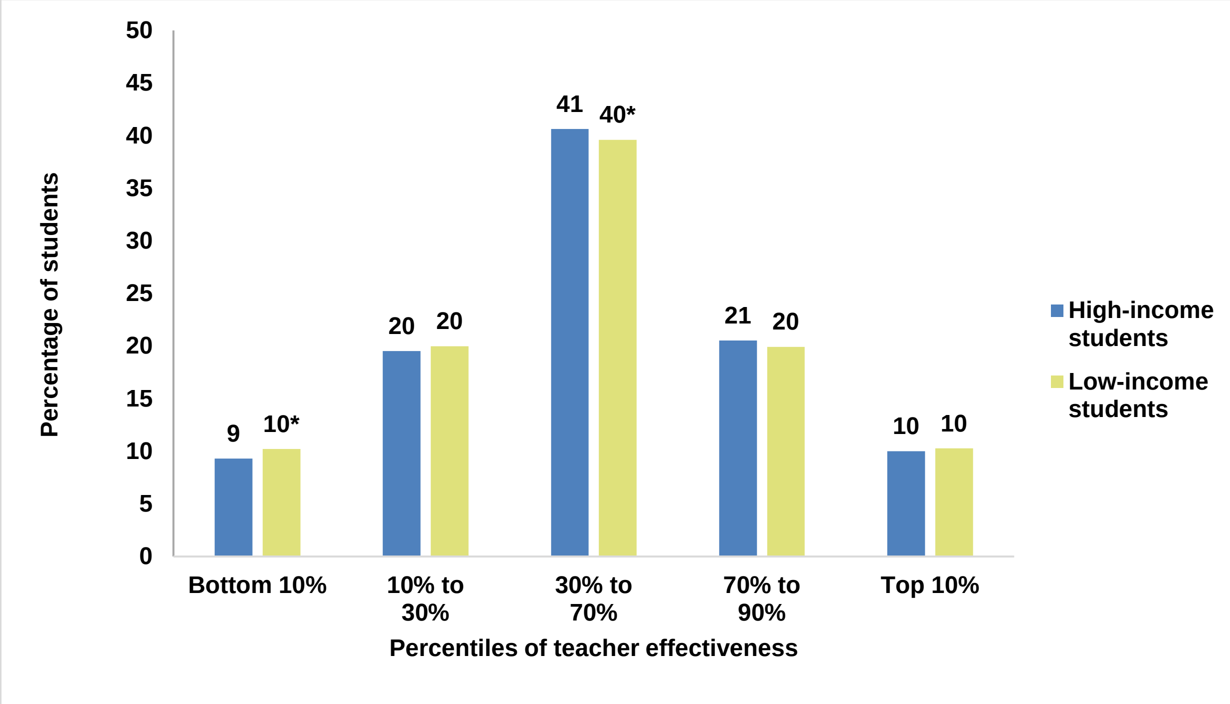
High- and low-income students have similar chances of having one of the most effective teachers or one of the least effective teachers within study districts

Although the small Effective Teaching Gaps suggest that there are small differences in the effectiveness of teachers of high- and low-income students on average, it is possible that pockets of inequity exist within the average study district. For example, low-income students may be more likely than high-income students to have one of the least effective teachers in the district. Or low-income students may be less likely than high-income students to have one of the most effective teachers. To explore this possibility, we examined the likelihood that high- and low-income students are taught by teachers with value added in the top or bottom 10 percent of district teachers.

In study districts, there are small differences or no differences between high- and low-income students in their chances of having one of the most effective teachers or one of the least effective teachers in the district. In both subjects, 10 percent of high-income and low-income students have one of the most effective teachers, on average. In ELA, 10 percent of low-income students have one of the least effective teachers compared with 9 percent of high-income students (this difference is statistically significant, but less than one percentage point). (Figure IV.3 and IV.4). In math, among both groups of students, 10 percent have one of the least effective teachers. Thus, the small difference in the average effectiveness of high- and low-income students' teachers as measured by the Effective Teaching Gap does not appear to be concealing larger differences in students' chances of having the most effective or least effective teachers in the district. In either case, the results indicate fairly equitable access to effective teachers in most study districts.

These figures also show small differences in the overall distribution of teachers for high- and low-income students in the average study district. While the most effective teachers boost student achievement substantially relative to the least effective teachers, high-income students are not consistently taught by more effective teachers than low-income students. Instead, both high- and low-income students are taught by a mix of more effective and less effective teachers.

Figure IV.3. Percentage of low-income and high-income students taught by teachers at different levels of effectiveness, English/language arts

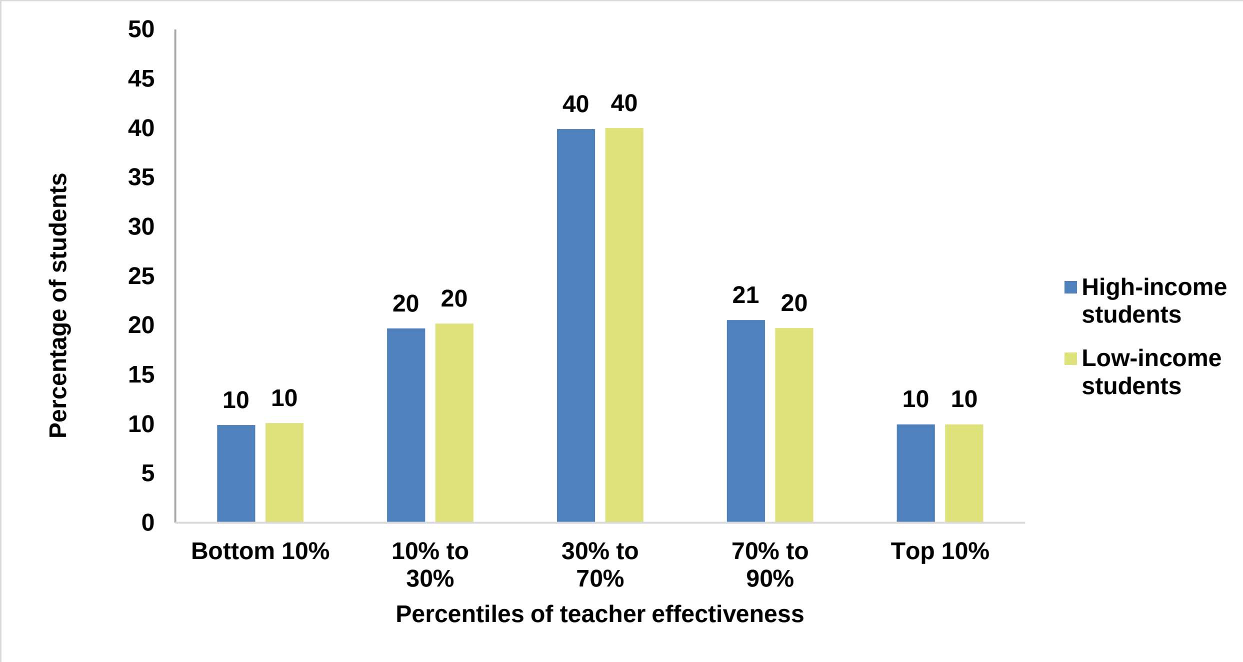


Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

* Differences in the percentage of low-income and high-income students are statistically significant at the 0.05 level, two-tailed test.

Figure IV.4. Percentage of low-income and high-income students taught by teachers at different levels of effectiveness, math



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

* Differences in the percentage of low-income and high-income students are statistically significant at the 0.05 level, two-tailed test.

Another way to measure access to effective teachers is to compare the effectiveness of the average teacher in a high-poverty school to the average teacher in a medium-poverty or low-poverty school. If teachers in a district's highest poverty schools are especially ineffective, there would be a gap when comparing the effectiveness of teachers at schools with different poverty rates. In study districts, however, the average teacher is similarly effective, whether teaching in a high-, medium-, or low-poverty school. See Section B of Appendix C for details of this analysis.

If low-income students had teachers at least as effective as those of high-income students, this would not substantially reduce the student achievement gap

Although high- and low-income students have similarly effective teachers, on average, they are not identical. Each year, high-income students have teachers who are slightly more effective than teachers of low-income students, on average, and this difference is statistically significant. A key question is whether these small differences translate into meaningful differences in student achievement between the two groups of students over multiple years. To measure teachers' contribution to student achievement gaps, we estimated how student achievement gaps would change if high- and low-income students had equally effective teachers between grades 4 and 8 (or between grades 6 and 8).[7] For districts where low-income students already have more effective teachers, we assumed that the current distribution of teachers would not change.[8] So, this analysis describes how student achievement gaps would change if low-income students had *at least* equally effective teachers for multiple years.

If low-income students had teachers at least as effective as those of high-income students from 4th through 8th grade, this would have relatively little effect on the student achievement gap in the average study district. We separately present results for the 12 districts where we could measure how the Effective Teaching Gap accumulates from 4th to 8th grade and the full set of 26 districts where we could measure how it accumulates from 6th to 8th grade.

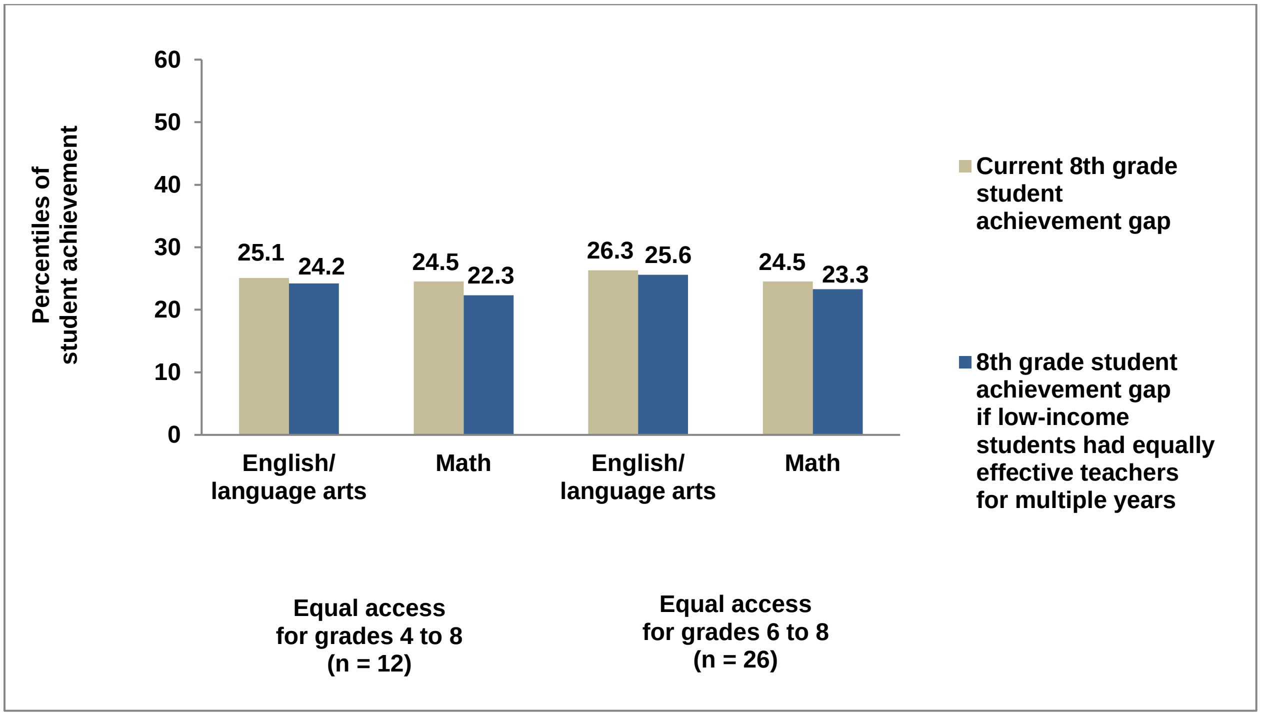
In the average district in ELA, the typical high-income student has achievement at the 61st percentile and the typical low-income student is at the 35th percentile—a student achievement gap of 25.1 percentile points. The gap in math is 24.5 points. Assuming low-income students had teachers at least as effective as those of high-income students over five years would reduce the student achievement gap in 8th grade in the average study district from 25.1 to 24.2 percentile points in ELA and from 24.5 to 22.3 percentile points in math (Figure IV.5). Based on the larger sample of 26 districts, providing low-income students with teachers at least as effective as those of high-income students over three years from 6th through 8th grade would reduce the student achievement gap in 8th grade by one percentile point or less in both subjects. See Section C of Appendix C for more details.

What if low-income students had *more effective* teachers than high-income students? We calculated the Effective Teaching Gap that would be needed to cut the student achievement gap in half if implemented from 4th through 8th grade (based on 12 districts). In ELA, the Effective Teaching Gap would have to be -0.102 (instead of 0.005 in these 12 districts) to make this amount of progress in reducing the student achievement gap. In math, the Effective Teaching Gap would need to be -0.080 (instead of 0.004 in these 12 districts) to cut the student achievement gap in half. Given the current placement of teachers, achieving these targets would require a substantial change. In ELA, 30 percent of teachers would have to switch places with each other to reach an Effective Teaching Gap of -0.102, assuming that it were possible for the best teachers in classrooms with mostly high-income students to switch places with the worst teachers in classrooms with mostly low-income students. In math, 11 percent of teachers would have to switch places to obtain an Effective Teaching Gap of -0.092.

[7] We accounted for the fact that the effect of a teacher on student achievement may fade out over time (McCaffrey et al. 2004; Rothstein 2010; Jacob et al. 2010; Chetty et al. 2014b). In other words, the effect of a 4th grade teacher is likely to weaken as students progress into 5th and 6th grades. See Section B of Appendix B for details about how we accounted for fade out.

[8] Low-income students have *more* effective teachers than high-income students in two of the twelve districts in ELA and one of the twelve districts in math. Rather than assuming that low-income students would have equal access to effective teachers in these districts—which would have required giving the low-income students less effective rather than more effective teachers—we assumed that the distribution of teachers, and thus the student achievement gap, would not change in these districts.

Figure IV.5. Change in 8th grade student achievement gap if low-income and high-income students had equally effective teachers for multiple years



Source: Author's calculations based on district administrative data.

Note: Results are based on 12 districts for the change in the student achievement gap over grades 4 to 8, and on 26 districts for the change in the student achievement gap over grades 6 to 8—both for years 1 to 5. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

What if we measure teacher effectiveness without accounting for the characteristics of other students in the classroom?

Our main results for the Effective Teaching Gap are based on a value-added model of teacher effectiveness that accounts for the characteristics of other students in the classroom (that is, a student's classroom peers). Accounting for these classroom characteristics is important because it ensures that the value-added model measures a teacher's contribution to student learning and does not capture factors beyond the teacher's control. However, data limitations sometimes lead researchers to estimate a value-added model that does not account for classroom characteristics. To gauge how sensitive the results are to this feature of the model, we estimated an alternative value-added model without classroom characteristics, similar to the main model used in the first report from this study (Isenberg et al. 2013).

When we measure teacher effectiveness without accounting for classroom characteristics, we do not find consistent, large-scale differences between high- and low-income students in access to effective teachers. The difference between high- and low-income students' teachers is somewhat larger than in our main results, but the same basic conclusion remains: providing equally effective teachers to the two groups would not dramatically reduce the student achievement gap between them.

The typical low-income student has a teacher whose value added is 0.034 lower in ELA than that of the typical high-income student. This is equivalent to the typical low-income student having a teacher at the 47th percentile and the typical high-income student having a teacher at the 56th percentile. In math, the Effective Teaching Gap is 0.029, equivalent to a difference between teachers at the 48th and 54th percentiles.

In both ELA and math, 11 percent of low-income students and 7 to 8 percent of high-income students are taught by one of the least effective teachers in a district. High-income students are 3 percentage points more likely to be taught by one of the most effective teachers in ELA and 1 percentage point more likely in math. Finally, providing high- and low-income students with equally effective teachers over the five years between grades 4 and 8 would reduce the student achievement gap by 3.4 to 3.8 percentile points in ELA and math. See Section G of Appendix C for more detailed findings and see Section K of Appendix D for hiring, mobility, and attrition results based on this alternative value-added model.

There is meaningful inequity in access to effective teachers in a small number of study districts

The first section summarizes the overall evidence on low-income students' access to effective teachers by describing results for the average study district. However, circumstances in an individual district may differ from the average study district. Even though there is relatively little inequity in students' access to effective teachers on average, there may be individual districts with more inequity. In this section, we describe low-income students' access to effective teachers separately by district.

There is variation across the study districts in the extent to which low-income students have equal access to effective teachers. The Effective Teaching Gap in the 26 study districts ranges from -0.024 to 0.023 in ELA and from -0.050 to 0.040 in math (Figures IV.6 and IV.7). This suggests that there are some districts in which low-income students have less effective teachers than high-income students, on average, and other districts in which the opposite is true.

We characterized study districts as having meaningful inequity in access to effective teaching if eliminating this inequity by providing high- and low-income students with equally effective teachers from grade four to eight would reduce the student achievement gap between high- and low-income students by at least a tenth of a standard deviation of student achievement, or about 4 percentile points, over a period of five years.[9] This threshold is equivalent to an Effective Teaching Gap of 0.034 in ELA and 0.028 in math. We refer to districts with Effective Teaching Gaps smaller than these thresholds (in either direction) as having differences in the effectiveness of high- and low-income students' teachers that are not meaningful.

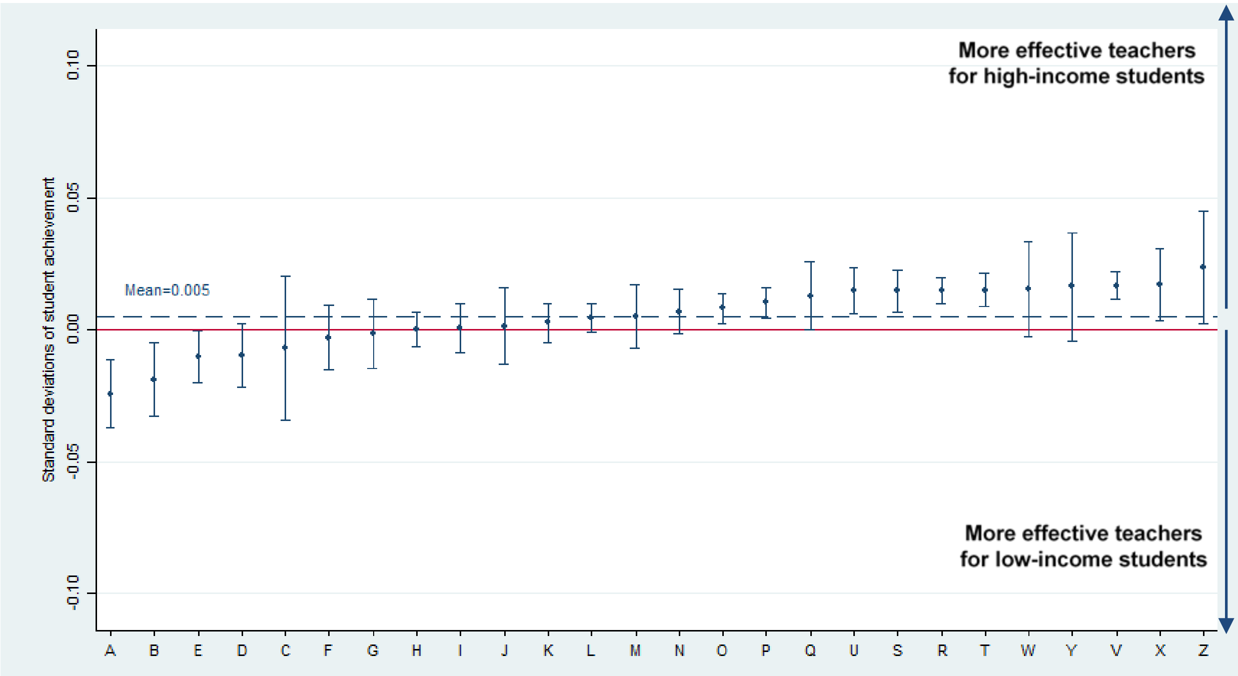
In all study districts in ELA and in 22 of 26 study districts in math, the effectiveness of low-income students' teachers does not differ by a meaningful amount from the effectiveness of high-income students' teachers. In another district, the Effective Teaching Gap in math suggests that teachers of low-income students are *more effective* than those of high-income students by a meaningful amount. In a majority of study districts, in other words, low-income students have teachers whose effectiveness is not meaningfully lower than the teachers of high-income students.

There is evidence of meaningful inequity in a few study districts in math, with low-income students receiving less effective teachers than high-income students

In a small number of study districts, differences between teachers of high- and low-income students are large enough to meaningfully contribute to the student achievement gap in math. The Effective Teaching Gap is 0.034 or greater in none of the 26 study districts in ELA and 0.028 or greater in 3 out of 26 districts in math (Figures IV.6 and IV.7). In the study district with the greatest inequity among math teachers, the Effective Teaching Gap implies that the typical high-income student has a teacher at the 54th percentile, whereas the typical low-income student has a teacher at the 46th percentile.

[9] We defined a threshold for this analysis because the statistical significance of the Effective Teaching Gap is not a useful indicator of practical significance or importance of the difference between the effectiveness of teachers of high- and low-income students. In particular, the analysis relies on very large samples that yield statistically significant estimates even when they are close to zero. We did not have a specific guideline or precedent for setting a threshold for meaningful inequity, so we chose a somewhat conservative standard: a threshold effect size that corresponds to the target minimal detectable effect size of 0.10 often used in studies of education interventions.

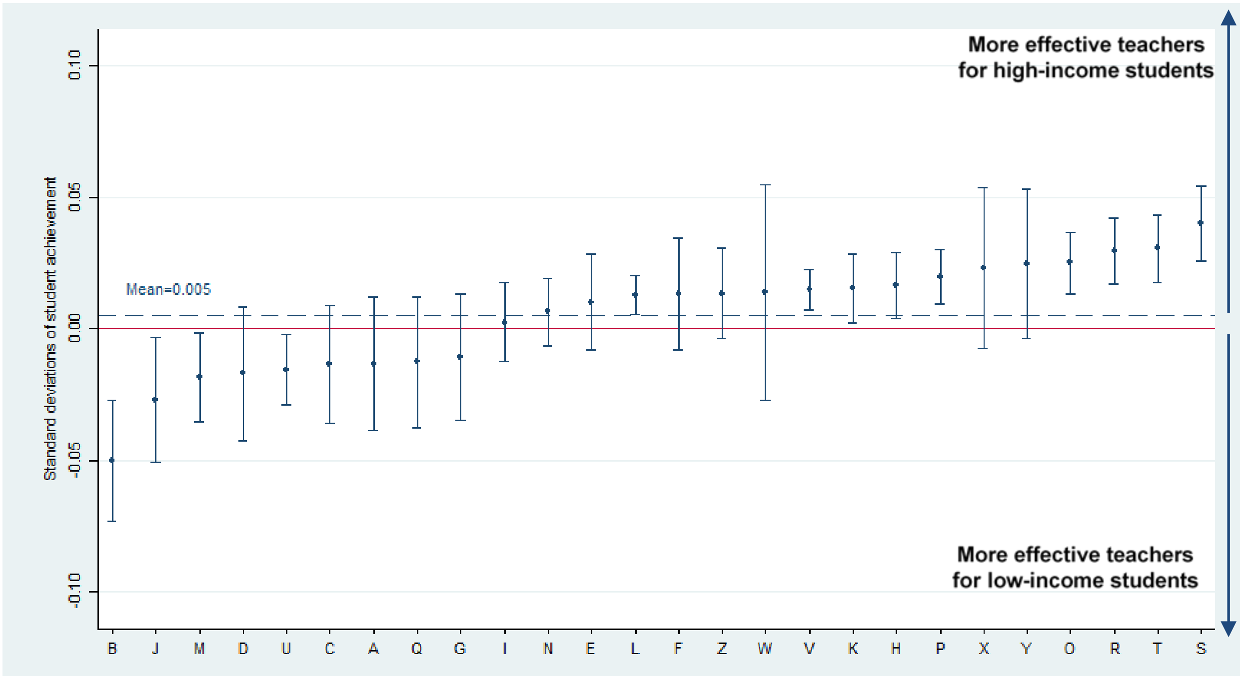
Figure IV.6. Average Effective Teaching Gap in English/language arts, by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). Effective Teaching Gaps are computed within each district-grade-year combination and averaged with equal weight across years within each district. The points represent the district-level Effective Teaching Gaps and the vertical lines show the 95-percent confidence intervals around each point. The cross-district average of 0.005 standard deviations is shown by the dashed horizontal line. To reduce the risk that districts, particularly those with relatively few teachers and students, will receive a very high or very low Effective Teaching Gaps by chance, we applied an empirical Bayes shrinkage procedure to the estimates.

Figure IV.7. Average Effective Teaching Gap in math, by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). Effective Teaching Gaps are computed within each district-grade-year combination and averaged with equal weight across years within each district. The points represent the district-level Effective Teaching Gaps and the vertical lines show the 95-percent confidence intervals around each point. The cross-district average of 0.004 standard deviations is shown by the dashed horizontal line. To reduce the risk that districts, particularly those with relatively few teachers and students, will receive a very high or very low Effective Teaching Gaps by chance, we applied an empirical Bayes shrinkage procedure to the estimates.

We also see larger inequity in a few districts when we examine the likelihood that students have the most or least effective math teachers. In the three districts in math with meaningful inequity, for example, an average of 11 percent of low-income students have one of the least effective teachers in the district, compared with 8 percent of high-income students (see Figures C.5 through C.8 in Appendix C).

Given that low-income students' access to effective teachers varies from district to district, it raises the question of whether certain types of district characteristics are associated with greater inequity. This information might help policymakers identify which districts are more likely to have meaningful inequity. To address this question, we examined the relationship between a district's characteristics and the size of its Effective Teaching Gap.

There are few characteristics policymakers might use to pinpoint the types of districts where meaningful inequity is more likely to exist. Just two characteristics—district size and region—are significantly related to low-income students' access to effective teachers in both math and ELA. Districts that are larger and located in the southern United States tend to have a less equitable distribution of teachers than other districts. These findings are related, as districts in the south tend to be larger than those in other regions.

Low-income students' access to effective teachers is not consistently related to the other district characteristics that we examined, including the student achievement gap, the extent to which high- and low-income students are separated across schools, or the percentage of black, Hispanic, and white students in the district. In ELA, the Effective Teaching Gap is significantly larger in districts with a larger percentage of low-income students and those with a larger percentage of minority students, but these relationships are not significant in math. See Section I of Appendix C for details.

What do other studies find?

There is a growing research literature on low-income students' access to effective teachers and the results of these studies vary. Some studies find that low-income students have less effective teachers than high-income students; others find only small differences in the effectiveness of teachers of high- and low-income students, or that low-income students have more effective teachers than high-income students. However, there are three ways in which the findings of the literature are consistent with the findings presented in this report.

First, several studies that account for classroom characteristics when measuring teacher effectiveness find only small differences in the effectiveness of teachers of high- and low-income students, or that low-income students have more effective teachers than high-income students. Chetty et al. (2014b) find that an increase in family income of $10,000 is associated with an increase in teacher value added of just 0.0008 in a large urban district. Steele et al. (2014) concludes that teachers with more low-income, minority students are more effective than those with fewer of these students, on average across the three school districts and one charter school consortium. Mansfield (2015) finds that differences in access to effective high school teachers in North Carolina account for only 3 percent of the student achievement gap between more and less disadvantaged students. One exception is Sass et al. (2012), who find that teachers in high-poverty elementary schools are less effective than those in low-poverty schools in Florida and North Carolina, with average differences ranging from 0.02 to 0.04 standard deviations of student achievement. The last two studies account not only for differences within a district (like ours) but also of differences between districts. (We examined the issue of whether measuring inequity only *within* districts may have affected the results in Section D of Appendix C by measuring access to effective teaching in five county-wide districts that included urban and suburban areas.) Also, Sass et al. (2012) examine only grades 4 to 5; in the study districts, there are slightly larger Effective Teaching Gaps at grades 4 to 5 than in grades 6 to 8.

Second, most of the studies that find that low-income students have less effective teachers than high-income students measure teacher effectiveness without accounting for the influence of classroom characteristics (Goldhaber et al. 2015, Steele et al. 2015, and Glazerman and Max 2011). When we use a similar approach, our results look more similar—we find an Effective Teaching Gap in study districts of 0.035 in ELA and 0.021 in math, while Goldhaber et al. (2015) finds gaps of 0.035 to 0.037 in ELA and 0.035 to 0.059 in math using data from Washington state. Like Sass et al. (2012), this study measures differences both within and between districts. Steele et al. (2015) use a different approach for measuring inequity, but find less inequity in ELA and math than in science and social studies. Moreover, measuring teacher effectiveness without accounting for classroom characteristics risks confounding a teacher's effectiveness with the environment in which they teach.

Third, prior studies suggest that the level of inequity in students' access to effective teachers varies from district to district. In the four locations they study, Steele et al. (2014) finds differences in teacher effectiveness that favor low-income students in two cases, differences that favor high-income students in one case, and few differences in the other case. Glazerman and Max (2011) also find that their results vary across the 10 districts they study. Finally, to the extent that different studies produce different findings in general, this may reflect not only differences in methodology but also different samples of teachers in different districts and states. See Appendix A for a summary of findings from other studies.

Summary

An examination of low-income students' access to effective teachers in 26 study districts produced two key findings. First, in the average study district, there are small differences in the effectiveness of teachers of high- and low-income students. While individual teachers differ substantially in their effectiveness, both high- and low-income students have a mix of the most effective and the least effective teachers. As a result, providing the two groups of students with equally effective teachers—even over a period of five years—would not substantially reduce the student achievement gap in most study districts.

The second key finding is that in a small number of study districts, there is inequitable access to effective teachers between high- and low-income students in math. In 3 districts in math, the student achievement gap between high- and low-income students would be reduced by a meaningful amount—4 percentile points or more over a period of five years—if the two groups had equally effective teachers.

V. HOW DO TEACHER HIRING, TRANSFER, AND ATTRITION RELATE TO LOW-INCOME STUDENTS' ACCESS TO EFFECTIVE TEACHERS?

Policies designed to improve low-income students' access to effective teachers are often based on the assumption that high-poverty schools have difficulty recruiting and retaining effective teachers. Prior research suggests the presence of teacher hiring and mobility patterns that could potentially lead to greater inequity—for example, high-poverty schools have more turnover and hire more new teachers than low-poverty schools (Goldring et al. 2013, 2014). In this chapter, we examine the relationship between low-income students' access to effective teachers and patterns of teacher hiring, movement between schools in a district, and attrition out of a district.

To understand how teacher hiring, transfer, and attrition patterns might contribute to inequitable access for low-income students, we measured differences between high- and low-poverty schools in (1) the percentage of teachers who experience each type of career transition, and (2) the effectiveness of these teachers. Both of these factors may influence teacher equity. For example, if high-poverty schools have greater attrition, this could lead to greater inequity if the most effective teachers are leaving, but could decrease inequity if the least effective teachers are leaving.

We focus on the following patterns:

- **Hiring.** The percentage of new hires in high-poverty and low-poverty schools, and the effectiveness of teachers hired into high- and low-poverty schools.
- **Transfers**. The percentage of teachers who transfer between high- and low-poverty schools. We compare the effectiveness of teachers who transfer into higher poverty schools and those who transfer into lower poverty schools.
- **Attrition.** The percentage of teachers who leave the district from high- and low-poverty schools. For both high- and low-poverty schools, the effectiveness of leavers are compared to those who stay.

Similar to the previous chapter, the results in this chapter are presented in two parts. We first focus on average patterns across the full sample. For example, we describe the average effectiveness of new hires in high-, medium-, and low-poverty schools across all study districts. These results show how hiring patterns could contribute to inequity on average for all districts. Just as the average Effective Teaching Gap presented in Chapter IV reflected the situation in most study districts, the average patterns presented in this chapter reflect hiring, transfer, and attrition in most study districts.

The second part of the chapter explores variation across districts in hiring, transfer, and attrition patterns. Since the previous chapter showed evidence of meaningful inequity in selected study districts, we also examine whether district-specific patterns of hiring, transfer, and attrition are related to inequity in access to effective teachers at the district level. Therefore, we present the results from a correlational analysis examining whether certain hiring, transfer, or attrition patterns tend to occur in districts with greater (or lesser) inequity in access to effective teachers.

Hiring patterns are consistent with small differences in the effectiveness of teachers of high- and low-income students

Hiring could contribute to low-income students having less effective teachers than high-income students in two ways. First, the amount of hiring by schools could affect the average effectiveness of their teachers. New hires—defined as novice or experienced teachers who are new to a district—tend to be less effective than other district teachers, so schools with more new hires will tend to have less effective teachers than schools with fewer new hires overall. Second, the effectiveness of the teachers that high- and low-poverty schools hire matters as well. Any differences between high- and low-poverty schools in the effectiveness of their new hires could have consequences for low-income students' access to effective teachers. Using data from the study districts, the following section compares the extent of new hires and their effectiveness in high- and low-poverty schools.

Summary of findings for teacher hiring

We find that study schools' hiring patterns likely have a small contribution to inequity in access to effective teachers. High-poverty schools do more hiring and thus have a larger proportion of new hires, and new hires are less effective than continuing teachers. But the likely influence of these patterns on low-income students' access to effective teachers is small for three reasons: (1) the difference in the prevalence of new hires in high- and low-poverty schools is small (and new hires make up a small percentage of the teaching staff in both high- and low-poverty schools); (2) high- and low-poverty schools hire teachers who are similarly effective in their first year in the district; and (3) new hires improve quickly.

New hires are more common in high-poverty schools than in low-poverty schools but make up a small percentage of the teaching staff in both high- and low-poverty schools

Overall, 8 percent of the teachers in study districts (in math and ELA in grades 4 to 8) are newly hired by their districts. The prevalence of new hires varies across study districts, ranging from 2 to 16 percent of teachers (Appendix Figure D.1).[10] Overall, however, most of the teaching staff in study schools—85 to 98 percent—are not new hires.

Although districts hire a mix of novice and experienced teachers, the majority of new hires are novices. Sixty percent of new hires are novices entering their first, second, or third year of teaching.[11] Forty percent of the teachers who are newly hired in the school have at least three years of previous experience in other districts. See Section I of Appendix D for details.

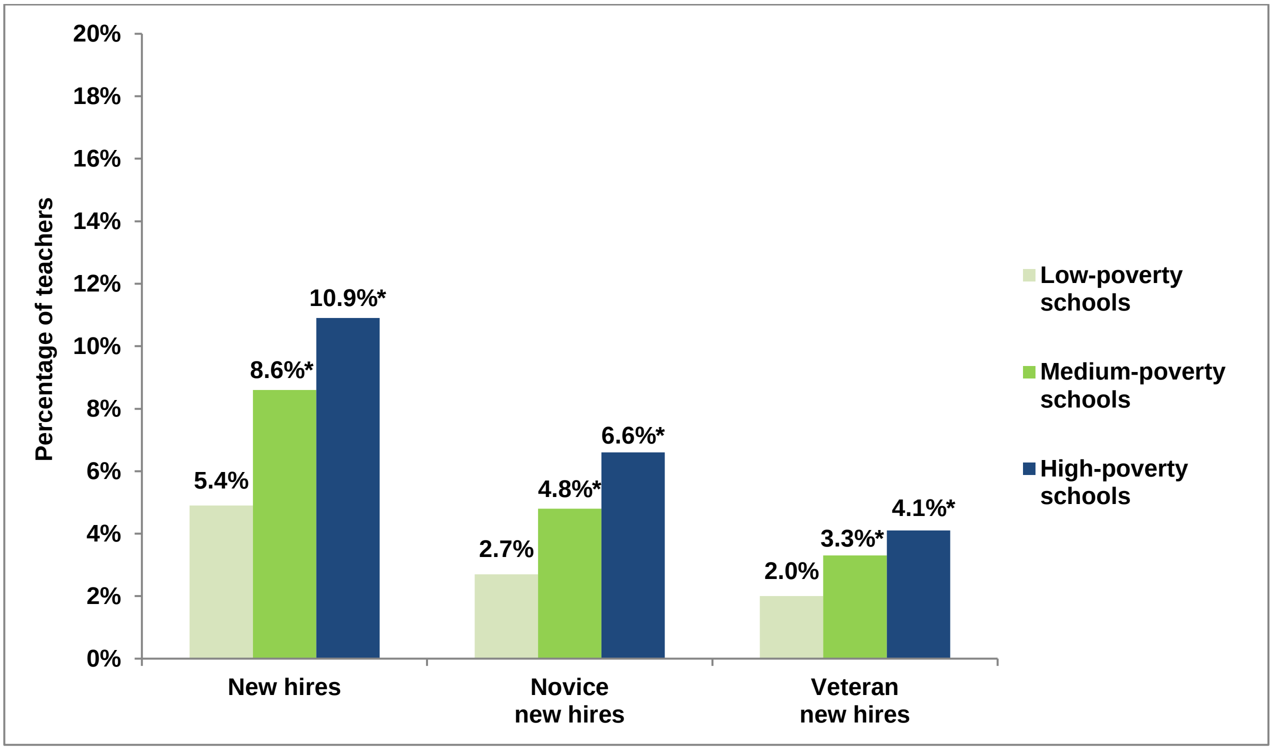
High-poverty schools are significantly more likely than low-poverty schools to hire new teachers. In high-poverty schools, 11 percent of teachers are new hires, compared with 9 percent in medium-poverty schools and 5 percent in low-poverty schools (Figure V.1). This difference in hiring patterns holds for both new hires who are novices and those who are veterans with three or more years of teaching experience. This finding is consistent with existing research, which also

[10] See Section A of Appendix D for a discussion of district-by-district results on hiring, transfer, and attrition.

[11] To measure the proportion of novice and veteran new hires, we excluded nine districts that only provided information on years of experience in the district, because we did not have information on whether new hires in these districts had experience teaching outside the district.

found that novice new hires are more common in high-poverty schools (for example, Boyd et al. 2008b; Kalogrides and Loeb 2013).

Figure V.1. Percentage of new hires by school poverty level



Source: Author's calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 2 through 5. New hires are teachers who were not teaching in the district during the previous school year. The results are presented as an average across districts, weighted by the number of students taught by each teacher in the analysis. The sample contains 114,893 teacher-year observations. There are 39,107 teacher-year observations in the low-poverty category, 41,431 observations in the medium-poverty category, and 34,355 observations in the high-poverty category. The results for novice and veteran teachers exclude five districts that could not provide data on teachers' total teaching experience and also exclude teachers with missing data on experience, reducing the total sample from 114,893 to 105,369 teacher-year observations.

* Indicates whether the percentage of new hires in low-poverty schools is significantly different from the percentage of new hires in medium- or high-poverty schools at the 0.05 level, two-tailed test.

High-poverty schools hire more new teachers than low-poverty schools in most study districts. In 16 of the 25 districts, new hires are more common at higher-poverty schools than at lower-poverty schools by statistically significant amounts (Appendix Figure D.7).

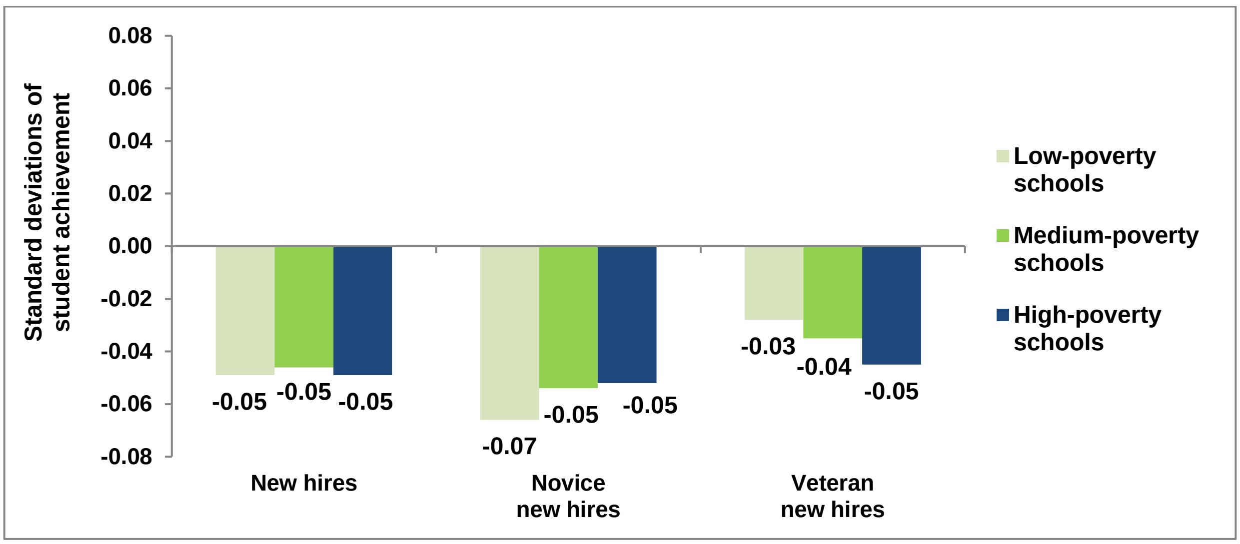
Because new hires are more common in high-poverty schools, this could contribute to low-income students having less effective teachers. The magnitude of such an effect depends on several factors, including how prevalent they are in high- and low-poverty schools, how effective they are in high- and low-poverty schools, and how quickly their teaching improves. As noted above, new hires make up a relatively small percentage of teachers—just over one in ten in high-poverty schools. In the sections that follow, we examine the other factors influencing how patterns of hiring relate to access to effective teachers.

Although new hires are less effective than the average teacher, high- and low-poverty schools hire teachers who are similarly effective

New hires are less effective than the average teacher in a district. The average value added of new hires is -0.05, which implies that their students score 0.05 standard deviations below what they would have if they had an average teacher in the district (who has a value added of zero by definition). A teacher with a value added of -0.05 would be at the 39th percentile of teacher effectiveness. This difference is not solely because new hires tend to have less teaching experience—we found that both novice and veteran new hires are less effective than other district teachers, with an average value added of -0.06 for novice new hires and -0.04 for veteran new hires.

Though new hires tend to be less effective than other district teachers overall, high- and low-poverty schools hire teachers who are similarly effective, on average. New hires have an average value added of -0.05 in their first year in the district whether they go into high-, medium-, or low-poverty schools (Figure V.2). There are no statistically significant differences in new hires' effectiveness across school type for either novice or veteran new hires.[12]

Figure V.2. Value added of new hires by school poverty level, grades 4 to 8



Source: Author's calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 2 through 5. New hires are teachers who were not teaching in the district during the previous school year. The results are presented as an average across districts, weighted by the number of students taught by each teacher in the analysis. The sample contains 116,072 teacher-year observations. There are 39,393 teacher-year observations in the low-poverty category, 41,985 observations in the medium-poverty category, and 34,694 observations in the high-poverty category. The results for novice and veteran teachers exclude five districts that could not provide data on teachers' total teaching experience and exclude teachers with missing data on experience, reducing the total sample from 114,893 to 105,369 teacher-year observations.

* Indicates whether the value added of new hires in low-poverty schools is significantly different from the value added of new hires in medium- or high-poverty schools at the 0.05 level, two-tailed test.

[12] Our results for novice new hires are different from those reported in Xu et al. (2015), which finds that novice teachers with less than two years of experience at high and medium-poverty schools have value added that is between 0.02 and 0.03 standard deviations lower than novice teachers at low-poverty schools, using definitions of low-, medium-, and high-poverty schools and years of experience that are consistent with ours.

New hires at high-poverty schools are about as effective as new hires at low-poverty schools in most study districts. In 18 of 25 districts, the difference in the effectiveness of new hires across different school types is not statistically significant. Of the seven districts in which the difference is significant, new hires are more effective at low-poverty schools in three districts and more effective at high-poverty schools in four districts (Appendix Figure D.8).

Because new hires are similarly effective regardless of the poverty level of the school where they begin teaching, the effectiveness of the teachers hired in the study districts' schools is not likely a major source of inequity in access to effective teachers. The presence of more new hires in high-poverty schools could contribute to inequity because new hires tend to be less effective in their first year than established teachers at a school. However, this contribution would be small because new hires make up a relatively small percentage of all teachers at both high- and low-poverty schools (11 percent and 5 percent respectively) and—as discussed below—new hires improve substantially by their second year when they are nearly as effective as the average teacher.

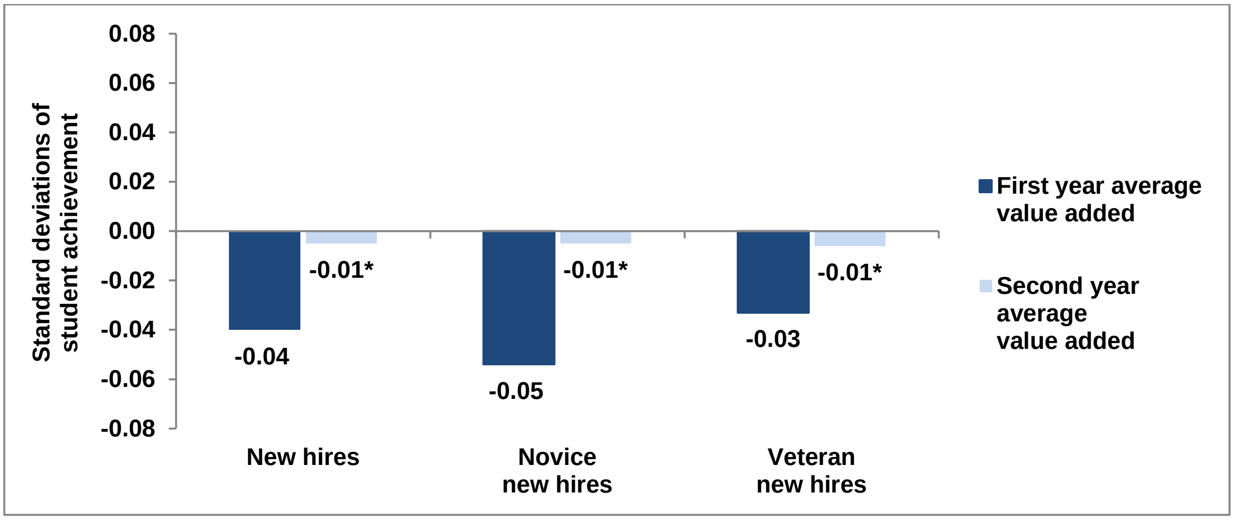
New hires improve quickly

New hires become significantly more effective during their second year in the district than they were in their first. New hires have an average value added of -0.04 in their first year, which is statistically different from zero.[13] In the second year, their average value added increases to -0.01, which is not statistically different from zero. This does not simply reflect novice teachers making strong strides early in their career, as similar results hold for both novice and veteran new hires (Figure V.3).[14] See Section B of Appendix D for more details.

[13] The average value added for new hires in this analysis is slightly different from the new hire average presented in Figure V.2 because the samples of new hires differ. In the analysis of how new hire value added changes from their first to second year, we dropped the new hires for which we did not observe a second year of teaching.

[14] In a separate analysis, we examined teacher development more generally over their careers. Teachers in study districts study improve rapidly during their first few years of teaching. Teachers become more effective over the first three to four years of their career, and then their effectiveness flattens with no significant improvements in effectiveness during the years that follow. Teachers in high-poverty and low-poverty schools improve at similar rates. We found no significant difference in the trajectories of teacher effectiveness over time in schools with different levels of poverty. See Section C of Appendix D for details.

Figure V.3. Value added of new hires in their first two years in the district



Source: Author's calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 2 through 5. New hires are teachers who were not teaching in the district during the previous school year. The sample is restricted to teachers in years 2, 3, and 4 who continued to teach in the next school year. The sample also excludes teachers with missing data on experience and excludes seven districts that could not provide data on teachers' total teaching experience. The results are presented as an average across districts, weighted by the number of students taught by each teacher in the analysis. A total of 48,241 teacher-year observations are included in the sample. The number of teacher-year observations included in the samples for the low-, medium-, and high-poverty categories are 19,208, 16,728, and 12,305, respectively.

* Indicates whether new hires' value added in the first year is significantly different from the second year at the 0.05 level, two-tailed test.

This rapid improvement in the effectiveness of new hires diminishes the extent to which hiring patterns could potentially lead to reductions in low-income students' access to effective teachers. High-poverty schools have more new hires, and these new hires are less effective in their first year than the average teacher. However, by their second year the typical new hire is about as effective as the average teacher in the district.[15]

Teacher transfer patterns are consistent with small differences in the effectiveness of teachers of high- and low-income students

Teacher mobility between schools has the potential to affect low-income students' access to effective teachers in a district. This could occur, for example, if a substantial number of a district's most effective teachers move from high- to low-poverty schools and/or the least effective teachers move in the opposite direction. Although earlier studies have examined teacher mobility between schools (for example, Goldhaber et al. 2011; Feng and Sass 2012; Sass et al. 2012; Xu et al. 2012; Jackson 2013), there is limited evidence on how these patterns might influence low-income students' access to effective teachers. In this section, we compare the extent of teacher mobility in study districts and the effectiveness of these transfer teachers in high- and low-poverty schools.

[15] Similarly, while high-poverty schools tend to have greater proportions of novice teachers than low-poverty schools, the consequences of this difference on inequity are small. For further discussion of this point, see Section J of Appendix D.

Summary of findings for teacher transfers

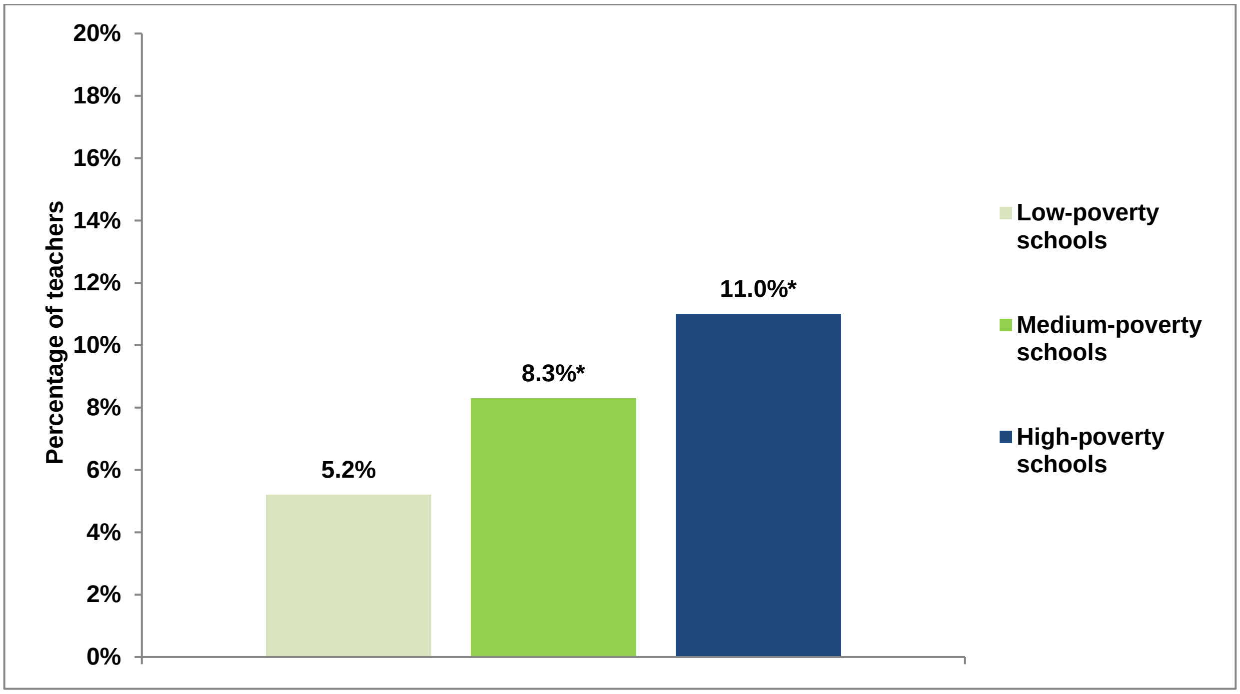
The story of teachers' transfer behavior and how it affects low-income students' access to effective teachers is a nuanced one. Teachers in high-poverty schools are more likely than those in low-poverty schools to transfer to a different school in their district. In addition, teachers who transfer to schools in a lower poverty category are more effective than those who transfer to a higher poverty category (48th percentile compared to 43rd percentile respectively). However, transfer patterns are consistent with a small amount of inequity in access to effective teachers because most teachers transfer to schools with poverty levels similar to their former schools. Just under 4 percent of all teachers transfer to a school in a higher or lower poverty category (a little less than 2 percent from higher- to lower-poverty and less than 2 percent from lower- to higher-poverty). A little more than 4 percent of all teachers—57 percent of teachers who transfer—move between schools with similar poverty rates.

Teachers in high-poverty schools are more likely than those in low-poverty schools to transfer

Overall, about 8 percent of teachers in the study transfer to a different school in the same district from one year to the next. The prevalence of transfers varies by district, ranging from 2 percent to 13 percent in study districts (Appendix Figure D.2).

Teachers in high-poverty schools are more likely than those in low-poverty schools to transfer (Figure V.4). On average, 11 percent of the teachers in high-poverty schools transfer to a different school in the district in a given year, compared with 8 percent in medium-poverty schools and 5 percent in low-poverty schools. This pattern holds in all 25 study districts, with 14 cases statistically significant (Appendix Figure D.9). Other research has found similar patterns of teachers transferring out of high- and low-poverty schools (Hanushek et al. 2004; Sass et al. 2012).

Figure V.4. Percentage of teachers transferring to other schools, by school poverty level



Source: Author's calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 1 through 4. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. The sample contains 110,466 teacher-year observations. There are 39,445 teacher-year observations in the low-poverty category, 41,737 observations in the medium-poverty category, and 29,284 observations in the high-poverty category.

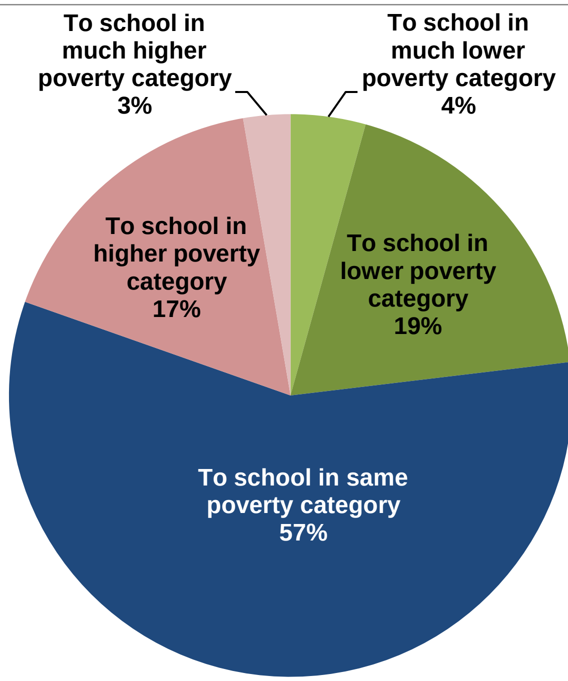
* Indicates whether the percentage of transfers out of low-poverty schools is significantly different from the percentage of transfers out of medium- or high-poverty schools at the 0.05 level, two-tailed test.

Most transfer teachers move to schools with poverty levels similar to their former schools

Despite concerns that many teachers transfer from high-poverty schools to low-poverty schools (Miller and Chait 2008), we found this to be rare in the districts and years we studied. Most transfers—57 percent—move to a school in the same poverty category (Figure V.5); 23 percent move to a school in a lower poverty category, and 20 percent move to a school in a higher poverty category. Because transfers make up 8 percent of teachers overall, this means that just under 2 percent of all teachers (23 percent of 8 percent) transfer to a school in a lower poverty category in a given year. Similarly, just under 2 percent of all teachers transfer to a school in a higher poverty category, while a little more than 4 percent transfer to a school in a similar poverty category.

Some teachers may transfer to schools within the same poverty category, but with a substantially different percentage of low-income students. For example, teachers could move from a school where 60 percent of the students are low-income to a school where 89 percent of the students are low-income; both schools would be classified as medium poverty. However, we did not find this to be the case overall. On average, transfer teachers move to a school where the percentage of low-income students is just 1.7 percentage points lower than their former school (Table V.2). In other words, the typical transfer moves to school with a lower poverty rate, but just barely.[16]

Figure V.5. Percentage of transfers moving to higher, lower, and similar poverty categories



Source: Author's calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 1 through 4. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. The sample contains 7,385 teacher-year observations.

Past research also shows that transfers are more likely to move to schools with lower poverty rates than to schools with higher poverty rates, although the magnitude of this effect varies across studies (Hanushek et al.2005; Scafidi et al. 2007; Clotfelter et al. 2007a; Boyd et al. 2008a; Feng and Sass 2012, and Sass et al. 2012).

Teachers who transfer to schools in a lower poverty category are more effective than those who transfer to a higher poverty category.

The previous section indicates that the most transfer teachers move to schools with a similar poverty level (57 percent of transfer teachers). To understand how teacher transfers could influence low-income students' access to effective teachers, however, it is important to understand the effectiveness of teachers who transfer to lower-poverty schools and those who transfer to higher-

[16] The reason that the typical transfer moves to a school with a similar poverty is not simply because most or all schools in the study districts have similar poverty rates. In the average district, the percentage of low-income students varies across schools from about 19 to 97 percent. The standard deviation of this poverty measure across schools in the average district is 20 percentage points.

poverty schools.[17] Teacher movement between schools could lead to greater inequity if teachers moving from higher- to lower-poverty schools are more effective than teachers moving from lower-to-higher poverty schools. We explored this issue by examining the effectiveness of transfers moving between the school poverty categories. Specifically, we examined the effectiveness of teachers moving to a higher school poverty category (from a low-poverty to a medium- or high-poverty school, and from a medium- to a high-poverty school), and the effectiveness of teachers moving to a lower school poverty category.

Teachers who transfer to schools in a lower poverty category are more effective than those who transfer to a higher poverty category (Table V.1). On average, teachers who transfer to schools in a lower poverty category within a district have value added at the 48th percentile (or -0.007 standard deviations of student achievement). Teachers who transfer to schools in a higher poverty category have value added at the 43rd percentile on average (-0.032 standard deviations of student achievement). In the end, this pattern of teacher transfers could lead to a slight decrease in the average effectiveness of teachers in high-poverty schools.

Table V.1. Difference in the effectiveness of teachers transferring to schools in lower, higher, and the same poverty categories

	Transfer to lower school poverty category	Transfer to same school poverty category	Transfer to higher school poverty category	All transfers
Average value added	-0.007	-0.017	-0.032*	-0.019
Teacher percentile	48th	46th	43rd*	46th

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 25 districts and in grades 4 and 5 in 12 of these districts, for years 1 through 4. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 7,385 teacher-year-grade-subject observations are included in the sample.

*Indicates whether teachers moving to the same poverty category or to a higher school poverty category have value added that significantly differs from that of teachers moving to a lower school poverty category at the 0.05 level.

Another way of looking at the same type of information is to examine the difference in school poverty between the schools that the most and least effective transfer teachers left and the schools they moved into. The most effective transfer teachers (those with value added in the top 20 percent of district teachers) tend to move to slightly lower poverty schools. On average, the most effective transfers move to schools where the percentage of students who qualify for free or reduced-price lunches is 3.4 percentage points lower than in their former schools (Table V.2). The least effective transfer teachers (those in the bottom 20 percent), by contrast, move to schools where the percentage of low-income students is not significantly different from their former school. These findings are consistent with those in Boyd et al. (2008a).[18]

[17] Overall, teachers who transfer tend to be below average in effectiveness, with an average value added significantly below zero (-0.019).

[18] Another way to examine whether teacher transfer patterns are consistent with small differences in access to effective teaching is to examine differences in the value added of teachers who transfer in and out of high-, medium-, and low-poverty schools. We describe these results in Section D of Appendix D.

Table V.2. Difference in poverty rates between the schools that teachers transfer to and from, by teacher effectiveness

	Low value added	Average value added	High value added	Overall average
Average change in the percent of students who receive a free or reduced-price lunch in teacher's school	-0.2%	-1.8%	-3.4%*	-1.7%*

Source: District administrative data

Note: Negative numbers indicate that teachers transfer to lower poverty schools.

The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 1 through 4. This table contains data on the change in school characteristics experienced by teachers who transferred schools within the same district. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. Low and high value-added teachers are teachers in the bottom and top quintile of each district's value-added distribution. Average value-added teachers are teachers in the middle three quintiles of each district's value-added distribution. A total of 7,385 teacher-year observations are included in the sample.

* Changes in the percent of free or reduced-price lunch students in schools teachers transfer in and out of are statistically significant at the 0.05 level, two-tailed test.

Transfer patterns are consistent with a small amount of inequity in access to effective teachers

Teacher transfer patterns are consistent with a small improvement in the average effectiveness of teachers at low-poverty schools and a small decline in the average effectiveness of teachers at high-poverty schools. However, even though there is a flow of less effective teachers to higher poverty schools, and vice versa, this is not likely to have a large influence on low-income students' access to effective teachers overall. As noted, just 8 percent of teachers transfer schools each year and a majority of these transfers go to schools in the same poverty category. Therefore, the difference in value added between teachers transferring to higher and lower school poverty categories will only matter for less than 4 percent of all teachers in a district—those who transfer to a school in a higher or lower poverty category (a little less than 2 percent from higher- to lower-poverty and less than 2 percent from lower- to higher-poverty).

Recent evidence suggests that the movement of teachers in and out of schools may have costs and benefits beyond its effect on how teachers are distributed across schools. For example, one study found that teachers who transfer schools improve their effectiveness, in part because these teachers find better matches for their skill sets in their new schools. Another study found in schools where teachers frequently transfer, the effectiveness of the teachers who remain (the stayers) declines (Ronfeldt et al. 2013).

We examined whether teachers who transferred to different schools improved their effectiveness, to better understand the potential costs and benefits of the transfer process (beyond its influence on how teachers are distributed). We found that teachers' effectiveness did not change significantly after they transferred to a new school, regardless of whether they moved to a higher- or lower-poverty school. This suggests that teacher transfers did not benefit schools by improving the effectiveness of the teachers who transfer. See Section E of Appendix D for details.

Teacher attrition patterns, on average, do not contribute to small differences in the effectiveness of teachers of high- and low-income students

Each year, districts lose teachers who move to another district or leave teaching altogether, whether voluntarily (by transferring out, resigning, retiring, or moving to an administrative role) or involuntarily (by being fired or laid off). There is some concern that high-poverty schools have a higher number of voluntary departures and that they may have difficulty holding on to their most effective teachers, with negative consequences for low-income students. In this section, we examine how frequently high- and low-poverty schools lose teachers through attrition, and describe the effectiveness of those teachers who leave the district.

Summary of findings for teacher attrition

Teachers in high-poverty schools are more likely than those in low-poverty schools to leave the district. On average, teachers who leave the district (the leavers) from both high- and low-poverty schools are less effective than teachers who stay in the district. In other words, all schools tend to lose their less-effective teachers, and high-poverty schools tend to lose more of them. Thus, attrition patterns likely lead to slightly less inequity in access to effective teachers for low-income students.

Teachers in high-poverty schools are more likely to leave the district than teachers in low-poverty schools

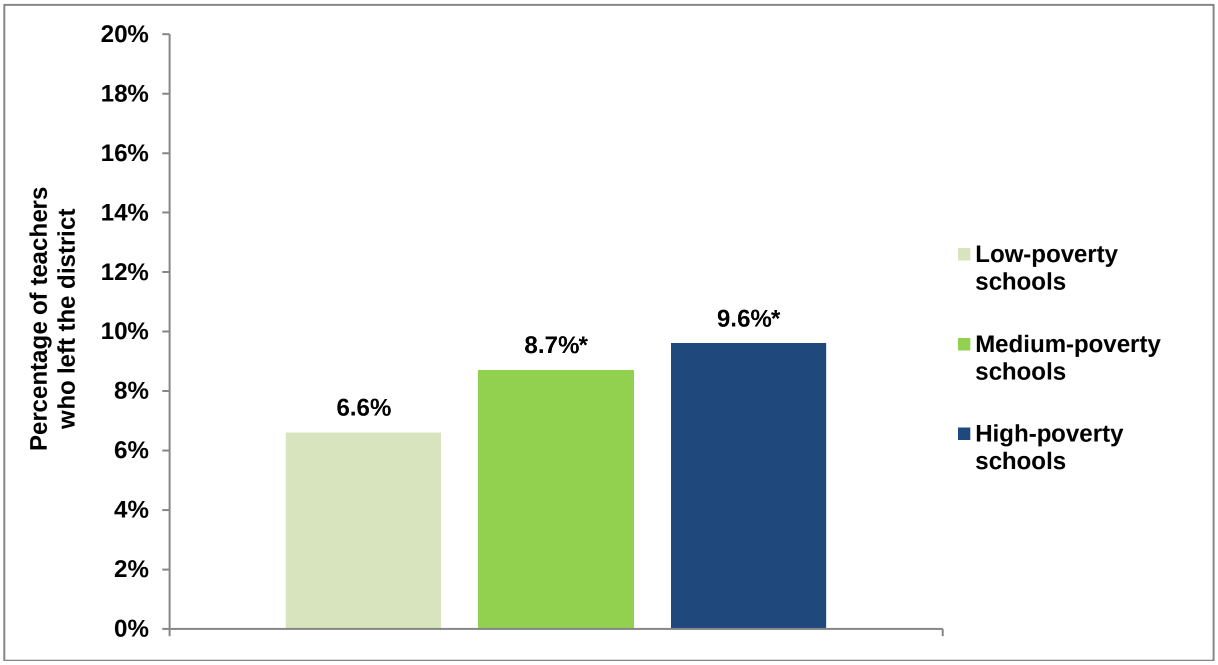
An average of 8 percent of the teachers in our study leave their districts in any given year. As with other types of career transitions, attrition levels vary from one district to another; they range from 4 percent to 17 percent across the study districts (Appendix Figure D.3).

Teacher attrition is more common at high-poverty schools than at low-poverty schools. On average, 10 percent of the teachers at high-poverty schools leave the district in a given year, compared with a significantly lower rate of 7 percent at low-poverty schools (Figure V.6). There were more leavers from high-poverty schools than from low-poverty schools in 16 of 25 districts, with the difference statistically significant in 10 districts. In the other nine districts, there were more leavers from low-poverty schools than from high-poverty schools, with the difference significant in one district (see Appendix Figure D.12). Other studies have also found that attrition is more common at high-poverty schools (Feng 2009; Ronfeldt et al. 2013).

Leavers are less effective than stayers in both high- and low-poverty schools

Teacher attrition could either benefit or harm students, because schools may lose their more effective or less effective teachers. In study districts, teachers who leave the district are less effective than those who stay in their school, on average. The average value added of leavers is significantly lower than that of stayers by 0.03 standard deviations. Leavers are less effective than stayers in most study districts (Appendix Figure D.6), a finding that is consistent with previous research (Goldhaber et al. 2011; Henry et al. 2011; Hanushek and Rivkin 2010; Steele et al. 2015).

Figure V.6. Percentage of leavers by school poverty level



Source: Author's calculations based on district administrative data.

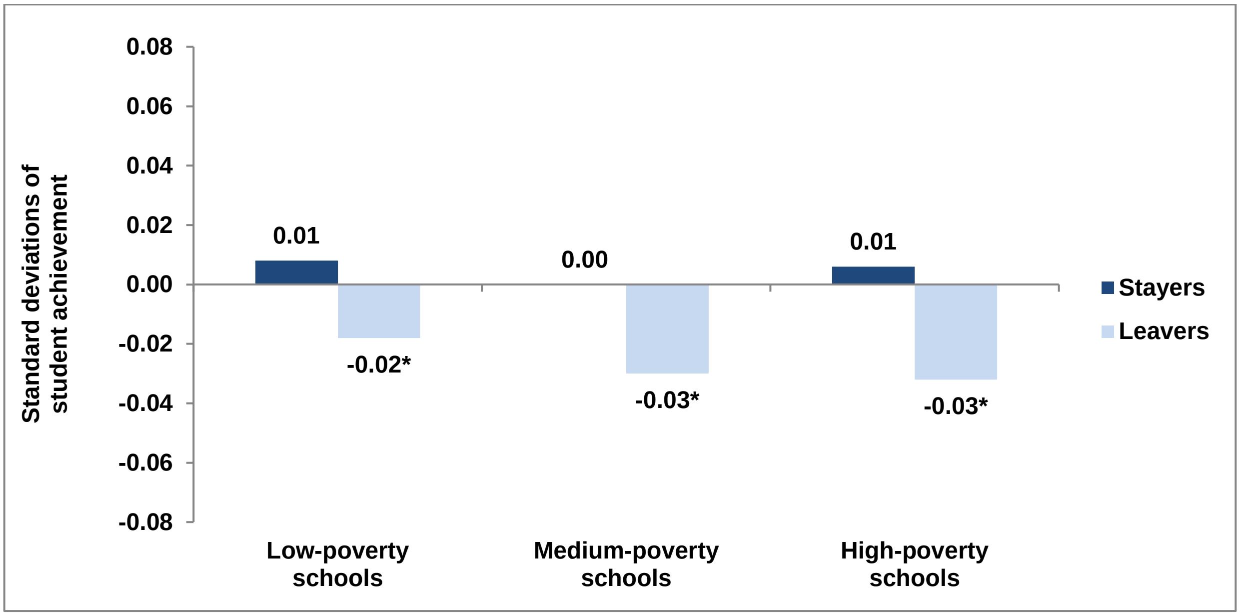
Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 1 through 4. Leavers are teachers who stop teaching in the district. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. The sample contains 110,466 teacher-year observations. There are 39,445 teacher-year observations in the low-poverty category, 41,737 observations in the medium-poverty category, and 29,284 observations in the high-poverty category.

* Indicates whether the percentage of teachers who left low-poverty schools significantly differs from the percentage that left medium-or high-poverty schools at the 0.05 level, two-tailed test.

Leavers are less effective than stayers regardless of school poverty level (Figure V.7). The average value added of leavers is 0.04 standard deviations lower than that of stayers in high-poverty schools, and 0.03 lower in both medium- and low-poverty schools, differences that are not statistically significant. Equivalently, the average leaver from a high-poverty school is at the 43st percentile of effectiveness and the average leaver from a low-poverty school is at the 46rd percentile.[19] These findings are consistent with the literature (Goldhaber et al. 2011; Hanushek and Rivkin 2010; Steele et al. 2015).

[19] We checked whether teachers become less effective in their last year. This could occur if they decrease their effort because they know they will not be back the following year. In study districts, the average value added of leavers decreases by 0.02 during their final year in the district. Because the change in the effectiveness of leavers during their final year did not differ across school poverty categories, however, this does not affect our conclusion that attrition does not contribute to inequity in access to effective teachers. See Section E of Appendix D for details.

Figure V.7. Value added of leavers by school poverty level



Source: Author's calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 1 through 4. Leavers are teachers who stop teaching in the district. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. The sample contains 110,466 teacher-year observations. There are 39,445 teacher-year observations in the low-poverty category, 41,737 observations in the medium-poverty category, and 29,284 observations in the high-poverty category.

* Indicates whether differences between stayers and leavers are statistically significant at the 0.05 level, two-tailed test.

Hiring patterns in individual study districts are correlated with low-income students' access to effective teachers in those districts

The previous sections described patterns of hiring, transfer, and attrition within the average study district. Now we focus on differences between study districts in these patterns, and whether the patterns of a district can explain the level of inequity in access to effective teachers in the district. In particular, we examine whether patterns of hiring, transfer, and attrition within study districts are correlated with the Effective Teaching Gap, our measure of inequity. We have shown that teacher hiring and transfers in study districts are consistent with small differences in inequitable access to effective teachers, on average. However, there are differences between districts in the Effective Teaching Gap and in these patterns. In a small number of study districts, there is meaningful inequity, as low-income students have less effective teachers than high-income students. Understanding which, if any, of the hiring, transfer, and attrition patterns are correlated with the Effective Teaching Gap could suggest which types of policy approaches states and districts might explore for improving equity.

To explore this issue, we estimated a regression model in which a district's Effective Teaching Gap was regressed on a set of variables indicating the district's patterns of hiring, transfer, and attrition. The goal of this analysis was to identify whether certain hiring, transfer, or attrition patterns in districts were associated with greater inequity (that is, larger Effective Teaching Gaps).

This analysis describes the relationship between hiring, transfer, and attrition patterns and inequity, but does not provide information about whether these patterns *caused* inequity in these districts.[20]

The patterns of hiring, transfer, and attrition we examine are the same ones described in the first part of the chapter. For each type of teacher career transition, we examine its prevalence as well as the effectiveness of the teachers involved (new hires, transfers, or leavers). Specifically, we included in the regression three independent variables capturing prevalence—the difference between high- and low-poverty schools in the percentage of all teachers who are (1) new hires, (2) teacher transfers, and (3) leavers. In addition, we included four variables capturing differences between high- and low-poverty schools in the effectiveness of teachers making these career transitions. Two of the variables measure this difference for new hires and leavers. The other two variables focus on transfers, measuring the average difference in school-poverty rate between transfer teachers' new school and former school separately for (1) above-average teachers, and (2) below-average teachers. In other words, these last two variables capture whether more effective transfer teachers tend to move to lower-poverty schools and/or less effective transfer teachers tend to move to higher-poverty schools.

As noted above, we regressed a district's Effective Teaching Gap on each of these measures. Since our measures of hiring, transfer, and attrition involve comparisons between schools (rather than within schools), we used the between-school Effective Teaching Gap in the analysis. This measure used differences in the average effectiveness of teachers at the school level, comparing schools having different percentages of low-income students. In other words, as hiring, transfer, and attrition are all measured at the school level, we also used the between-school ETG because it too is measured at the school level.[21]

A positive correlation between the teacher career transition measure and the between-school Effective Teaching Gap indicates that higher values of the measure are associated with greater inequity. For example, a positive correlation between the prevalence of new hires in high- versus low-poverty schools and the Effective Teaching Gap would suggest that in districts where high-poverty schools have more new hires than low-poverty schools there tends to be a higher Effective Teaching Gap (more inequity).

A negative correlation between the effectiveness of new hires in high- versus low-poverty schools and the Effective Teaching Gap would suggest that in districts where high-poverty schools have less effective new hires than low-poverty schools (the measure is negative) there tends to be a higher Effective Teaching Gap (more inequity). For teacher transfers, we capture effectiveness by measuring whether transfers move to higher-poverty schools or to lower-poverty schools, on

[20] The Effective Teaching Gap depends on both the *prevalence* and the *effectiveness* of new hires, transfers, and leavers. For this analysis, we separately examined the relationship between the Effective Teaching Gap and the prevalence and effectiveness of new hires (as well as transfers and leavers). This approach allows both aspects of hiring behavior to influence the Effective Teaching Gap, but also allows us to separately measure the relationship of each with the Effective Teaching Gap. This is important because the policy implications of the findings will differ depending on whether the Effective Teaching Gap is related to the proportion of new hires, the effectiveness of new hires, or both. If we had estimated a model that simultaneously measured the relationship for the prevalence and effectiveness of new hires (in mathematical terms, the proportion of new hires multiplied by their value added) we would not be able to distinguish the relationship between the amount of hiring in high- versus low-poverty schools or the effectiveness of new hires in each type of school.

[21] See Section B of Appendix B for details of how we calculated the between-school Effective Teaching Gap.

average (a positive value indicates a teacher moved to a higher poverty school, a negative value indicates a teacher moved to a lower poverty school). We measure this change in school poverty separately for transfer teachers with above-average effectiveness and those with below-average effectiveness. All else equal, one would expect more inequity when above-average teachers transfer to lower-poverty schools (that is, when the measure is negative for above-average teachers) and when below-average teachers transfer to higher-poverty schools (when the measure is positive).

Table V.3 summarizes the results of our correlational analysis. For each measure, the table shows that hypothesized direction of the relationship between the measure and a district's Effective Teaching Gap—that is, whether higher values of the measure would be expected to lead to low-income students having less effective teachers (a more positive gap) or more access to effective teachers (a smaller positive gap or a negative gap). The table also indicates whether the estimated correlation is positive and significant, negative and significant, or not significant. Section L of Appendix D presents the details of this analysis.

Table V.3. Correlation between district-specific measures of hiring, transfer, and attrition and the Effective Teaching Gap

Measure	Hypothesized correlation	Estimated correlation	Coefficient Estimate
Prevalence of new hires	Positive	Not significant	-0.008
Prevalence of transfers	Uncertain	Not significant	-0.002
Prevalence of leavers	Negative	Not significant	-0.016
Effectiveness of new hires	Negative	Negative and significant	-0.052*
Effectiveness of transfers: Above-average transfer teachers move to higher-poverty schools	Negative	Not significant	0.051
Effectiveness of transfers: Below-average transfer teachers move to higher-poverty schools	Positive	Not significant	0.028
Effectiveness of leavers	Positive	Not significant	-0.007

Source: Author calculations based on district administrative data.

Note: Table indicates whether each measure is significantly correlated with the between-school Effective Teaching Gap at the 0.05 level. The sample size is 25 districts. Observations are weighted by the number of teacher-year observations in the district that contribute to each summary measure. Districts are excluded if there are fewer than 10 teacher-year observations contributing to the analysis. Coefficient estimates are from a regression of the district's between-school Effective Teaching Gap (Math and ELA combined) on the measures of teacher hiring, transfer, and attrition listed in the leftmost column. See table D.21 in Appendix D for more detailed results.

We find that differences between study districts in the prevalence of new hires, transfers, or leavers are not significantly related to a district's Effective Teaching Gap. In other words, low-income students' access to effective teachers in a given study district is not significantly related to whether or not high-poverty schools experience a greater degree of teacher hiring, transfer, and attrition than low-poverty schools.

However, differences in the effectiveness of new hires between high- and low-poverty schools in a district is significantly related to a study district's Effective Teaching Gap (Table V.3). More specifically, inequity in access to effective teachers is greater (the Effective Teaching Gap is larger) in districts where new hires in high-poverty schools are less effective than those in low-poverty schools. By contrast, when new hires in high-poverty schools are just as effective as or more effective than those in low-poverty schools, the Effective Gap is less positive (or more negative) and low-income students have greater access to effective teachers in the district. By contrast, our measures of the effectiveness of teacher transfers and leavers are not significantly correlated with the Effective Teaching Gap.

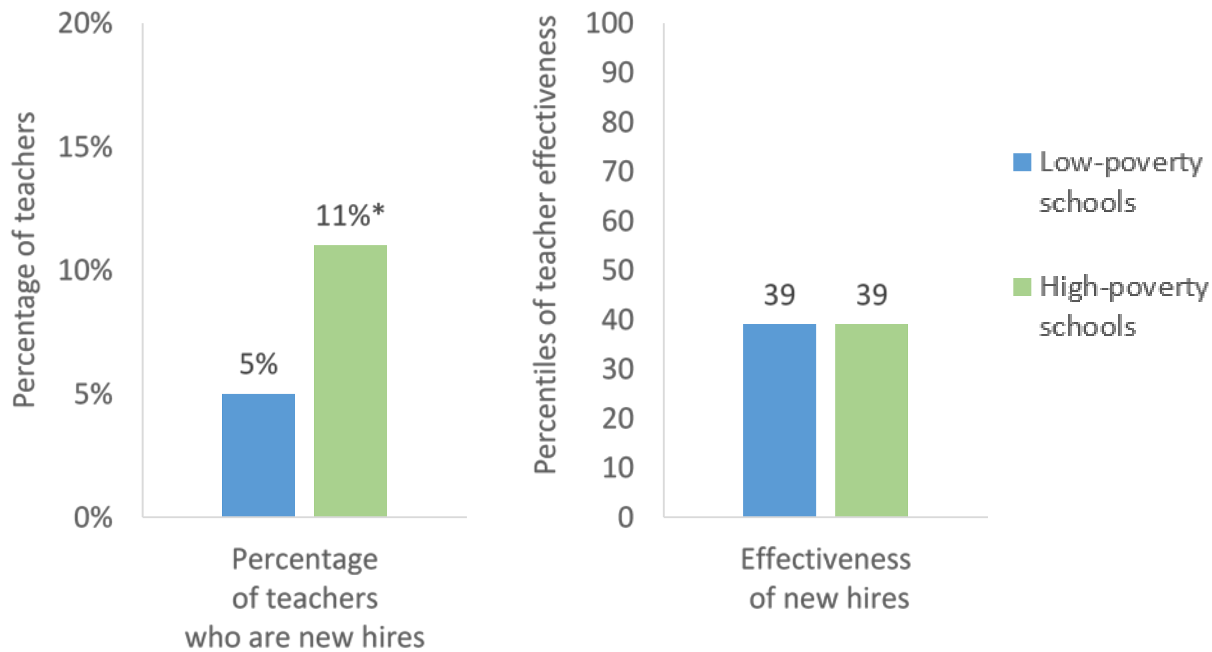
This analysis suggests that there are certain patterns of teacher hiring that—when present in individual study districts—are associated with greater inequity in those districts. In particular, the effectiveness of teachers at the time they are hired is most strongly with a district's Effective Teaching Gap. There tends to be greater inequity in districts where high-poverty schools have less effective new hires than low-poverty schools. This correlation reflects general trends and does not suggest that there is inequity in every district with these hiring patterns.

Summary of teacher hiring, transfer, and attrition analysis

This chapter examines patterns of teacher hiring, transfer, and attrition for districts in our study, with the goal of understanding the implications of these patterns for low-income students' access to effective teachers. Across the full study sample, our findings suggest that patterns of hiring and transfer are consistent with the small differences between high- and low-income students in their access to effective teachers described in Chapter IV. High- and low-poverty schools are similar to one another in terms of the kinds of teachers they hire, the movement of the teachers between schools, and their attrition from the district. Where differences between high- and low-poverty schools do occur, they affect a small percentage of teachers and so do not lead to large differences between high- and low-income students in their access to effective teachers.

In a typical year, high-poverty schools hire more new teachers than low-poverty schools do. As shown in Figure V.8, teachers newly hired to teach in high-poverty schools make up 11 percent of all teachers in those schools, while new hires make up 5 percent of all teachers in low-poverty schools. However, this has a small contribution to inequity for three reasons. First, most teachers in both high- and low-poverty schools are not new hires. Second, the new hires in high- and low-poverty schools turn out to be equally effective in their first year in the school, each at about the 39th percentile for teachers, on average. Third, while new hires tend to be below-average in effectiveness, they improve substantially by their second year and become nearly as effective as the average district teacher.

Figure V.8. Percentage and effectiveness of new hires for low- and high-poverty schools



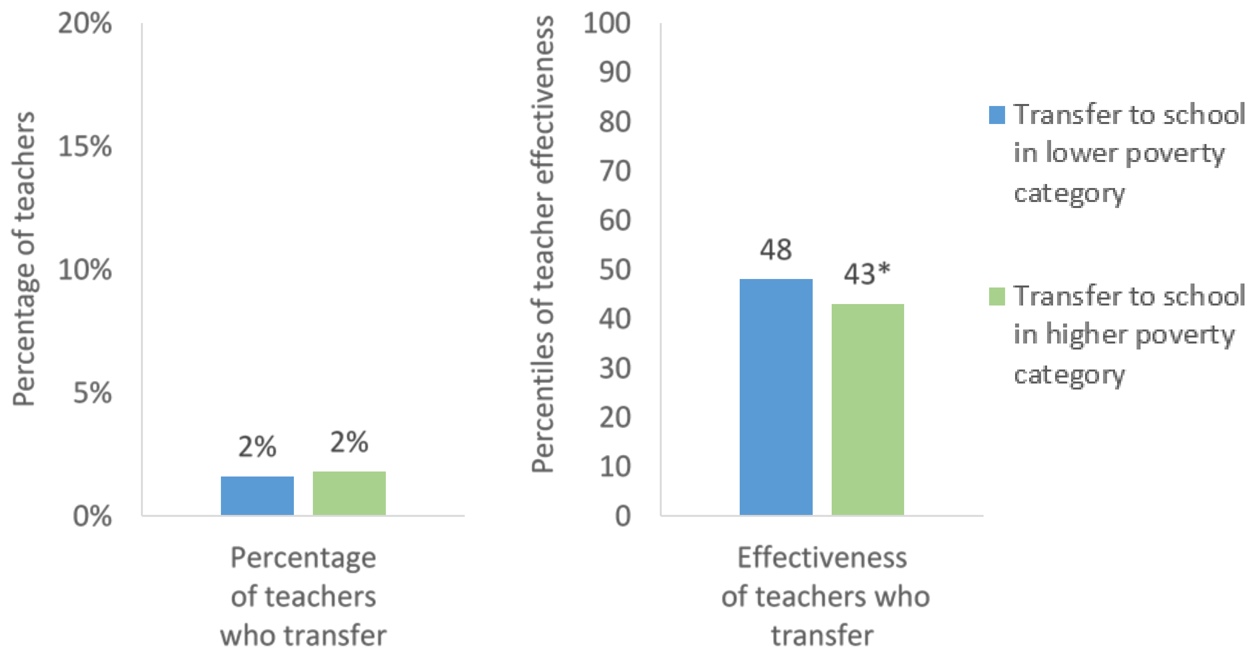
Source: Authors' calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 2 through 5.

* Differences between low- and high-poverty schools are statistically significant at the 0.05 level, two-tailed test.

Across the full study sample, transfers are likely to have only a small influence on low-income students' access to effective teachers. The influence of transfers ultimately depends on (1) how many there are, and (2) how effective the transfers into a school are relative to those who transfer out of the school. As with new hires, transfers are more common at high-poverty schools than low-poverty schools. The teachers who transfer into high-poverty schools (43rd percentile) are slightly less effective than those who transfer out (48th percentile), while the reverse is true for low-poverty schools (Figure V.9). But this movement of less effective teachers into high-poverty schools and more effective teachers into low-poverty schools has a small overall influence on low-income students' access to effective teachers because it involves a small number of teachers.

Figure V.9. Percentage and effectiveness of teachers transferring to schools in lower and higher poverty categories



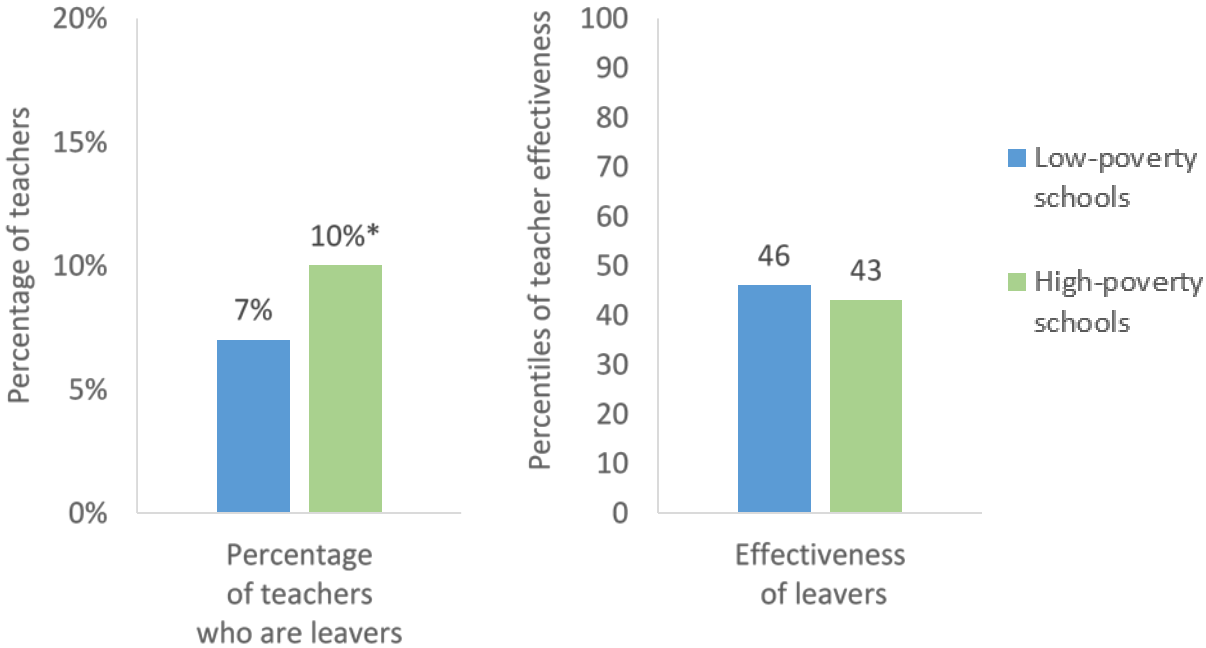
Source: Authors' calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 1 through 4.

* Differences between teachers who transfer to schools in a lower poverty category and those who transfer to schools in a higher poverty category are statistically significant at the 0.05 level, two-tailed test.

Attrition may actually contribute to slightly more equitable access to effective teachers for low-income students in study districts. Teachers lost to attrition in both high- and low-poverty schools are less effective than those who remain teaching in the district (Figure V.10). And there is more attrition from high-poverty schools than from low-poverty schools in the typical district. So attrition disproportionately increases average effectiveness in high-poverty schools because these schools have more leavers than low-poverty schools, although the magnitude of this effect is small.

Figure V.10. Percentage and effectiveness of leavers for low- and high-poverty schools



Source: Authors' calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 1 through 4.

* Differences between low- and high-poverty schools are statistically significant at the 0.05 level, two-tailed test.

Taken together, figures V.8 through V.10 characterize patterns of teacher hiring, transfer, and attrition in the typical study district, based on evidence from the full study sample. Consistent with the finding from Chapter IV, these patterns imply that there is little inequity in low-income students' access to effective teachers in the typical study district.

However, what is true in the typical study district is not necessarily true in each and every study district. Just as some districts have greater inequity than the typical district, some districts may have different patterns of teacher hiring, transfer, and attrition. Thus, we conducted a correlational analysis to measure the relationships between districts' hiring, transfer, and attrition patterns and their Effective Teaching Gap, our measure of low-income students' access to effective teachers.

We found that district-level patterns of teacher hiring are associated with greater inequity in these districts. In particular, inequity in access to effective teachers is greater (the Effective Teaching Gap is larger) in districts where new hires in high-poverty schools are less effective than those in low-poverty schools. By contrast, district-level teacher transfer and attrition patterns are not associated with greater inequity. Nor are differences in the prevalence of new hires, transfers, or leavers related to greater inequity.

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APPENDIX A

SUMMARY OF LITERATURE ON ACCESS TO EFFECTIVE TEACHING AND TEACHER HIRING, DEVELOPMENT, AND MOBILITY

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This appendix provides more detail about studies that have examined low-income students' access to effective teaching and teacher hiring, transfer, and attrition patterns. We provided an overview of these studies in Chapter I, but provide more details about the findings here.

A. Research on access to effective teachers

Studies have used a variety of approaches to measure low-income students' access to effective teachers. We first summarize studies that compare the average effectiveness of the teachers of high- and low-income students (or high- and low-poverty schools). Then we describe studies that examine the likelihood that low-income students (or high-poverty schools) have the most and least effective teachers.

Studies that measure average differences in teacher value added. We identified six studies that measure access to effective teaching by comparing average teacher value added for different groups of students or schools (Table A.1). Each of these studies uses a different approach, making it difficult to compare findings across studies. For example, one study compares average teacher effectiveness for high- and low-income students, another for high- and low-poverty schools, and yet another for students with different levels of family income.

Most of these studies find that the teachers of low-income students and high-poverty schools are less effective on average, but the magnitude of inequity varies across studies.

- The one study that calculated an Effective Teaching Gap found differences of 0.035 in 4th grade (ELA and math combined), 0.037 in 7th grade ELA, and 0.059 for 7th grade math (Goldhaber et al. 2015). These Effective Teaching Gaps differ from our main results in two ways—they are based on a value-added model that excludes classroom characteristics, they account for inequity across districts in addition to inequity between and within schools. The authors found a larger Effective Teaching Gap for 9th grade Algebra (0.092) and a smaller gap for 10th grade reading (0.006).
- A study of a large, urban district reported that a $10,000 increase in parental income is associated with an increase in teacher value added of 0.001 standard deviations of student achievement (Chetty et al. 2014b).
- Steele et al. (2014) examined three school districts and a charter school consortium and found that in two of the districts and the charter school consortium, low-income minority students have more effective teachers, though the differences are modest.
- One study measured differences in average value added between high- and low-poverty schools in Florida and North Carolina (Sass et al. 2012). The authors defined high-poverty schools as those with more than 70 percent of students eligible for a free or reduced-price lunch. The differences in value added range from 0.019 to 0.044 for the two states.
- Mansfield (2015) reported a difference of 0.03 between high schools in the top and bottom poverty quartile in North Carolina. This study combined information across a range of end-of-course tests taken by high school students.
- A study of a large, urban, southern district compared average teacher value added across schools with different proportions of black and Hispanic students (Steele et al. 2015). When comparing schools in the top and bottom quartile based on the proportion of

minority students, differences in average value added are 0.062 in ELA and 0.044 in math. The authors found much larger gaps in science (0.188) and social studies (0.163).

Studies that compare the likelihood of having a highly effective or highly ineffective teacher. Two studies identified the most and least effective teachers based on value added and compared the proportion of high- and low income students or high- and low-poverty schools taught by these teachers (Table A.2).

- Goldhaber et al. (2015) found that low-income students in Washington state are less likely to have the most effective teachers (top 10 percent for value added), and more likely to have the least effective teachers (bottom 10 percent for value added). Differences in the proportion of high- and low-income students taught by these teachers ranged from 2 to 6 percentage points.
- Glazerman and Max (2011) studied 10 large districts in 6 states and found that the highest performing teachers (those in the top 20 percent for value added) are less common in high-poverty middle schools, but equally present in high- and low-poverty elementary schools. For example, 15 percent of math teachers in the highest poverty middle schools were highest performing, compared to 29 percent in the lowest poverty schools.

The value-added model used in some studies does not control for the characteristics of other students in the classroom, and thus may overstate the extent to which low-income students are taught by less effective teachers. The three studies finding the greatest evidence of inequitable access—Glazerman and Max (2011), Goldhaber et al. (2015), and Steele et al. (2015)—used models that did not account for the characteristics of other students in the classroom. When a value-added model does not account for the characteristics of these other students, some differences in student achievement that might arise from the composition of students in the classroom are instead attributed to teachers (Isenberg et al. 2013).

Table A.1. Studies that measure access to effective teaching based on differences in teacher value added

Study	Location	Year	Grades and subjects	Value-added model included classroom characteristics?	Between districts (within a state)	Between schools (within a district)	Between teachers (within a school)	ELA	Math	Combined
Difference in average value added between high- and low-income students (Effective Teaching Gap)										
Goldhaber et al. 2015	Washington		Grade 4	No	X	X	X			0.035
(based on correspondence with authors)			Grade 7	No	X	X	X	0.037	0.059	
			Grade 9, Algebra	No	X	X	X		0.092	
			Grade 10, reading	No	X	X	X	0.006		
Change in value added associated with 20 percentage point decrease in proportion of a teacher's students who are low-income or minority students										
Steele et al. 2014[a]	Aspire Public Schools		Grades 4-8	Yes		X	X	-0.030	-0.027	
	Pittsburgh		Grades 4-8	Yes		X	X	-0.006	-0.016	
	Hillsborough County		Grades 4-8	Yes		X	X	0.000	-0.009	
	Memphis		Grades 4-8	Yes		X	X	0.039	-0.003	
Change in value added associated with $10,000 increase in parental income										
Chetty et al. 2014b	Large, urban district		Grades 4-8	Yes		X	X			0.001
Difference in average value added between low- and high-poverty schools										
Sass et al. 2012[b]	Florida		Grades 4-5	Yes	X	X		0.041	0.019	
	North Carolina		Grades 4-5	Yes	X	X		0.044	0.043	
Mansfield 2015[c]	North Carolina		Grades 9-12	Yes	X	X				0.03
Difference in average value added between schools with low and high proportion of minority students										
Steele et al. 2015[d]	Large, urban district in the south		Grades 4-8	No		X	X	0.062	0.044	0.188 (science) 0.163 (social studies)

[a] We follow the authors' approach of translating the results into the change in value added associated with a 20 percentage point change in the proportion of low-income and minority students taught by a teacher. The authors report the change in value added for a 20 percentage point increase in the proportion of low-income and minority students, but we describe the change for a 20 percentage point decrease to make the results comparable with other studies. Although Steele et al. reported results separately by year, we calculated an equally weighted average across years.

[b] Sass et al. (2012) define high-poverty schools as those with more than 70 percent of students eligible for a free or reduced-price lunch, and low-poverty schools as those with less than 70 percent of students eligible for the benefit.

[c] Mansfield (2015) defines high- and low-poverty schools as those in the top and bottom quintile for the proportion of students eligible for a free or reduced-price lunch. In addition, the study combines the following end-of-course tests: Biology, English 1, U.S. History, Econ/Law/Politics, and Algebra 1, Algebra 2, Geometry, Physics, Physical Science, and Chemistry.

[d] Steele et al. (2015) compare schools in the top and bottom quartile for the proportion of students who are a black or Hispanic.

Table A.2. Studies that measure access to effective teaching based on the likelihood of being taught by one of the most or least effective teachers

Study	Location	Grades and subjects	Value-added model included classroom characteristics?	ELA	Math	Combined
Proportion of students taught by teachers in the top 10% for value added						
Goldhaber et al. 2015	Washington	Grade 4	No			11% high-income students vs. 9% low-income students
		Grade 7	No	12% high-income students vs. 8% low-income students	12% high-income students vs. 7% low-income students	
		Grade 9, Algebra	No			
		Grade 10, reading	No	11% high-income students vs. 9% low-income students	12% high-income students vs. 8% low-income students	
Proportion of students taught by teachers in the bottom 10% for value added						
Goldhaber et al. 2015	Washington	Grade 4	No			11% high-income students vs. 9% low-income students
		Grade 7	No	8% high-income students vs. 12% low-income students	7% high-income students vs. 14% low-income students	
		Grade 9, Algebra	No		8% high-income students vs. 13% low-income students	
		Grade 10, reading	No	9% high-income students vs. 11% low-income students		
Difference in proportion of teachers in low-poverty and high-poverty schools who are in the top 20% for value added						
Glazerman and Max	10 large urban districts	Grades 4-5	No			22% low-poverty schools vs. 19% high-poverty schools
		Grades 6-8	No	32% low-poverty schools vs. 12% high-poverty schools	29% low-poverty schools vs. 15% high-poverty schools	

B. Research on teacher hiring, development, transfer, and attrition

Several studies have examined patterns of teacher hiring, development, transfer between schools, and attrition. We focused on studies that showed how these career transitions differ by school poverty and that use value-added models to measure the effectiveness of new hires, transfers, and leavers. The key findings from these studies are described in the bullets below, and Table A.3 provides more detail about each study.

- **Novice teachers are more common in high-poverty schools than in low-poverty schools.** Many studies find that novice teachers are more common in high-poverty schools than in low-poverty schools (Clotfelter et al. 2007a; DeAngelis et al. 2005; Loeb et al. 2005; Lindsey et al. 2006; Boyd et al. 2008b; Kalogrides and Loeb 2013). Because novice teachers tend to be less effective than experienced teachers (Clotfelter et al. 2007b, Boyd et al. 2008a, Kane et al. 2008, Kraft and Papay 2014, Ladd and Sorenson 2014, Xu et al. 2015), the disproportionate number of novice teachers in high-poverty schools has raised concerns about how this might affect the achievement of low-income students.
- **The rate of teachers' development is similar across high- and low-poverty schools.** The one study we found that showed changes in teachers' effectiveness over time concludes that rates of development are similar for teachers in schools in different poverty categories (Xu et al. 2015). The authors of another study conclude that teachers in schools with more supportive environments (for example, supportive principals, collaboration among teachers, time for professional development) improve faster, and that supportive environments are more common in low-poverty schools, but the authors did not directly address the relationship between school poverty and teacher development (Kraft and Papay 2014).
- Teachers are more likely to transfer out of high-poverty schools than low-poverty schools, but transferring teachers often move to other schools with higher poverty levels and are less effective than those who remain in their school, on average. Studies have consistently shown that teachers are more likely to transfer out of high-poverty schools (Clotfelter et al. 2007a; Scafidi et al. 2007; Boyd et al. 2008b; Feng and Sass 2012; Sass et al. 2012; Xu et al. 2012; Jackson 2013). However, most studies show relatively small differences in the poverty levels of the students in the original school and destination schools. Also, transferring teachers tend to be less effective than those who keep teaching in the same school (Hanushek et al. 2005; Hanushek and Rivkin 2010; Goldhaber et al. 2011; Feng and Sass 2012), so the link between teacher transfers and access to effective teachers is unclear.
- Teachers in high-poverty schools are more likely to leave the district or leave teaching than teachers in low-poverty schools, but these leavers tend to be less effective than the teachers who remain. Most studies have shown that teachers are more likely to leave the district from high-poverty than from low-poverty schools (Shen 1997, Scafidi et al. 2007, Feng 2009, Ronfeldt et al. 2013). Studies have also found that leavers tend to be less effective than teachers who stay at their schools (Hanushek et al. 2005, Boyd et al. 2008a, Henry et al. 2011) and it is high-poverty schools that are most likely to lose their least effective teachers (Hanushek and Rivkin 2010, Goldhaber et al. 2011).

Table A.3. Research on teacher hiring, development, transfer, and attrition

Study	Main findings	Location	Grades and subjects	Years	Additional notes
Barnes et al. (2007)	**Transfer/Attrition** • High-poverty schools in Chicago had higher turnover rates (30 percent) relative to low-poverty schools (24 percent). This pattern held in Milwaukee Public Schools as well, with high-poverty schools having a turnover rate of 19 percent compared to 13 percent at low-poverty schools. The opposite pattern was present in Granville, where high-poverty schools had an average turnover rate of 10 percent compared to 17 percent at low-poverty schools.	Chicago Public Schools, Milwaukee Public Schools, and Granville County Schools	All grades and subjects	2002-2003	Low-poverty schools have less than 50 percent of students eligible for free or reduced-price lunch, whereas high-poverty schools had 75 percent or more students eligible for free or reduced-price lunch. The study includes results for two additional school districts in New Mexico, however there was insufficient variation in school poverty to report results separately for each poverty category.
Boyd et al. (2005)	**Transfer** • Teachers transfer out of low-achieving schools to other schools in the district at a rate of 6.2 percent compared to a rate of 9.7 percent for teachers at high-achieving schools. **Attrition** • Teachers at low-achieving schools are as likely to move to a school in the state but outside the district as teachers at high-achieving schools. The rate of movement out of the district is 2.1 percent at low-achieving schools and 1.5 percent at high-achieving schools. • Teachers in New York City public schools exit teaching at a higher rate from low-achieving schools than from high-achieving schools. The exit rate is 14.1 percent from low-achieving schools and 7.3 percent at high-achieving schools.	New York City	Elementary school teachers	1995–1996 through 2003–2004	Study includes data for all teachers in New York state, but examines teaching decisions in New York City; analysis limited to teachers with zero to four years of prior teaching experience. The results are based on simulations using parameter estimates from a multinomial logit model of teacher mobility decisions. High-achieving schools are those in the 2nd decile of a composite measure of student achievement. Low-achieving schools are those in the 9th decile.
Boyd et al. (2008a)	**Transfer** • Math teachers who transfer move to schools with lower poverty levels. Net of regression to the mean, teachers who transfer see an average decrease of 1.5 percentage points in the percentage of students eligible for free or reduced-price lunch at the school. • More effective math teachers who transfer see larger declines in school poverty relative to less effective teachers who transfer. Net of regression to the mean, transfers in the bottom quartile of the value-added distribution see	New York City	Math and ELA, grades 4–8	1999–2000 through 2005–2006	Study includes only teachers with zero to two years of prior teaching experience.

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
	increases of 0.7 percentage points in percentage of students eligible for free or reduced-price lunch. Transfers in the top quartile of the value-added distribution see an average decrease of 1.8 percentage points, while transfers in the middle two quartiles see an average decrease of 4.1 percentage points. • Transfer patterns for ELA teachers are not presented. **Attrition** • In math, less effective teachers are more likely to leave teaching than more effective teachers. Among first-year math teachers in grades 4 to 5, the attrition rate of low value-added (bottom quartile) teachers is approximately 8 percent compared to an attrition rate of approximately 4.5 percent for high value-added (top quartile) teachers. • For ELA teachers, there is no strong relationship between effectiveness and the likelihood of attrition.				
Boyd et al. (2008b)	**Hiring** • In 2000, 25 percent of teachers in the highest-poverty schools had less than two years of prior teaching experience compared to 15 percent of teachers in the lowest-poverty schools. In 2005, 22 percent of teachers in the highest-poverty schools had less than two years of prior teaching experience compared to 15 percent in the lowest poverty schools.	New York City	Math and ELA, grades 4–8	1999–2000 through 2005–2006	Highest- and lowest-poverty schools are those at the 90th and 10th percentiles for poverty. Experience is defined as years teaching in the New York City public school system.
Clotfelter et al. (2005)	**Hiring** • In math and ELA, Black students are more likely than their White counterparts to have a teacher with no experience. The probability that a typical Black 7th grade student has a math teacher with no prior experience is 0.128 compared to a probability of 0.083 for a typical White 7th grade student. • Exposure to a teacher with no experience is driven by within-district differences in teacher assignment rather than across-district differences.	North Carolina	Math and ELA, grade 7	2000–2001	

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
Clotfelter et al. (2007a)	**Hiring** • In 2004 high-poverty schools had a higher proportion of teachers with less than three years of experience than low-poverty schools. Across all grade levels, 17 to 25 percent of teachers in high-poverty schools had less than three years of experience, compared to a range of 13 to 15 percent of teachers in low-poverty schools. • Across all grade levels, 23 to 27 percent of teachers at high-poverty schools are new teachers, compared to 18 to 21 percent at low-poverty schools. Among new teachers at high-poverty schools, between 30 and 35 percent of them had no prior teaching experience, compared to between 25 and 26 percent of new teachers with no prior teaching experience at low-poverty schools.	North Carolina	All grades and subjects	1995–1996 through 2003–2004	High-poverty schools are those in the top quartile of the state school poverty distribution. Low-poverty schools are in the bottom quartile of the distribution. The authors define a "new teacher" as a teacher who is teaching for the first time at a given school. This definition includes both teachers who are new to the district and teachers who transferred from one school to another in the district.
	Transfer • Between 1999 and 2004 in elementary and middle school, teachers who transfer on average experienced a decrease of 1.3 to 1.5 percentage points in the number of students eligible for free or reduced-price lunch at their new school. • In high school, teachers who transfer on average experienced an increase of 0.7 percentage points in the number of students eligible for free or reduced-price lunch at their new school.				
Cook (2011)	**Transfer** • A 25 percentage point increase in the proportion of students eligible for free or reduced-price lunch is associated with an increase of 0.55 percentage points in the probability that a teacher will transfer to another school within the district. **Attrition** • A 25 percentage point increase in the proportion of students eligible for free or reduced-price lunch is associated with an increase of 0.2 percentage points in the probability that a teacher will move to a school	North Carolina	All grades and subjects	1995–2007	The results are based on a simulated model of teacher mobility decisions.

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
	outside the district and an increase of 0.2 percentage points in the probability that a teacher will leave teaching.				
DeAngelis et al. (2005)	**Hiring** • In Illinois, 18 percent of teachers in the median high-poverty school had less than four years of experience, compared to 17 percent in the median low-poverty school. • In Chicago, 18 percent of teachers in the median high-poverty school had less than four years of experience, compared to 14 percent in low-poverty schools.	Illinois	All grades and subjects	2002–2003	High-poverty schools are those with a school poverty rate in the highest quartile, and low-poverty schools are those in the lowest quartile. For the Illinois analysis the state distribution is used to determine the poverty quartiles, whereas for the Chicago analysis the district distribution is used to determine the poverty quartiles.
The Education Consortium for Research and Evaluation (2013)	**Transfer** • At low-poverty schools, 3.8 percent of teachers transferred to a new school in the district compared with 7.5 percent of teachers at medium-poverty schools and 6 percent of teachers at high-poverty schools. • Teachers transferring out of medium- and high-poverty schools were less effective than teachers transferring out of low-poverty schools.	Washington, DC	All grades and subjects	2009–2010 and 2010–2011	Low-poverty schools are defined as those that have fewer than 60 percent of students eligible for free or reduced-price lunch. Medium-poverty schools have between 60 and 80 percent of students eligible for free or reduced-price lunch. High-poverty schools have more than 80 percent of students eligible for free or reduced-price lunch.
	Attrition • At low-poverty schools, 13.2 percent of teachers left teaching in the district compared with 9.2 percent of teachers at medium-poverty schools and 32.4 percent of teachers at high-poverty schools. • Teachers leaving teaching from medium- and high-poverty schools were less effective than teachers leaving from low-poverty schools.				
Elfers et al. (2006)	**Transfer/Attrition** • Teachers were more likely to move out of schools or exit teaching from schools with higher poverty rates. The correlation between the probability of staying at the same school and school poverty rate ranged between -0.11 and -0.49 across three urban and three suburban districts.	Washington State	All grades and subjects	1996–1997 through 2002–2003	The study analyzed total transfer and attrition rates over a five-year span.

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
Eller et al. (2000)	**Transfer/Attrition** • Higher poverty schools have higher teacher turnover rates relative to lower poverty schools.	Texas	All grades and subjects	1994–1995 through 1997–1998	Includes all districts with more than 1,000 students in Texas. The authors do not state whether their measure of turnover includes just leavers or both transfers and leavers.
Feng (2009)	**Transfer** • Teachers with higher fractions of poor and minority students are more likely to transfer to another school. **Attrition** • Teachers with higher fractions of poor and minority students are more likely to leave teaching.	Florida	All grades and subjects	1997–1998 through 2003–2004	Analysis sample limited to new teachers with no prior experience in Florida public schools. The author includes both school-level and classroom-level average student characteristics and finds the classroom-level averages to be stronger predictors of teacher mobility.
Feng and Sass (2012)	**Transfer** • Teachers who transfer are less effective than those who remain in their schools. Across subjects and teacher quality measures, the average value added of teachers who transfer ranges from -0.01 to -0.03 standard deviations compared to an average value added ranging from 0.00 to 0.03 for stayers. • Teachers who transfer are more likely to move to schools with lower poverty levels and fewer minority students. On average, teachers who transfer see a decrease of approximately 9 percentage points in the percentage of students eligible for free or reduced-price lunch.	Florida	Math and ELA, grades 4–10	2000–2001 through 2003–2004	
	Attrition • For both math and ELA, teachers in the top and bottom quartiles of teacher effectiveness are more likely to leave teaching than those in the middle quartiles.				
Goldhaber et al. (2011)	**Transfer** • More effective teachers are less likely to transfer to another school than less effective teachers. The likelihood of female teachers transferring to another school within the district decreases by 11 percent when teacher value added increases by one standard deviation.	North Carolina	Math and ELA, grades 4–6	1996–2002	

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
	Attrition • Less effective teachers are more likely to leave teaching relative to more effective teachers. The likelihood of female teachers leaving the district to teach in another North Carolina district decreases by 12 percent when teacher value added increases by one standard deviation. The likelihood of female teachers leaving teaching in North Carolina decreases by 22 percent when teacher value added increases by one standard deviation. • The effectiveness of teachers who leave to teach in another district decreases in their last year of teaching relative to prior years but this does not happen for teachers who leave teaching in North Carolina.				
Gritz and Theobald (1996)	**Attrition** • For female teachers with three to nine years of experience, teaching in a district with a higher percentage of minority students is associated with a higher probability of leaving teaching in the district.	Washington State	All grades and subjects	Year of teaching entry through 1991–1992	Includes White teachers who began their teaching careers during 1981–1990.
Hanushek et al. (2004)	**Transfer** • Teachers are more likely to transfer out of high-poverty schools. Seven percent of teachers in the highest quartile of school poverty transfer each year compared to 5.7 percent of teachers in the lowest quartile of school poverty. **Attrition** • Teachers are equally likely to exit public schools from high- and low-poverty schools. The attrition rate is 7.3 percent from schools in the highest quartile of school poverty compared to 7.2 percent from schools in the lowest quartile of school poverty. • Teachers are more likely to transfer to another school district from a high-poverty school compared to a low-poverty school. The rate of out-of-district moves was 4.2 percent from schools in the highest quartile of school poverty compared to 3.2 percent from schools in the lowest poverty quartile.	Texas	All grades and subjects	1993–1994 through 1995–1996	

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
	• Teachers with up to nine years of experience who transfer to another school district move to schools with 5.8 percent fewer students eligible for free or reduced-price lunch, on average. • Attrition is higher among teachers in their first two years of teaching. They are twice as likely as teachers with 11 or more years of teaching experience to exit teaching and four times as likely to change districts.				
Hanushek et al. (2005)	**Transfer** • Teachers who transfer to another school within the district are significantly less effective than those who remain in their school. The difference between the average value added of teachers who transfer and of teachers who stay ranges from -0.05 to -0.09 across specifications. • Teachers who transfer tend to move to schools with fewer students eligible for free or reduced-price lunch. Transfers see an average decrease in school poverty of 4.7 percentage points. **Attrition** • Teachers who exit teaching are less effective on average than those who remain. The difference between the average value added of teachers who exit and teachers who stay ranges between -0.04 and -0.10 across specifications. • Teachers who leave teaching show decreases in effectiveness during their last year relative to previous years. The difference in effectiveness is approximately 0.06 standard deviations.	Large urban district in Texas	Math, grades 4–8	1995–1996 through 2001–2002	
Hanushek and Rivkin (2010)	**Transfer** • Teachers who transfer to another school within the district are significantly less effective than those who remain in their school. The difference in average value added is equal to 0.048 standard deviations. • Teachers leaving schools with low-achieving students or high percentages of minority students have lower value added than teachers	Large urban district in Texas	Math, grades 4-8	1995–1996 through 2001–2002	

Study	Main findings	Location	Grades and subjects	Years	Additional notes
	leaving schools with high-achieving students or low percentages of minority students.				
	Attrition • Teachers who exit teaching in Texas are less effective on average than those who remain. The average value added of teachers who exit is 0.058 standard deviations lower than the average value added of teachers who remain. Teachers who exit teaching in the district to move to another district in Texas are 0.019 standard deviations more effective on average than teachers who remain. • There is no statistically significant difference between the value added of teachers who leave schools with high percentages of minority students and teachers who leave schools with low percentages of minority students. The same result is obtained when comparing teachers of low-achieving and high-achieving students.				
Harrington and Grissom (2010)	**Attrition** • In 2006, 16 percent of teachers in Missouri moved to another school or left teaching. This turnover rate has been increasing over time, starting at 13 percent in 1992. • In 2006, 7 percent of teachers left teaching, 8 percent moved to another school either in the same district or in a new district, and 1 percent moved to a non-teaching position. • Teacher turnover in districts surrounding urban districts is lower than turnover in the urban districts.	Missouri	All grades and subjects	1992–1993 through 2006–2007	Statewide analysis that includes district-specific results. Classifies teachers in four groups: stayers (stay in the same school), movers (change schools), leavers (leave teaching in Missouri), and others (transition to non-teaching roles)
Henry et al. (2011)	**Hiring** • Teacher effectiveness increases significantly during the second year of teaching. This increase ranges between 0 and 0.03 across grade levels and subjects. • For teachers who continue to teach for five years, their effectiveness does not increase significantly after the third year of teaching. **Attrition** • New teachers who leave teaching after the first year are less effective than other new teachers.	North Carolina	Math and ELA, upper elementary through high school grades	2004-2005 through 2008-2009	The analysis sample is limited to teachers in their first five years of teaching.

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
	The difference in effectiveness ranges between 0 and 0.04 across grade levels and subjects. • Teachers who leave in their third or fourth years are less effective than teachers who continue to teach into their fifth year. The difference in effectiveness ranges between 0 and 0.04 across grades and subjects. • Teachers who leave teaching show decreases in effectiveness during their last year relative to the previous year. The difference in effectiveness ranges between -0.01 and 0.03 across grade levels and subjects.				
Ingle (2009)	**Transfer** • There is no significant relationship between teacher value added and the likelihood that a teacher will transfer. Transfers are defined as teachers moving to a different classroom in the district, meaning that teachers who stay in the same school but teach a different grade or subject are counted as transferring. **Attrition** • Teachers are more likely to leave from high-poverty schools relative to low-poverty schools. Leavers are defined as teachers who no longer teach in a tested grade or subject in the district. Teachers who stay in the same school but move to a non-tested grade and subject are counted as leavers. • In ELA, teacher with lower value added are more likely to leave. There is no significant relationship between value added and the likelihood of a teacher leaving in math.	Medium-sized urban district in Florida	Math and ELA, grades 3 through 10	2000–2001 through 2004–2005	High-poverty schools are those with 50 percent or more students eligible for free or reduced-price lunch. Low-poverty schools are those with fewer than 50 percent of students eligible for free or reduced-price lunch.
Imazeki (2005)	**Attrition** • Male teachers who teach larger fractions of minority students are more likely to leave the district or exit teaching compared to males who teach small fractions of minority students. There is no statistically significant relationship between these variables for female teachers.	Wisconsin	All grades and subjects	1992–1993 through 1997–1998	Sample includes only teachers who became full-time teachers in Wisconsin public schools during the specified timeframe. The study followed teachers through their time in the school system or until 1998–1999. Transfer is defined as moving to a different district in the state.
Ingersoll (2001)	**Transfer**	Nationwide	All grades and subjects	1991–1992	High-poverty schools are those with 50 percent or more students eligible for free or reduced-price lunch. Low-

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
	• Approximately 9 percent of teachers transfer out of high-poverty schools compared with 6 percent at low-poverty schools. Transfers include teachers moving both within and across districts. **Attrition** • Approximately 6 percent of teachers exit teaching from high-poverty schools compared with 5 percent of teachers from low-poverty schools.				poverty schools are those with fewer than 15 percent of students eligible for free or reduced-price lunch.
Ingersoll and May (2012)	**Transfer** • The majority of math and science teachers who transferred from high-poverty moved to schools with similar poverty levels. The percentage of transfers from high-poverty schools transferring to low-poverty schools was similar to the percentage of transfers from low-poverty schools moving to high-poverty schools. However, because there were many more transfers from high-poverty schools, approximately 4 times as many teachers transferred from high- to low-poverty schools as moved in the reverse direction. **Transfer/Attrition** • After accounting for other teacher and school characteristics related to teacher turnover, the authors find that teachers in high-poverty schools are more likely to transfer or exit teaching. A 10 percentage point increase in the proportion of students eligible for FRL was associated with a 2 to 5 percent increase in the likelihood of teacher turnover, depending on the model specification.	Nationwide	All grades and subjects	2003-2004	Low-poverty schools have less than 29 percent of students eligible for free or reduced-price lunch, whereas high-poverty schools had more than 57 percent of students eligible for free or reduced-price lunch. The study bases results on differences across schools nationwide rather than focusing on within-district comparisons. Data are from the 2004–2005 Teacher Follow-up to the 2003–2004 School and Staffing Survey.
Jackson (2013)	**Transfer** • Teachers who transfer to another school (both within and across districts) on average experience a 3.8 percentage point decrease in the percentage of students eligible for free or reduced-price lunch. • Teachers who transfer schools on average experience an increase in value added in their new school.	North Carolina	The author estimates teacher value-added models but does not explicitly state the grades and subjects included	1995–2006	

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
Kaiser (2011)	**Attrition** • Among teachers who began teaching in 2007–2008, 14.1 percent of those teaching at high-poverty schools left teaching by 2009–2010 compared with 10.6 percent of teachers at low-poverty schools.	Nationwide	All grades and subjects	2007–2008 through 2009–2010	Low-poverty schools are those with less than 50 percent of students eligible for free or reduced-price lunch. High-poverty schools are those with 50 percent or more students eligible for free or reduced-price lunch.
Kalogrides and Loeb (2013)	**Hiring** • Within schools, disadvantaged students are more likely to be taught by a teacher in their first or second year than non-disadvantaged students. • In elementary school grades, free and reduced-price lunch students are on average between 0.4 and 4.7 percentage points more likely to be taught by a teacher in their first or second year, depending on the specification and district analyzed. • In middle and high school grades, free and reduced-price lunch students are on average between 0.8 and 3.5 percentage points more likely to be taught by a teacher in their first or second year, depending on the specification and district analyzed.	Miami-Dade County Public Schools (MDCPS), Milwaukee Public Schools (MPS), and San Francisco Unified School District (SFUSD)	All grades and subjects	MDCPS and MPS: 2003–2004 through 2009–2010; SFUSD: 2001–2002 through 2009–2010	
Keigher (2010)	**Transfer** • The rates of teacher transfers out of low- and high-poverty public schools were 5.9 and 10.3 percent, respectively. Transfers include teachers moving within and across districts. **Attrition** • The rates of teacher exits from low- and high-poverty public schools were 7.6 and 5.1 percent, respectively.	Nationwide	All grades and subjects	2008–2009	Low-poverty schools are those with 34 percent or fewer students eligible for free or reduced-price lunch. High-poverty schools are those with 75 percent or more students eligible for free or reduced-price lunch.
Kelly (2004)	**Transfer/Attrition** • Teachers who voluntarily choose to stop teaching at their current school are equally likely to do so at high- and low-poverty and high- and low-minority schools after controlling for whether a school is designed for students with behavioral problems, urban/rural location, census region, and school size. Involuntary	Nationwide	All grades and subjects	1991–1992	The study bases results on differences across schools nationwide rather than focusing on within-district comparisons. Data are from the 1992 Teacher Follow-up to the 1990–1991 School and Staffing Survey.

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
	transfers/leavers (10 percent of the initial sample) were excluded from the analysis.				
Kraft and Papay (2014)	**Development** • Teachers at schools with less supportive professional environments develop at slower rates. After 10 years, teachers working in schools at the 75th percentile in terms professional environment ratings grew in effectiveness 38 percent more than teachers at schools in the 25th percentile. • Higher poverty schools tend to have less supportive professional environments.	Charlotte-Mecklenburg Schools in North Carolina	Math grades 4 through 8	2000-2001 through 2009-2010	The measure of professional support is derived from a working conditions survey administered to teachers in 2006, 2008, and 2010.
Krieg (2004)	**Attrition** • In Math, Reading, Writing, and Listening, Female teachers who exit teaching have significantly lower value-added than female teachers who continued to teach in the following year. The difference in average value-added between stayers and leavers ranged between 0.066 and 0.111 across subjects. Male leavers had an average value added that was also lower than stayers in all four subjects. The difference ranged between 0.049 and 0.062, and was only statistically significant in Listening.	Washington State	Math and ELA, grade 4	2001-2002	
Lankford et al. (2002)	**Transfer** • Teachers who transfer typically leave schools with high poor and minority student populations. In New York State, teachers who transfer within a district see decreases in the amount of students eligible for free or reduced-price lunch of 4.3 percentage points. In the New York City metropolitan area, this difference is 5.8 percentage points. **Attrition** • In the New York City metropolitan area, urban districts have higher teacher turnover rates than suburban districts. In urban districts, the five-year attrition rate is 35 percent compared to 25 percent in suburban districts.	New York	All grades and subjects	1984–1985 through 1999–2000	Examined teachers in the system during the 1999–2000 school year
Lindsey et al. (2006)	**Hiring**	Milwaukee Public Schools	All grades and subjects	2005–2006	The report does not clearly state what grades and subjects and years of data

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
	• Teachers with three or fewer years of experience are more prevalent at high-poverty schools compared to low-poverty schools. • At high-poverty schools (less than 80 percent free or reduced-price lunch students), 17 percent of teachers have three or fewer years of experience, compared to 15 percent at medium-poverty schools (50–80 percent free or reduced-price lunch) and 11 percent at low-poverty schools (less than 50 percent free or reduced-price lunch students).				are included in the analysis. Experience is defined as years of employment in the Milwaukee public school system.
Loeb et al. (2005)	**Hiring** • Schools with higher percentages of students eligible for free or reduced-price lunch have significantly more first-year teachers relative to schools with fewer students eligible for free or reduced-price lunch after controlling for teacher characteristics and teacher survey responses about school characteristics.	California	All grades and subjects	2000–2001	The study analyzes survey data linked with district administrative data. The survey was conducted in 2002 and includes results for 1,071 teachers. The teacher sample consists of a random, representative sample.
Mansfield (2015)	**Transfer** • Teachers are more likely to transfer into schools with fewer disadvantaged students relative to schools with more disadvantaged students.	North Carolina	High school students taking various end-of-course exams in ELA, math, science, and social studies	1997–2006	Student disadvantage is defined as a predicted test score index based on the student's observable characteristics and prior test scores. Transfers include teachers moving within and across districts.
Marvel et al. (2007)	**Transfer** • The rates of teacher transfers out of low-, medium-, and high-poverty public schools were 6.4, 7.2, and 10.3 percent, respectively. Transfers include teachers moving within and across districts. **Attrition** • The rates of teacher exits from low-, medium-, and high-poverty public schools were 7.9, 7.4, and 9.7 percent, respectively.	Nationwide	All grades and subjects	2004–2005	Low-poverty schools are those with less than 15 percent of students eligible for free or reduced-price lunch. Medium-poverty schools are those with between 15 and 49 percent of students eligible for free or reduced-price lunch. High-poverty schools are those with 50 percent or more students eligible for free or reduced-price lunch.
Neild et al. (2005)	**Hiring** • Teachers with no prior experience were more likely to work at high-poverty schools relative to low-poverty schools. At high-poverty schools 17 percent of teachers were had no prior	Philadelphia	All grades and subjects	1999-2000, 2003-2004	Low-poverty schools are those with fewer than 80 percent low-income students. High-poverty schools are those with 90 percent or higher low income students. Experience is defined

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
	experience, compared to 9.2 percent at low-poverty schools. • At high-poverty schools 70 percent of open positions were filled by new teachers, compared to 47 percent at low-poverty schools. New teachers were more likely to fill vacancies at high-poverty schools at both elementary schools, K-8 schools, and middle schools. **Attrition** • Teachers who were new to the district in 1999-2000 were more likely to leave the district after their first year from a middle school (34 percent) compared to a high school (26 percent), elementary school (21 percent), or K-8 school (29 percent). New teachers at high-poverty middle schools were 11 percentage points more likely to exit after their first year compared to new hires at low-poverty schools. This pattern did not hold for the other grade spans, however. In other grade spans teachers were either equally or less likely to exit from high-poverty schools compared to low-poverty schools.				as years teaching in the Philadelphia public school system.
Provasnik and Dorfman (2005)	**Hiring** • 6 percent of teachers at low-poverty schools were new hires who did not transfer from another school, compared to 9 percent of teachers at high-poverty schools. **Transfer** • 9 percent of teachers at low-poverty schools transferred in from other schools compared to 7 percent of teachers at high-poverty schools. Transfers include teachers moving within district and teachers moving from other districts. • 5 percent of teachers at low-poverty schools transferred to other schools compared to 10 percent of teachers at high-poverty schools. **Attrition** • 9 percent of teachers at low-poverty schools left teaching compared to 8 percent of teachers at high-poverty schools.	Nationwide	All grades and subjects	1999–2000	Low-poverty schools have less than 15 percent of students eligible for free or reduced-price lunch, whereas high-poverty schools had more than 75 percent of students eligible for free or reduced-price lunch. The study bases results on differences across schools nationwide rather than focusing on within-district comparisons. Data are from the 2000–2001 Teacher Follow-up to the 1999–2000 School and Staffing Survey.

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
Ronfeldt et al. (2013)	**Transfer/Attrition** • Teachers are more likely to move out of or leave teaching from high-poverty schools than low-poverty schools. • Teacher turnover has a negative effect on student achievement. The negative effect of turnover is larger in schools with higher proportions of low-achieving and Black students.	New York City	Math and ELA, grades 4 and 5	2001–2002 through 2009–2010	
Sass et al. (2012)	**Hiring** • In both North Carolina and Florida, a higher fraction of teachers at high-poverty schools have two or fewer years of experience compared to low-poverty schools. • In Florida, there is a statistically significant difference between the value added of teachers with two or fewer years of experience at high-poverty schools and the value added of teachers with two or fewer years of experience at low-poverty schools. In math, the median teacher at a low-poverty school has a value added that is 0.02 standard deviations above that of the median teacher at a high-poverty school. In reading, the median teacher at a low-poverty school has a value added that is 0.04 standard deviations above that of the median teacher at a high-poverty school. • In North Carolina, teachers with two or fewer years of experience at high-poverty schools also generally have lower value added than teachers with two or fewer years of experience at low-poverty schools, though the differences are not statistically significant. In math, the difference between the median teacher at low- and high-poverty schools is 0.06 standard deviations. In reading, the difference between the median teacher at low- and high-poverty schools is 0.03 standard deviations.	North Carolina and Florida	Math and ELA, grades 4 and 5	2000–2001 through 2004–2005 in both Florida and North Carolina	High-poverty schools are defined as those with 70 percent or more students eligible for free or reduced-price lunch. Low-poverty schools are defined as those with fewer than 70 percent of students eligible for free or reduced-price lunch. Transfers include teachers moving both within and across districts.
	Transfer • In Florida, approximately four times as many teachers move from high- to low-poverty schools as move from low- to high-poverty schools. Teachers who transfer from high- to				

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
	low-poverty schools experience a statistically significant increase in value added of 0.03 standard deviations. In North Carolina, approximately twice as many teachers move from high- to low-poverty schools as move from low- to high-poverty schools. Teachers who transfer from high- to low-poverty schools do not experience a statistically significant change in value added. **Attrition** • In Florida, math teachers who leave at the end of their first year of teaching at high-poverty schools are more effective than teachers who stay beyond their first year at high-poverty schools. The opposite is true for math teachers who leave from high-poverty schools at the end of their second year relative to teachers who stay beyond their second year. • In Florida, reading teachers who leave at the end of their first year of teaching at high-poverty schools are less effective than teachers who stay beyond their first year at high-poverty schools. The opposite is true for reading teachers who leave from high-poverty schools at the end of their second year relative to teachers who stay beyond their second year. • In North Carolina there are no statistically significant differences in effectiveness between teachers who stay and teachers who leave during their first or second years in the district. **Development** • In Florida and North Carolina the difference in value added between teachers with two or fewer years of experience and more experienced teachers is greater at low-poverty schools than at high poverty schools. This observation is based on cross-sectional data, so the authors unable to determine whether these differences are due to differing rates of teacher development across low- and high-poverty schools.				

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
Scafidi et al (2007)	**Transfer** • Teachers who transfer to another school within a district move to schools with lower poverty rates. Transfers see an average decrease in school poverty of 5.4 percentage points. **Attrition** • Teachers in schools with large fractions of low-income and minority students are more likely to exit teaching than teachers in schools with fewer low-income and minority students.	Georgia	Elementary school grades	1994–1995 through 2000–2001	Includes teachers who were under age 27 when they began their teaching careers
Shen (1997)	**Transfer** • Teachers who moved to another school within a district or across districts were more likely to transfer from schools with higher fractions of students eligible for free or reduced-price lunch. **Attrition** • Teachers who left teaching were more likely to leave from schools with higher fractions of students eligible for free or reduced-price lunch.	Nationwide	All grades and subjects	1990–1991 and 1991–1992	Data from the Schools and Staffing Survey and the Teacher Follow-up Survey. Only stayers and voluntary movers or leavers are included in the sample.
Steele et al. (2015)	**Hiring** • Schools with higher fractions of minority students have more teachers with less than three years of experience. **Transfer** • Teachers who transfer are less effective than stayers. • Teachers are more likely to transfer schools when they teach in schools with more Black and Hispanic students. • There is no systematic relationship between value added and the change in the fraction of minority students experienced by movers. **Attrition** • Leavers are less effective than stayers. • There is no systematic relationship between leaving teaching in the district and the percentage of minority students at the school.	Large urban district in southern U.S.	Grades 4 through 8 in ELA, math, science, and social studies	2004–2005 through 2008–2009	Study does not distinguish between teachers who leave tested grades and subjects and teachers who leave teaching entirely. Experience is defined as years teaching in the school district.

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
Stinebrickner (1998)	**Attrition** • Certified teachers are similarly likely to leave teaching from schools where the majority of students are from the low, middle, or high economic class after controlling for teacher characteristics, wage, student-teacher ratio at the school, and whether the school is a private or parochial school. The study does not define the economic class variable.	Nationwide	All grades and subjects		The sample consists of individuals included in the National Longitudinal Study of the Class of 1972 who became certified to teach between 1975 and 1985.
Wisconsin Department of Public Instruction (2006)	**Hiring** • In Wisconsin, teachers with less than three years of experience are more likely to teach at high-poverty schools compared to low-poverty schools. At the highest school poverty decile, 26 percent of teachers have less than three years of experience. At the lowest poverty decile, 12 percent of teachers have less than three years of experience. These results similar when reported separately for elementary, middle, and high schools. • The results differ when the city of Milwaukee is compared to the rest of the state. In Milwaukee at the highest school poverty decile, 29 percent of teachers have less than three years of experience compared to 13 percent of teachers at the lowest school poverty decile. In the rest of Wisconsin at the highest school poverty decile, 10 percent of teachers have less than three years of experience compared to 8 percent of teachers at the lowest school poverty decile.	Wisconsin	All grades and subjects	2003–2004	
Xu et al. (2012)	**Transfer** • In elementary schools, teachers who transfer to another school are more likely to move to lower-poverty schools than higher-poverty schools. In North Carolina, 28 percent of teachers who transferred moved to lower-poverty schools, 53 percent transferred to schools with similar poverty levels, and 19 percent transferred to higher-poverty schools. In Florida, 38 percent of teachers who transferred moved to lower-poverty schools, 44 percent transferred to schools with similar poverty levels, and 18	Florida and North Carolina	Florida: math and ELA, grades 4,5,9 and 10 North Carolina: math and ELA, grades 4 and 5, Algebra I and English I (typically grade 9)	Florida: 2002–2003 through 2008–2009; North Carolina: 1998–1999 through 2008–2009	The authors include teachers moving to a new district in their sample of teachers who transferred to another school. They defined lower (higher) poverty schools as schools with a poverty rate more than 15 percentage points below (above) the origin school's poverty rate. Similar-poverty schools have poverty rates within 15 percentage of the origin school.

Table A.3. (*continued*)

Study	Main findings	Location	Grades and subjects	Years	Additional notes
	percent transferred to higher-poverty schools. • In high school, teachers who transferred to another school were similarly likely to move to lower- and higher-poverty schools. In North Carolina, 64 percent of transfers moved to schools with similar free and reduced-price lunch rates; and in Florida, 59 percent of transfers did so.				
Xu et al. (2015)	**Hiring** • In North Carolina, teachers in their first two years of teaching at high-poverty schools have value added that is between 0.02 and 0.03 standard deviations lower than teachers in their first two years of teaching at low-poverty schools. • In Florida, teachers in their first two years of teaching at high-poverty schools have value added that is 0.03 standard deviations lower than teachers in their first two years of teaching at low-poverty schools. **Development** • There are no consistent differences in the rate at which teachers develop across high- and low-poverty schools.	Florida and North Carolina	Math grades 4 and 5	Florida: 2002–2003 through 2009–20010; North Carolina: 1998–1999 through 2008–2009	The authors define high-poverty schools as those with 60 percent or more students eligible for free or reduced-price lunch. They define low-poverty schools as those with fewer than 60 percent of students eligible for free or reduced-price lunch. The sample included only teachers who (1) did not switch school poverty settings and (2) could be followed for up to five years.

APPENDIX B

ANALYTIC METHODS AND DATA

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This appendix provides technical details of the analyses we conducted: value-added models used to measure teacher effectiveness, the method by which we calculated the Effective Teaching Gap from value-added estimates (including the cumulative and maximum Effective Teaching Gaps), the method for measuring the percentage of low-income and high-income students taught by teachers at different levels of effectiveness, and our approach to comparing teacher hiring, development, transfer, and attrition outcomes across high- and low-poverty schools. We also detail how we measured the degree to which differences in the likelihood of having a novice teacher could lead to inequitable access. The last section describes how we defined whether or not a district was implementing a set of policies that might affect access to effective teaching.

A. Value-added models

In this section, we describe our statistical approach to estimating teacher value added. We describe the basic statistical model in the first subsection. We then explain, sequentially, our approach for handling co-teaching, imprecisely measured pre-test scores, students with missing data, and multiple end-of-course tests for the same subject given within a grade. In the final two subsections we present the approach we used to estimate the error-adjusted standard deviation of value-added estimates and an alternative specification of the value-added model used to conduct sensitivity analyses.

1. Framework for estimating teacher value added

Our basic approach for estimating teacher value added was to use a regression model that accounted for a series of baseline student and classroom characteristics that could be related to academic achievement or might otherwise be confounded with the assignment of students to teachers. We assumed that a student's post-test score depended on prior achievement, background characteristics, characteristics of other students in the classroom, the student's current teacher, and additional unmeasured factors unrelated to teaching assignments.

We accounted for student characteristics and classroom characteristics that were common to all study districts. This approach ensured that any differences we document in access to effective teaching across districts are not a result of using different statistical models in different districts. The common value-added model included the following individual student characteristics, which we obtained from district administrative records:

- Math and ELA scores from the prior school year (we accounted for prior-year scores in math and ELA regardless of the post-test subject)
- Free or reduced-price lunch (FRL) status
- Limited English proficiency
- Special education status
- Gender
- Whether a student is African American or Black
- Whether a student is Hispanic, Native American, multi-race, or "other" race
- Whether a student transferred across schools during the year

Accounting for classroom characteristics allowed for the possibility that (1) having more high-performing students in a classroom improved the performance of a given student, (2) having fewer low-income students in a classroom improved that student's performance, and (3) having a narrower range of achievement in a given classroom improved the performance of students in that classroom. Thus, we included the following classroom-level variables:[1]

- Classroom average same-subject test scores from the prior school year
- The standard deviation of the scores within a student's classroom
- The proportion of students in the classroom who were eligible for free or reduced-price lunch.

The specification we estimated assumed that the above characteristics potentially influenced a student's achievement linearly.

To avoid estimating unstable teacher effects due to collinearity of student characteristics and teacher fixed effects, we required that a teacher have at least 4 students in a grade level for us to estimate a coefficient for a teacher for that grade level. Furthermore, to avoid assigning value-added estimates to teachers who may be linked erroneously to a few students in the data, we estimated a coefficient for a teacher only if he or she taught at least 10 students in a given year across all grades. The students assigned to teachers who did not meet these criteria were omitted from the analysis.

We collected test score data on students in the district on state ELA and math tests. All original scale scores were converted to z-scores by subtracting the mean test score of students in the same state, year, and grade who took the same assessment, and dividing by the standard deviation of the test scores of students in the state. Thus, the value-added estimates obtained from the regression are stated in terms of achievement effect size units—that is, standard deviation units within a statewide population of students.[2]

Because classroom characteristics were calculated at the classroom level, we used multiple classrooms per teacher to provide variation in the peer effect variables for individual teachers.[3] Otherwise, we might have confounded the characteristics of students in a teacher's classroom with the selection of teachers who work with students like these.[4] Unlike estimation of individual

[1] We calculated classroom variables individually for each student, excluding that student's contribution to the classroom statistic.

[2] One possible challenge with using student scores on state assessments is the possibility of ceiling effects. If a large proportion of students achieve the maximum score, then the assessment is no longer measuring which of these students is achieving at relatively higher or lower levels; that is, which students within this group are learning more or less. Fortunately, ceiling effects do not appear to be a problem in our data. Less than 1 percent of students in the sample had the observed maximum score for the assessment they took.

[3] Districts provided a classroom identifier to distinguish between different classrooms of students and they provided consistent teacher identifiers to link teachers across school years.

[4] Using the "fixed effects" strategy described here avoided biasing results that could arise from confounding teacher selection with peer effects, but involved two trade-offs. First, we assumed that differences in effects of peer composition between classrooms of the same teacher extrapolated to larger differences in peer composition that might occur across classrooms of different teachers. Second, because relatively few classrooms are taught by the

student characteristics, which was based on differences in student achievement across different types of students assigned to the same teacher, estimating the impact of classroom characteristics required multiple “observations” of a teacher’s classroom. In particular, we used variation in classroom-level characteristics for teachers of multiple sections in a given grade and subject. For teachers with multiple years of data, we also captured year-to-year variation in the composition of a teacher’s class.

Estimating this model required two steps because we used multiple years of data to estimate the impact of classroom characteristics on student achievement, but were interested in teacher value added from each year separately. First, we estimated a pooled regression across all available years within a district-grade combination;[5]

$$\text{(B.1)} \qquad Y_{it} = \boldsymbol{\lambda}'_{*}\mathbf{L}_{\mathbf{i(t-1)}} + \boldsymbol{\eta}'_{*}\mathbf{X}_{\mathbf{it}} + \boldsymbol{\psi}'_{*}\mathbf{C}_{\mathbf{it}} + \boldsymbol{\theta}'_{*}\mathbf{R}_{\mathbf{it}} + \varepsilon^{*}_{it}.$$

In this equation, Y_{it} is the post-test score for student i in year t, and $\boldsymbol{L}_{i(t-1)}$ represents test scores for that student in English/language arts (ELA) and math in the prior year. The pre-test scores capture prior inputs into student achievement. Control variables for individual student background characteristics were included in $\mathbf{X}_{it}$, while $\boldsymbol{C}_{it}$ is the classroom characteristics variables. $\mathbf{R}_{it}$ represents a set of binary indicator variables for the teachers.[6] Finally, ε^{*}_{it} is an error term that captures unobserved factors that influence student achievement and measurement error in the post-test, and $\boldsymbol{\lambda}_{*}$, $\boldsymbol{\eta}_{*}$, $\boldsymbol{\psi}_{*}$, and $\boldsymbol{\theta}_{*}$ are vectors of parameters to be estimated. The coefficients are subscripted by an asterisk to indicate that they are constrained to be the same across years. This restriction is necessary to calculate stable estimates of $\boldsymbol{\psi}_{*}$, which measures the relationships between the post-test and the classroom-level characteristics. In the absence of this restriction, year-to-year variability in $\boldsymbol{C}_{it}$ needed to estimate effects of classroom characteristics would be fully absorbed by the year-specific teacher effects or could be confounded with changes over time in the other coefficients.

Based on the estimated coefficients on the classroom characteristics $\boldsymbol{\psi}_{*}$, we then calculated a classroom-adjusted post-test score:

same teacher, measurement error in the classroom characteristics would lead the estimates of their associated coefficients to be too small (attenuation bias).

[5] We could not estimate the value-added model in two districts that did not provide classroom identifiers and one district that did not have consistent teacher identifiers to track teachers across years. This resulted in a sample of 26 districts for the analysis of low-income students’ access to effective teachers. We excluded upper elementary teachers (grades 4 and 5) in 14 of the 26 districts because they provided data that linked elementary students to their homeroom teacher rather than to specific ELA and/or math teachers. Given that students in these grades may not receive ELA and math instruction from their homeroom teacher (Isenberg et al. 2015), we could not ensure that the homeroom teacher instructed students in both subjects.

[6] In classrooms with less than 10 students, we imputed the classroom characteristics variables to avoid estimating classroom averages based on insufficiently large numbers of students. This imputation could lead to attenuated estimates of the classroom characteristics coefficients. To avoid this problem, we generated distinct indicators for teacher-class combinations in which the class had fewer than 10 students. Because the classroom characteristics only use variation within teacher indicators, imputed classrooms do not contribute to the estimation of these coefficients.

$$\text{(B.2)}\quad Y_{it}^{adjusted} = Y_{it} - \widehat{\boldsymbol{\psi}}_*'\mathbf{C_{it}}\,.$$

In the second step, we regressed the adjusted post-test score on individual characteristics and teacher fixed effects, separately for each district-grade-year combination, using the following regression model:

$$\text{(B.3)}\quad Y_{it}^{adjusted} = \boldsymbol{\lambda}'\mathbf{L_{i(t\text{-}1)}} + \boldsymbol{\eta}'\mathbf{X_{it}} + \boldsymbol{\theta}'\mathbf{R_{it}} + \varepsilon_{it}\,.$$

The key parameters are those included in the vector θ, which are the value-added regression coefficients for individual teachers. They represent the effect of a teacher on the achievement of his or her students, after accounting for student and classroom characteristics, in a particular year and grade. This two-step process allowed us to account for classroom characteristics in our value added estimates by using cross-year, within-teacher variation in classrooms, while also allowing us to estimate separate effects for each teacher-year-grade combination.

2. Accounting for multiple teachers responsible for the same students

Because students may be taught a subject by more than one teacher over the course of a school year, we used a procedure we call the Full Roster Method to estimate value added (Hock and Isenberg 2012). This approach can be used to account for team teaching, supplemental course taking, and students who transfer across schools. The method is based on the assumption that the combined efforts of team teachers constitute a single input into student achievement, with these teachers' joint effectiveness attributed to all teachers on the team. It yields results very similar to a method that would form an extra variable for each set of team teachers, but does not require specifying these team variables explicitly. For teachers who teach some students individually and others as part of a team, the Full Roster Method results in value-added estimates approximately equal to the student-weighted average of their individual estimates and team estimates.

To implement the Full Roster Method, we modified the regressions so that the teacher–student link, rather than the student, was the unit of observation. A student contributed one observation to the model for each teacher to whom he or she was linked. For example, students who have a single math class taught by two teachers each contributed two observations to the analysis file, while those whose math class was taught by a single teacher contributed a single observation. The corresponding regression equation for student *i* taught by teacher *j* is expressed as:

$$\text{(B.4)}\quad Y_{ijt} = \boldsymbol{\lambda}_*'\mathbf{L_{i(t\text{-}1)}} + \boldsymbol{\eta}_*'\mathbf{X_{it}} + \boldsymbol{\theta}_*'\mathbf{R_{ijt}} + \boldsymbol{\psi}_*'\mathbf{C_{ijt}} + \varepsilon_{ijt}^*$$

where the notation largely parallels that of equation (B.1) (with the same adjustments made to equations (B.2) and (B.3)). The term $\mathbf{R}_{ijt}$ is a vector of binary indicators (one for each teacher in the sample) that indicate whether student *i* appeared on the roster of teacher *j* during year *t*. For teacher–student link *ij*, the *j*th element of $\mathbf{R}_{ijt}$ is one, and the remaining values are zero. If all students in the data are linked to a single teacher for the whole year, equation (B.4) reduces to the teacher fixed effects approach described by equation (B.1). As in the basic model, θ_* represents the value-added estimate for teacher *j*.

The Full Roster Method accommodates any pattern of team teaching and shared instructional responsibility. In addition to accounting for multiple teachers, we incorporated information, if available, on the proportion of the year that each student spent with each teacher (the dosage) using weights. We calculated dosage explicitly from enrollment and detailed roster information, if available.

To account for cases in which the student spent only part of the year with a given teacher, we estimated the coefficients using weighted least squares (WLS) rather than ordinary least squares (OLS). In this technique, each teacher–student combination is weighted by the dosage associated with that combination. For a student who split time equally between two math teachers, the weight associated with each of the two observations for the student was 0.5. We addressed the correlation in the error term, ε^{*}_{ijt}, across multiple observations by using a cluster-robust sandwich variance estimator (Liang and Zeger 1986; Arellano 1987) to obtain standard errors that are consistent in the presence of both heteroskedasticity and clustering at the student level.

3. Addressing measurement error

We corrected for measurement error in the pre-tests by using grade-specific reliability data available from test publishers. As a measure of true student ability, standardized tests contain measurement error, causing standard regression techniques to produce potentially biased estimates of effective teaching. This occurs because unadjusted coefficients on pre-test scores are likely to be attenuated due to measurement error. To address this issue, we implemented a measurement error correction that uses the test/retest reliability of the tests used in our value-added models. By netting out the known amount of measurement error, the errors-in-variables correction eliminates this source of bias.

The specific errors-in-variables method we used is a moment-based correction to the linear regression estimator based on the reliability ratio, which is the proportion of the observed variability in the pre-tests that is not due to measurement error (Buonaccorsi 2010). Focusing first on the case in which each student was linked to only one teacher, the uncorrected OLS estimate of the full set of regression coefficients could be written as

$$\text{(B.5)} \quad \hat{\boldsymbol{\beta}}^{OLS} = \left[\mathbf{Z}_t'\mathbf{Z}_t\right]^{-1}\mathbf{Z}_t'\mathbf{y}_t$$

where $\mathbf{y}_t$ is a stacked vector of post-tests for year t, and matrix $\mathbf{Z}_t = [\mathbf{L}_t, \mathbf{X}_t, \mathbf{C}_t]$ represents a stacked matrix of pre-tests, characteristics, and teacher-student link variables for the same year. The corresponding moment-corrected set of estimates is

$$\text{(B.6)} \quad \hat{\boldsymbol{\beta}}^{EIV} = \left[\mathbf{Z}_t'\mathbf{Z}_t - \mathbf{Q}_t\right]^{-1}\mathbf{Z}_t'\mathbf{y}_t,$$

where $\mathbf{Q}_t$ is a diagonal matrix with the kth element equal to $(1 - r_t^k)\,v_t^k$; the terms r_t^k and v_t^k represent the reliability ratio and the total observed variability for the kth variable contained in $\mathbf{Z}_t$. It can be shown that equation (B.6) yields a consistent estimator of the true regression coefficients under traditional assumptions about the measurement error structure.[7] To apply this correction, we obtained reliability information for the pre-test variables from published information about state tests by year, grade, and subject.[8,9] The reliability ratio for the other variables is assumed to be one, so that only the first two diagonal elements of **Q** (corresponding to the pre-tests) are non-zero.

Implementing the moment-based errors-in-variables correction in conjunction with the Full Roster Method required two modifications. First, as noted previously, we used a matrix of dosage to estimate a WLS analogue of equation (B.4). Second, we used a multi-step procedure to calculate standard errors that account for repeated student observations. In the first step, the errors-in-variables method applied to equation (B.1) obtains unbiased estimates of the set of classroom characteristics coefficients, $\hat{\psi}_*$, which allow us to calculate the classroom-adjusted post-test score given in equation (B.2): $Y_{ijt}^{adjusted} = Y_{ijt} - \hat{\boldsymbol{\psi}}_*'\mathbf{C}_{\mathbf{ijt}}$.[10] In the second step, the classroom-adjusted post-test score was regressed on the individual student covariates and teacher indicators, again using the errors-in-variables method, but for each district-grade-year combination separately. This step allowed us obtain unbiased estimates of the pre-test coefficients, $\hat{\lambda}$, and to calculate another adjusted post-test score: $A_{ijt} = Y_{ijt}^{adjusted} - \hat{\boldsymbol{\lambda}}'\mathbf{L}_{\mathbf{i(t-1)}}$ Finally, A_{ijt} is regressed on all of the covariates in (B.3) except for the pre-test scores, and standard errors were clustered at the student level. This regression yields the same point estimates of teacher value added as the previous step, but yields standard errors that are robust to clustering.

The multi-step procedure will tend to underestimate the standard errors of the teacher effects. The dependent variable in the second step, A_{ijt}, is calculated using estimated pre-test coefficients, and the estimates will contain some amount of error. The second-step regression did not account for this common source of error affecting all students in a grade. Nonetheless, large

[7] The specific assumptions are that: (1) the main regression error term is mean-independent of the measurement error in all of the covariates, (2) the measurement error term for any covariate is mean independent of the level of all covariates, and (3) the measurement error terms are uncorrelated across all covariates.

[8] Reliability information was obtained from technical reports distributed by the test publishers or state education departments, if available. In cases where test information could not be found for a given state, year, grade, and subject, we set the reliability to be 0.9, which was approximately equal to the mean of the reliability measures for cases in which the information was available.

[9] We use a single measure of test/re-test reliability for each test. A more efficient estimator would account for varying reliability across the range of test scores, which tend to be most reliable in the middle of the distribution of student achievement, and less reliable toward the extremes of the test score distribution for a given grade. Sullivan (2001) describes a Heteroskedastic Errors-in-Variables (HEIV) estimator that accounts for varying levels of measurement error for different observations. Sullivan (2001) emphasizes that (1) failing to correct for measurement error will lead to estimates that are biased and inconsistent; and (2) the advantage of using the HEIV approach over the errors-in-variables approach lies in greater asymptotic efficiency. In other words, our choice to use the errors-in-variables approach and not HEIV implies that our approach addresses the potential problems of bias and inconsistency but produces less precise estimates. For estimating value added in this study, implementing HEIV would be very resource-intensive, requiring incorporating information on measurement error for every possible test score for hundreds of pre-tests, while the gains of such an approach would be small, given that the coefficient on pre-test scores tends to be estimated very precisely using the errors-in-variables method that we follow.

[10] We use the eivreg command in Stata (StataCorp, 2013).

sample sizes of student observations yielded relatively precise estimates of $\hat{\lambda}$, which mitigated this potential concern.

4. Imputation of missing data

We imputed values of missing student covariates so that the value-added regression made use of the non-missing data elements for every student.[11] This imputation was done using a regression-based method that estimated the relationships among characteristics for observations with non-missing data. This information was then used to fill in the missing data elements for students with partially missing data based on the values of their non-missing data elements.

Due to the importance of FRL status for the calculation of the Effective Teaching Gap, we took extra steps to ensure the accuracy of these data. Two federal regulations, known as Provision 2 and Provision 3, posed a particular challenge to identifying individual students' FRL status in some districts. Under these provisions, schools offered free meals to all students, without determining the students' eligibility for the benefits based on their household circumstances. The reimbursement received by a school for each free meal served was based on the pattern of reimbursement from a base year in which the school determined individual students' FRL eligibility status. Schools commonly chose to participate in Provision 2 or Provision 3 if a large proportion of students were eligible for FRL, because the administrative cost of distinguishing between eligible and ineligible students can be higher than the cost of providing free lunches to ineligible students. Therefore, in student-level administrative data sets in districts that included Provision 2 or Provision 3 schools, all students may have appeared as FRL-eligible, even though not all students met the eligibility criteria. Alternatively, districts may not have updated students' free or reduced-price lunch status after the base year in Provision 2 or Provision 3 schools.

In our data, 6 of the 29 study districts had students enrolled in schools participating in Provision 2 or Provision 3.[12] We imputed FRL status for students at these schools. For all students attending Provision 2 or 3 schools, we followed a two-step process. First, we used the FRL status for the student from the Provision 2 or 3 "base year" in which the school determined the FRL status of all students, if these data were available. Second, for students for whom these data are not available, we used the regression-based method based on other student characteristics used as control variables in the value-added model, parents' education (when available), and the percentage of FRL students in the school before the school began to participate in this program (according to the Common Core of Data). Apart from issues related to Provision 2 or Provision 3, we encountered one district for which there were implausible upward

[11] We did not impute outcome (post-test) data that was missing for students who left the district before the end of the year or were absent on the day of the test.

[12] One district implemented the Community Eligibility Provision of the school lunch program that allows districts to provide free breakfast and lunch to all students. Although students in these schools did not complete applications for the school lunch program, the district still collected information from students that allowed them to determine their eligibility for the program.

or downward spikes in the percentage of FRL students in one year. For these years, we used each student's FRL status from other years in place of the FRL status from the abnormal year.[13]

We did not impute missing values of pre-test scores in the same subject as the post-test, as doing so for this key control variable may introduce unacceptably large errors in the estimates of individual teacher effectiveness. If we had access to statewide databases that allow us to track mobile students across districts, we filled in as many post-test and pre-test score values as possible from the statewide data. Otherwise, student observations with missing pre-test scores were excluded from the value-added regressions. Among the excluded students were those who had skipped or repeated a grade because they had a pre-test score that is from a different grade level than their classmates.[14]

5. Multiple tests for the same subject given within a grade

Some states tested middle school students using end-of-course tests rather than end-of-grade tests. For example, seventh-grade students may have taken general math, a lower-level course, or pre-algebra, a higher-level course, and were tested accordingly. This complicates the value-added approach, as we had to calculate value added for teachers in the same grade based on different tests administered to different sets of students within the grade. Continuing the example, there were a set of value-added estimates for teachers of general math and another for teachers of pre-algebra. We ultimately had to create a single set of grade-level estimates to preserve comparability in the measure of the Effective Teaching Gap between districts that used multiple tests within a grade and those that do not.

If there was systematic sorting of teachers to different courses, we needed a way to rank teachers of different courses against each other. This could not be done directly, because their students took different end-of-year tests. For example, a school might have assigned its better teachers to the higher-level courses. In this case, we would not have wanted to simply pool value-added estimates of these two groups of teachers from separate regression models, as that would have presumed that the average teacher of, for example, seventh grade pre-algebra is of equal effectiveness as the average teacher of seventh grade general math when teachers may have been assigned to courses based in part on school principals' knowledge of their effectiveness.

Our approach was to measure value added separately for the different tests that students take and then equate the value-added estimates of teachers across the two tests using teachers who taught both courses and therefore had students who took both tests.[15] The difference in the differences of average value-added estimates between two-course and one-course teachers

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[13] For example, there was an implausible change in the percentage of FRL students in Year 2, so we replaced students' FRL status in Year 2 with their status in Year 3. If a student was in the data for only two years, we replaced their FRL status in Year 2 with either Year 1 or Year 3.

[14] On average across the districts, fewer than one percent of students were excluded because they skipped or repeated a grade.

[15] We also equated the standard deviation of the value-added estimates for teachers of different courses using the teachers of both courses as a bridge between teachers who taught only one type of course. After running separate value-added models by course, we multiplied the post-test scores of one group of students by a constant that equalized the standard deviation of value-added estimates for teachers who taught both courses.

measured the degree to which teachers are sorted across courses according to their effectiveness. For example, assume that two-course teachers outperformed one-course teachers of general math 7 by half a standard deviation of value-added estimates. Furthermore, assume that two-course teachers lagged one-course teachers of pre-algebra by half a standard deviation. This implies that one-course pre-algebra teachers achieved results that were a full standard deviation above those of one-course general math 7 teachers. We used this gap as a means of comparing the value added for teachers of different courses. For the two-course teachers themselves, we combined their two course-specific scores by first adjusting them and then using a weighted average of the two scores, where the weights are the proportion of students that a teacher had in that course relative to the number of students the teacher had in all courses combined.[16]

6. Calculating the error-adjusted standard deviation of teacher value-added estimates

In some statistics, we presented the standard deviation of value-added estimates, a measure of the variability of teacher value added for a given district-grade combination. When doing so, we used an adjusted standard deviation that removes estimation error. Because value-added estimates are not known quantities, the unadjusted standard deviation of value-added estimates partly reflects estimation error in each value-added estimate. Therefore, the unadjusted standard deviation of value-added estimates tends to overstate the true variability of teacher value added.

We calculated the error-adjusted variance of teacher value-added estimates by subtracting the mean squared standard error of the value-added estimate from the variance of the unadjusted value-added estimates. Both the calculation of the variance of the unadjusted estimates and the mean squared standard error were weighted. We used an empirical Bayes procedure described by Morris (1983) to derive the weights using an iterative procedure. In general, using this procedure, estimates that have a larger standard error received less weight, and vice versa.

7. Alternative value-added specification used for sensitivity analyses

As described in Chapter II, we estimated an alternative value-added model that did not account for the possibility that a student's classroom peers influence the student's achievement. Given that the inclusion of classroom characteristics led to different results in the first study report, we compared the Effective Teaching Gap results when including and excluding classroom characteristics.

The non-classroom characteristics model is a simplified version of the classroom characteristics model. We omitted the first step of estimating the coefficients on classroom characteristics and adjusting the post-test scores for classroom characteristics—equations (B.1) and (B.2). Instead, we specified an alternative version of equation (B.3) in which we used the actual test score as the outcome instead of the classroom characteristics-adjusted test score. As with the approach we took with the classroom characteristics model, we (1) estimated separate error-in-variables regressions for each district-grade-year combination to yield unbiased

[16] Because the standard deviation of general math test scores and standard deviation of pre-algebra scores underestimates the standard deviation of test scores of all students had they taken a common test, we applied a final adjustment to the value-added estimates. We used the teacher-level equating parameters for the mean and standard deviation of teacher value added to translate all student post-tests onto the scale of a general math, and then calculated the ratio of the standard deviation of all test scores to the standard deviation of general math scores. We then multiplied value-added estimates by this ratio.

estimates of the pre-test coefficients; and (2) obtained the final value-added estimates and standard errors by regressing pretest-adjusted test scores on the individual student characteristics and teacher indicators, clustering at the student level.

B. Effective Teaching Gap measure

To document the differences in access to effective teaching between different types of students, we used a measure called the Effective Teaching Gap. In this section, we describe our general method for calculating Effective Teaching Gaps based on FRL as well as race/ethnicity. We explain how the Effective Teaching Gap is aggregated across grades, districts, and years. We then describe our approach for calculating the cumulative Effective Teaching Gap, which we used to estimate how reducing the Effective Teaching Gap to zero over several years would affect the student achievement gap. Finally, we discuss the sources of variation across districts in the maximum Effective Teaching Gap and document our method for calculating the maximum Effective Teaching Gap for each district.

1. Single-grade measures of the Effective Teaching Gap

The district Effective Teaching Gap is the average value added of the teachers of high-income (non-FRL) students minus the average value added of teachers of low-income (FRL) students. Teachers who have both types of students in their classrooms counted toward both averages in proportion to the number of FRL and non-FRL students they taught. We computed the district Effective Teaching Gap using a simple regression:

$$\text{(B.7)} \quad V_{jk} = \alpha + \delta FRL_{jk} + e_{jk} ,$$

where V_{jk} is the value added of teacher j. Each teacher contributed two observations for a given subject: one for FRL students and one for non-FRL students. We regressed V_{jk} on FRL_{jk}, a binary variable that takes a value of one for a teacher's non-FRL students and zero for a teacher's FRL students. That is, each teacher had two observations, with $V_{j1} = V_{j0}$, $FRL_{j1} = 1$, and $FRL_{j0} = 0$. Each observation was weighted according to the total dosage for students of that type. For example, a teacher who had 20 FRL students and 10 non-FRL students would have weights of 20 and 10.[17] The estimated coefficient δ measures the estimated mean difference in effective teaching between non-FRL and FRL students in the district, with a positive δ indicating an inequitable gap—with higher-income non-FRL students having more effective teachers on average—and a negative δ indicating a compensatory gap, with lower-income FRL students having more effective teachers. To compute an appropriate standard error that accounts for using two observations per teacher, we estimated the regression using cluster-robust standard errors at the teacher level (Liang and Zeger 1986; Arellano 1987).

The Effective Teaching Gap can measure relative access to effective teachers, even though the value-added model used to generate measures of teacher effectiveness included FRL as a control variable. Because we included teacher fixed effects when estimating value added, the estimates of the coefficients on the covariates, including FRL, were based on within-teacher

[17] Since students could be assigned to more than one teacher, these totals were actually "student-equivalents." For example, if an FRL-eligible student was assigned to two teachers, they would count as half a student toward the FRL-eligible count of each teacher.

variation. We distinguished between differences in outcomes for FRL and non-FRL students due to access to effective teaching and differences due to other factors correlated with FRL status because there was always a group of teachers in our study districts who taught both FRL and non-FRL students. This allowed us to estimate the coefficient on FRL status in the value-added model. For example, suppose that FRL students score, on average, 0.1 standard deviations below non-FRL students who have the same teacher and the same other baseline characteristics. The value-added model would assign a coefficient of -0.1 to the FRL indicator. Now, suppose that two students—one FRL and one non-FRL—otherwise have the same baseline characteristics but are taught by two different teachers, and the FRL student scores 0.3 standard deviations below the non-FRL student. Since the FRL student scored even lower than what would have been expected based on FRL status, the model attributes this difference to the FRL student having had a less effective teacher.

We also measured whether the Effective Teaching Gap arises because low-income students attend schools with less effective teachers (the between-school Effective Teaching Gap) or low-income students are assigned to less effective teachers within schools (the within-school Effective Teaching Gap). We measured the between-school Effective Teaching Gap by first calculating the average value added of all teachers in a given grade *at each school* in a district. Then we followed the same steps we employed in calculating the overall Effective Teaching Gap, but we used this average school value added instead of each teacher's individual value added. In particular:

- We assigned each student the average value added of their school (that is, the value added of the average teacher in their grade at the school). Most schools enroll both high- and low-income students, and students in each group would be assigned the same school value added, provided they attended the same school.
- For all low-income students in the district, we calculated the average school value added. We made a similar calculation for all high-income students.
- We subtracted the average school value added among low-income students from the average school value added among high-income students. This difference is the between-school Effective Teaching Gap. It captures whether high-income students attend schools that have better teachers, on average, than the schools low-income students attend.

To estimate the between-school component of the Effective Teaching Gap, we calculated a weighted average of the teachers' value-added estimates at the school-grade level, where each teacher is weighted by the number of student-equivalents linked to that teacher in the analysis file. We then linked this average to every student in that school-grade, and estimated equation (B.7) using school-grade level j in place of teacher j.

The within-school Effective Teaching Gap is the difference between the overall Effective Teaching Gap (based on teacher value added) and the between-school Effective Teaching Gap (based on school value added). It captures whether, on average, high-income students are assigned to better teachers within schools than low-income students.

The between- and within-school Effective Teaching Gaps can reinforce or offset each other. For example, they reinforce each other if low-income students attend schools that have less effective teachers (a positive between-school gap) and are disproportionately assigned to less effective teachers within these schools (a positive within-school gap). The between- and within-school gaps would offset each other if, for example, low-income students attend schools with more effective teachers but are assigned to less effective teachers within those schools.

2. Effective Teaching Gap based on student race and ethnicity

We also measured Black/White and Hispanic/White gaps in access to effective teaching. To do this, we alternatively replaced FRL status in equation (B.7) with (1) an indicator for being Black, and (2) an indicator being Hispanic. We limited these analyses to districts in which at least 15 percent of the students are White and 15 percent from the relevant minority group. We used value-added results based models that included all eligible students, but we excluded a teacher's Hispanic students from the calculation of the Black/White gap and non-Hispanic Black students from the calculation of the Hispanic/White gap. For example, when calculating the Black/White gap using equation (B.7), for a teacher with 10 Black students, 8 White students, and 6 Hispanic students, the teacher would have received a weight of 10 for Black students and a weight of 8 for White students. The 6 Hispanic students would not have played a role in the calculation of the Black/White Effective Teaching Gap.

3. Aggregation across grades, districts, and years

We computed a district-wide Effective Teaching Gap by estimating equation (B.7) with teachers in all grades and years in the district. Because all test scores were converted to z-scores before they were used in the value-added model, the metric for each district-grade Effective Teaching Gap is student effect size units relative to the state population of test takers, which is the same metric as the value-added estimates for each district-grade. In addition to calculating the Effective Teaching Gap for all grades, we also separately calculated the Effective Teaching Gap for upper elementary grades and middle school grades, and compared the Effective Teaching Gap across districts and years.

For analyses in Chapter IV, when we averaged Effective Teaching Gap results across multiple years to create a single statistic for each district, we weighted the results by the total number of student-equivalents included in the analysis each year. When we combined results across districts, we weighted each district equally. By contrast, for analyses in Chapter V that make use of the (between-School) Effective Teaching Gap, we weighted the results for each district by the number of student-equivalents in the district, rather than weighting each district equally. This approach to weighting aligns with how we conducted the hiring, development, and mobility analyses.

4. Empirical Bayes Adjustment for Comparing Results Across Individual Districts

To reduce the risk that districts, particularly those with relatively few teachers and students, will receive a very high or very low Effective Teaching Gaps by chance, we applied an empirical Bayes (EB) shrinkage procedure to the estimates. Using the EB procedure outlined in Morris (1983), we computed a weighted average of an estimate for the average district and the initial estimate based on a district's own data. For districts with relatively imprecise initial estimates based on their own data, the EB method effectively produces an estimate based more on the average district. For districts with more precise initial estimates based on their own data, the

EB method puts less weight on the value for the average district and more weight on the value obtained from the district's own data.

The EB estimate for a district is approximately equal to a precision-weighted average of the district's initial estimated Effective Teaching Gap and the overall mean of all estimated districts:

$$\text{(B.8)} \qquad \hat{\delta}_i^{EB} \approx \left(\frac{\hat{\sigma}^2}{\hat{\sigma}^2 + \hat{\sigma}_i^2} \right) \hat{\delta}_i + \left(\frac{\hat{\sigma}_i^2}{\hat{\sigma}^2 + \hat{\sigma}_i^2} \right) \overline{\delta} \,,$$

where $\hat{\delta}_i^{EB}$ is the EB estimate of the Effective Teaching Gap for district *t*, $\hat{\delta}_i$ is the initial estimate of the Effective Teaching Gap for district *t* based on Equation (B.7), $\hat{\sigma}_i$ is the standard error of the estimate for district *t*, $\overline{\delta}$ is the average Effective Teaching Gap for all districts in the sample, and $\hat{\sigma}$ is an estimate of the standard deviation of the Effective Teaching Gap for all districts in the sample (purged of sampling error).[18] The term $[\hat{\sigma}^2 / (\hat{\sigma}^2 + \hat{\sigma}_i^2)]$ must be less than one. Thus, the EB estimate is always closer to the mean than the initial estimate—that is, the EB estimate "shrinks" from the initial estimate toward the mean of all estimates. The greater the precision of the initial estimate—that is, the smaller $\hat{\sigma}_i^2$ is—the closer $[\hat{\sigma}^2 / (\hat{\sigma}^2 + \hat{\sigma}_i^2)]$ is to one and the smaller the shrinkage in $\hat{\delta}_i$. Conversely, the larger the variance of the initial estimate, the greater the shrinkage in $\hat{\delta}_i$. By applying a greater degree of shrinkage to less-precisely estimated measures, the procedure reduces the likelihood that the estimate of the Effective Teaching Gap for a district falls at either extreme of the distribution by chance. We calculated the standard error for each $\hat{\delta}_i^{EB}$ using the formulas provided by Morris (1983).[19]

5. Cumulative Effective Teaching Gap

Overview. In Chapter IV, we discussed how the student achievement gap between high- and low-income students would be affected by hypothetically reducing the Effective Teaching Gap to

[18] In Morris (1983), the EB estimate does not exactly equal the precision-weighted average of the two values, due to a correction for bias. This adjustment decreases the weight on the estimated effect by a factor of (K – 3)/(K – 1), where K is the number of districts. For ease of exposition, we have omitted this correction from the description given here.

[19] The variance of the unadjusted estimates across districts will generally overestimate the true variance due to sampling error in the estimates of each individual district. However, the estimated variance of the EB estimates will generally underestimate the true variance because it excludes a component that captures the variance of each individual district's EB estimate. So, to estimate the variance of the Effective Teaching Gap across districts, we supplemented the calculation of empirical Bayes estimates by adding an additional step that accounted for the missing variance component. We obtained these estimates, known as the constrained empirical Bayes estimates, by mean-centering the EB estimates, multiplying each by a constant, and then adding back the mean to obtain a variance of all estimates that is larger than the variance of EB estimates but smaller than the variance of the unadjusted estimates (Carlin and Louis 2000). This constant is derived by constraining the distribution of the EB estimates to have the correct variance. When examining the individual constrained EB estimates of the Effective Teaching Gap, we found that they differed little from the EB estimates. In particular, the same districts with meaningful inequity, as defined in Chapter IV, using the EB estimates have meaningful inequity using the constrained EB estimates.

zero over multiple years. To do that, for each district-subject combination for which we had the necessary data, we calculated a statistic we called the cumulative Effective Teaching Gap, which calculates the difference in teacher effectiveness experienced by high- and low-income students over the course of multiple years. In estimating the multi-year effect, we assumed that teacher effectiveness fades out over time.

Our strategy is to express the student achievement gap in 8th grade as a function of the 3rd grade student achievement gap, student characteristics, a set of annual relationships between characteristics and achievement, and the Effective Teaching Gap for each year. This expression is an identity, from which we could derive the actual 8th grade student achievement gap using parameters from the value-added model.

By setting the Effective Teaching Gap in each grade to zero, we derived a hypothetical 8th grade student achievement gap—the gap that would have been obtained if we started with the same 3rd grade student achievement gap, the same students from grades 3 to 8, and the same relationships between student characteristics and achievement each year but there were no differences in teacher assignment based on student income (that is, no Effective Teaching Gap) throughout grades 4 to 8. The difference between the actual 8th grade student achievement gap and this hypothetical student achievement gap is the cumulative Effective Teaching Gap. Any other differences in student achievement between high- and low-income students in 8th grade could be attributed to (1) differences in achievement that were already present in 3rd grade, and (2) differences in student characteristics of the two groups that affected the evolution of test scores from year to year.

Algebraic treatment. To calculate the cumulative Effective Teaching Gap, we began by expressing the student achievement gap in 8th grade as a function of the data and the parameters in the value-added model (equation B.8):

$$\text{(B.9)} \quad \bar{Y}_8^{HI} - \bar{Y}_8^{LI} = \boldsymbol{\lambda}_8'(\bar{\mathbf{L}}_7^{\mathbf{HI}} - \bar{\mathbf{L}}_7^{\mathbf{LI}}) + \boldsymbol{\eta}_8'(\bar{\mathbf{X}}_8^{\mathbf{HI}} - \bar{\mathbf{X}}_8^{\mathbf{LI}}) + \boldsymbol{\psi}_8'(\bar{\mathbf{C}}_8^{\mathbf{HI}} - \bar{\mathbf{C}}_8^{\mathbf{LI}}) + ETG_8 .$$

$\bar{Y}_8^{HI} - \bar{Y}_8^{LI}$ represents the average difference in 8th grade post-test scores (in ELA or math) between high-income and low-income students, $\bar{L}_7^{HI} - \bar{L}_7^{LI}$ represents the average difference in prior test scores (from 7th grade), $\bar{X}_8^{HI} - \bar{X}_8^{LI}$ represents the average difference in student characteristics, $\bar{C}_8^{HI} - \bar{C}_8^{LI}$ represents the average difference in classroom characteristics, and ETG_8 is the 8th grade Effective Teaching Gap. The parameters $\boldsymbol{\lambda}_8$, $\boldsymbol{\eta}_8$, and $\boldsymbol{\psi}_8$ are taken from the value-added model for 8th grade teachers in the subject (ELA or math) for which we are modeling the student achievement gap, and they represent the relationships of prior (7th grade) scores, student characteristics, and classroom characteristics with 8th grade scores.

Intuitively, because the elements of $\boldsymbol{\lambda}_8$ (the coefficients on 7th grade pretest scores) are almost always less than one, the first term of equation (B.9) shrinks the student achievement gap from its baseline in 7th grade. Because low-income students tend to have student and classroom characteristics associated with lower achievement, the second and third terms are positive; these terms offset the decrease in the student achievement gap to some degree. The final term, the

Effective Teaching Gap, increases the student achievement gap if it is positive and decreases the student achievement gap if it is negative.

The next step is to begin a recursive process by replacing the difference in the pre-test scores, $\bar{L}_7^{HI} - \bar{L}_7^{LI}$, by a version of equation (B.9) that describes the 7th grade student achievement gap and substituting that expression into equation (B.9):

$$\text{(B.10)}\quad \bar{Y}_8^{HI} - \bar{Y}_8^{LI} = \boldsymbol{\lambda}_8'[\boldsymbol{\lambda}_7'(\bar{\mathbf{L}}_6^{\mathbf{HI}} - \bar{\mathbf{L}}_6^{\mathbf{LI}}) + \boldsymbol{\eta}_7'(\bar{\mathbf{X}}_7^{\mathbf{HI}} - \bar{\mathbf{X}}_7^{\mathbf{LI}}) + \boldsymbol{\psi}_7'(\bar{\mathbf{C}}_7^{\mathbf{HI}} - \bar{\mathbf{C}}_7^{\mathbf{LI}}) + \mathbf{ETG_7}] + \boldsymbol{\eta}_8'(\bar{\mathbf{X}}_8^{\mathbf{HI}} - \bar{\mathbf{X}}_8^{\mathbf{LI}}) + \boldsymbol{\psi}_8'(\bar{\mathbf{C}}_8^{\mathbf{HI}} - \bar{\mathbf{C}}_8^{\mathbf{LI}}) + ETG_8 .$$

The parameters and variables for the 7th grade equation are analogous to those used for the 8th grade equation. By repeating this process, we are able to derive an identity that relates the 8th grade student achievement gap to the 3rd grade student achievement gap, student characteristics, the ETG for each grade, and the parameters of the value-added models from grades 4 to 8. Setting the ETG to zero in each grade produces the hypothetical student achievement gap. For example, equation (B.11) shows the hypothetical student achievement gap in 8th grade, taking 6th grade test scores as given:

$$\text{(B.11)}\quad \bar{Y}_8^{HI} - \bar{Y}_8^{LI} = \boldsymbol{\lambda}_8'[\boldsymbol{\lambda}_7'(\bar{\mathbf{L}}_6^{\mathbf{HI}} - \bar{\mathbf{L}}_6^{\mathbf{LI}}) + \boldsymbol{\eta}_7'(\bar{\mathbf{X}}_7^{\mathbf{HI}} - \bar{\mathbf{X}}_7^{\mathbf{LI}}) + \boldsymbol{\psi}_7'(\bar{\mathbf{C}}_7^{\mathbf{HI}} - \bar{\mathbf{C}}_7^{\mathbf{LI}})] + \boldsymbol{\eta}_8'(\bar{\mathbf{X}}_8^{\mathbf{HI}} - \bar{\mathbf{X}}_8^{\mathbf{LI}}) + \boldsymbol{\psi}_8'(\bar{\mathbf{C}}_8^{\mathbf{HI}} - \bar{\mathbf{C}}_8^{\mathbf{LI}})$$

We subtracted the right-hand side of equation (B.11) from equation (B.10) to generate the cumulative Effective Teaching Gap.

Fadeout of teacher effects. When subtracting the right-hand side of equation (B.11) from the right-hand side of equation (B.10), all terms related to student or classroom characteristics cancel out. Thus the cumulative Effective Teaching Gap from the end of 6th grade to the end of 8th grade is $ETG_8 + \lambda_8' ETG_7$. The 7th grade Effective Teaching Gap contributes to the differences in post-test scores in 7th grade, and thereby contributes to the differences in pre-test scores in 8th grade. Because λ_8 (the coefficient on the pre-test score) is almost always less than one, the 7th grade ETG contributes less to the cumulative ETG than the 8th grade ETG does. Similarly, when we extend this expression back to the student achievement gap at the end of 3rd grade, we find

$$\text{(B.12)}\quad \text{Cumulative Effective Teaching Gap} \approx ETG_8 + \boldsymbol{\lambda}_8'\mathbf{ETG_7} + \boldsymbol{\lambda}_8'\boldsymbol{\lambda}_7'\mathbf{ETG_6} + \boldsymbol{\lambda}_8'\boldsymbol{\lambda}_7'\boldsymbol{\lambda}_6'\mathbf{ETG_5} + \boldsymbol{\lambda}_8'\boldsymbol{\lambda}_7'\boldsymbol{\lambda}_6'\boldsymbol{\lambda}_5'\mathbf{ETG_4} .$$ [20]

[20] This is not a strict identity because setting the Effective Teaching Gap to zero in one subject will affect the evolution of test scores in the other subject, since the differences in the opposite-subject pre-test play a role in determining the student achievement gap in any year. These changes will, in turn, feed back into the calculation of the student achievement gap in the original subject. Because the coefficients on the opposite-subject pre-test tend to be small, this feedback effect is small as well.

As equation (B.12) shows, the further removed from the final year, the less the ETG for that year contributes to the cumulative ETG. One interpretation of this phenomenon is that it reflects the fadeout in teacher effects over the years.[21]

Calculating the cumulative Effective Teaching Gap. We calculated the cumulative Effective Teaching Gap by substituting parameters from the value-added model estimated in Equation B.3 into Equation B.12. For each district, we averaged coefficients on pre-test scores for a given grade level across all years and averaged Effective Teaching Gaps across all years to obtain estimates of each element in Equation B.12. For grades in which districts administered multiple post-tests (discussed in Section A.5), we approximated the coefficient on the post-test score by using a weighted average of the coefficients from separate regressions of post-tests on pre-tests. We weighted by the proportion of students contributing to the regression model for a given post-test. We then used Equation B.12 to obtain an estimate of the cumulative Effective Teaching Gap in that district. For a pooled result, we averaged the cumulative Effective Teaching Gap across all districts. In parallel with how we obtained the average single-year Effective Teaching Gap, each district received an equal weight in this calculation.

Effective Teaching Gap necessary to cut the student achievement gap in half. In Chapter IV, we document the Effective Teaching Gap that would be required to cut the student achievement gap in half if it were in place from grades 4 to 8. Here, we show how that calculation was made.

By definition, the cumulative Effective Teaching Gap (*CETG*) equals the difference between the actual student achievement gap in eighth grade (SAG_8^a) and the hypothetical student achievement gap that would be obtained if the Effective Teaching Gap were zero from grades 4 to 8 (SAG_8^h):

$$\text{(B.13)} \quad CETG = SAG_8^a - SAG_8^h$$

To achieve an Effective Teaching Gap that cuts the student achievement gap in half over grades 4 to 8 ($CETG_{0.5}$), the hypothetical student achievement gap must be half of the actual student achievement gap:

$$\text{(B.14)} \quad CETG_{0.5} = 0.5 * SAG_8^a$$

Substituting a modified version of Equation B.11 for $CETG_{0.5}$ gives

[21] This is just one way of measuring teacher fade-out. For examples of other approaches, see McCaffrey et al. (2004); Rothstein (2010); Jacob et al. (2010); and Chetty et al. (2014b). Each of these studies provided a different estimate of fade-out in both the short term and long term. Our approach tends to result in less short-term fade-out than these alternative approaches have found. For example, Chetty et al. (2014b) finds that about 55 percent of a teacher's effect persists one year later. Our estimates imply less fade-out, with about 70 to 80 percent of a teacher's effect in one year persisting to the next. However, our approach only captures fade-out over a five-year period, which in effect implies that no longer-term effects are captured. Chetty et al. (2014b) finds that teacher effects seem to stabilize after about four to five years in the 0.20 to 0.25 range.

$$\text{(B.15)} \quad 0.5 * SAG_8^a = ETG_{0.5} + \boldsymbol{\lambda}_8'\mathbf{ETG_{0.5}} + \boldsymbol{\lambda}_8'\boldsymbol{\lambda}_7'\mathbf{ETG_{0.5}} + \boldsymbol{\lambda}_8'\boldsymbol{\lambda}_7'\boldsymbol{\lambda}_6'\mathbf{ETG_{0.5}} + \boldsymbol{\lambda}_8'\boldsymbol{\lambda}_7'\boldsymbol{\lambda}_6'\boldsymbol{\lambda}_5'\mathbf{ETG_{0.5}},$$

Where $ETG_{0.5}$ is the one-year Effective Teaching Gap required to cut the student achievement gap in half over five years. We assume that $ETG_{0.5}$ is constant over five years.

Solving for $ETG_{0.5}$ and rearranging the terms yields this equation:

$$\text{(B.16)} \quad ETG_{0.5} = (0.5 * SAG_8^a) / \left(1 + \lambda_8\left(1 + \lambda_7\left(1 + \lambda_6\left(1 + \lambda_5\right)\right)\right)\right).$$

Thus the Effective Teaching Gap required to cut the student achievement gap in half over grades 4 to 8 depends on the actual student achievement gap in eighth grade and the same-subject pre-test coefficients from the value-added models from grades 5 to 8. At the end of Section B.5, we describe how we calculated the percentage of teachers who would have to switch teaching assignments to bring about an Effective Teaching Gap sufficient to cut the student achievement gap in half.

6. Maximum Effective Teaching Gap

To help put the Effective Teaching Gap into context, we calculated the maximum Effective Teaching Gap for each district. The thought experiment underlying the maximum Effective Teaching Gap asks what effective teaching gap we would obtain if teachers were reassigned to classrooms in such a way that the most effective teachers were assigned to as many high-income students as possible and the least effective teachers were assigned to as many low-income students as possible.

There are two key district characteristics that affect the size of the maximum Effective Teaching Gap: (1) the degree of student separation and (2) the variation in teacher value added. Our discussion highlights how more separation and greater variation in teacher value added can increase the Effective Teaching Gap if more effective teachers are assigned to high-income students. However, this can work in the opposite direction as well—if more effective teachers are assigned to low-income students, the same phenomena can make the Effective Teaching Gap negative and "large" (in absolute value).

Student separation. In general, more separation of students by income status between *schools* can lead to higher between-school Effective Teaching Gaps, and more separation between *classrooms* within schools can lead to higher within-school Effective Teaching Gaps. In the extreme case, if low-income and high-income students were perfectly integrated across teachers, there would be equal access to effective teaching on average for the two groups of students.[22] The Effective Teaching Gap would be zero. For example, if every teacher in a school had classes in which 70 percent of students are low-income, the average value added for low-income and high-income students within the school would be the same, regardless of how

[22] On the other hand, complete segregation of students would lead to a circumstance in which we could not disentangle the relationship between income status and student achievement from the effective teaching gap because there would be no within-teacher variation in student-level income status, which allows us to measure the relationship between income status and student achievement. This situation does not occur in the study districts, however.

teachers were distributed. Similarly, if 70 percent of students in every school were low-income, the average value added across schools for low-income and high-income students would be the same.

The variation in teacher value added. The greater the total variation is, the greater the maximum Effective Teaching Gap. There cannot be gaps in effective teaching if teacher value added does not vary, even if low-income and high-income students are segregated. If all teachers were equally effective, the average value added for teachers of low-income and high-income students would be the same, regardless of how students were distributed. More generally, the greater the variation in teacher value added, the greater the maximum Effective Teaching Gap. This is relevant for measuring between- and within-school Effective Teaching Gaps—greater variation in value added between schools can increase the between-school Effective Teaching Gap and greater within-school variation in teacher value added can increase the within-school Effective Teaching Gap.

Measuring the maximum Effective Teaching Gap. To measure the maximum Effective Teaching Gap in each district, we assumed that the group of students to which each teacher was assigned stayed intact but teachers were reassigned both within and between schools in a way that most benefited high-income students. For example, if a teacher taught two 7th grade math classes with 25 students each and two 8th grade math classes with 25 students each, we kept this group of 100 students together but supposed that a different teacher—with a different value-added estimate—had been assigned to teach them.

Because many teachers in the study districts teach multiple grades, we created a single value-added estimate for each teacher, which averaged across the individual grade-specific estimates. To make the estimates comparable across grades, we first translated the grade-specific estimates into z-scores of teacher value added within a grade by dividing each estimate by the error-adjusted standard deviation of teacher value added for that grade. (The estimates were already mean-centered at zero so no other adjustment was needed to create z-scores.) We then averaged across grade-specific estimates for each teacher, weighting each grade-specific estimate by the number of student-equivalents taught at that grade level. We converted this value-added estimate back into approximate units of student standard deviations by multiplying it by a conversion factor equal to the average error-adjusted standard deviation of teacher value added across grade levels for a given district, year, and subject.[23]

After grouping students according to the original teacher assignment and creating a single across-grade individual estimate for each teacher, we calculated a weight for how each teacher contributed to the Effective Teaching Gap in their year and grade span, based on the number of low-income and high-income students taught. To derive the weight, we wrote the Effective Teaching Gap as follows:

$$\text{(B.17)} \quad ETG = \sum_j \frac{w_j^H VA_j}{W^H} - \sum_j \frac{w_j^L VA_j}{W^L}$$

[23] We averaged estimates only within elementary school and middle school grade spans. A few teachers had estimates in both grade spans. In these cases, we counted them as separate teachers.

where *ETG* is the Effective Teaching Gap, w_j^H is the number of high-income student-equivalents taught by teacher *j*, w_j^L is the number of low-income student-equivalents taught by teacher *j*, W^H is the total number of high-income students in the district, W^L is the total number of low-income students in the district, and VA_j is the value added of teacher *j*. We then rearranged terms to give

$$\text{(B.18)} \quad ETG = \sum_j ETG_j = \sum_j \left[\frac{w_j^H}{W^H} - \frac{w_j^L}{W^L} \right] VA_j$$

Equation (B.18) shows that each teacher contributes to the overall Effective Teaching Gap according to the product of the teacher's value added and the teacher's weight $\left[\frac{w_j^H}{W^H} - \frac{w_j^L}{W^L} \right]$, which is the difference in the proportion of high-income students and the proportion of low-income students taught by teacher *j*. The weight is positive for teachers with a greater proportion of high-income students, zero for teachers with equal-sized proportions, and negative for teachers with a greater proportion of low-income students. Thus, if a teacher has equal proportions of high- and low-income students, the teacher cannot contribute positively or negatively to the Effective Teaching Gap, regardless of the teacher's value added. For a teacher with a greater share of the high-income students than low-income students in the district (making the weight positive), the teacher will contribute toward positive Effective Teaching Gap (favoring high-income students) if the teacher is has a positive value added (equivalent to being an above-average teacher) and toward a negative Effective Teaching Gap (favoring low-income students) if the teacher has a negative value added.

For teachers in grades 6 to 8, the next step was to assign the teacher with the highest value added to the teaching assignment with the largest weight, the teacher with the second highest value added to the teaching assignment with the second largest weight, and so on, until all teachers had been matched with students. By virtue of this matching process, teachers could change the number of students they taught between their actual assignment and their hypothetical assignment. We carried out this procedure separately by subject.

For teachers in grades 4 to 5, most of whom taught both ELA and math ("homeroom teachers"), we used a modified approach because the effectiveness of elementary school teachers generally differed across subjects and we wanted to avoid assigning a teacher to teach ELA in one school and math in another. So for each homeroom teacher, we averaged their value added (stated in terms of teacher standard deviations) across both subjects. For single-subject elementary school teachers, we paired up the teacher with the highest value added in ELA with the teacher with the highest value added in math, then the teachers with the second-highest math and ELA value added, and so forth until we created a set of pairs of all single-subject teachers.[24] Similar to the procedure we used for middle school grades, we then proceeded to match either the single homeroom teacher or the pair of teachers with the highest average value added to the

[24] Because the number of single-subject teachers in ELA was not necessarily identical to the number of single-subject teachers in math, for the subject with more teachers, we dropped a sufficient number of teachers at random until we equalized the number of ELA and math teachers. We used the teacher assignments of the subject with fewer teachers.

teaching assignment with the largest weight, the second-highest value added with the second-largest weight, and so on.

Finally, based on the most inequitable teaching assignments, we calculated the Effective Teaching Gap using the same procedure as we did for the actual teaching assignments, as outlined in Section B.1. We also reversed this process, assigning the best teachers to the teaching assignments with the lowest (most negative) weight, to calculate the minimum Effective Teaching Gap (that is, the Effective Teaching Gap that most favors low-income students).

Percentage of teachers needing to change teacher assignments to cut the student achievement gap in half. To illustrate the magnitude of the Effective Teaching Gap required to cut the student achievement gap in half over grades 4 to 8 (described in Section B.4), we calculated the minimum percentage of teachers who would need to change teaching assignments in a district to bring this about. This would require exchanging effective teachers who teach a disproportionate percentage of low-income students with ineffective teachers who teach a disproportionate percentage of high-income students. To do this mathematically, we examined each teacher's contribution to the Effective Teaching Gap $ETG_j = \left[\frac{w_j^H}{W^H} - \frac{w_j^L}{W^L} \right] VA_j$. We identified the teacher with the largest value of ETG_j. We then examined how the Effective Teaching Gap would change if this teacher were to exchange teaching assignments with the teacher with the second highest value of ETG_j, how the Effective Teaching Gap would change if this teacher instead were to exchange teaching assignments with the teacher with the third highest value of ETG_j, and so forth. After examining all possible exchanges, we exchanged the teaching assignments of the teacher with the largest value of ETG_j and the teacher for whom the exchange gave the maximum possible reduction in the Effective Teaching Gap. We then repeated this process, using the teacher with the next-largest value of ETG_j, with the stipulation that no teacher could exchange teaching assignments more than once. In this way, the Effective Teaching Gap decreased with each exchange. We continued to do this until the Effective Teaching Gap equaled the value necessary to cut the student achievement gap in half in that district. We repeated this process for each district and reported the simple cross-district average of the percentage of teachers who had moved.[25]

C. Measuring the percentage of low-income and high-income students taught by teachers at different levels of effectiveness

In Chapter IV, we discuss the degree to which low-income and high-income students are taught by teachers at different levels of effectiveness, showing the percentage of each group of students who are taught by teachers in the top 10 percent, the next highest 20 percent, and so forth. Here, we discuss the method used to arrive at these statistics. We conducted this analysis separately by subject.

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[25] In 10 percent of district-grade span-subject cases in ELA, this algorithm did not produce an Effective Teaching Gap sufficient to cut the student achievement gap in half, even after making all possible exchanges. On average, the Effective Teaching gap obtained in these cases was 0.022 higher than the target Effective Teaching Gap. In math, the algorithm always reached the target Effective Teaching Gap.

For this analysis, we used a modified version of the value-added estimates analyzed elsewhere. Because we were interested in analyzing the value added of individual teachers, rather than for groups of teachers (as in the main analysis), we took two additional steps after estimating value added at the grade level: (1) as with the analysis of the maximum Effective Teaching Gap, we combined results across grades for teachers who taught in more than one grade so that each teacher had no more than one estimate per subject per year per grade span, stated in terms of standard deviations of teacher effectiveness; (2) we applied empirical Bayes shrinkage to the estimates. This adjustment reduced the risk that teachers will receive a very high or very low value-added estimate by chance, particularly if they teach fewer students or teach disadvantaged students (whose achievement is generally harder to predict, giving rise to larger standard errors) (Herrmann et al. 2016). We used the same procedure described in Section B, where we explain how we applied empirical Bayes shrinkage to district-level measures of the Effective Teaching Gap. When applied to value-added estimates, each estimate is a weighted average of an estimate for the average teacher in a district-year-subject combination and the initial estimate based on each teacher's own students. For teachers with relatively imprecise initial estimates based on their own students, this method effectively produces an estimate based more on the average teacher. For teachers with more precise initial estimates based on their own students, this method puts less weight on the value for the average teacher and more weight on the value obtained from the teacher's own students.

After applying empirical Bayes shrinkage, we then converted each value-added estimate into a percentile rank within each district-year-subject combination. We combined the ranks across years within a district and subject. Then we divided the teachers into deciles based on this rank-ordering. When creating these decile rankings, we weighted each teacher by the number of student-equivalents so that an equal number of students were represented in each decile. We compared the percentage of low-income students who had teachers in each decile to the percentage of high-income students who had teachers in each decile. We then averaged the results across districts. In parallel with how we obtained the average single-year Effective Teaching Gap, each district received an equal weight in this calculation.

D. Analysis of new hiring, development, transfer, and attrition

Framework for analyzing new hiring, transfer, and attrition. In Chapter V, we analyzed the prevalence and effectiveness of new hires, teachers who transfer, and leavers across high-, medium-, and low-poverty schools. To measure prevalence, we calculated the percentage of all teachers at a given school who were new hires, transfers, or leavers, separately for each school type. To compare the effectiveness of new hires, transfers, and leavers across schools, we computed the average value added of new hires, transfers, and leavers separately for low-poverty, medium-poverty, and high-poverty schools. To calculate these averages, we restricted the sample to one type of teacher (new hires, transfers, or leavers).

We used a regression analysis to generate these results. The basic idea was to compare the average value of the outcome of interest (for example, the value added of new hires shown in Figure IV.2) for teachers in low-, medium-, and high-poverty schools within districts, grade spans/subjects (middle school ELA, middle school math, and upper elementary grades), and years. We mean-centered the average within each district, grade span/subject, and year before taking an average across teachers in low-, medium-, and high-poverty schools, a process known as "differencing out" the effect of each district, grade span/subject, and year. In so doing, we removed any independent effects on the averages due to idiosyncratic factors associated with district, grade spans/subjects, or years.

Differencing out district effects ensures that differences in hiring and mobility patterns across school poverty categories represent differences between schools within a district rather than differences between districts in the number of high- or low-poverty schools. For example, if almost all of district A's teachers are in high-poverty schools and almost all of district B's teachers are in low-poverty schools, a comparison of high- and low-poverty schools in our combined sample of districts (without averaging within a district) would primarily reflect differences in the outcome between districts A and B. By differencing out district effects, we focused the analysis on differences in outcomes between high- and low-poverty schools within a district, not differences that arose between districts. A similar logic can be applied to differencing out effects for grade spans/subjects and years.

Statistically, this process was accomplished by estimating this regression model for each outcome of interest:

$$\text{(B.19)}\quad Y_{igjt} = \boldsymbol{\alpha}'\mathbf{P}_{ijt} + \boldsymbol{\beta}'\mathbf{D}_j + \boldsymbol{\gamma}'\mathbf{G}_{igjt} + \boldsymbol{\delta}'H_t + \varepsilon_{igjt}$$

where Y_{igjt} is the outcome of interest for teacher *i* in grade *g* in district *j* in year *t.* In our analyses, the outcome of interest is either the value added of a teacher (in terms of standard deviations of teacher value added) or an indicator variable for whether a teacher is in a particular mobility category (new hire, transfer teacher, or leaver). $\mathbf{P}_{ijt}$ represents a set of indicator variables for each school poverty category, $\mathbf{D}_j$ represents a set of district indicator variables, $\mathbf{G}_{igjt}$ represents a set of grade span/subject indicator variables, H_t represents a set of year indicators. Finally, ε_{igjt} represents unexplained variation in the outcome, and $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$, $\boldsymbol{\gamma}$, and $\boldsymbol{\delta}$ are vectors of parameters to be estimated. The key parameters that we report are in the vector $\boldsymbol{\alpha}$, the coefficients of the school poverty categories. The observations in the regression are weighted by the number of student-equivalents taught by each teacher because teachers with more students have a greater influence on access to effective teaching (in the calculation of the Effective Teaching Gap). Standard errors are clustered at the teacher level to account for the fact that each regression contained multiple observations for each teacher if a teacher taught in more than one grade, subject, or year.

The use of indicator variables for school poverty categories accounts for differences between these categories but not for differences in school poverty within the categories. So, as a sensitivity analysis, we replaced $\mathbf{P}_{ijt}$ with the percentage of low-income students at a school, a continuous rather than categorical measure of school poverty. Results using a continuous measure of school poverty are shown in Appendix D. Results based on a continuous measure are used in the analysis relating differences in the Effective Teaching Gap across districts to measures of teacher hiring, transfer, and attrition, described in Section F of this appendix. These results are also used in creating figures characterizing district-by-district patterns of hiring, transfer, and attrition, shown in Section A of Appendix D.

Framework for analyzing development. We modified this approach for analyzing whether teachers develop at different rates across high-, medium-, and low-poverty schools. Here, we used a within-teacher approach to examine teacher value added at each level of experience.[26] After accounting for any differences between teachers, we compared the average value added for teachers in high-, medium-, and low-poverty schools at each level of experience. The within-teacher approach is important because it allows us to distinguish between (1) the gains that the typical teacher makes from an additional year of experience and (2) compositional effects that occur from selective attrition. For example, we show in Chapter V that less effective teachers tend to exit teaching, leading to differences in the composition of teachers by years of experience, favor teachers with more years of experience. If we did not use a within-teacher approach, late-career teachers may appear to be gaining more effectiveness from year to year than they actually do because we would be conflating the return to experience with the tendency of less effective teachers to leave the profession.

To implement this approach, we estimated this regression:

$$\text{(B.20)} \quad V_{ijt} = \boldsymbol{\alpha}'\mathbf{P}_{ijt} + \boldsymbol{\beta}'Exp_{ijt} + \boldsymbol{\gamma}'\mathbf{P}_{ijt} * Exp_{ijt} + \boldsymbol{\delta}'\mathbf{T}_i + \varepsilon_{ijt}$$

where V_{ijt} is the value added of teacher *i* in district *j* in year *t*. $\mathbf{P}_{ijt}$ represents a set of indicator variables for each school poverty category, Exp_{ijt} represents a set of indicator variables for each year of experience, $\mathbf{T}_i$ represents a set of teacher fixed effects, ε_{ijt} is an error term capturing all unmeasured inputs into teacher effectiveness, and $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$, $\boldsymbol{\gamma}$, and $\boldsymbol{\delta}$ are vectors of parameters to be estimated. The interaction between the school poverty indicator variables and the experience indicator variables allows us to measure whether the change in value added as teachers gain experience (that is, teacher development) differs by school poverty. We clustered standard errors at the teacher level to account for the fact that there were multiple observations per teacher.

To set up the data for the development analysis, we collapsed observations to the teacher-year level and averaged over a teacher's value added in different grades if that teacher taught in multiple grades in the same year. We excluded observations where a teacher had greater than 35 years of experience due to small sample sizes of teachers. In some districts experience was capped such that all experience levels greater than that value appeared to be top-coded at that value. In these cases we excluded teachers from the analysis if they were first observed with a top-coded experience value.

[26] Study districts provided information on total years of experience (that is, experience in any district) or provided each teacher's step on the salary schedule as a way to measure total experience. For some districts, information on total teaching experience only included experience teaching in the state. Teachers typically earn a salary step for each additional year of teaching, and districts often provide credit for prior teaching experience in other districts (for example, one district provided a maximum of three years of credit for teaching in other districts). Two of the districts had a cap on their salary schedules at 10 steps, so the district could not distinguish the experience level of teachers beyond 10 years. In addition, 12 of the 25 districts provided data on teaching experience whereas the other 13 provided data on the years of experience in the field of education. The years of experience would overstate the years of teaching experience for teachers who worked in non-teaching positions within a district (e.g. teachers could earn credit for time spent as a teaching aide, school counselor, or principal).

Some researchers who measure teacher development include year fixed effects in addition to teacher fixed effects in their regression models (Kraft and Papay 2014; Ladd and Sorenson 2014). The inclusion of year fixed effects accounts for the possibility that different cohorts of teachers have different levels of average effectiveness. To identify the year fixed effects separately from the experience indicators, these researchers assume that there is a set of years of experience over which there is no return to experience. We chose not to account for year fixed effects for two reasons. First, the assumption underlying this approach is fairly arbitrary and estimates can differ if, for example, one assumes that there are no returns to experience after 20 years of experience in a district versus assuming no returns between years 10 and 15. Second, this strategy can induce substantial bias in the estimates if the assumption of no returns to experience is false over the presumed range.

E. Analysis of the contribution of novice teachers to the Effective Teaching Gap

This section shows how to formally decompose the Effective Teaching Gap into the parts due to (1) low-income students being more likely to receive instruction from novices (who are generally less effective than veterans) and (2) low-income students receiving instruction from less effective teachers, whether novices or veteran teachers. In Section J of Appendix D, we show the results based on this decomposition.

The Effective Teaching Gap is defined as the difference in average teacher value added between low-income students and high-income students. The Effective Teaching Gap can therefore be represented by the following equation, where *LI* refers to low-income students, *HI* refers to high-income students, and $\overline{VA}$ indicates the average value added of teachers of low-income or high-income students:

(B.21) $$ETG = \overline{VA}^{HI} - \overline{VA}^{LI}$$

$\overline{VA}^{HI}$ can be separated into the part due to veteran teachers (*vet*) and the part due to novice teachers (*nov*) as follows:

(B.22) $$\overline{VA}^{HI} = P_{vet}^{HI}\overline{VA}_{vet}^{HI} + P_{nov}^{HI}\overline{VA}_{nov}^{HI}$$

Here P^{HI} indicates the proportion of high-income students taught by novice or veteran teachers. The average value added of teachers of high-income students can therefore be written as the sum of the average value added of veteran teachers of high-income students (weighted by the proportion of high-income students taught by veteran teachers) plus the average value added of novice teachers of high-income students (weighted by the proportion of high-income students taught by novice teachers). $\overline{VA}^{LI}$ can be written in a similar manner:

(B.23) $$\overline{VA}^{LI} = P_{vet}^{LI}\overline{VA}_{vet}^{LI} + P_{nov}^{LI}\overline{VA}_{nov}^{LI}$$

This gives us the following expression for the Effective Teaching Gap:

$$ETG = \left(P_{vet}^{HI}\overline{VA}_{vet}^{HI} + P_{nov}^{HI}\overline{VA}_{nov}^{HI} \right) - \left(P_{vet}^{LI}\overline{VA}_{vet}^{LI} + P_{nov}^{LI}\overline{VA}_{nov}^{LI} \right) \tag{B.24}$$

Rearranging terms and adding and subtracting $P_{nov}^{HI}\overline{VA}_{nov}^{LI}$ from the first expression and $P_{vet}^{HI}\overline{VA}_{vet}^{LI}$ from the second expression gives:

$$\begin{aligned} ETG = &\left(P_{nov}^{HI}\overline{VA}_{nov}^{HI} - P_{nov}^{LI}\overline{VA}_{nov}^{LI} + P_{nov}^{HI}\overline{VA}_{nov}^{LI} - P_{nov}^{HI}\overline{VA}_{nov}^{LI} \right) \\ &+ \left(P_{vet}^{HI}\overline{VA}_{vet}^{HI} - P_{vet}^{LI}\overline{VA}_{vet}^{LI} + P_{vet}^{HI}\overline{VA}_{vet}^{LI} - P_{vet}^{HI}\overline{VA}_{vet}^{LI} \right) \end{aligned} \tag{B.25}$$

Rearranging terms and substituting $1 - P_{nov}^{LI}$ for P_{vet}^{LI} and $1 - P_{nov}^{HI}$ for P_{vet}^{HI} gives:

$$\begin{aligned} ETG = &\left((P_{nov}^{HI})(\overline{VA}_{nov}^{HI} - \overline{VA}_{nov}^{LI}) + (P_{vet}^{HI})(\overline{VA}_{vet}^{HI} - \overline{VA}_{vet}^{LI}) \right) \\ &+ \left(P_{nov}^{HI}\overline{VA}_{nov}^{LI} - (1 - P_{nov}^{LI})\overline{VA}_{vet}^{LI} + (1 - P_{nov}^{HI})\overline{VA}_{vet}^{LI} - P_{nov}^{LI}\overline{VA}_{nov}^{LI} \right) \end{aligned} \tag{B. 26}$$

Multiplying out terms in the second line and rearranging gives:

$$\begin{aligned} ETG = &\left[(P_{nov}^{LI} - P_{nov}^{HI})(\overline{VA}_{vet}^{LI} - \overline{VA}_{nov}^{LI}) \right] \\ &+ \left[(P_{nov}^{HI})(\overline{VA}_{nov}^{HI} - \overline{VA}_{nov}^{LI}) + (P_{vet}^{HI})(\overline{VA}_{vet}^{HI} - \overline{VA}_{vet}^{LI}) \right] \end{aligned} \tag{B.27}$$

= Difference in Likelihood of Being Assigned a Novice Teacher +

Difference in Teacher Effectiveness, Accounting for Experience

As shown in equation (B.27), the first component of the Effective Teaching Gap reflects the portion of the Effective Teaching Gap due to the difference between high-income and low-income students in the likelihood of being assigned to a novice teacher. If low-income students are more likely to be assigned a novice teacher, this contributes to the Effective Teaching Gap because novice teachers are less effective than veteran teachers, on average. This is captured in the equation by the difference in value added between veteran and novice teachers of low-income students. The second component of the Effective Teaching Gap shown in equation (B.27) reflects the portion of the Effective Teaching Gap due to differences in the effectiveness of the teachers of low-income students versus those of high-income students, controlling for their experience level. There are two parts to this component of the Effective Teaching Gap—the first captures differences in the effectiveness of novice teachers assigned to high-income students versus low-income students; the second captures differences in the effectiveness of veteran teachers assigned to the two groups.

This decomposition can be better understood by considering two extreme cases. First, suppose that low-income students are equally likely to be assigned to novice teachers, but that high-income students are assigned to more effective novice teachers as well as more effective veteran teachers. In this scenario, the first component of the Effective Teaching Gap would be zero but the second component would be positive. Second, suppose that low-income students are more likely to be assigned to novice teachers (who are less effective than veteran teachers), but they are assigned to novice teachers who are just as effective as the novice teachers to whom high-income students are assigned. Similarly, when low-income students are assigned to veterans, these teachers are just as effective as the veterans to whom high-income students are assigned. In this scenario, the first component of the Effective Teaching Gap would be positive and the second component would be zero.

F. District-level analysis of the relationship between mobility measures and the effective teaching gap

In this section we describe an analysis that relates differences across districts in the Effective Teaching Gap to district-level patterns of hiring, transfer, and attrition. We report the results of this analysis in Chapter V and give more details in Section L of Appendix D.

We related the Effective Teaching Gap to six measures of differences between high- and low-poverty schools in patterns of hiring, transfer, and attrition. For each type of teacher career transition, we created (1) a measure of the difference between high- and low-poverty schools in the average *effectiveness* of teachers making that type of transition; and (2) a measure of the difference between high- and low-poverty schools in the *prevalence* of teachers making that type of transition. We describe each measure below.

Effectiveness of new hires. To capture differences between high- and low-poverty schools in the effectiveness of new hires, we estimated a regression for each district-subject combination of the value added of new hires on the percentage of low-income students at a school and year fixed effects—a continuous version of equation (B.19) absent the district and subject/grade span fixed effects. The sample for this regression included only the new hires in each district. The coefficient on the value added of low-income students in this regression measures differences in the value added of new hires across schools of different poverty levels.

Prevalence of new hires. To measure differences in the prevalence of new hires, we constructed a measure in a similar way. First, for each district-subject combination we estimated a parallel set of regressions using equation (B.19) in which we regressed an indicator for a teacher being a new hire on the percentage of low-income students at the teacher's school and a set of year fixed effects. We estimated these regressions using samples of all of a district's teachers. The coefficient on the percentage of low-income students in this regression measures differences in the likelihood of hiring a new teacher across schools of different poverty levels.

Effectiveness of transfers. We capture effectiveness by measuring the change in school poverty between the schools that transfer teachers leave and the schools they transfer into. We calculate this change in school poverty separately for transfer teachers with above average effectiveness (value added above 0) and for transfer teachers with below average effectiveness (value added below 0). A positive value indicates that a teacher moved to a higher-poverty school while a negative value indicates a teacher moved to a lower-poverty school.

Prevalence of transfers. To measure differences in the prevalence of transfers, we again used equation (B.19), but regressed an indicator for whether a teacher transferred out of a school on the percentage of low-income students at the teacher's school and a set of year fixed effects. We used the coefficient on the percentage of low-income students in this regression to measure differences in the likelihood of teachers transferring out of schools of different poverty levels.

Effectiveness of leavers. To measure how the effectiveness of leavers affected the Effective Teaching Gap, we needed to capture how the difference in the effectiveness of leavers and stayers differed across high- and low-poverty schools. To do this, we estimated two versions of equation (B.19). First, we restricted the data set to stayers, and regressed the value added of stayers on the percentage low-income and year fixed effects. Second, we restricted the data set to leavers, and regressed the value added of leavers on the percentage low-income and year fixed effects. We extracted the coefficient on the percentage of low-income students in both cases, and took the difference between these two coefficients.

Prevalence of leavers. We also measured how differences in the prevalence of leavers influenced the Effective Teaching Gap. To do so, we estimated equation (B.19) by regressing an indicator for leaving the district on the percentage of low-income students and year fixed effects.

We estimated separate models where the Effective Teaching Gap was regressed on each summary measure. For each district, we used the average between-school Effective Teaching Gap across the 5 years of the study as well as average hiring, transfer, and attrition patterns that occurred during that time span. We used teacher-level standard deviation units for both the Effective Teaching Gap and the summary measures related to value added to prevent the analysis from being influenced by differences across grades, subjects, or districts in the size of student-level standard deviations. There are two observations for each district, one for the ELA Effective Teaching Gap and another for the math Effective Teaching Gap. We clustered the standard errors at the district level to account for the fact that we had more than on observations for each district. We weighted each district by the number of teacher-year observations entering the analysis in order to give greater weight to districts with more precise summary measures. To ensure comparability across districts, the analysis included middle-school grades only. We did not estimate separate models for elementary school grades because there were too few districts where these data were available to conduct a cross-district analysis.

An important consideration when interpreting the results is that this analysis is based on hiring, transfer, and attrition patterns that occurred during the 5 study years. However, the current Effective Teaching Gap is affected by both past and current hiring, transfer, and attrition patterns. The validity of the results, therefore, depends on the extent to which past patterns of hiring, transfer, and attrition are similar to the patterns observed during the 5 study years.

G. District policies

In Chapter III, we present information about the number of districts implementing policies that could influence access to effective teaching. We identified a set of 13 policies that could disproportionately improve the effectiveness of teachers in high-need schools that primarily serve disadvantaged students. Although there is minimal evidence on the impact of most of these policies, we focused on policies that have been proposed by policymakers at the federal, state, and district levels to address inequity. All of these policies are designed to address the distribution of teachers across schools, but districts targeted different types of high-need schools. Some districts focused on high-poverty schools, others on low-performing schools or schools serving a high proportion of minority students. We collected information about any policies that focused on improving teacher effectiveness in a subset of high-need schools, regardless of how the district defined high-need school.

Teacher compensation policies. We documented the implementation of two policies that used teacher pay to attract teachers into high-need schools or incentivize high performing teachers in these schools. These types of policies have been supported by the federal Teacher Incentive Fund grants as well as through state and local programs such as South Carolina's Teacher Advancement Program and the District of Columbia Public School's IMPACT evaluation system.

- **Bonuses for teaching in high-need schools.** We identified districts that offered additional pay for teaching in high-need schools. This included recruitment bonuses to encourage new teachers and teachers in low-need schools to teach in high-need schools, as well as retention bonuses for teachers who were already teaching in high-need schools. The bonuses for teaching in a high-need school ranged from $1,000 to $11,500.
- **Performance-pay in high-need schools**. Districts that offered opportunities for additional pay based solely on teacher's performance in high-need schools were counted as implementing this policy. These districts may have offered bonuses on the basis of school- and/or teacher-level performance, and could have evaluated performance on the basis of classroom observations and/or student achievement. We excluded districts that offered performance pay to teachers in *all* schools because of our focus on policies that could disproportionately influence teacher effectiveness in high-need schools.

Teacher recruitment and hiring policies (other than compensation). We identified three policies that could potentially influence the effectiveness of teachers hired into high-need schools. All three policies are designed to improve the pool of teachers that are available for high-need schools to hire. The federal Race to the Top grants supported these efforts to improve the effectiveness of new hires in high-need schools.

- **Highly selective alternate routes into teaching**. We documented districts that partnered with one of two highly selective alternate route into teaching: Teach for America and TNTP's Teaching Fellows. These programs are designed to attract recent college graduates and mid-career changers into teaching in high-need schools. They differ from other alternative routes into teaching because they set a high bar for program entry, admitting fewer than 15 percent of applicants (Clark et al. 2009).
- **Early hiring timelines for high-poverty schools**. Based on a case study of X large, urban districts, a TNTP report raised the concern that late hiring timelines reduced the quality of applicants and teachers hires in these districts. Although shifting a district's hiring timeline for all schools may be difficult (especially if it is linked to the district's budget process), districts have allowed high-need schools to hire teachers on an earlier timeline to improve the quality of applicants and new hires in these schools. Given that this policy could disproportionately affect new hires in high-poverty schools, we identified districts that provided high-need schools an earlier hiring timeline than other schools.
- **Targeted recruitment activities for high-need schools**. Each year school districts recruit a pool of teacher applicants and then hire from this pool to fill vacancies in the coming school year. Districts may use a variety of recruitment activities to attract applicants and

encourage teachers to apply—for example, job fairs, career panels at local teacher preparation programs, and outreach activities to attract applicants. We tracked whether districts conducted recruitment activities specifically designed to improve the applicant pool and new hires in high-need schools.

Teacher transfer and retention policies (other than compensation). We tracked three policies that could influence access to effective teachers through their effect on teacher transfer and attrition patterns.

- **Mutual consent for teacher transfers into high-need schools**. Districts typically need to move teachers between schools each year as a result of shifts in student enrollment. These transfers are involuntary—teachers are forced to change schools—and they differ from transfers in which teachers voluntarily decide to move to different schools. TNTP's case studies described above suggest that teachers affected by this involuntary transfer process are less effective than other teachers—either because these transfers disproportionately affect less experienced teachers or because principals propose their least effective teachers for involuntary transfer. As an alternative to these forced transfers, some districts require "mutual consent" where both the teacher and school must agree before a teacher is involuntarily transferred. We identified districts that prevented forced transfers into high-need schools only by requiring mutual consent for these schools. We exclude districts that eliminated forced placements for all schools, and focus on those that provide this flexibility only to high-need schools.
- **Performance-based teacher layoffs**. When districts need to layoff teachers, they often use a first-in, first-out policy that lays off the least experienced teachers first. Some researchers have raised concerns that this approach could lead to the layoff of less experienced teachers who are more effective than some of their more experienced peers (Goldhaber and Theobald 2010; Boyd et al. 2011). An alternative is to prioritize teachers for layoff based on performance, laying off the lowest performing teachers first. We identified districts that used teacher performance as the primary criterion to determine which teachers will be laid off. For districts that used multiple criteria to prioritize teachers for layoffs, we included those that assigned at least half of the weight to teacher performance. Although this is a policy that affects teachers in all schools—not just those in high-need schools—if less effective teachers are more common in high-need schools, then this layoff policy would disproportionately affect high-need schools.
- **Performance-based tenure decisions**. Districts typically grant tenure to new teachers after two to three years of teaching in the district. Although districts evaluate the performance of new teachers, and those evaluations can influence decisions about tenure, there is evidence suggesting that current evaluation systems based solely on classroom observation measures may not adequately distinguish teacher performance (Weisberg et al. 2009). As a result, some researchers have suggested that states and districts use measures of teacher performance based on student achievement growth to avoid granting tenure to low performing teachers. This policy does not directly target high-need schools, but these schools could be disproportionately affected if they have more novice teachers than other schools.

Teacher development. In addition to teacher hiring, transfers, and attrition, teacher development is another mechanism through which districts can influence access to effective teachers. We identified two policies that could potentially improve how quickly teachers in high-poverty schools develop and become more effective over time.

- **Teacher professional development in high-need schools**. Districts invest a substantial amount of funds into professional development each year (TNTP 2015), including Title I funds that can be used to support professional development targeted to teachers in high-need schools. Although there is limited evidence on effective professional development interventions (Gersten et al. 2014), districts could potentially improve the effectiveness of teachers in high-need schools quicker than in other schools by targeting professional development resources to these schools.
- **Comprehensive teacher induction**. One way districts can support new teachers in their district is by providing a comprehensive induction program that is instructionally focused induction and provides trained, full-time mentors for new teachers. Even if this program is provided to new teachers in all schools, it could disproportionately increase the effectiveness of teachers in high-need schools if these schools have more new teachers.

School improvement. Districts use school improvement efforts to substantially turnaround the performance of chronically low-performing schools. A school improvement initiative can take different forms, may involve meaningful change such as replacing a principal or teachers at a school, implementing a new curriculum, shifting management of a school to an external organization, and at the extreme, closing down a school and shifting students to other schools. Because these initiatives target high-need schools and can influence the effectiveness of teachers in these schools, we documented whether districts implemented school improvement activities.

- **School improvement activities in chronically low-performing schools**. We tracked whether districts implemented one of the four school improvement models defined by Race to the Top and the School Improvement Grants. This included initiatives funded by these two grant programs, as well as initiatives funded by other sources but based on one of the following four school improvement models: (1) replacing the principal and at least half of the staff and implementing instructional reforms (turnaround model), (2) replacing the principal and implementing instructional reforms (transformation model), (3) reopening the school under the management of a charter school or other management organization (re-start model), and (4) closing the school and reassigning students to other schools (school closure).

APPENDIX C

ADDITIONAL TABLES AND SENSITIVITY ANALYSES FOR CHAPTER IV

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Chapter IV described low-income students’ access to effective teachers in the 26 study districts. This appendix provides more details about those findings, presents district-level results, and examines the sensitivity of the findings to alternative assumptions.

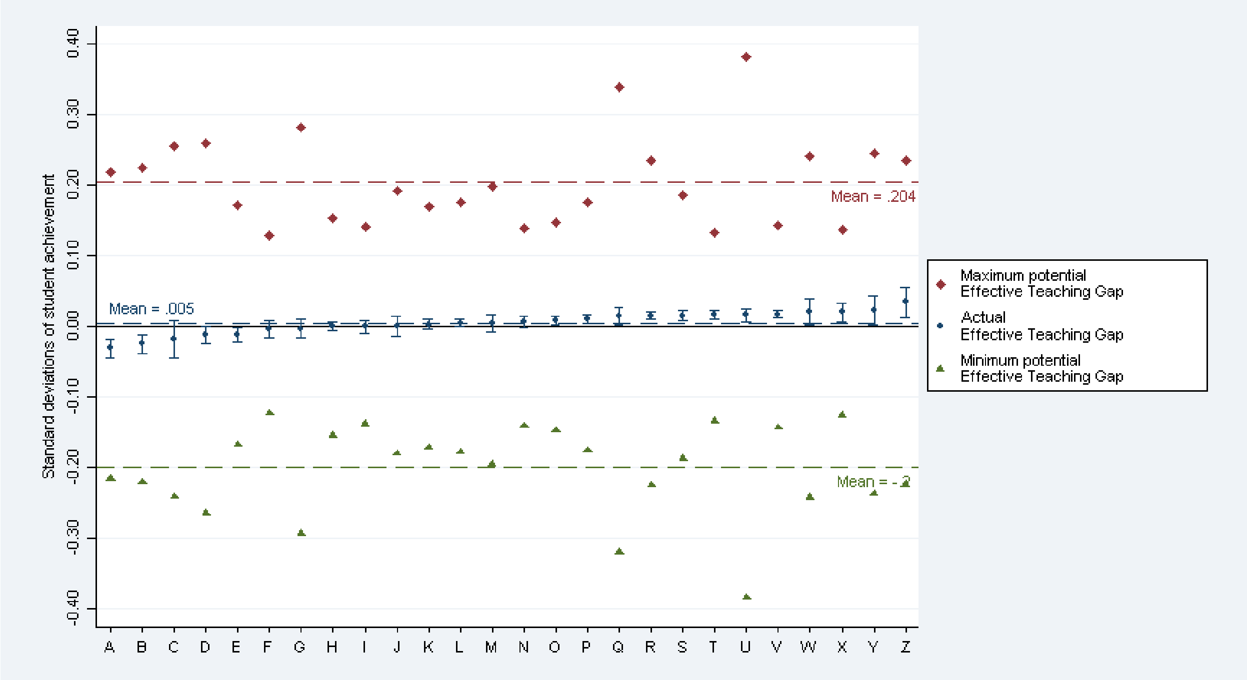
A. Maximum and minimum Effective Teaching Gaps

We described access to effective teachers using a measure called the Effective Teaching Gap, which represents the difference in average value added between the teachers of low-income students and the teachers of high-income students. To provide additional context for these findings, we compared the actual Effective Teaching Gap in study districts to what the gap would be under a worst-case scenario in which the most effective teachers were assigned to the classrooms with the most high-income students, and the least effective teachers were in the classrooms with the most low-income students. We refer to this as the maximum Effective Teaching Gap.

In Chapter IV, we showed that the Effective Teaching Gap is much less than the maximum Effective Teaching Gap on average across the study districts. We found similar results when we examined the maximum Effective Teaching Gap by district. For example, the maximum Effective Teaching Gap is at least 0.10 standard deviations larger than the actual Effective Teaching Gap in all of the districts for both ELA and math (Figures C.1 and C.2). This indicates that within each district there was a wide enough variation in teacher effectiveness and sufficient separation of high- and low-income students into different schools and classrooms that the Effective Teaching Gap could have been much larger than it was. In no district was the Effective Teaching Gap constrained to be near zero by a lack of variation in teacher effectiveness or by an equal distribution of students across classrooms.

We also calculated the minimum Effective Teaching Gap, based on the opposite scenario where classrooms with the most high-income students have the least effective teachers and those with the most low-income students have the most effective teachers. As shown in Figures C.1 and C.2, the minimum Effective Teaching Gap is approximately equal in absolute value to the maximum Effective Teaching Gap. For example, the maximum Effective Teaching Gap for district A, the furthest to the left in Figure C.1, is 0.22 and the minimum Effective Teaching Gap is -0.22.

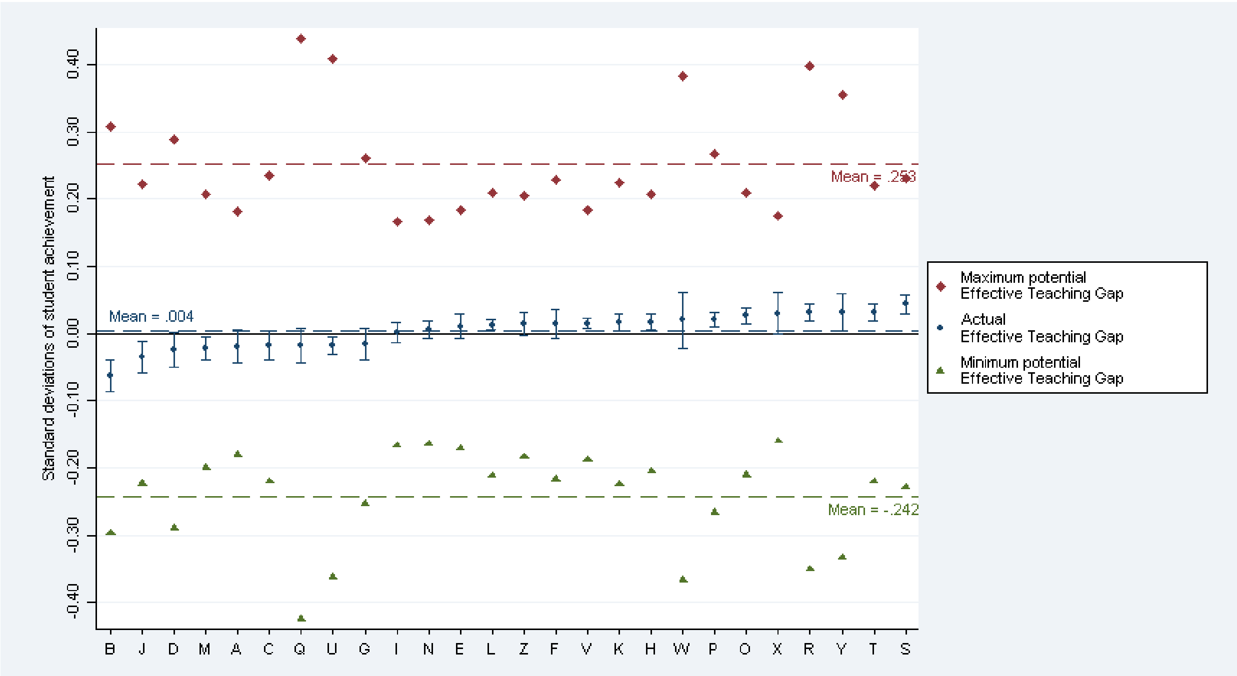
Figure C.1. Comparison of the actual Effective Teaching Gaps to the minimum and maximum Effective Teaching Gaps, English/language arts, by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. District identifiers A to Z assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures. Effective Teaching Gaps are computed within each district-grade-year combination and averaged with equal weight across years within each district. The blue points represent the actual Effective Teaching Gaps for each district and the vertical lines show the 95-percent confidence intervals around each point. The red diamonds represent the maximum potential Effective Teaching Gaps and the green triangles represent the minimum potential Effective Teaching Gaps. The cross-district averages are shown by each dashed horizontal line.

Figure C.2. Comparison of the actual Effective Teaching Gaps to the minimum and maximum Effective Teaching Gaps, math

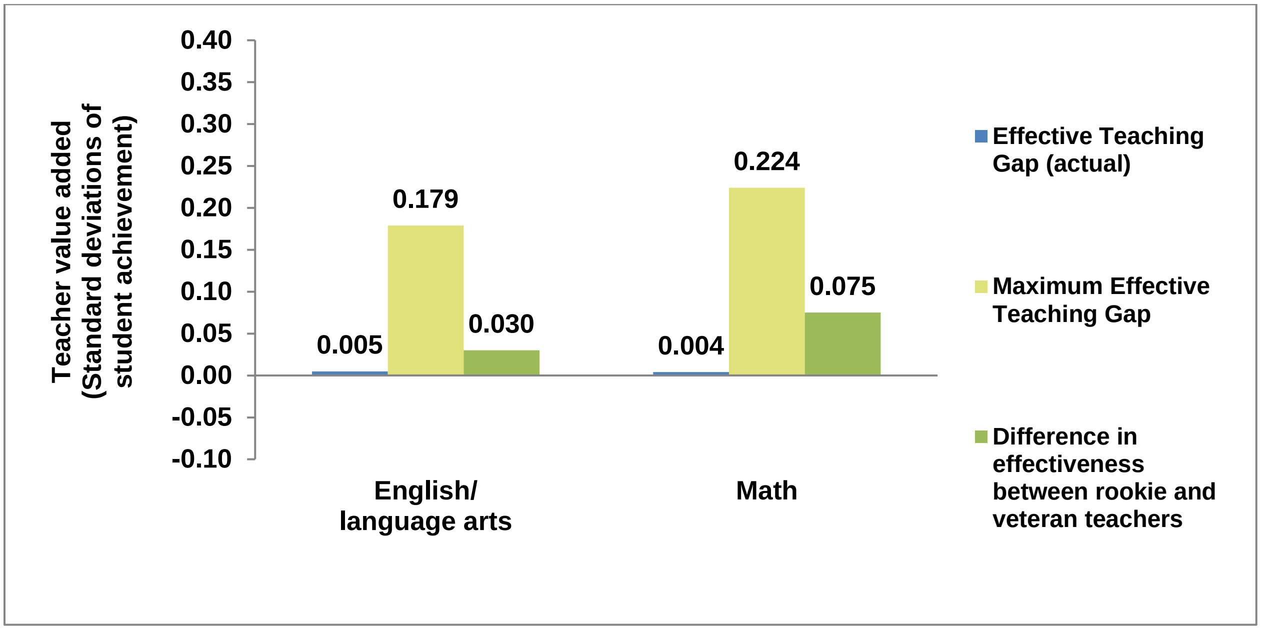


Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures. Effective Teaching Gaps are computed within each district-grade-year combination and averaged with equal weight across years within each district. The blue points represent the actual Effective Teaching Gaps for each district and the vertical lines show the 95-percent confidence intervals around each point. The red diamonds represent the maximum potential Effective Teaching Gaps and the green triangles represent the minimum potential Effective Teaching Gaps. The cross-district averages are shown by each dashed horizontal line.

To provide an additional point of comparison, we compared the Effective Teaching Gap to the difference in the estimated effectiveness of a veteran teacher (with three or more years of experience) versus a first-year teacher (Figure C.3). In study districts, veteran teachers are more effective than first-year teachers by 0.030 standard deviations of student achievement in ELA and 0.075 in math, on average. Thus, the difference in the effectiveness of high- versus low-income students' teachers is much less than the difference between being taught by a veteran teacher versus a rookie teacher.

Figure C.3. Comparison of the Effective Teaching Gap to the maximum possible, and to differences in rookie and veteran teachers other measures



Source: Author's calculations based on district administrative data.

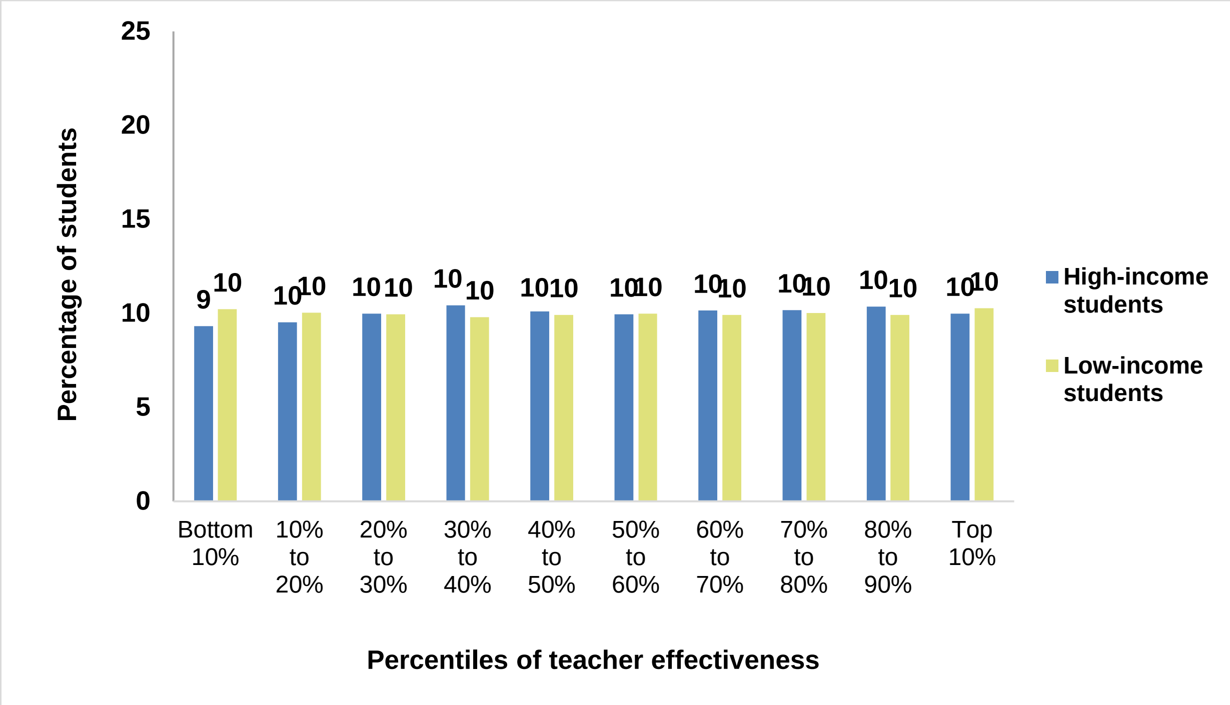
Note: Results are based on 26 districts for years 1 to 5, including grades 6 to 8 for 14 districts and grades 4 to 8 for 12 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. Differences in the effectiveness of rookie and veteran teachers are based on middle school teachers in 18 districts for years 1 through 5. Rookie teachers have no prior teaching experience and veterans have three or more years of prior experience. That calculation is based on a sample of 36,558 teacher-year observations, and excludes teachers with missing experience data and 7 districts that could not provide data on teachers' total teaching experience.

B. Proportion of high-income and low-income students taught by effective and ineffective teachers

In addition to measuring access to effective teaching using the Effective Teaching Gap, we compared high- and low-income students in terms of the likelihood that they are taught by effective teachers and by ineffective teachers. In Chapter IV, we showed that low-income students are about equally likely to be taught by teachers with value added in the top and bottom 10 percent of all teachers. In addition, there are minimal differences between these groups of students in the likelihood of being taught by more broadly defined groups of effective and ineffective teachers.

To examine these results in more detail, we compared the likelihood of low-income and high-income students being taught by teachers at each decile of performance (Figures C.4 and C.5). Similar percentages of high- and low-income students are taught by teachers at each level of effectiveness. For each decile of teacher performance, differences between high- and low-income students are less than one percentage point, in both subjects.

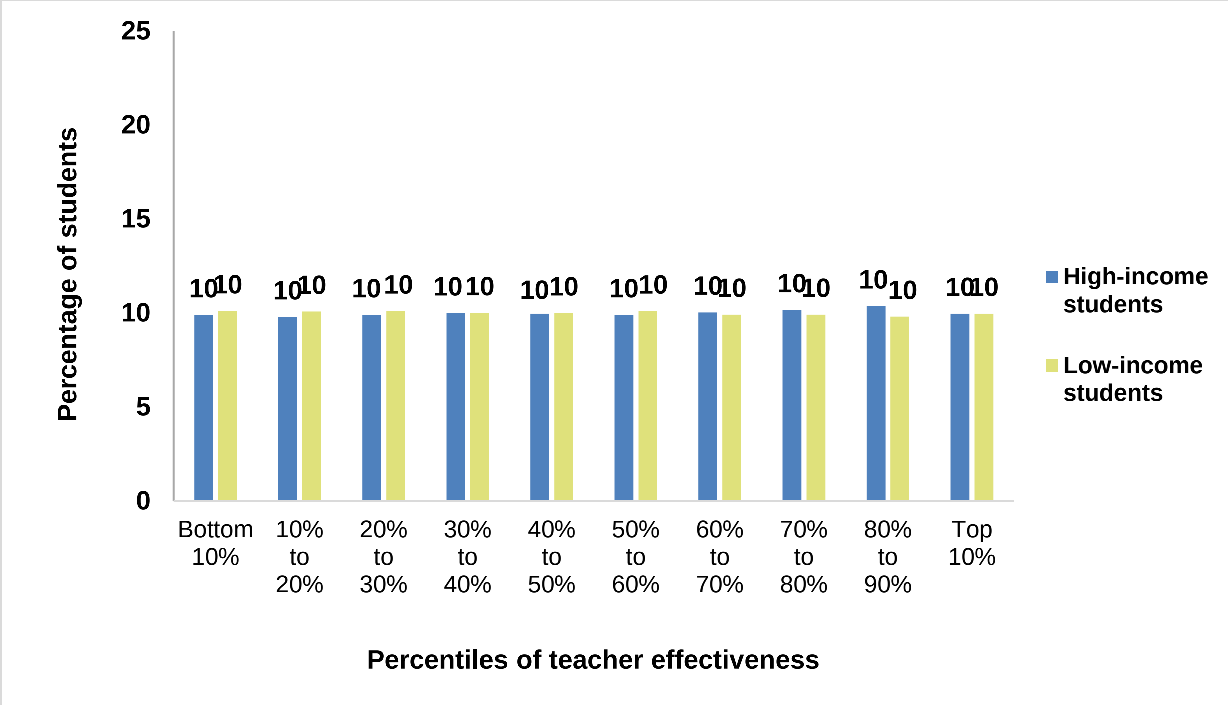
Figure C.4. Percentage of low-income and high-income students taught by teachers at different levels of effectiveness, English/language arts



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

Figure C.5. Percentage of low-income and high-income students taught by teachers at different levels of effectiveness, math

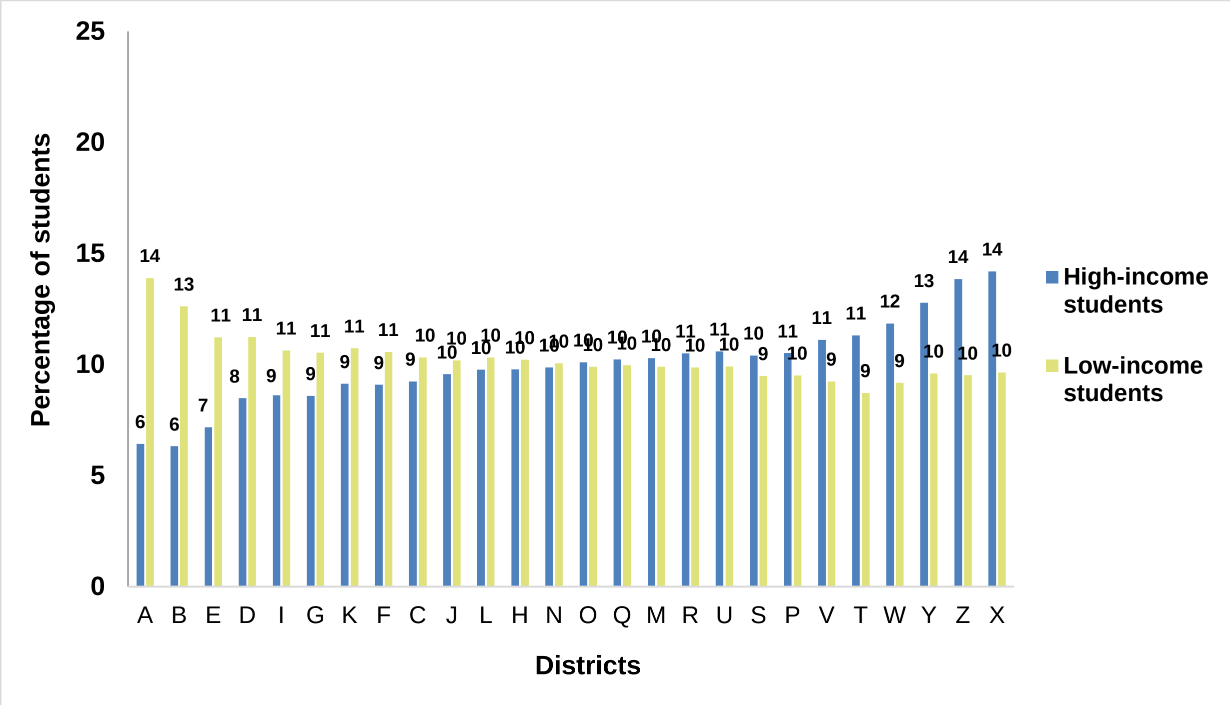


Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

We also examined the proportion of high- and low-income students taught by top and bottom decile teachers separately by district (Figures C.6 through C.9). As noted in Chapter IV, there are a few districts with larger inequity. For example, high-income students are 4 percentage points more likely than low-income students to have one of the *most* effective teachers in two districts for ELA and one district for math. In addition, low-income students are 4 percentage points more likely than high-income students to have one of the *least* effective teachers in three districts for ELA and two districts for math.

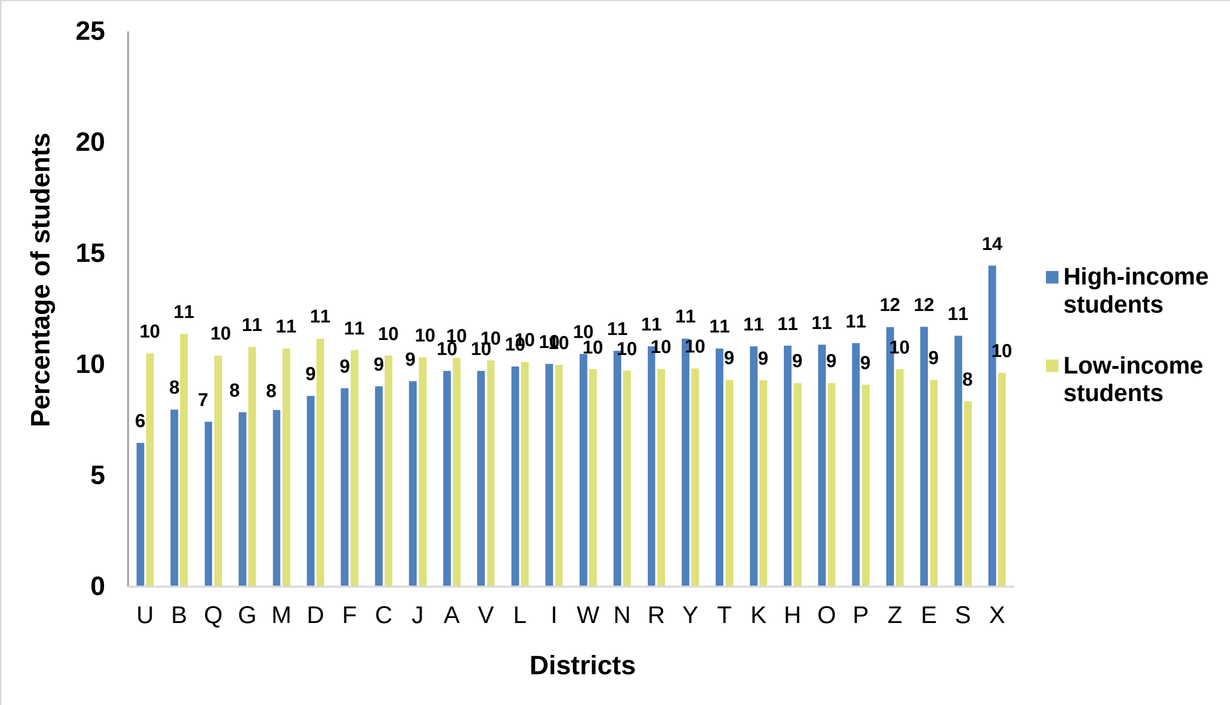
Figure C.6. Percentage of low-income and high-income students taught by top decile teachers, English/language arts



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. These results are based on a value-added model that accounts for classroom characteristics. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

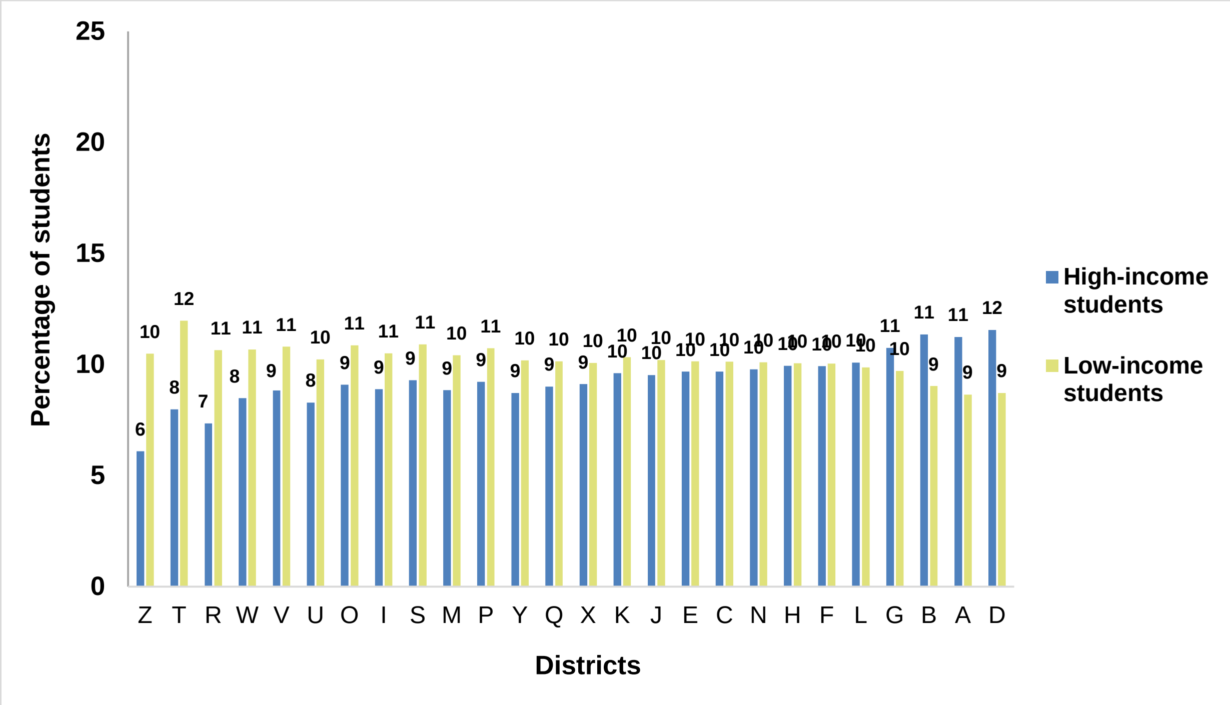
Figure C.7. Percentage of low-income and high-income students taught by top decile teachers, math



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. These results are based on a value-added model that accounts for classroom characteristics. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

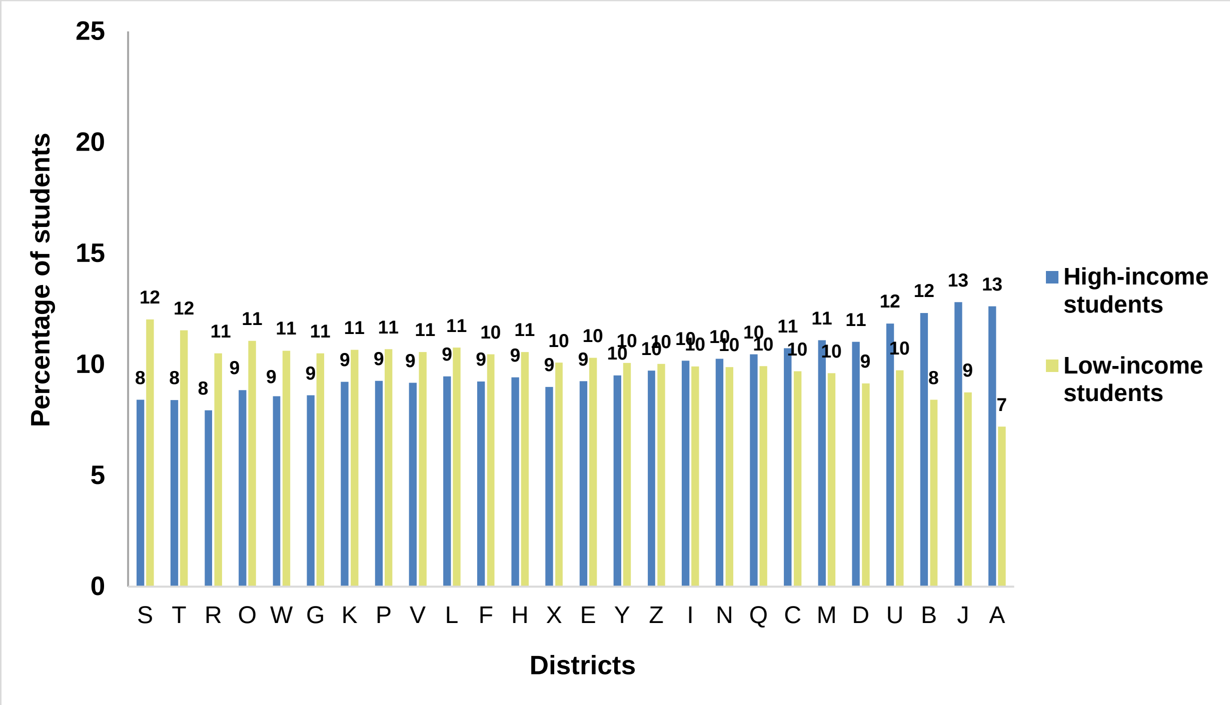
Figure C.8. Percentage of low-income and high-income students taught by bottom decile teachers, English/language arts



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. These results are based on a value-added model that accounts for classroom characteristics. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

Figure C.9. Percentage of low-income and high-income students taught by bottom decile teachers, math



Source: Author’s calculations based on district administrative data.

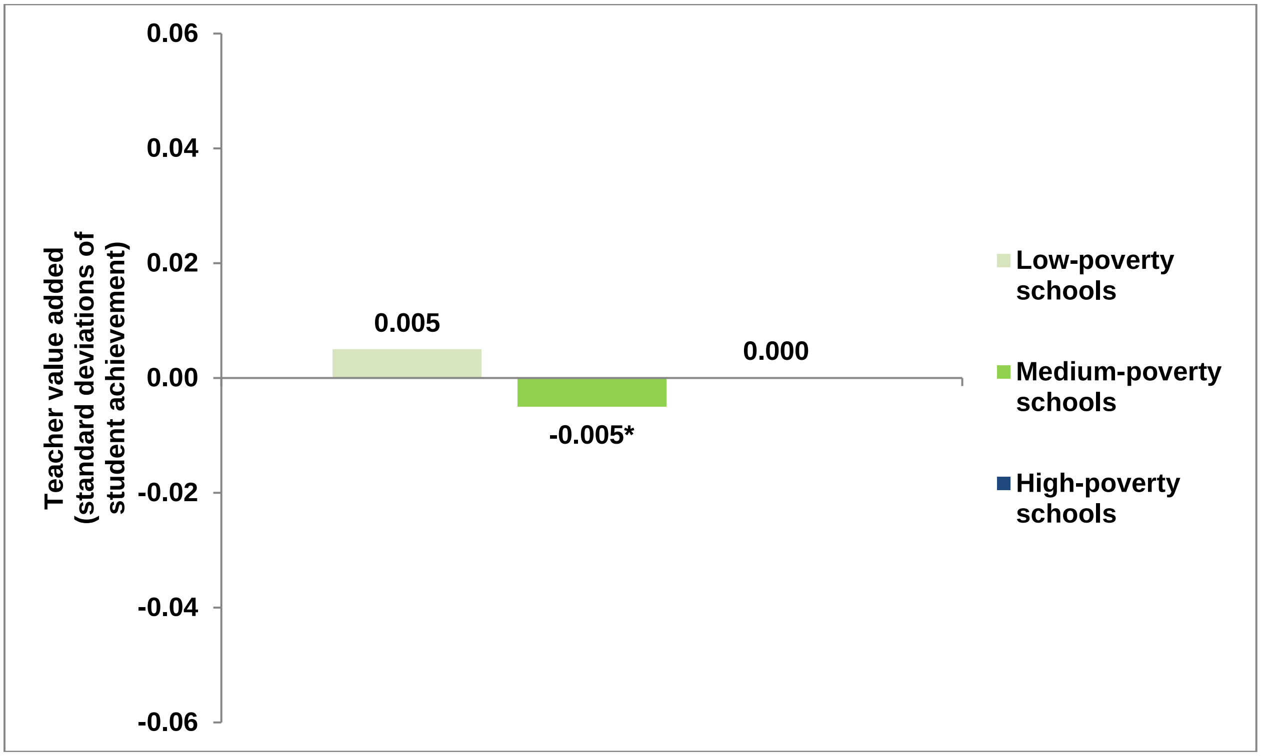
Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. These results are based on a value-added model that accounts for classroom characteristics. District identifiers A to Z are assigned in alphabetical order by the size of each district’s Effective Teaching Gap in ELA and are consistent across figures.

Even if low-income students have teachers who are nearly as effective as those of high-income students, on average, it is possible that schools with the highest poverty concentrations may have less effective teachers than schools with the lowest poverty concentrations. We find that the effectiveness of teachers is similar across high-, medium-, and low-poverty schools, on average across study districts.

We grouped schools into three categories—high-poverty schools, with 90 percent or more low-income students, medium-poverty schools, with 60 to 90 percent low-income students, and low-poverty schools, with fewer than 60 percent of low-income students. These definitions are consistent with the definitions we use in examining teachers’ career transitions in Chapter V, though we also investigated differences in the effectiveness of teachers across schools in different poverty categories based on alternative cut-points.

The effectiveness of the average teacher in high-, medium-, and low-poverty schools is similar. Within each of these three poverty categories, the average teacher has a value added that is very close to zero, suggesting that he or she is like the average teacher in the district as a whole (Figure C.10). The typical teacher in a high-poverty school is exactly average (a value added of 0.000), whereas the typical teacher in a low-poverty school is slightly above average (0.005) and the typical teacher in a medium-poverty school is below average (-0.005). Just as the average low-income student has a teacher nearly as effective as the average high-income student, the average teacher in a high-poverty school is nearly as effective as the average teacher in a low-poverty school, with a difference of 0.005.

Figure C.10. Teacher value added, by school poverty level



Source: Author's calculations based on district administrative data.

Note: The results are for teachers in grades 6 to 8 in 25 districts and for grades 4 to 8 in 12 of these districts, for years 1 to 5. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. The sample contains 110,466 teacher-year observations.

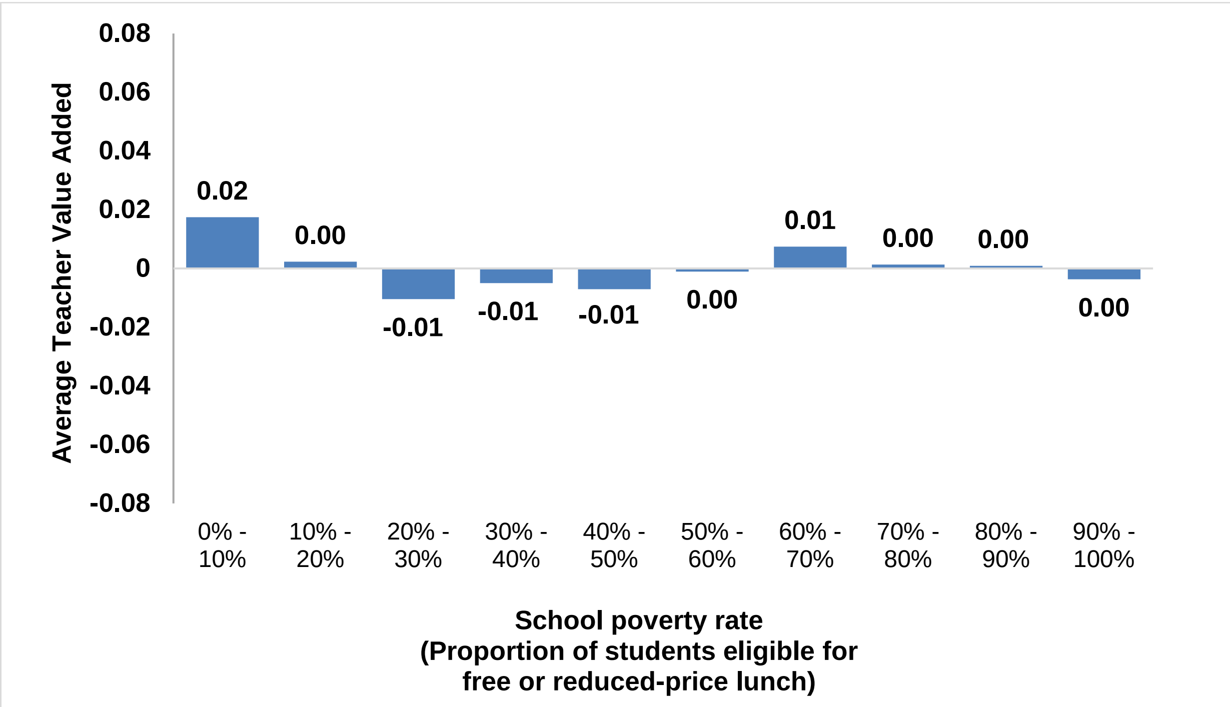
*Indicates that the difference in average value added between low-poverty schools and medium- and high-poverty schools is statistically significant at the 0.05 level, two-tailed test.

To test whether these results are sensitive to how we defined the school poverty categories, we also compared average teacher value added for schools using more fine-grained school-poverty categories (Figures C.11 and C.12). We grouped schools into 10 categories based on the proportion of students in the school who are low-income.

We found relatively small differences across these more fine-grained school poverty categories. Average value added ranged from 0.02 to -0.01 across the school poverty categories for ELA, and ranged from 0.03 to -0.02 for math. In addition, there was no pattern of average value added decreasing school poverty rates increased. For example, the average teacher in schools in each of the top three poverty categories—70 to 80 percent, 80 to 90 percent, and more than 90 percent—had value added of 0.00 or 0.01. In other words, across the full sample the average teacher in the schools with the highest poverty rates is as effective as the average teacher in their district as a whole. It does turn out that teachers in the lowest poverty schools—0 to 10 percent in ELA and 0 to 20 percent in math—have with the highest average value added, at 0.02

to 0.03. However, less than two percent of students in study districts attend schools in the 0 to 10 percent range and 6 percent attend schools in the 0 to 20 percent range.

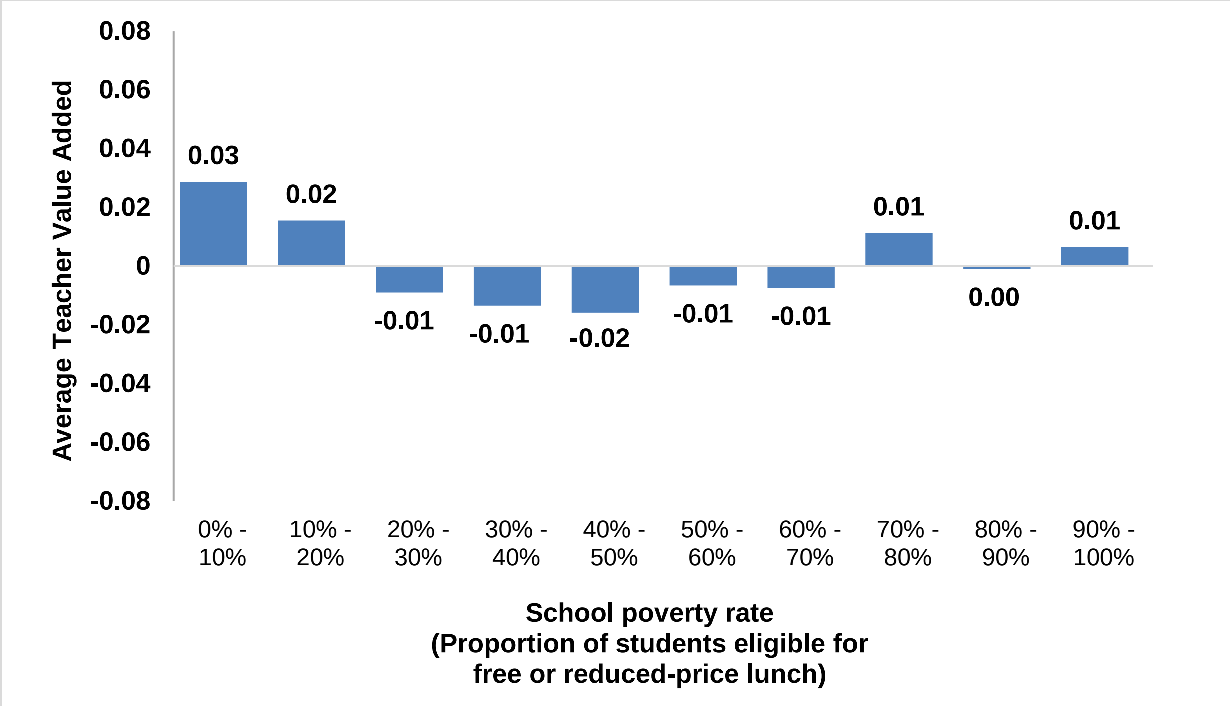
Figure C.11. Average value added by school poverty rate, English/language arts



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

Figure C.12. Average value added by school poverty rate, math



Source: Author's calculations based on district administrative data.

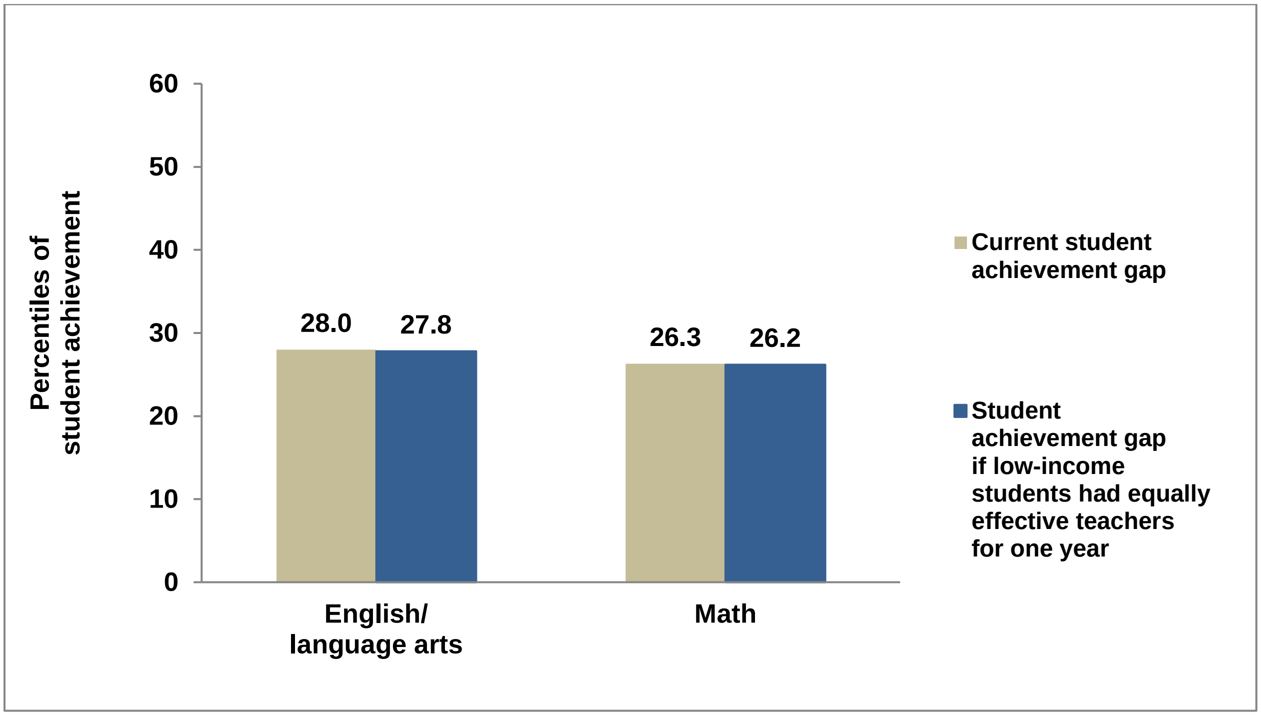
Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

C. How access to effective teachers contributes to the student achievement gap

In Chapter IV, we describe how equalizing access to effective teachers would affect the student achievement gap. This section provides more details about those results.

We find that providing high- and low-income students with equally effective teachers for one year would reduce the student achievement gap by less than one percentile point in both subjects (Figure C.13). Across the 26 study districts, the student achievement gap of 28.0 percentile points in ELA would decrease to 27.8 percentile points if low-income students had equal access to effective teachers. In math, the student achievement gap of 26.3 percentile points would decrease to 26.2 percentile points. These results are consistent with our earlier finding—the typical low-income student has a teacher barely below average in terms of effectiveness. In other words, equalizing access to effective teachers for one year would not have a substantial influence on the difference in student achievement levels between high- and low-income students.

Figure C.13. Change in student achievement gap if high- and low-income students had equally effective teachers for one year



Source: Author's calculations based on district administrative data.

Note: Results are based on 14 districts for grades 6 to 8 and 12 districts for grades 4 to 8, for years 1 to 5. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

When we measured access to effective teaching over five years, we restricted the sample to a subset of 12 districts where we can analyze grades 4 through 8. The single-year Effective Teaching Gap in this subset of districts is 0.012 in ELA and math (Table C.1). By way of comparison, the Effective Teaching Gap in the full sample is 0.005 in ELA and 0.004 in math. In other words, there is somewhat more inequity in the subset of districts used in this analysis than there is in the full study sample.

Table C.1. Five-Year Effective Teaching Gap, 12 districts, grades 4 through 8

	1-Year Effective Teaching Gap A	5-Year Effective Teaching Gap B	Student achievement gap in grade 8 (percentiles) C	Student achievement gap in grade 8 if equal access to effective teachers for 5 years (percentiles) D	Change in 8th grade student achievement if equal access to effective teachers for 5 years (percentiles) E
English/language arts					
Average	0.012	0.025	25.1	24.2	-1.0
Standard Deviation	0.010	0.034			
Minimum	0.000	-0.010	20.4	18.7	-4.0
Maximum	0.034	0.118	33.6	33.6	0.0
Math					
Average	0.012	0.046	24.5	22.3	-2.2
Standard Deviation	0.019	0.063			
Minimum	-0.022	-0.100	16.0	13.8	-5.2
Maximum	0.043	0.139	31.0	30.0	0.0

Source: Author's calculations based on district administrative data.

Note: Results are based on 12 districts for years 1 to 5 and grades 4 to 8. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. The first two columns are in standard deviations of student achievement. Column D sets the five-year Effective Teaching Gap to 0 only for those districts with positive five-year Effective Teaching Gaps. Column E shows the change in the student achievement gap by comparing columns C and D. In districts where low-income students already have more effective teachers than high-income students, we assumed that the student achievement gap would not change in columns C and D.

Table C.2. Three-Year Effective Teaching Gap, 26 districts, grades 6 through 8

	1-Year Effective Teaching Gap A	3-Year Effective Teaching Gap B	Student achievement gap in grade 8 (percentiles) C	Student achievement gap in grade 8 if equal access to effective teachers for 3 years (percentiles) D	Change in 8th grade student achievement if equal access to effective teachers for 3 years (percentiles) D – C
English/language arts					
Average	0.003	0.008	26.3	25.6	-0.7
Standard Deviation	0.016	0.035			
Minimum	-0.031	-0.077	19.0	17.4	-3.6
Maximum	0.041	0.107	40.2	40.2	0.0
Math					
Average	0.002	0.007	24.5	23.3	-1.2
Standard Deviation	0.026	0.064			
Minimum	-0.063	-0.112	12.6	9.9	-3.7
Maximum	0.039	0.102	35.7	35.7	0.0

Source: Author's calculations based on district administrative data.

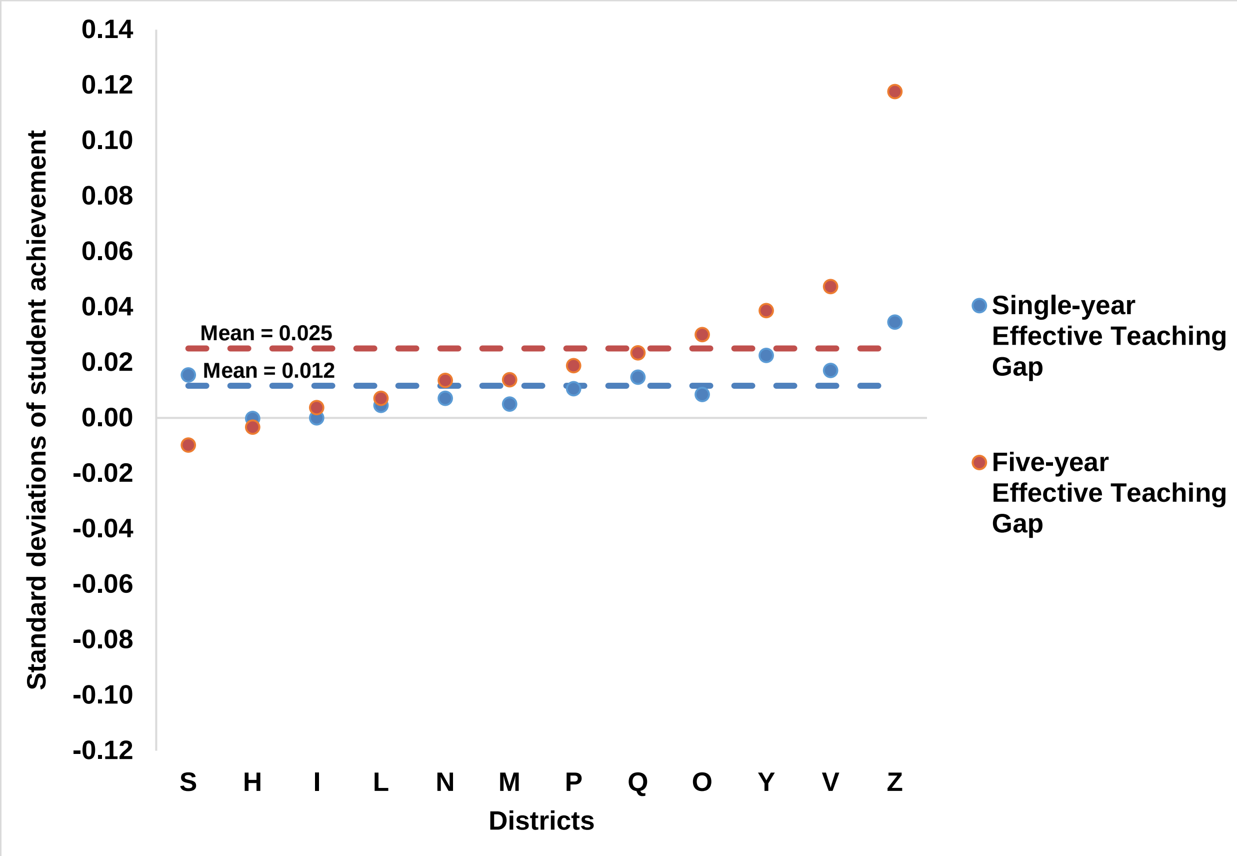
Note: Results are based on 26 districts for years 1 to 5 and grades 6 to 8. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. The first two columns are in standard deviations of student achievement. Column D sets the three-year Effective Teaching Gap to 0 only for those districts with positive three-year Effective Teaching Gaps. Column E shows the change in the student achievement gap by comparing columns C and D. In districts where low-income students already have more effective teachers than high-income students, we assumed that the student achievement gap would not change in columns C and D.

In Chapter IV, we present the multi-year Effective Teaching Gaps by describing how equalizing access over multiple years would reduce the student achievement gap. Tables C.1 and C.2 describe the size of the multi-year Effective Teaching Gaps in terms of standard deviations of student achievement. The five-year Effective Teaching Gap is 0.025 standard deviations of student achievement in ELA and 0.046 in math for the 12 districts that had sufficient data to include in this analysis. The three-year Effective Teaching Gap is 0.008 in ELA and 0.007 in math based on all 26 districts.

Among the 12 districts where we could calculate the five-year Effective Teaching Gap, seven had gaps that were within 0.02 standard deviations of the cross-district average in ELA and four had gaps this close to the average in math (Figures C.14 and C.15). In the district with the largest five-year Effective Teaching Gap (in math), equalizing access for five years would decrease the student achievement gap by 5 percentile points.

In most districts (14 of the 26 districts), the three-year Effective Teacher Gap in ELA is within 0.02 standard deviations of the cross-district average (Figures C.16). For math, 5 of the 26 districts are within 0.02 standard deviations of the cross-district average (Figure C.17). In the districts with the largest three-year Effective Teaching Gaps, equalizing access to effective teachers for three years would lead to moderate declines in the student achievement gap—a decline of 3 or more percentile points in one district in ELA and six districts in math. In the remaining districts, however, equalizing access to effective teachers for a three-year period would reduce the student achievement gap by less than 3 percentile points.

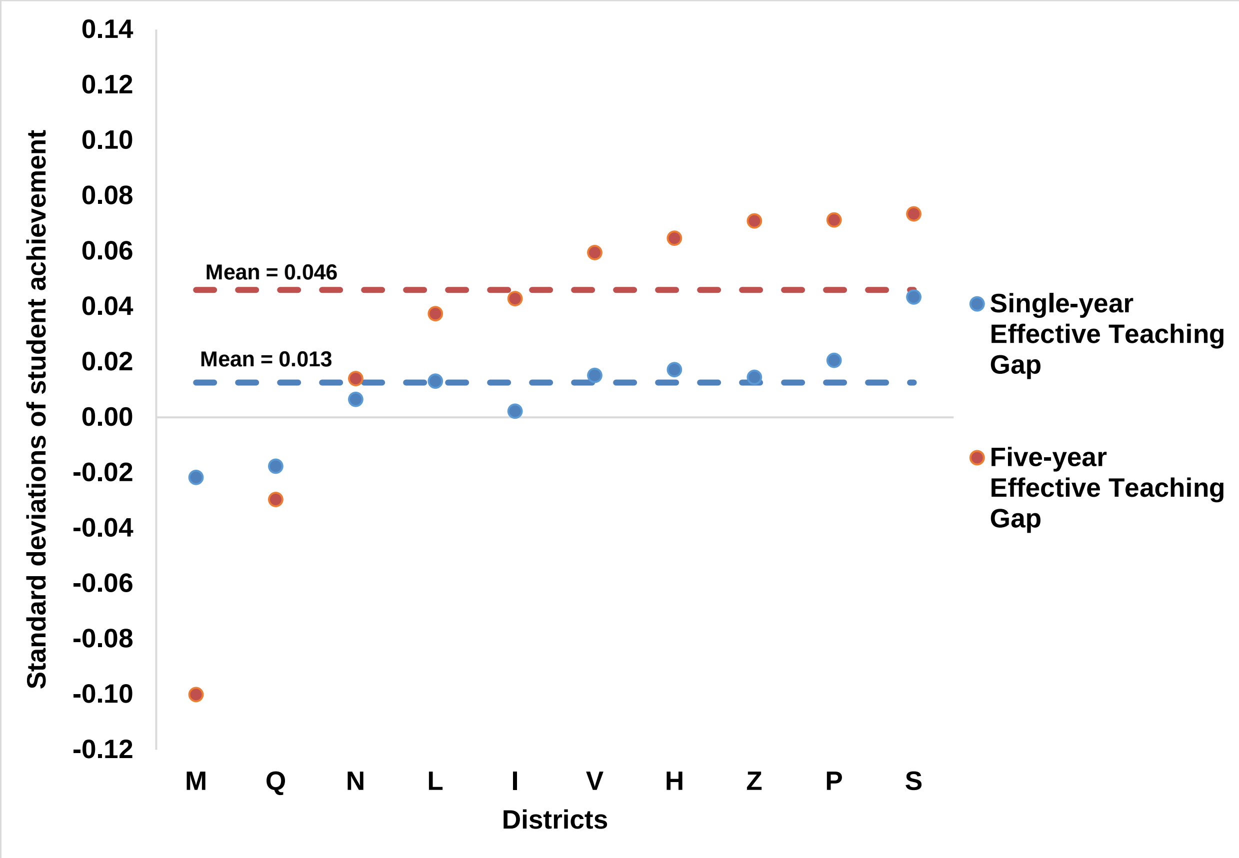
Figure C.14. Single-year and five-year Effective Teaching Gaps, grades 4 through 8, English/language arts, by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 12 districts for years 1 to 5 and grades 4 to 8. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. The blue circles represent the single-year Effective Teaching Gaps and the red circles represent the five-year Effective Teaching Gaps. The cross-district averages are shown by each dashed horizontal line. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

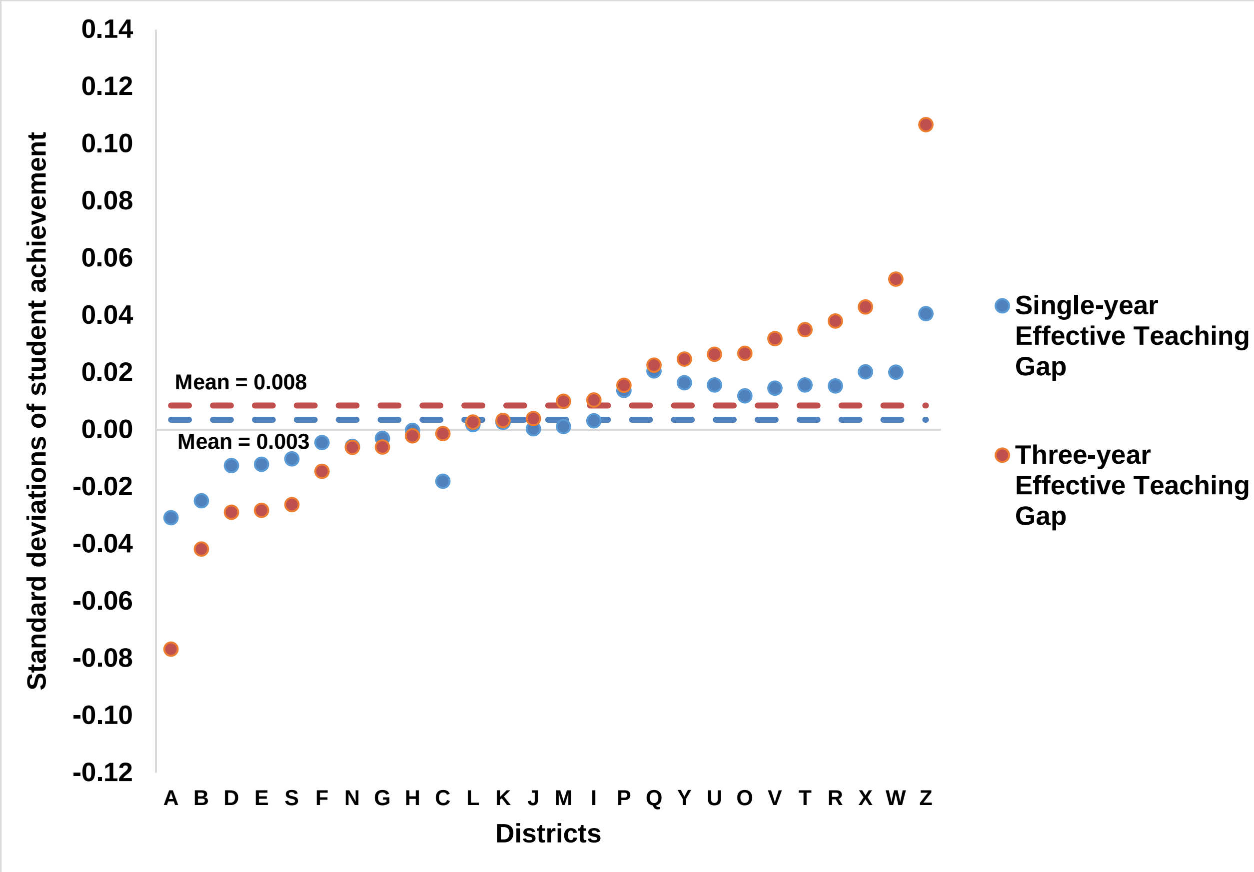
Figure C.15. Single-year and five-year Effective Teaching Gaps, grades 4 through 8, math, by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 12 districts for years 1 to 5 and grades 4 to 8. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. The blue circles represent the single-year Effective Teaching Gaps and the red circles represent the five-year Effective Teaching Gaps. The cross-district averages are shown by each dashed horizontal line. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

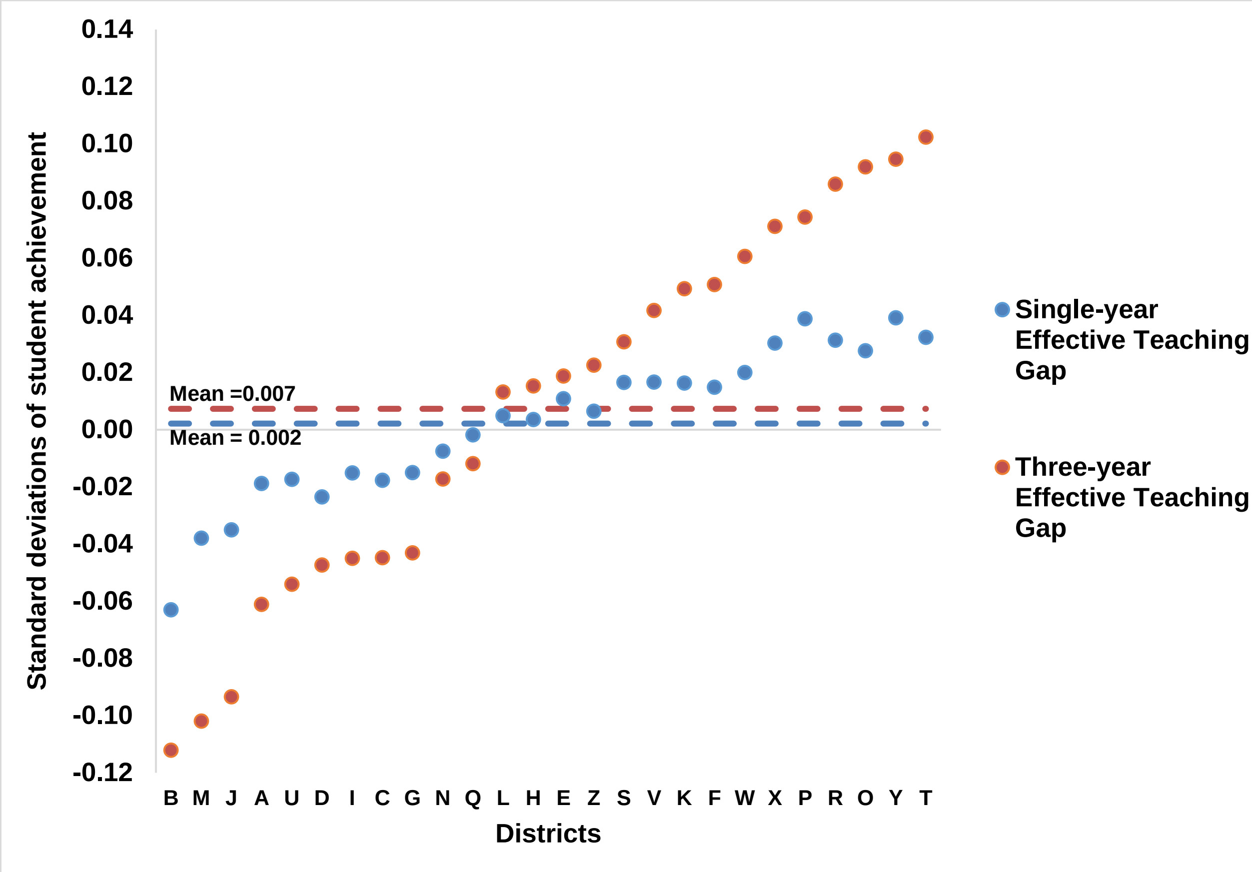
Figure C.16. Single-year and three-year Effective Teaching Gaps, grades 6 through 8, English/language arts, by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5 and grades 6 to 8. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. The blue circles represent the single-year Effective Teaching Gaps and the red circles represent the three-year Effective Teaching Gaps. The cross-district averages are shown by each dashed horizontal line. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

Figure C.17. Single-year and three-year Effective Teaching Gaps, grades 6 through 8, math, by district



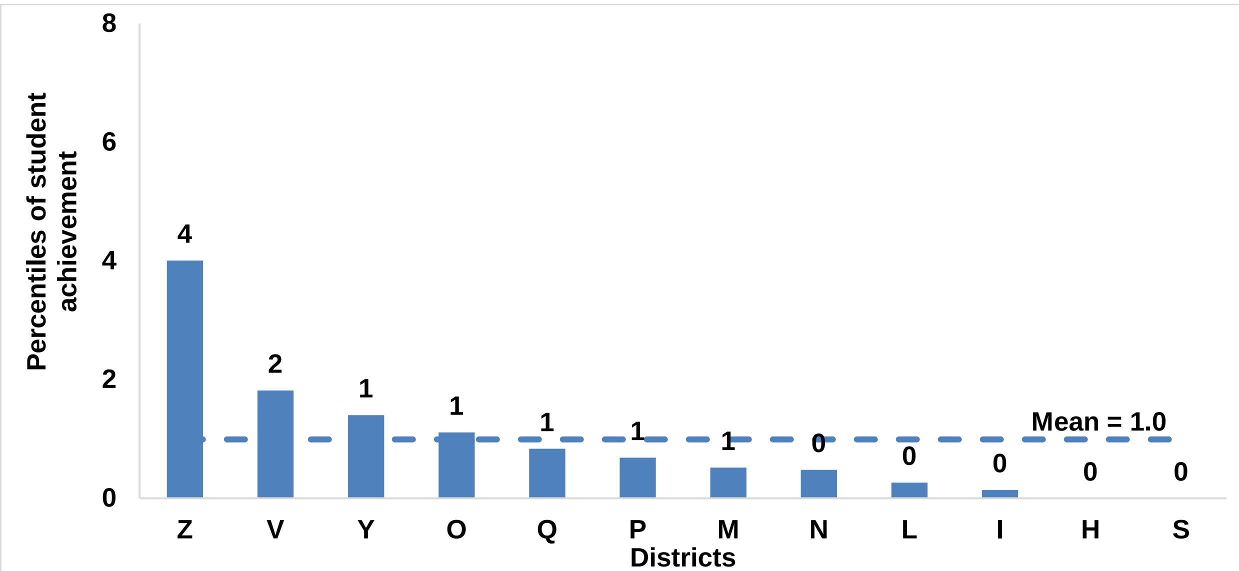
Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5 and grades 6 to 8. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. The blue circles represent the single-year Effective Teaching Gaps and the red circles represent the three-year Effective Teaching Gaps. The cross-district averages are shown by each dashed horizontal line. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

In Chapter IV, we describe how much the student achievement gap would decrease if low-income students had equal access to effective teaching over multiple years. The chapter described the results on average across the study districts, we present the results separately by district in Figures C.18 through C.21. In the 12 districts with sufficient data, providing equal access to effective teachers from grades 4 to 8 would reduce the student achievement gap by 4 or more percentile points in one district in ELA and two districts in math (Figures C.18 and C.19). In the district with the greatest inequity in access, for example, the actual 8th grade student achievement gap is 28 percentile points, with the typical high-income student at the 71st percentile and the typical low-income student at the 43rd percentile. If high- and low-income students had been taught by equally effective teachers in each year between 4th and 8th grade, we estimate that the student achievement gap would have been 22 percentile points. In this case, the typical high-income student would be at the 68th percentile and the typical low-income student would be at the 46th percentile.

We can measure how the student achievement gap would decrease over a three-year period from grade 6 through 8 for all 26 districts. Three years of equal access to effective teaching would reduce the student achievement gap in 8th grade by 4 or more percentile points in one district in ELA and one district in math. In another five districts in math, the student achievement gap would decrease by 3 percentile points over three years. Although the student achievement gap in these districts would decrease if low-income students had equal access to effective teachers over multiple years, it would remain substantial.

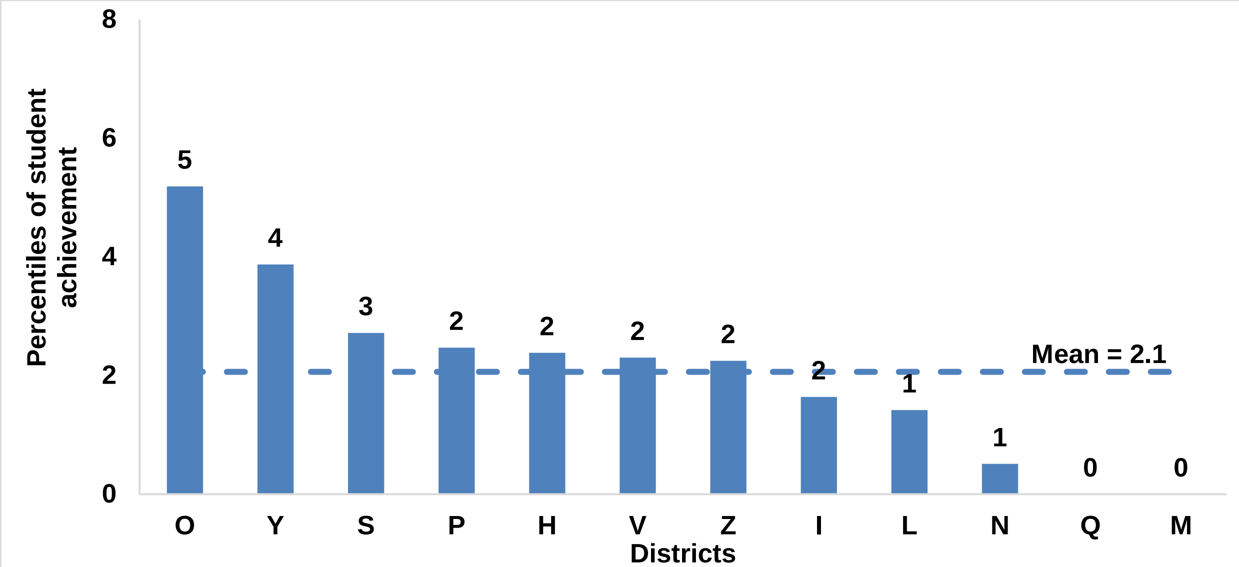
Figure C.18. Reduction in student achievement gap if low-income students had five years of equal access to effective teachers, grades 4 through 8, English/language arts, by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 12 districts for years 1 to 5 and grades 4 to 8. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. The blue circles represent the amount that the student achievement gap would decrease if low-income students had equal access to effective teachers for one year. The cross-district average is shown by the dashed horizontal line. In two districts where low-income students already have more effective teachers than high-income students, we assumed the student achievement gap would not change. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

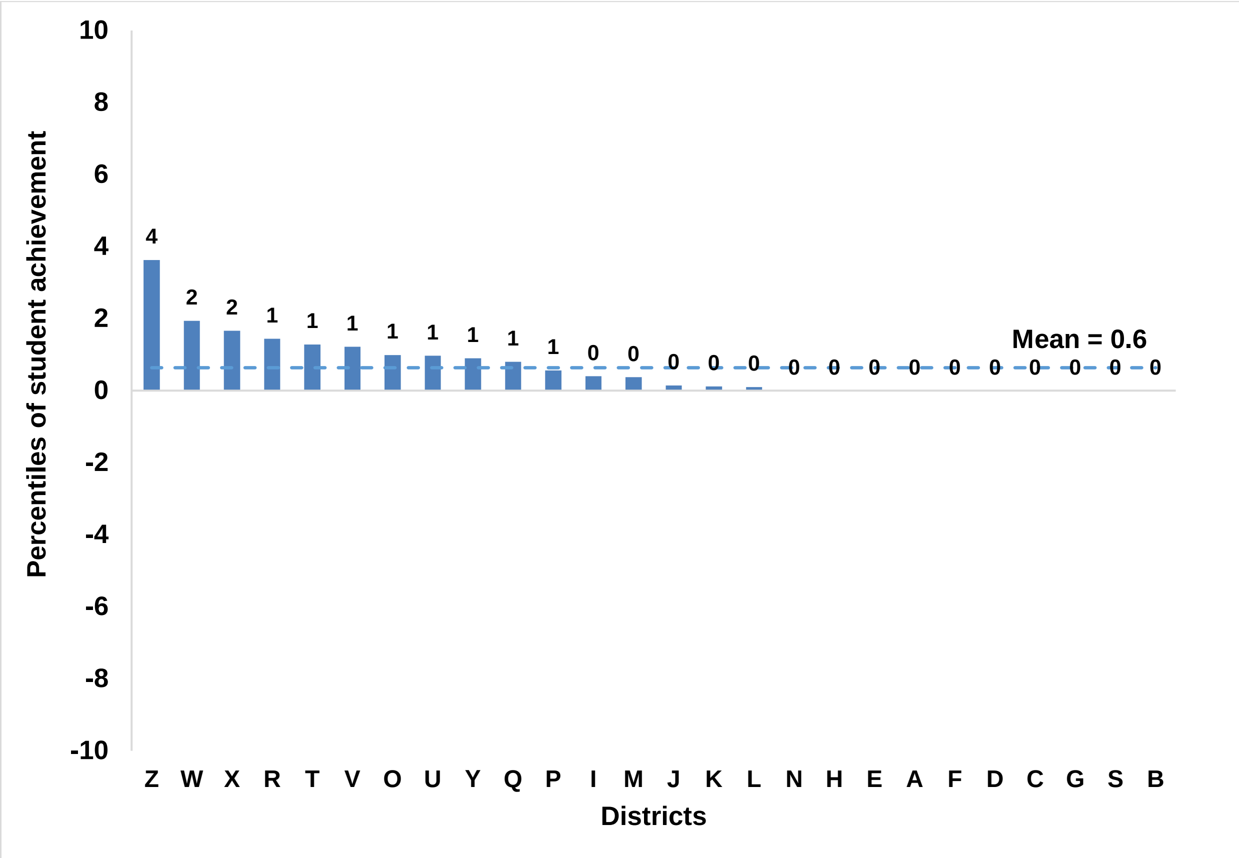
Figure C.19. Reduction in student achievement gap if low-income students had five years of equal access to effective teachers, grades 4 through 8, math, by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 12 districts for years 1 to 5 and grades 4 to 8. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. The blue circles represent the amount that the student achievement gap would decrease if low-income students had equal access to effective teachers for one year. The cross-district average is shown by the dashed horizontal line. In one district where low-income students already have more effective teachers than high-income students, we assumed the student achievement gap would not change. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

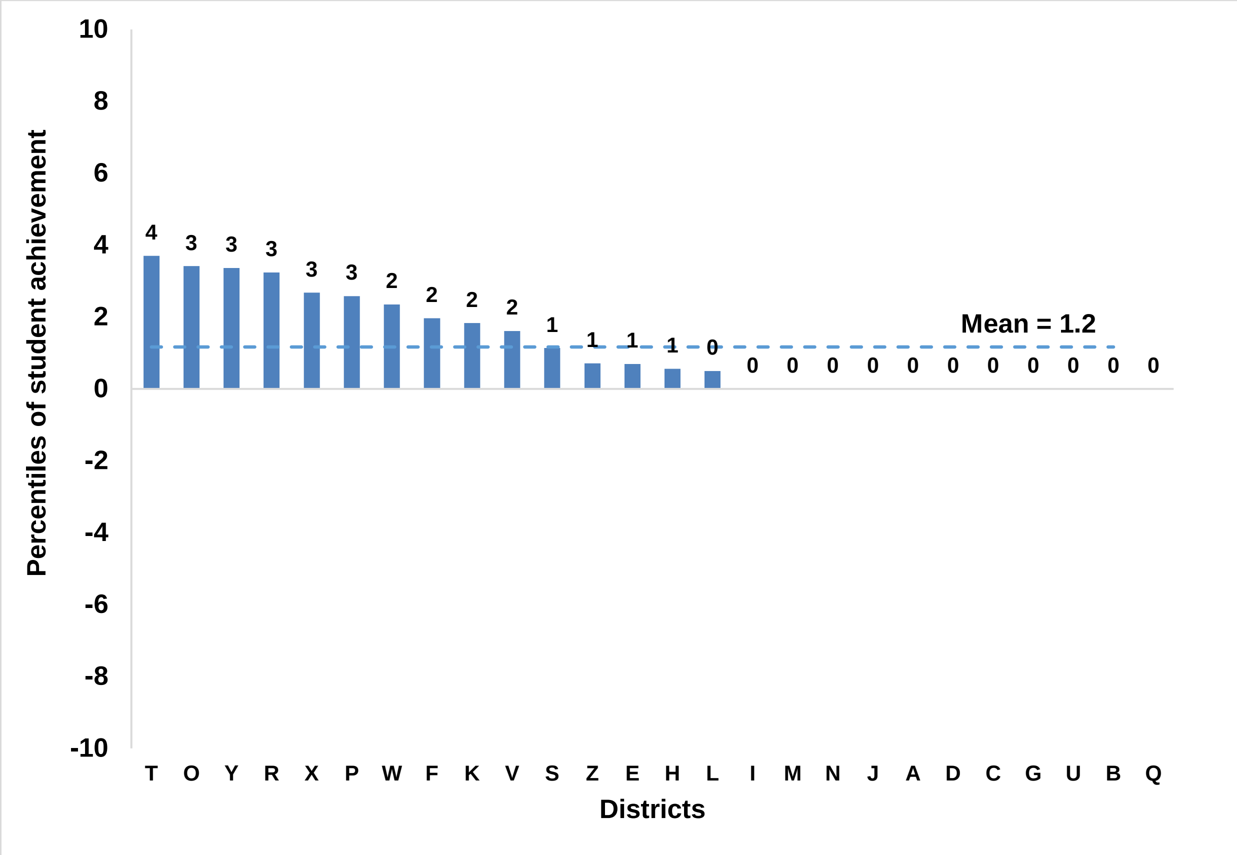
Figure C.20. Reduction in student achievement gap if low-income students had three years of equal access to effective teaching, grades 6 through 8, English/language arts, by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5 and grades 6 to 8. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. The cross-district average is shown by the dashed horizontal line. In ten districts where low-income students already have more effective teachers than high-income students, we assumed the student achievement gap would not change. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

Figure C.21. Reduction in student achievement gap if low-income students had three years of equal access to effective teaching, grades 6 through 8, math, by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5 and grades 6 to 8. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics. The cross-district average is shown by the dashed horizontal line. In eight districts where low-income students already have more effective teachers than high-income students, we assumed the student achievement gap would not change. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

D. Access to effective teachers in county-wide districts

One potential concern about our analysis of low-income students' access to effective teachers is that it only examines the distribution of teachers within districts and does not account for inequity in the distribution of teachers between districts. For example, the most effective teachers may be located in affluent suburban districts, where there are fewer low-income students. Low-income students may have nearly equal access to effective teachers within a given urban district, but the best teachers may be in neighboring suburban districts that serve few low-income students.

To address this concern, we examined low-income students' access to effective teachers in four study districts that each encompass an entire county. If urban-suburban differences in access are important, low-income students may have equal access to effective teachers within the urban core of the districts, but not when the full district including the suburban areas is examined. Thus, we developed a measure of the Effective Teaching Gap based only on students and teachers in schools in the urban core of these districts, and compared that with the Effective Teaching Gap in the full district.

We found little difference in the Effective Teaching Gap whether we based it on the full county-wide district or only on the urban core. The Effective Teaching Gap in the districts where we conducted this analysis was 0.007 in ELA, compared to 0.006 when we only included the urban core. In math, the Effective Teaching Gap did not differ at all, whether based on all schools or only those in the urban core.

E. Access to effective teachers between and within schools

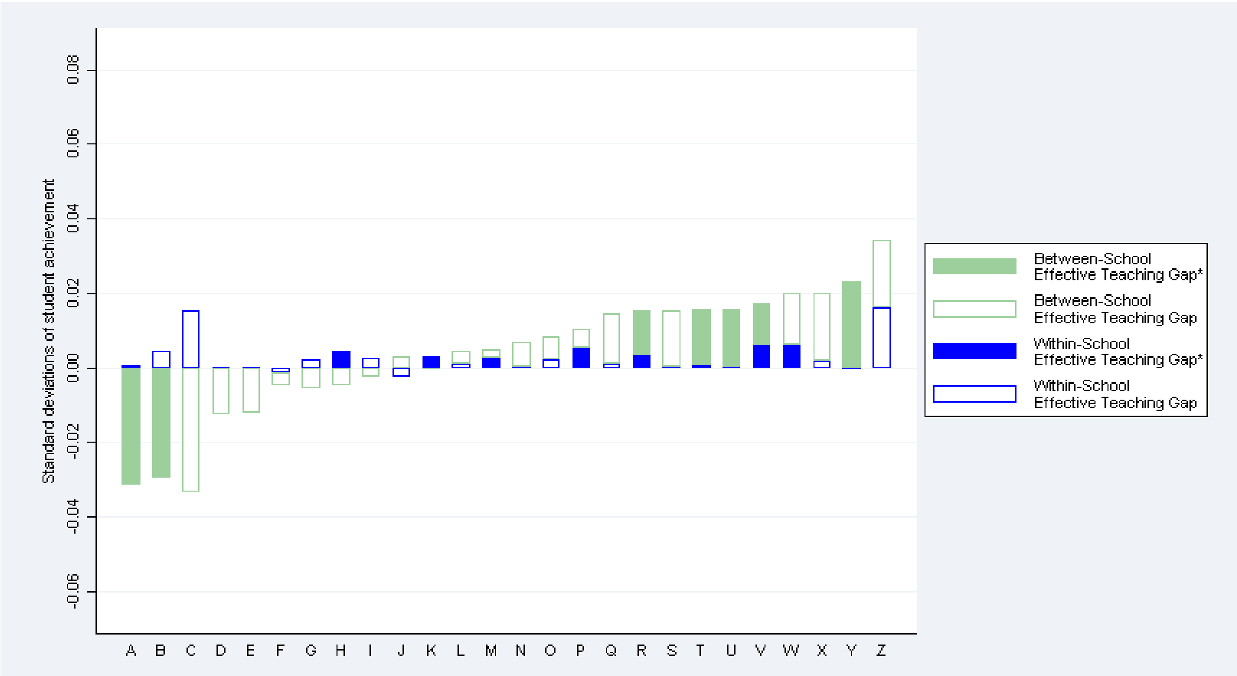
Inequitable access to effective teachers could occur if low-income students attend schools with less effective teachers (the between-school Effective Teaching Gap) and/or if they are assigned to less effective teachers within schools (the within-school Effective Teaching Gap). Even when low-income students have approximately equal access to effective teachers overall, there are two benefits to understanding whether inequities arise between or within schools. First, small overall differences between high- and low-income students in access to effective teachers could result from inequities between and within schools that work in opposite directions. Second, separating the between- and within-school components of the Effective Teaching Gap can inform policy. For example, if there is evidence that low-income students attend schools with less effective teachers, district leaders might consider policies designed to address inequitable access between schools. However, these policies would not address any within-school inequity.

On average, in our study districts, low-income students have nearly equal access to effective teachers, both between and within schools. The overall between-school Effective Teaching Gap is not statistically significant in either subject. The within-school gap is 0.003 in ELA and 0.006 in math (statistically significant in both subjects), a relatively small difference in effectiveness between the teachers of high- and low-income students within schools.

The between-school component of the Effective Teaching Gap varies more widely by district than the within-school component. It is positive and significant in some districts and negative and significant in others. Overall, the between-school component ranges from -0.03 to 0.02 across study districts in ELA and from -0.06 to 0.04 in math. In contrast, low-income students’ within-school access to effective teachers is consistent across study districts. The within-school component of the Effective Teaching Gap is between -0.010 and 0.020 for both subjects in a large majority of the study districts (Figures C.22 and C.23). As a result, in districts where there is evidence that low-income students are assigned to less effective (or more effective) teachers overall, these inequities are typically related to the schools that low-income students attend, rather than the teachers they are assigned within schools.

This pattern of results suggests that an individual district’s overall Effective Teaching Gap depends largely on the between-school component of the gap. In districts in which there is more evidence that low-income students have less access to effective teachers, this is usually because they attend schools with less effective teachers, not because they are assigned to less effective teachers within schools.

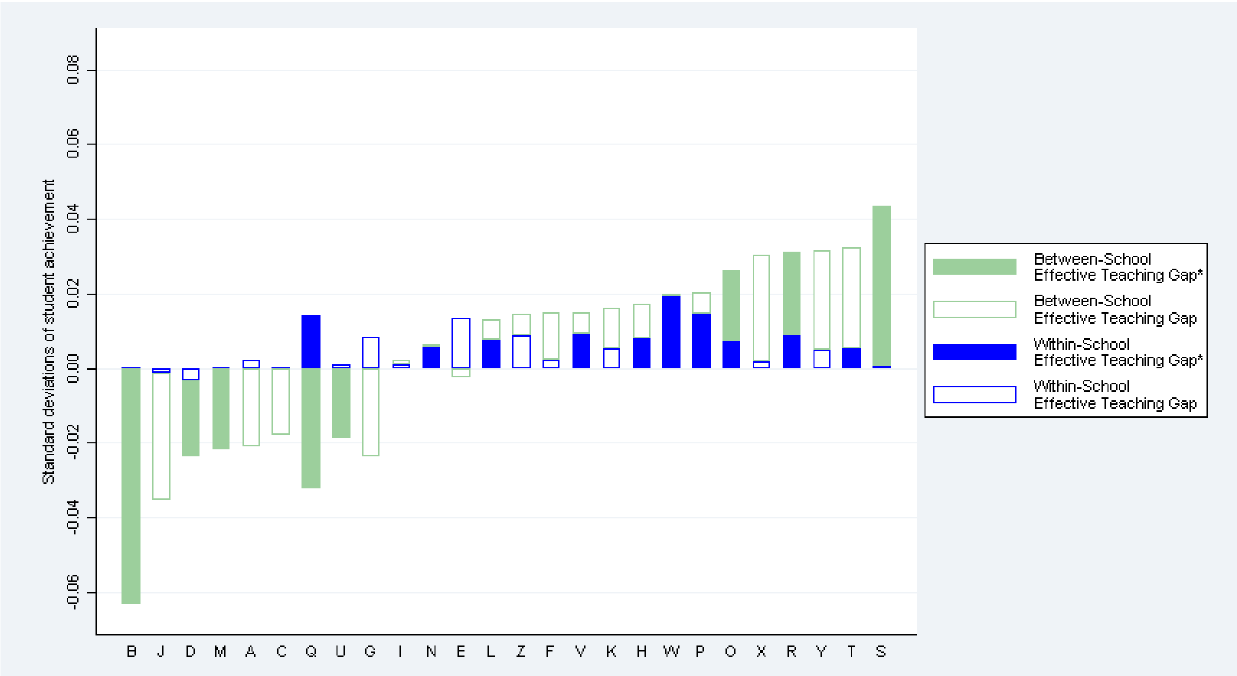
Figure C.22. Effective Teaching Gap between and within schools, English/language arts, by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures. The green bars show the between-school Effective Teaching Gap and the blue bars show the within-school Effective Teaching Gap. The solid bars show between- or within-school Effective Teaching Gaps that are significantly different from zero at the 0.05 level; the hollow bars indicate between- or within-school Effective Teaching Gaps that are not significantly different from zero. District-level results are weighted across grades and years by the number of students. These results are based on a value-added model that accounts for classroom characteristics.

Figure C.23. Effective Teaching Gap between and within schools, math, by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 26 districts for years 1 to 5, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures. The green bars show the between-school Effective Teaching Gap and the blue bars show the within-school Effective Teaching Gap. The solid bars show between- or within-school Effective Teaching Gaps that are significantly different from zero at the 0.05 level; the hollow bars indicate between- or within-school Effective Teaching Gaps that are not significantly different from zero. District-level results are weighted across grades and years by the number of students. These results are based on a value-added model that accounts for classroom characteristics.

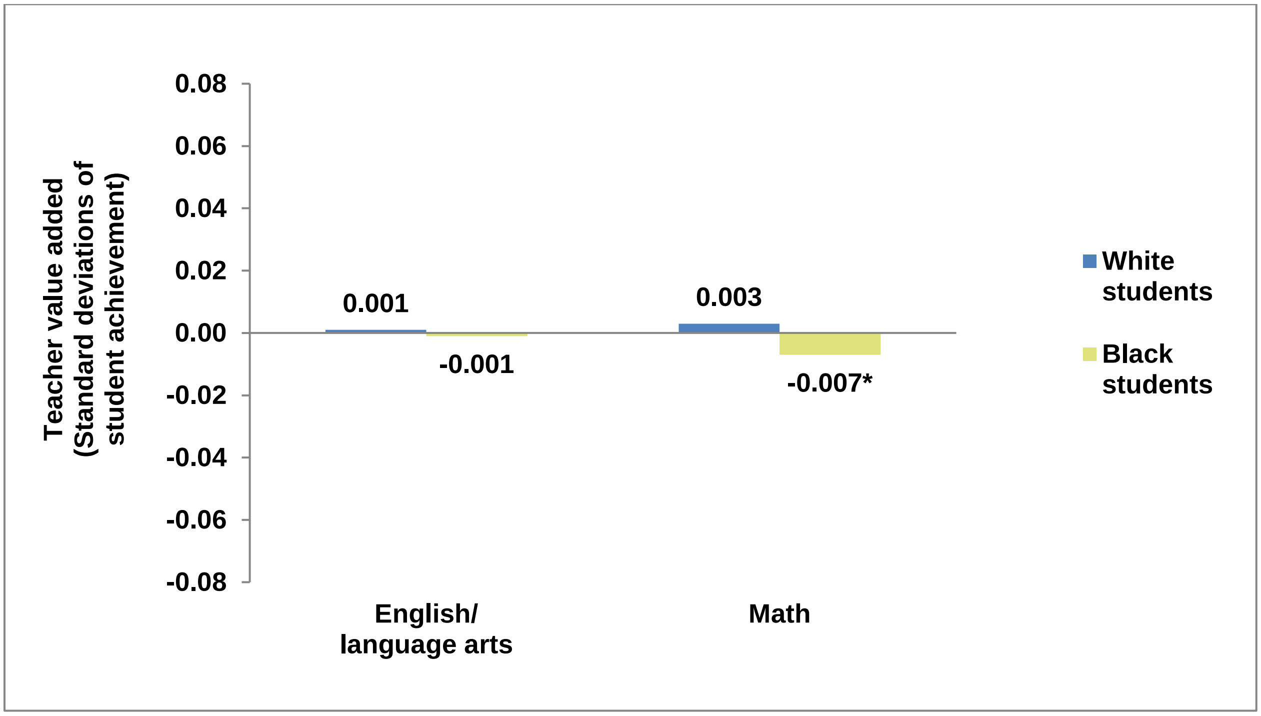
F. Access to effective teachers by student race, ethnicity, and ELL status

There are substantial achievement gaps between students of different races and ethnic groups, just as there are differences between students from different economic backgrounds. In study districts, for example, the average achievement level of black students lags behind that of non-Hispanic white students by 26 percentile points in ELA and 29 percentile points in math. Student achievement gaps between Hispanic students and non-Hispanic white students are 28 percentile points in both subjects. To examine whether differences in these groups' teachers might play a role in the student achievement gaps, we measured access to effective teachers for black, Hispanic, and ELL students using the same approach we used to measure low-income students' access to effective teachers.

To avoid including districts that enroll just a few students of a given race or ethnicity, we limited this analysis to districts where at least 15 percent of the students are black or Hispanic and at least 15 percent of students are white. Similarly, we included districts where at least 15 percent of students are ELLs. Thus, our analysis of black students' access to effective teachers was based on 13 districts, our analysis of Hispanic students' access to effective teachers was based on 16 districts, and we used 18 districts to measure ELL students' access to effective teachers.

On average, minority students have teachers who are as effective as those who teach white students. Although the teachers of black students have slightly lower value added than those of non-Hispanic white students, these differences are not statistically significant in ELA and are small in math (0.002 in ELA and 0.010 in math) (Figure C.24). The differences in average teacher effectiveness between Hispanic students and non-Hispanic white students are not statistically significant in either subject (0.003 in ELA and 0.005 in math; Figure C.25). These estimates indicate that on average, both minority students and non-Hispanic white students are taught by teachers at about the 50th percentile.

Figure C.24. Average teacher effectiveness by race of students (standard deviations of student achievement)

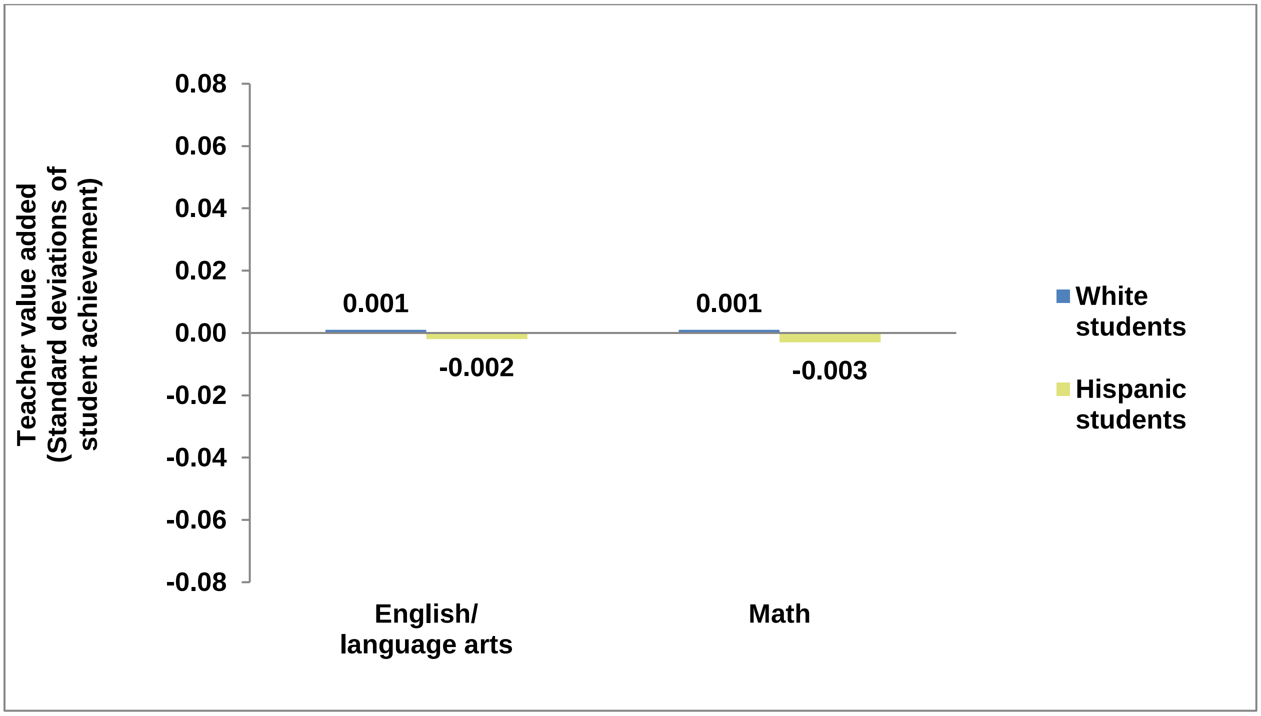


Source: Author's calculations based on district administrative data.

Note: Results are based on 13 districts, including 6 districts for grades 6 to 8 and 7 districts for grades 4 to 8, for years 1 to 5. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

* Differences in the value added of teachers of white students and black students are statistically significant at the 0.05 level, two-tailed test.

Figure C.25. Average teacher effectiveness for Hispanic and white students (standard deviations of student achievement)



Source: Author's calculations based on district administrative data.

Note: Results are based on 16 districts, including 9 districts for grades 6 to 8 and 7 districts for grades 4 to 8, for years 1 to 5. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

* Differences in the value added of teachers of white students and Hispanic students are statistically significant at the 0.05 level, two-tailed test.

Access to effective teachers by race and ethnicity is similar to access by family income, with Effective Teaching Gaps of 0.01 or less in both subjects (Table C.3). In addition, districts with larger Effective Teaching Gaps by family income tend to have larger Effective Teaching Gaps by race and ethnicity. Correlations between the gaps by family income and the gaps by race and ethnicity range from 0.77 to 0.95. Similar to the Effective Teaching Gaps by family income, the Effective Teaching Gaps by race vary across districts (Figures C.26 through C.29). The Effective Teaching Gaps by race range from -0.01 to 0.02 in ELA and from -0.02 to 0.05 in math, while the gaps by ethnicity range from -0.03 to 0.02 in ELA and from -0.07 to 0.05 in math.

Table C.3. Average Effective Teaching Gaps by family income, race (13 Districts), and ethnicity (16 Districts)

	English/ language arts	Math
Black/White Gaps		
Effective Teaching Gap by family income	0.005*	0.005
Effective Teaching Gap by race (black vs. white students)	0.002	0.010*
Correlation	0.77	0.95
Sample Size (districts)	13	13
Hispanic/White Gaps		
Effective Teaching Gap by family income	0.005*	0.005
Effective Teaching Gap by ethnicity (Hispanic vs. white students)	0.003	0.005
Correlation	0.88	0.95
Sample Size (districts)	16	16
English language learner/non-English language learner Gaps		
Effective Teaching Gap by family income	0.000	-0.007
Effective Teaching Gap by English language learner status	-0.006	-0.003
Correlation	0.54	0.86
Sample Size (districts)	9	9

Source: Author's calculations based on district administrative data.

Note: Results are for grades 4 through 8, years 1 to 5, and 13 districts for Black/White gaps and 16 districts for Hispanic/White gaps. Based on value-added model that includes classroom characteristics. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts.

*Indicates statistical significance at the 0.05 level, two-tailed test. Statistical significance is tested using the standard error of each district's estimate.

Figure C.26. Effective teaching gaps by race, English/language arts, 13 districts

Source: Author's calculations based on district administrative data.

Note: Results are for grades 4 through 8, years 1 to 5, and 13 districts. Based on value-added model that includes classroom characteristics. District-level results are weighted across grades and years by the number of students. Blue bars represent Effective Teaching Gaps between low-income and high-income students, while green bars represent gaps between black and white students. Filled bars indicate that the gap is statistically significant at the 0.05 level, two-tailed test, while hollow bars represent gaps that are not statistically significant. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

Figure C.27. Effective teaching gaps by race, math, 13 districts

Source: Author's calculations based on district administrative data.

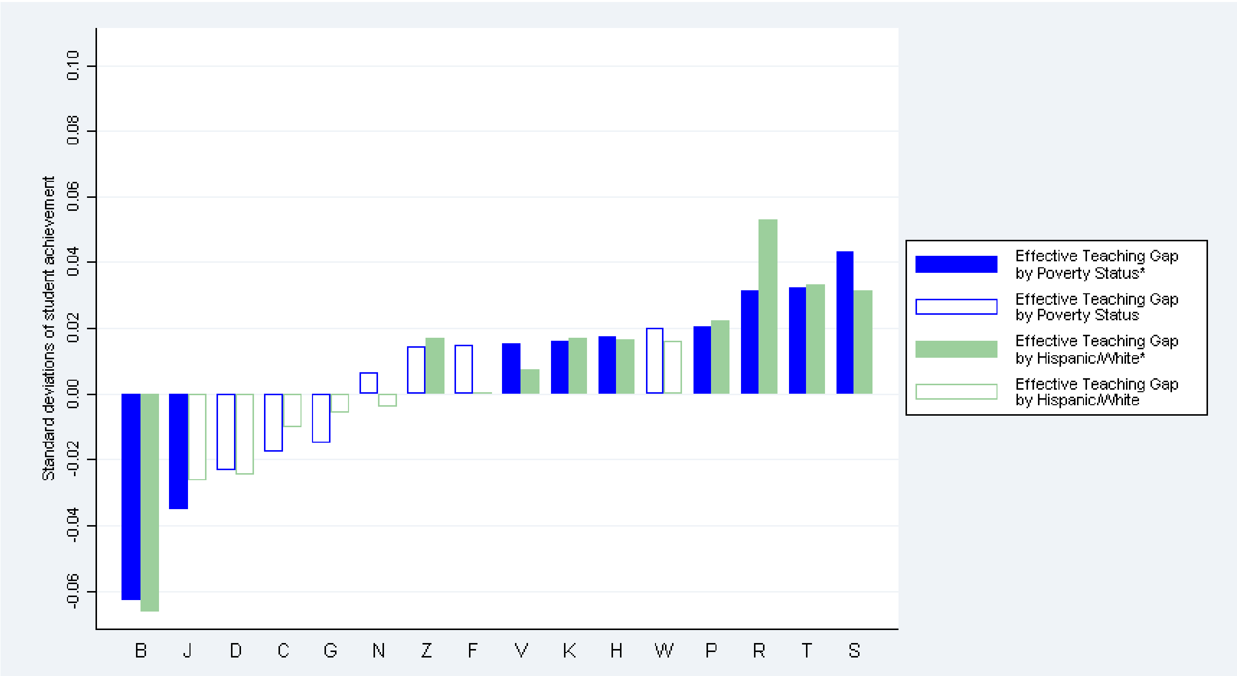
Note: Results are for grades 4 through 8, years 1 to 5, and 13 districts. Based on value-added model that includes classroom characteristics. District-level results are weighted across grades and years by the number of students. Blue bars represent Effective Teaching Gaps between low-income and high-income students, while green bars represent gaps between black and white students. Filled bars indicate that the gap is statistically significant at the 0.05 level, two-tailed test, while hollow bars represent gaps that are not statistically significant. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

Figure C.28. Effective teaching gaps by ethnicity, English/language arts, 16 districts, years 1 through 5

Source: Author's calculations based on district administrative data.

Note: Results are for grades 4 through 8, years 1 to 5, and 16 districts. Based on value-added model that includes classroom characteristics. District-level results are weighted across grades and years by the number of students. Blue bars represent Effective Teaching Gaps between low-income and high-income students, while green bars represent gaps between Hispanic and white students. Filled bars indicate that the gap is statistically significant at the 0.05 level, two-tailed test, while hollow bars represent gaps that are not statistically significant. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

Figure C.29. Effective teaching gaps by ethnicity, math, 16 districts, years 1 through 5

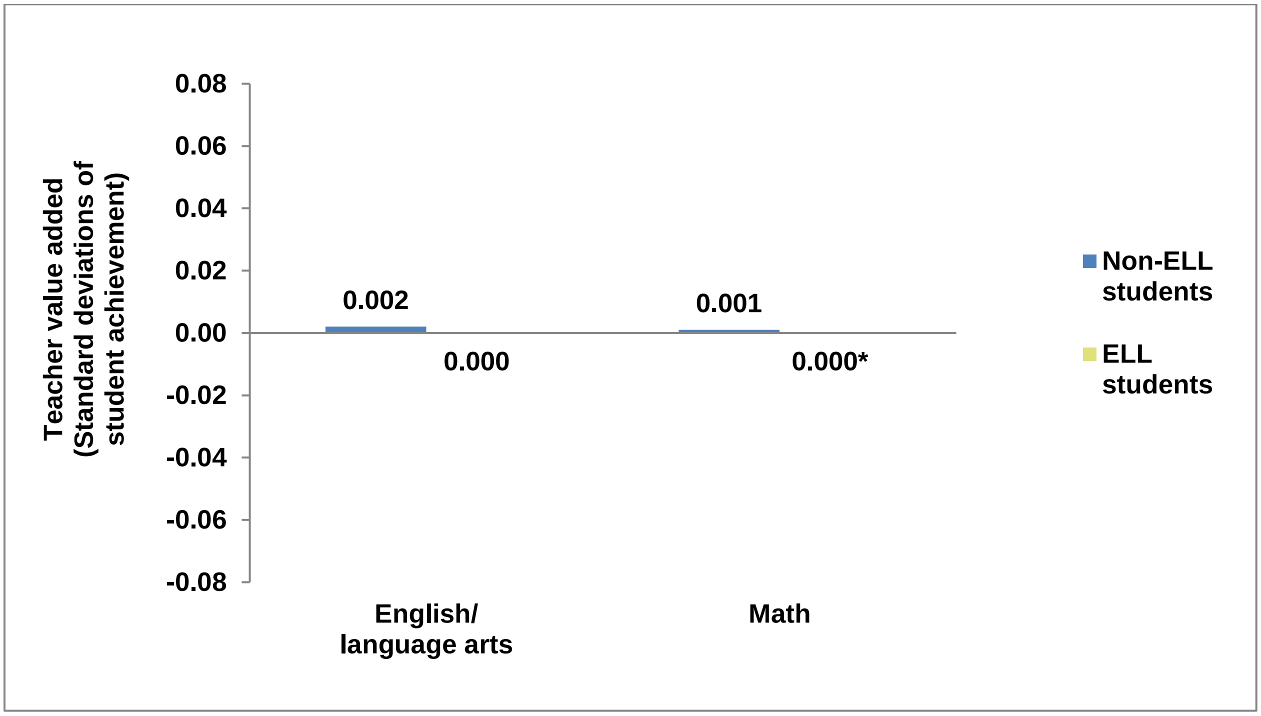


Source: Author's calculations based on district administrative data.

Note: Results are for grades 4 through 8, years 1 to 5, and 16 districts. Based on value-added model that includes classroom characteristics. District-level results are weighted across grades and years by the number of students. Blue bars represent Effective Teaching Gaps between low-income and high-income students, while green bars represent gaps between Hispanic and white students. Filled bars indicate that the gap is statistically significant at the 0.05 level, two-tailed test, while hollow bars represent gaps that are not statistically significant. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

On average, English language learners have teachers who are as effective as those who teach other students (Figure C.30). The differences between the value added for teachers of English language learners and value added of teachers of other students are not statistically significant. Although the Effective Teaching Gaps by English language learner status varies across districts (Figures C.31 and C.32), even in the districts with the greatest inequity, equalizing access to effective teachers would reduce the student achievement gap between English language learners and other students by 1 to 2 percentiles points in both subjects.

Figure C.30. Average teacher effectiveness by English language learner status of students (standard deviations of student achievement)

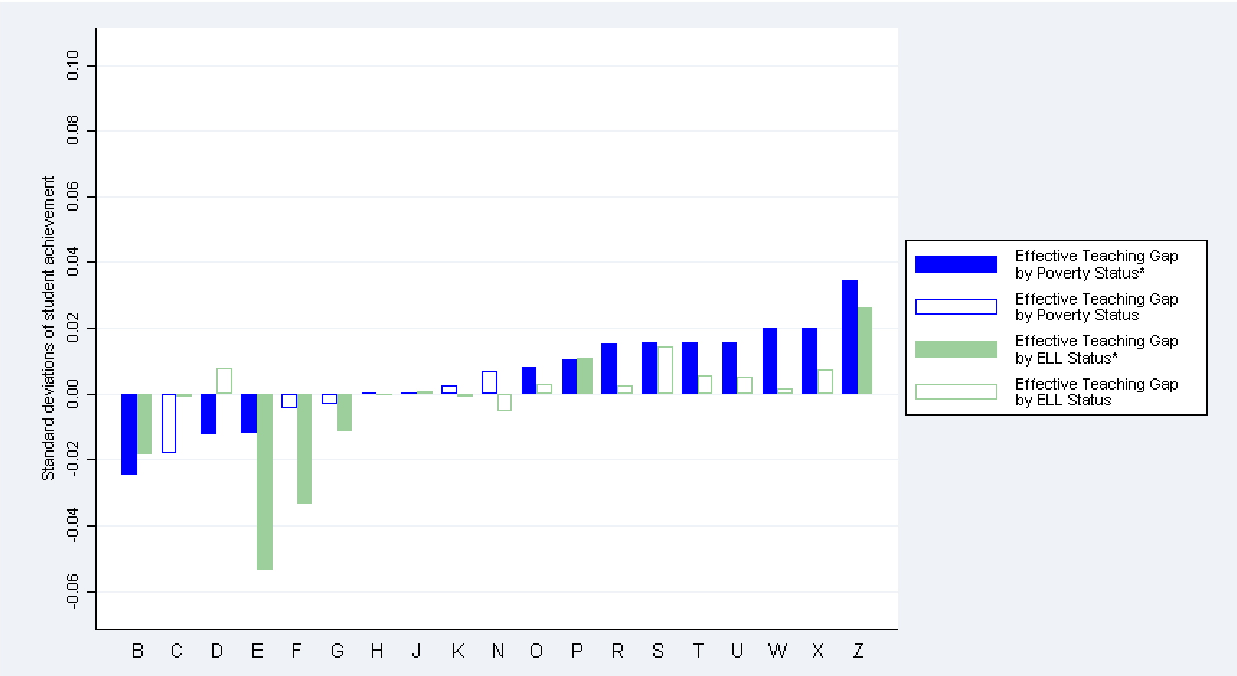


Source: Author's calculations based on district administrative data.

Note: Results are based on 13 districts, including 6 districts for grades 6 to 8 and 7 districts for grades 4 to 8, for years 1 to 5. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that accounts for classroom characteristics.

* Differences in the value added of teachers of white students and ELL students are statistically significant at the 0.05 level, two-tailed test.

Figure C.31. Effective teaching gaps by English language learner status, English/language arts, 19 districts



Source: Author's calculations based on district administrative data.

Note: Results are for grades 4 through 8, years 1 to 5, and 19 districts. Based on value-added model that includes classroom characteristics. District-level results are weighted across grades and years by the number of students. Blue bars represent Effective Teaching Gaps between low-income and high-income students, while green bars represent gaps between ELL and non-ELL students. Filled bars indicate that the gap is statistically significant at the 0.05 level, two-tailed test, while hollow bars represent gaps that are not statistically significant. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

Figure C.32. Effective teaching gaps by English language learner status, math, 19 districts

Source: Author's calculations based on district administrative data.

Note: Results are for grades 4 through 8, years 1 to 5, and 19 districts. Based on value-added model that includes classroom characteristics. District-level results are weighted across grades and years by the number of students. Blue bars represent Effective Teaching Gaps between low-income and high-income students, while green bars represent gaps between ELL and non-ELL students. Filled bars indicate that the gap is statistically significant at the 0.05 level, two-tailed test, while hollow bars represent gaps that are not statistically significant. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures.

G. Additional results based on value-added model that excludes classroom characteristics

Our primary analysis of access to effective teachers is based on a value-added model that accounts for the characteristics of other students in the classroom. As described in Chapter II, this value-added model limits our analysis to 26 of the 29 districts and does not allow us to make use of data from grades 4 and 5 in 14 of the 26 districts. To expand the number of districts and grades we could include, we calculated the Effective Teaching Gap using a value-added model that excludes classroom characteristics. We thereby measured access to effective teaching in grades 4 through 8 for all 29 study districts. However, using this value-added model, some amount of student achievement attributed to a teacher may be due instead to the types of students in the classroom. As a result, the teachers of high-income students may appear more effective and the teachers of low-income students may appear less effective, on average, leading to larger Effective Teaching Gaps.

The Effective Teaching Gaps are in fact larger when using a value-added model that excludes classroom characteristics and including grades 4 through 8 for all 29 study districts (Table C.4), at 0.034 standard deviations of student achievement in ELA and 0.029 in math. The

Effective Teaching Gaps ranged in value across districts from 0.009 to 0.086 in ELA and from -0.009 to 0.087 in math.

We also examined whether the larger Effective Teaching Gaps when using a value-added model that excludes classroom characteristics are due to changes in the sample or to the value-added model. We measured Effective Teaching Gaps based on a value-added model that excludes classroom characteristics, but limited the sample to the same districts, grades, and years included in the primary analysis based on a value-added model that includes classroom characteristics. The Effective Teaching Gaps are still larger when excluding classroom characteristics, with gaps of 0.029 in ELA and 0.031 in math. This suggests that the larger Effective Teaching Gaps in the model that excludes classroom characteristics are being driven by the value-added model, not the inclusion of additional districts or additional grades.

Table C.4. Comparing effective teaching gaps based on value-added models with and without classroom characteristics

	Effective teaching gaps					
	Value-added model without classroom characteristics				Value-added model with classroom characteristics	
	All 29 districts, grades 4 to 8		Districts and grades in value-added model with classroom characteristics		Districts and grades in value-added model with classroom characteristics	
	ELA	Math	ELA	Math	ELA	Math
Cross-district Average	0.034*	0.029*	0.029*	0.031*	0.005*	0.004*
Standard Deviation	0.021	0.021	0.020	0.023	0.015	0.025
Minimum	0.009	-0.009	0.005	-0.010	-0.031	-0.063
Maximum	0.086	0.087	0.085	0.087	0.034	0.043

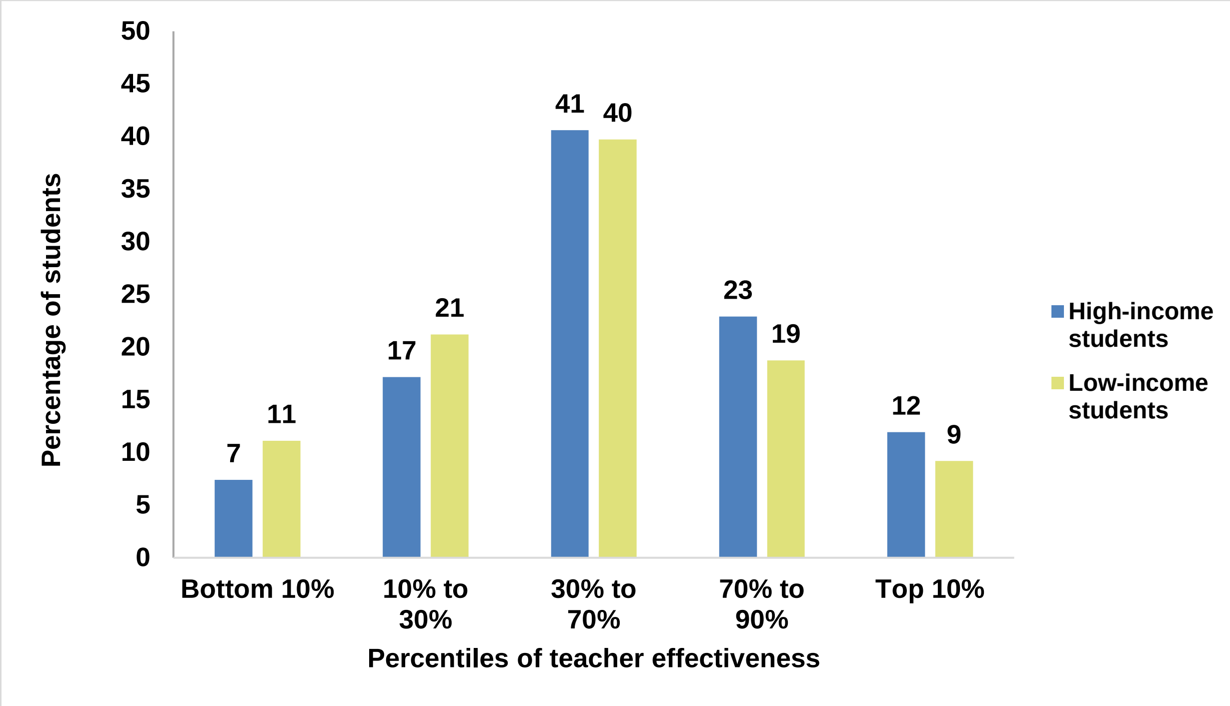
Source: Author's calculations based on district administrative data.

Note: Results in the first two columns are based on grades 4 through 8 in all 29 districts, and the remaining columns are based on 26 districts, including grades 4 to 8 for 12 districts and grades 6 to 8 for 14 districts. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. The Effective Teaching Gaps are statistically significant at the 0.05 level, two-tailed test. The standard error of each district's estimate is used to test whether the average Effective Teaching Gap is different from zero.

* The difference between models is statistically significant at the 0.05 level, two tailed test. The standard error of the difference for each district is used to test whether the average difference is different from zero.

In addition to measuring the Effective Teaching Gap based on the value-added model that excludes classroom characteristics, we also examined the proportion of high- and low-income students that have the most and least effective teachers (Figures C.33 and C.34). High-income students are more likely than low-income students to have a teacher in the top 10 percent of value added (by three percentage points in ELA and two percentage points in math), and less likely to have a teacher in the bottom 10 percent (by four percentage points in ELA and three percentage points in math).

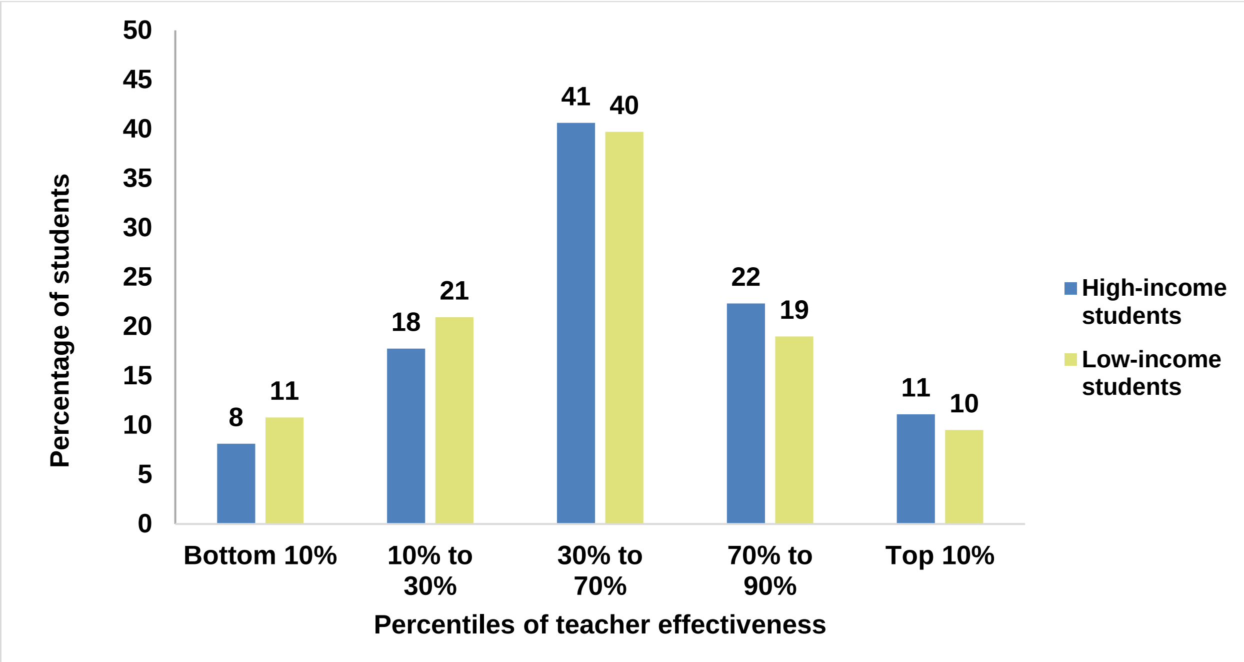
Figure C.33. Percentage of low-income and high-income students taught by teachers at different levels of effectiveness, English/language arts, alternative value-added model (without classroom characteristics)



Source: Author's calculations based on district administrative data.

Note: Results are based on 29 districts for years 1 to 5 and grades 4 to 8. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that does not account for classroom characteristics.

Figure C.34. Percentage of low-income and high-income students taught by teachers at different levels of effectiveness, alternative value-added model (without classroom characteristics), math

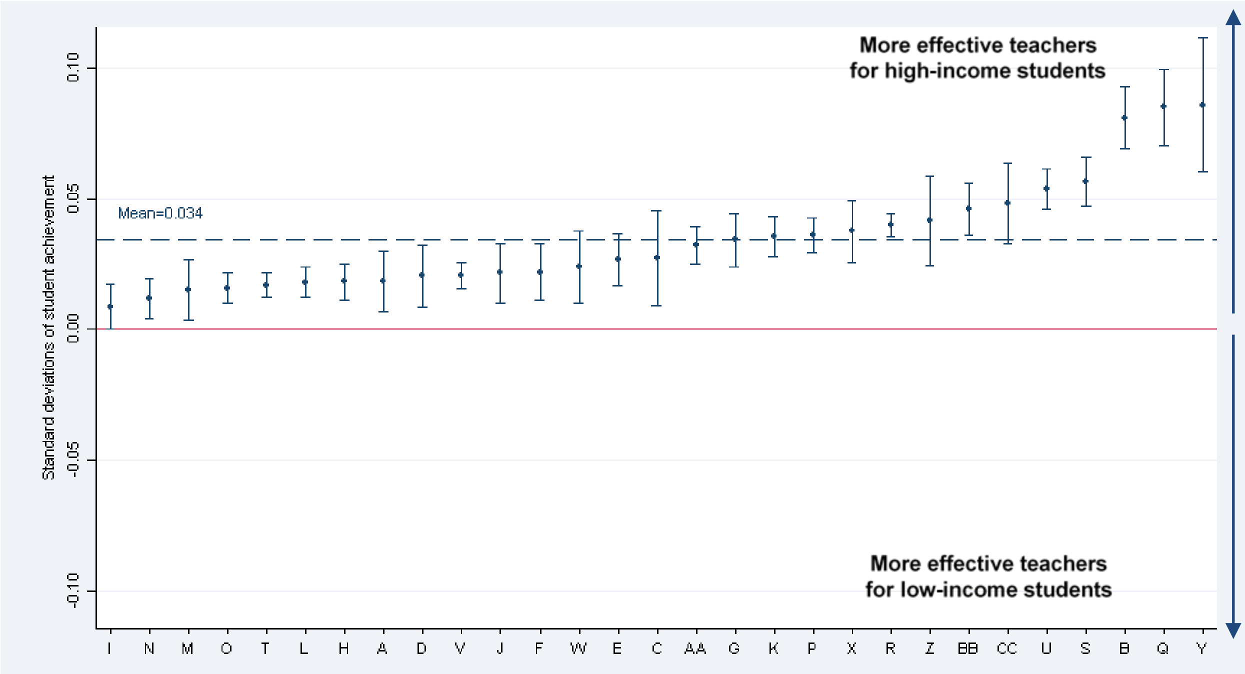


Source: Author's calculations based on district administrative data.

Note: Results are based on 29 districts for years 1 to 5 and grades 4 to 8. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts. These results are based on a value-added model that does not account for classroom characteristics.

The district-level Effective Teaching Gaps based on the value-added model that excludes classroom characteristics vary from 0.009 to 0.086 in ELA, and from -0.009 to 0.087 in math (Figures C.35 and C.36). In the district with the largest Effective Teaching Gap, eliminating access to effective teaching for one year would reduce the student achievement gap in ELA by 3 percentile points.

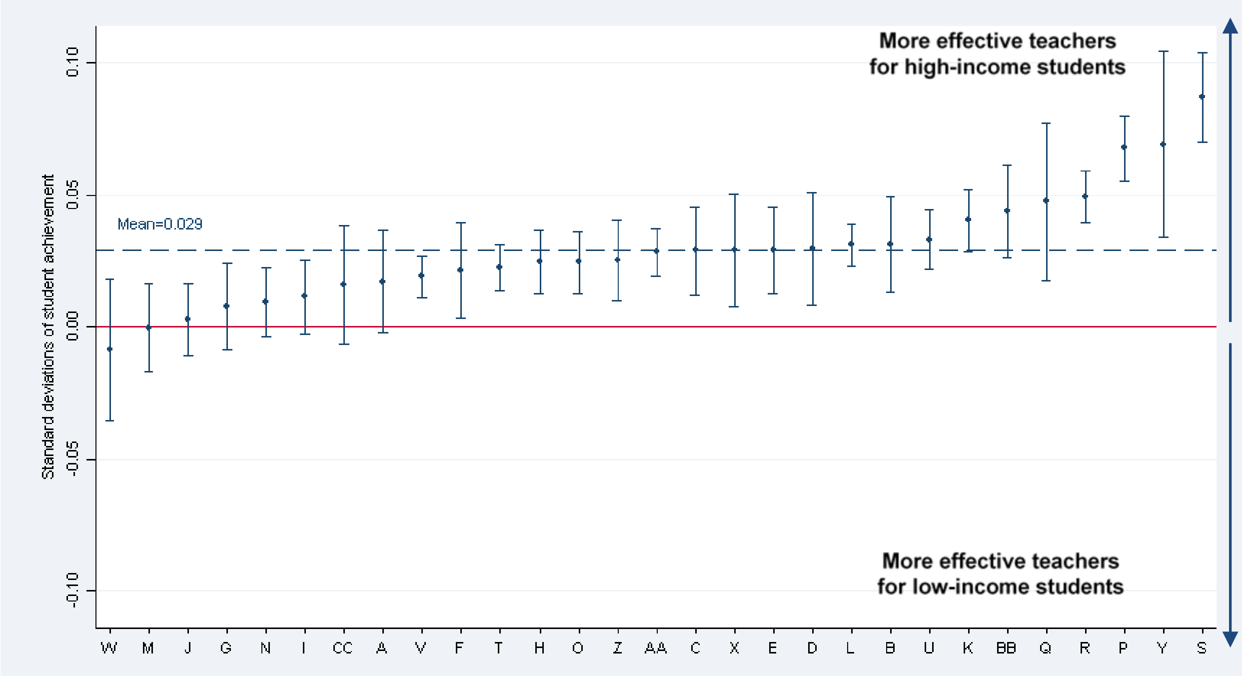
Figure C.35. Average Effective Teaching Gap in English/language arts, alternative value-added model (without classroom characteristics), by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 29 districts for years 1 to 5 and grades 4 to 8 for . District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures. Districts identifiers AA, BB, and CC are for the three districts that are only included in the results based on the value-added model that excludes classroom characteristics. Effective Teaching Gaps are computed within each district-grade-year combination and averaged with equal weight across years within each district. The points represent the district-level Effective Teaching Gaps and the vertical lines show the 95-percent confidence intervals around each point. The cross-district average of 0.005 standard deviations is shown by the dashed horizontal line.

Figure C.36. Average Effective Teaching Gap in math, alternative value-added model (without classroom characteristics), by district



Source: Author's calculations based on district administrative data.

Note: Results are based on 29 districts for years 1 to 5 and grades 4 to 8. District identifiers A to Z are assigned in alphabetical order by the size of each district's Effective Teaching Gap in ELA and are consistent across figures. Districts identifiers AA, BB, and CC are for the three districts that are only included in the results based on the value-added model that excludes classroom characteristics. Effective Teaching Gaps are computed within each district-grade-year combination and averaged with equal weight across years within each district. The points represent the district-level Effective Teaching Gaps and the vertical lines show the 95-percent confidence intervals around each point. The cross-district average of 0.004 standard deviations is shown by the dashed horizontal line.

The five-year Effective Teaching Gaps based on the value-added model that excludes classroom characteristics are larger than those based on the value-added model that included classroom characteristics. The average district has a five-year Effective Teaching Gap of 0.092 in ELA and 0.101 in math.[48] This cumulative gap suggests that equalizing low-income students' access to effective teachers over five years would reduce the student achievement gap by 3.4 percentile points in ELA and 3.8 percentile points in math. These results suggest more substantial differences in the effectiveness of high- and low-income students' teachers than results based on a value-added model that includes classroom characteristics, although equalizing access to effective teachers would reduce the student achievement gap only modestly. In addition, it must be remembered that in a value-added model without classroom characteristics, some amount of student achievement attributed to a teacher may result from the mix of students in the teacher's classroom.

[48] Due to fewer data restrictions for the non-classroom characteristics model, we can calculate five-year Effective Teaching Gaps for all 26 districts. These results are based on all 26 districts instead of the 12 districts we included in the classroom characteristics version.

H. Accounting for measurement error in free and reduced-price lunch eligibility

Although free and reduced-price lunch status provides a way to distinguish between low-income and high-income students, it is an imperfect measure of student income for three reasons:

- Free and reduced-price lunch status is measured with error in both directions. Some eligible students do not apply for or are incorrectly denied the benefit, and some ineligible students receive it. By one estimate, 9.3 percent of students receiving free and reduced-price lunch are misclassified in that they are not eligible for the benefit (Moore et al. 2015).
- Household income can vary among both those who are eligible and ineligible for free and reduced-price lunch. There can be a wide range of household incomes on either side of the eligibility threshold. In particular, high-income students who are ineligible for a free or reduced-price lunch and hence categorized as "high income" may have household incomes just above 185 percent of the poverty line or substantially above the poverty line.
- Federal regulations allow some schools to serve free meals to all students. This can complicate the measurement of free and reduced-price lunch status because program eligibility information may not be collected annually in these schools.

In this section, we describe two sensitivity tests that examine the potential impact of this measurement error on the Effective Teaching Gap.

First, we used a statistical technique to adjust for the imperfect measurement of free and reduced-price lunch status when calculating the Effective Teaching Gap. The calculation of the Effective Teaching Gap regresses teacher value added on a student's free and reduced-price lunch status. As described in Appendix B, the technique to statistically adjust for measurement error in free and reduced-price lunch status works by multiplying the original Effective Teaching Gap by an adjustment factor, which depends on the proportion of students eligible for a free or reduced-price lunch who are incorrectly identified as ineligible, and vice versa. Using a finding from Moore et al. (2015), we assumed that 9.3 percent of students identified as eligible for free or reduced-price lunch students are not truly eligible based on family income. For the percentage of students who are classified as ineligible for a free or reduced-price lunch but are truly eligible, we applied a range of plausible assumptions: 5 percent, 10 percent, and 20 percent.

Under these assumptions, the adjustment factor ranges from 1.16 to 1.41 (that is, it leads to an increase in the gap of 16 to 41 percent). Because the Effective Teaching Gaps are well under 0.010, multiplying by these adjustment factors still gives Effective Teaching Gaps that are less than 0.010 (Table C.5). This indicates that measurement error in FRL status is not a major problem with our methodology.

Table C.5. Comparing Effective Teaching Gaps with and without correction for measurement error in poverty status, 26 districts, years 1-5

	Adjustment factor	ELA effective teaching gap	Math effective teaching gap
Without Correcting for Measurement Error in FRL	1.00	0.005	0.004
Assuming 5 percent of non-FRL students are truly FRL-eligible	1.16	0.006	0.005
Assuming 10 percent of non-FRL students are truly FRL-eligible	1.24	0.006	0.005
Assuming 20 percent of non-FRL students are truly FRL-eligible	1.41	0.007	0.006

Source: Author's calculations based on district administrative data.

Note: For each of the three rows correcting for measurement error, we assume that 9.1 percent of FRL students who are classified as FRL are not truly eligible for FRL based on family income.

Second, we redefined low-income students to include only students identified as eligible for a free lunch. This excludes an average of 8.0 percent of students who are eligible for a reduced-price lunch in these districts. The rationale for excluding students eligible for a reduced-price lunch is that this group of students is more error-prone—that is, they are more likely than students eligible for a free lunch to have family income above the 185 percent of the poverty line threshold (Moore et al. 2015). We conducted this analysis in the 15 districts where we can separately distinguish between students eligible for a free and reduced-price lunch.

In these 17 districts, the Effective Teaching Gap when defining disadvantaged students as those eligible for free or reduced-price lunch is 0.002 for ELA and 0.004 for math (Table C.6). Similarly, when we exclude reduced-price lunch students from the classification of disadvantaged, the Effective Teaching Gap is 0.002 for ELA and 0.005 for math.

Table C.6. Effective Teaching Gaps by Free/Paid Status (15 districts), years 1 to 5

	English/ language arts	Math
Effective Teaching Gap for free and reduced-price lunch students	0.002	0.004
Effective Teaching Gap for free lunch students	0.002	0.005
Sample Size (districts)	15	15

Source: District administrative data.

Note: Results are for grades 4 through 8, years 1 to 5, and 15 districts for free/paid gaps. District-level results are weighted across grades and years by the number of students. Overall results are weighted equally across districts.

* None of the results were statistically significant at the 0.05 level, two-tailed test. Statistical significance is tested using the standard error of each district's estimate.

I. Relationships between district characteristics and the Effective Teaching Gap

Since low-income students' access to effective teachers varies to some extent from district to district, we examined whether it is possible to identify the characteristics associated with districts where low-income students have the least (or most) effective teachers.

We examined the relationship between selected district characteristics and the size of the Effective Teaching Gap. We find statistically significant relationships between a district's size and region and low-income students' access to effective teachers. Districts that are larger and located in the southern United States tend to have a less equitable distribution of teachers than other districts, although the average Effective Teaching Gaps across all regions and district sizes are relatively small (Table C.7). We grouped districts into three categories by size—medium-sized districts have fewer than 40,000 students, large districts have 40,000 to 100,000 students, and very large districts have more than 100,000 students. Medium-sized districts have significantly smaller Effective Teaching Gaps than large and very large districts in both subjects. Southern districts (in both subjects) tend to have larger Effective Teaching Gaps than districts in other regions. These findings are related, as districts in the south tend to be larger than those in other regions.

Table C.7. Average Effective Teaching Gap by district size and region

	Effective teaching gap		
	English/ language arts	Math	Number of districts
All districts	0.005*	0.004*	26
District size			
Medium districts	0.000	-0.010*	7
Large districts	0.004	0.010*	14
Very large districts	0.014*	0.010	5
Region			
Midwest	-0.003*	-0.014*	6
North	0.007	-0.008*	3
South	0.009*	0.014*	11
West	0.003	0.013	6

Source: District administrative data.

Note: Estimates in the table represent the mean Effective Teaching Gaps for districts within each group. Results are based on 26 districts, grades 4 to 8, and years 1 to 3. Small districts have fewer than 40,000 students, medium districts have 40,000 to 100,000 students, and large districts have more than 100,000 students. Geographic region is based on Census region.

* Indicates whether the Effective Teaching Gap in a given category is significantly different from all other districts combined at the 0.05 level, using the standard error of each district's estimate.

We also examined whether access to effective teaching is related to other district characteristics, but do not find that Effective Teaching Gaps were consistently related to these characteristics. Our analysis included the following district characteristics: the size of student achievement gaps, the proportion of low-income, white, Black, and Hispanic students, the extent to which high- and low-income students are separated across schools,[49] and the maximum

[49] We describe the extent to which low-income and high-income students are separated in different schools using a measure known as the Index of Dissimilarity (D-Index). This measure can be interpreted as the percentage of

potential Effective Teaching Gap. In ELA, the proportion of students eligible for a free or reduced price in a district is positively correlated with the Effective Teaching Gap and the proportion of white students in a district is negatively correlated with the gap (Table C.8). However, these relationships are not significant in math. When we examine results separately by grade span, the proportion of free and reduced-price lunch students and the proportion of white students are significantly correlated with Effective Teaching Gaps in the middle school grades but not the elementary grades. In addition, the proportion of Black students is significantly correlated with Effective Teaching Gaps in the middle school grades.

Table C.8. Relationships between Effective Teaching Gaps and district characteristics, years 1 to 5

Correlation of effective teaching gap with...	All grades	Upper elementary grades	Middle school grades
ELA			
Student Achievement Gap	-0.152	-0.303	-0.119
D-index	-0.126	0.183	-0.167
Percent free and reduced-price lunch	0.421*	-0.065	0.490*
Percent Black	0.354	-0.080	0.397*
Percent Hispanic	0.213	0.392	0.176
Percent White	-0.590*	-0.256	-0.593*
Maximum Effective Teaching Gap	0.025	0.190	0.060
Math			
Student Achievement Gap	-0.335	-0.182	-0.306
D-index	-0.279	-0.208	-0.223
Percent free and reduced-price lunch	-0.095	-0.308	-0.022
Percent Black	-0.023	-0.609*	0.087
Percent Hispanic	0.065	0.546	0.037
Percent White	-0.048	0.298	-0.129
Maximum Effective Teaching Gap	-0.136	-0.444	0.009
Sample Size	26	12	26

Source: District administrative data.

Notes: Based on value added results that include classroom characteristics. The student achievement gap is based on pretest data from the first year of the study, such that it is not a direct function of the estimated Effective Teaching Gap.

J. Differences in student learning between high- and low-income students

In Chapter III, we describe how the student achievement gaps between high- and low-income students in study districts are similar to those at the national level. Differences in student achievement levels provide one motivation for examining low-income students' access to effective teachers. However, differences in student achievement between high- and low-income students may already exist when these students first enter school, so we also examined differences in year-to-year student learning between high- and low-income students. If

students from one group (low-income or high-income) who would have to change schools to achieve a perfectly even distribution. The D-index is calculated as $D = \frac{1}{2}\sum_{j=1}^{N}\left|p_j^{LI} - p_j^{HI}\right|$, where N is the number of teachers in the district, p_j^{LI} is the proportion of the district's low-income population with teacher j, and p_j^{HI} is the proportion of the district's high-income population with teacher j.

substantial differences in student learning exist between high- and low-income students, this provides an additional motivation for examining differences in effective teaching between the two groups.

To compare student learning for high- and low-income students, we regressed student test scores in a given year on their scores in the previous year (thus accounting for their prior achievement) and an indicator for whether the student was a low-income student. Just as in the value-added model (Equation B.1), we accounted for measurement error in prior achievement levels. We used this approach—rather than simply comparing the test score gains of high and low income students—to make this comparison within the same framework that we used to measure the Effective Teaching Gap. We ran regressions separately by grade, subject, and district then aggregated within-district weighting by the number of student-equivalents. We averaged across districts giving equal weight to each district.

We found that low-income students had significantly lower scores than high-income students after accounting for prior achievement, with a difference of 0.076 standard deviations in ELA and 0.070 in math. In other words, these differences were substantially larger than the estimated Effective Teaching Gaps of 0.005 in ELA and 0.004 in math.

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APPENDIX D

ADDITIONAL TABLES AND SENSITIVITY ANALYSES FOR CHAPTER V

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We conducted additional analyses to test the sensitivity of the hiring, development, and mobility results to different analytical approaches and subsamples of teachers and districts. In this appendix, we describe the results of those analyses, which suggest that the findings are robust.

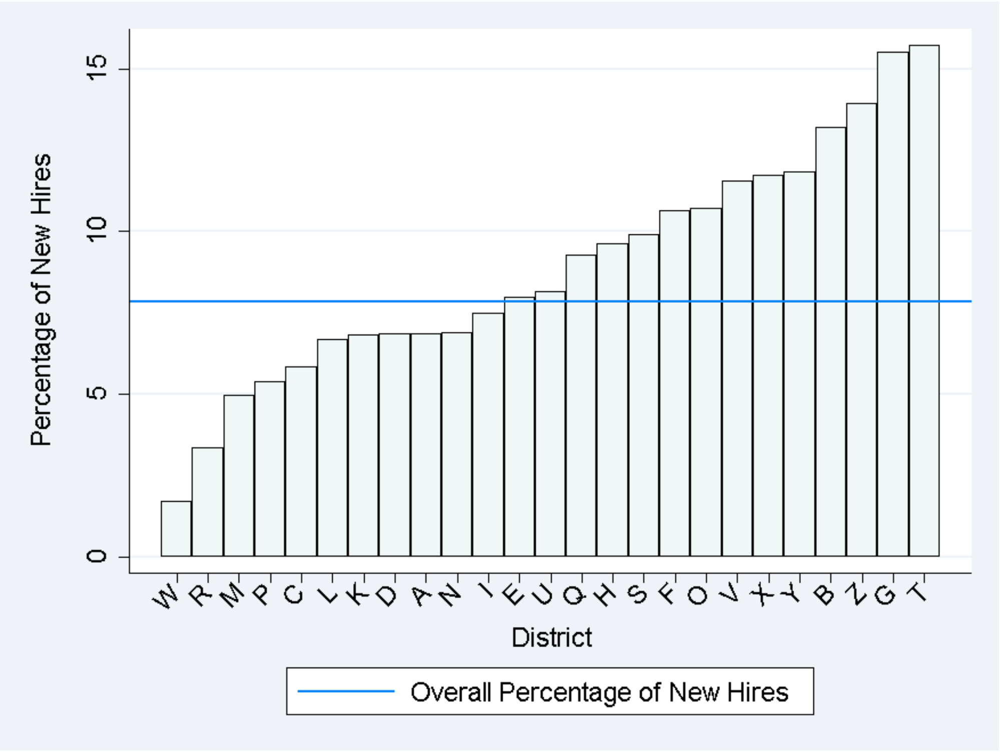
A. Results for individual districts

We examined district-level variation in our findings by examining each district individually to see if the conclusions we drew based on all districts combined were supported by the results in all, or at least a large majority of, individual districts. First we examined variation across districts in the *amount* of hiring, transfer, and attrition, and the *average effectiveness* of new hires, transfers, and leavers. Second, we examined variation across districts in the relationship between school poverty level and the prevalence and effectiveness of new hires, transfers, and leavers.

1. Prevalence and effectiveness of new hires, transfers, and leavers, by district

We found statistically significant variation across districts in the amount of hiring and mobility and the effectiveness of teachers in these categories. In the majority of districts, the prevalence of new hires, transfers, and leavers ranged between 5 and 15 percent (Figures D.1-D.3). New hires, transfers, and leavers were usually less effective than the average teacher in the district, as indicated by a negative average value added. Of the 25 districts in the sample, there was a negative value added in 24 districts for new hires (Figure D.4), 20 districts for transfers (Figure D.5), and 21 districts for leavers (Figure D.6).

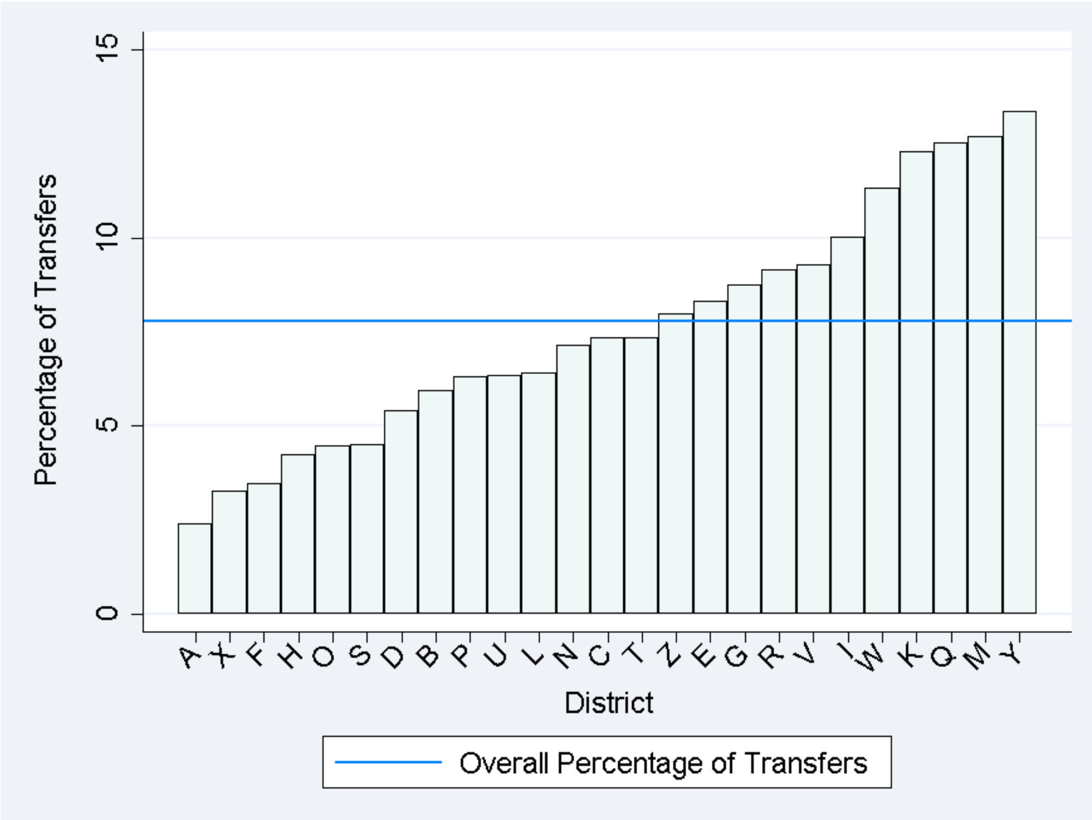
Figure D.1. Percentage of new hires by district



Source: Author calculations based on district administrative data.

Note: Results are for grades 4 through 8 and years 2 through 5, and include 25 districts. The cross-district average of 7.8 percentage points is shown by the solid blue line. Districts are ordered by the percentage of new hires. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). The identifiers are consistent across figures.

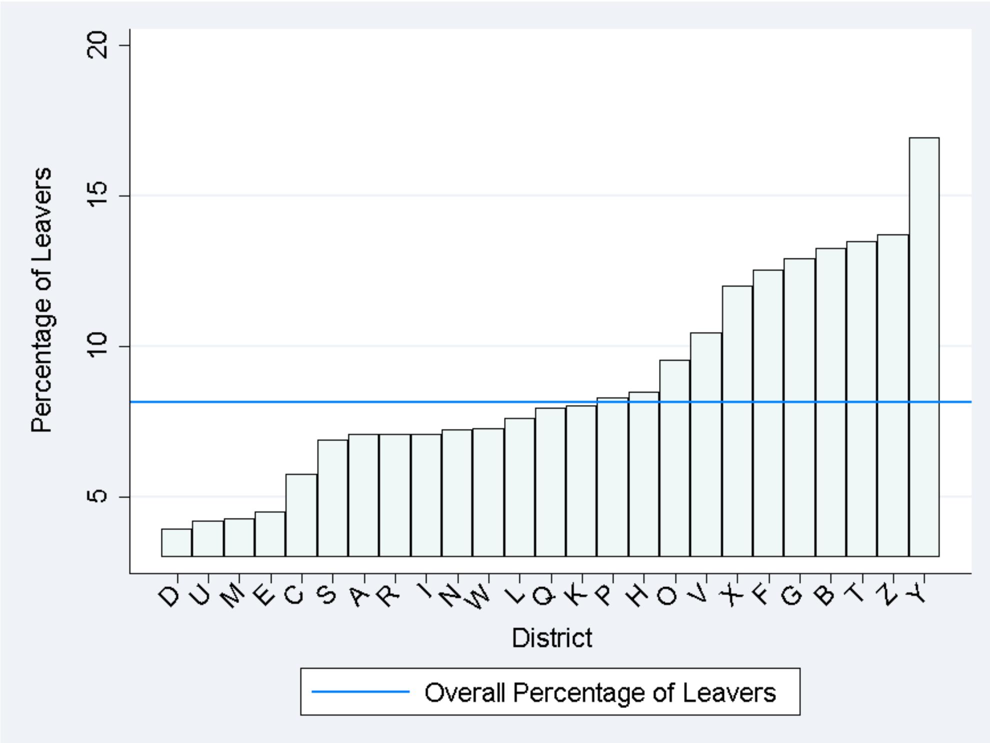
Figure D.2. Percentage of transfers by district



Source: Author calculations based on district administrative data.

Note: Results are for grades 4 through 8 and years 2 through 5, and include 25 districts. The cross-district average of 7.8 percentage points is shown by the solid blue line. Districts are ordered by the percentage of transfers. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). The identifiers are consistent across figures.

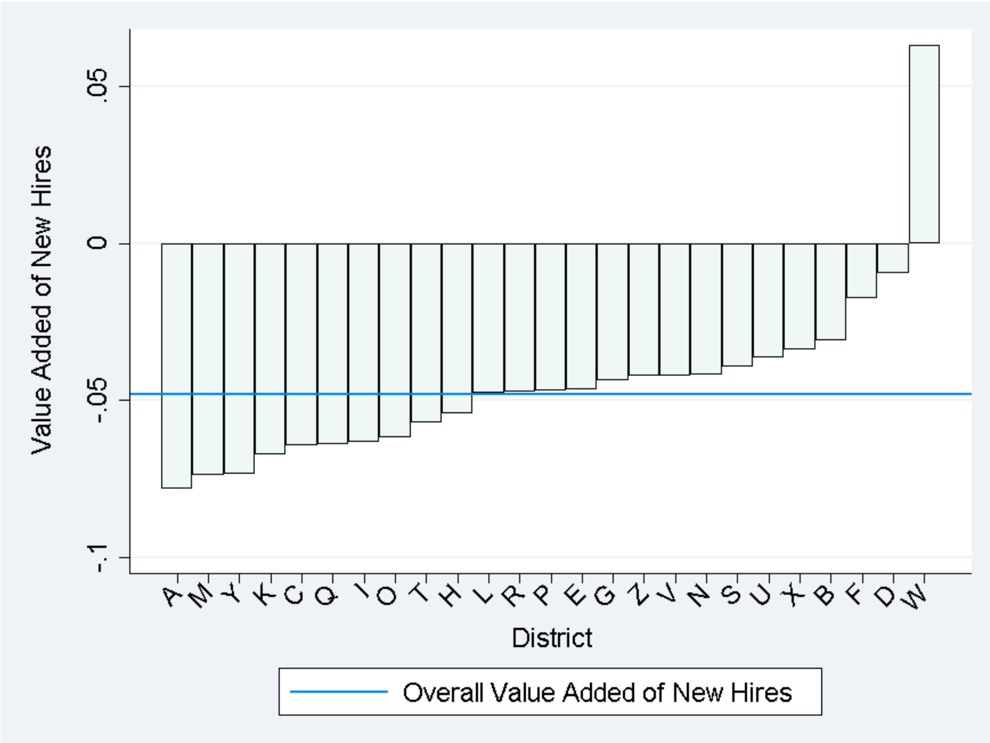
Figure D.3. Percentage of leavers by district



Source: Author calculations based on district administrative data.

Note: Results are for grades 4 through 8 and years 2 through 5, and include 25 districts. The cross-district average of 8.1 percentage points is shown by the solid blue line. Districts are ordered by the percentage of leavers. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). The identifiers are consistent across figures.

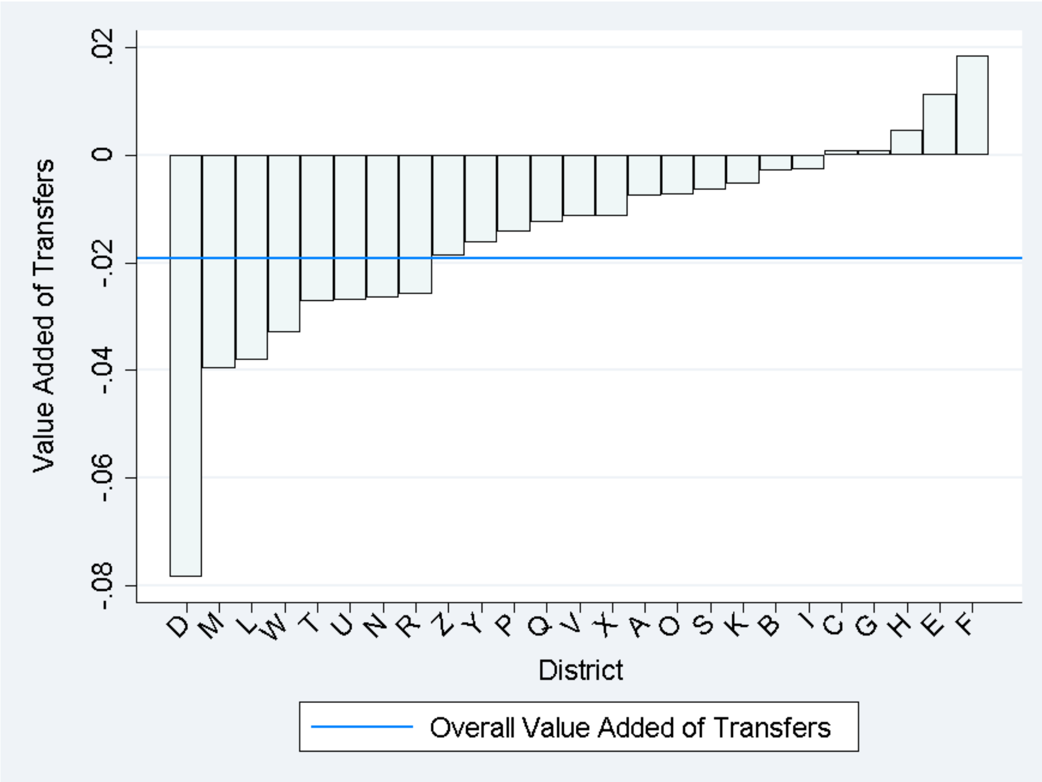
Figure D.4. Average value added of new hires by district



Source: Author calculations based on district administrative data.

Note: Results are for grades 4 through 8 and years 2 through 5, and include 25 districts. The cross-district average of -0.048 is shown by the solid blue line. Districts are ordered by the average value added of new hires. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). The identifiers are consistent across figures.

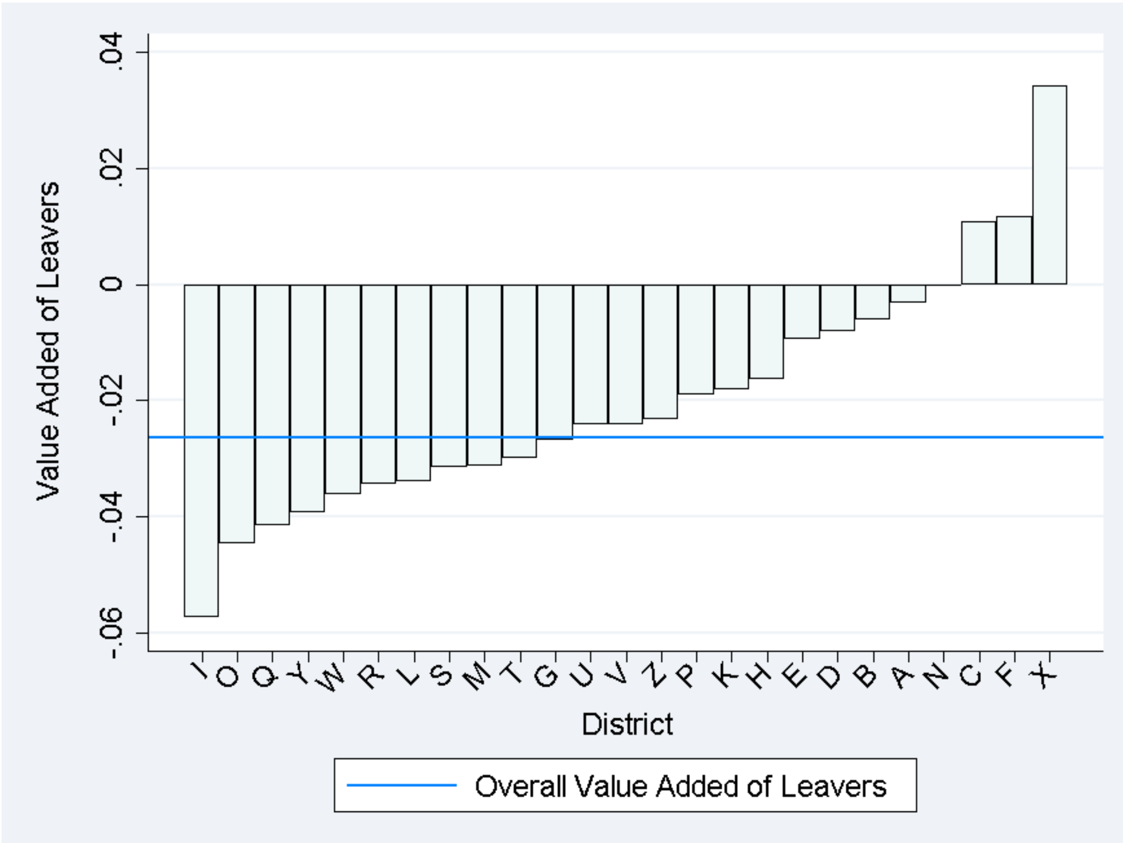
Figure D.5. Average value added of transfers by district



Source: Author calculations based on district administrative data.

Note: Results are for grades 4 through 8 and years 2 through 5, and include 25 districts. The cross-district average of -0.019 is shown by the solid blue line. Districts are ordered by the average value added of transfers. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). The identifiers are consistent across figures.

Figure D.6. Average value added of leavers by district



Source: Author calculations based on district administrative data.

Note: Results are for grades 4 through 8 and years 2 through 5, and include 25 districts. The cross-district average of -0.026 is shown by the solid blue line. Districts are ordered by the average value added of leavers. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). The identifiers are consistent across figures.

2. Relationship between school poverty and patterns of hiring, transfer, and attrition, by district

We next examined the variation across districts in the relationship between school poverty and the prevalence and effectiveness of new hires, transfers, and leavers. Because some districts have few teachers in either high-poverty or low-poverty schools, comparisons across the high- and low-poverty school categories are not meaningful for all districts. To address this issue when making cross-district comparisons of these differences, we used a continuous measure of school poverty and approximated the difference between high- and low-poverty schools by examining a 60-percentage point difference in the continuous measure (see Section G for details). Within each district, we evaluated whether the difference between high- and low-poverty schools in the prevalence or effectiveness of a particular group of teachers was significantly different from zero. [50]

[50] Because all results in Chapter V are weighted by size, larger districts exert more influence on the results than small districts. However, when we excluded the two largest districts—which accounted for 30 percent of teachers in the sample—we continued to find similar results based on the remaining districts.

Figures D.7 to D.13 show the district-level results for new hires (D.7 to D.8), transfers (D.9 to D.11) and leavers (D.12 to D.13). In each figure, each bar represents an individual school district. The height of the bar represents the difference in outcomes associated with a 60 percentage point change in a school's poverty rate.[51] This 60 percentage point difference is approximately equivalent to the average difference in poverty rates between high- and low-poverty schools across all districts in the sample. For example, the bar at the far right of Figure D.7 shows that in one district, the prevalence of new hires in high-poverty schools is 12 percentage points greater the prevalence of new hires in low-poverty schools. The blue line across the middle of each figure shows the overall district average.

New hires are more common at high-poverty schools than at low-poverty schools in 23 of 25 districts (16 statistically significant) (Figure D.7). While our main results indicated that across districts new hires are equally effective at high- and low-poverty schools, there is variation in this result across districts. New hires are significantly more effective in low-poverty schools in 3 districts and significantly more effective at high-poverty schools in 4 districts (Figure D.8).

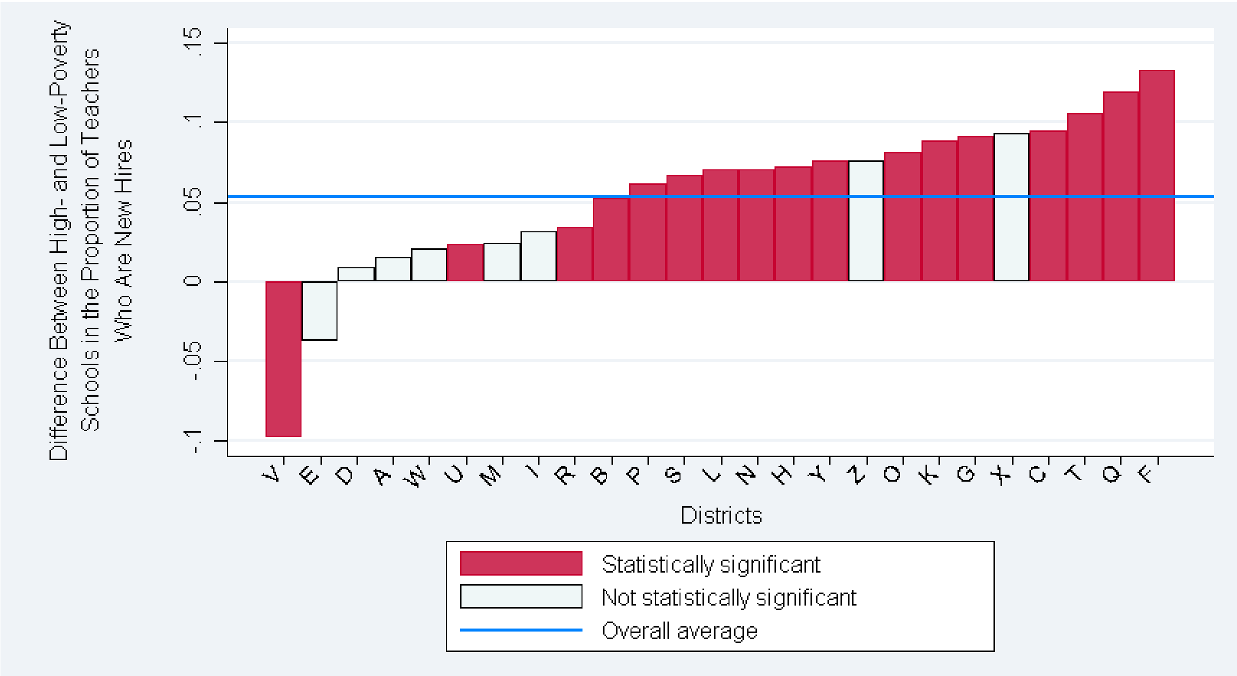
Transfers are more common at high-poverty schools than at low-poverty schools in all 25 districts (14 statistically significant) (Figure D.9). Most typically, a district's transfers move to schools with lower poverty rates, although districts differ on the extent to which this occurred. In 17 districts (6 statistically significant), teachers transfer to a school with a lower poverty rate than their previous school, on average (Figure D.10). In 6 of these districts, the percentage of low-income students at the teacher's new school is at least 5 percentage points less than that at their former school. In 8 districts (2 statistically significant), the typical teacher who transfers moves to a school with a higher poverty rate than their former school. More effective teachers tended to experience a larger decrease in the school poverty rate compared to less effective transfers. In 15 districts (4 statistically significant) transfers with above-average value added experienced a larger decrease in school poverty rates than teachers with below-average value added (Figure D.11).

There is some variation across districts in the relationship between school poverty and the prevalence and effectiveness of teachers who leave the district. In 16 of 25 districts, attrition from the district is more common among teachers in high-poverty schools than among those in low-poverty schools, with the difference statistically significant in 10 of these districts. In the other 9 districts, attrition is more common among teachers in low-poverty schools, with just one of these cases significant (Figure D.12).

There is also variation across districts in terms of the relationship between school poverty and the effectiveness of leavers. In 15 districts (5 significant), leavers from high-poverty schools are relatively less effective than leavers from low-poverty schools. In the other 10 districts (2 significant), the opposite is true (Figure D.13).

[51] Figures D.10 and D.11 are exceptions to this pattern. Figure D.10 reports the difference in the school poverty rate between the schools a teacher transferred to and from. Figure D.11 displays the additional difference in the school poverty rate for transfers who have one standard deviation higher value added.

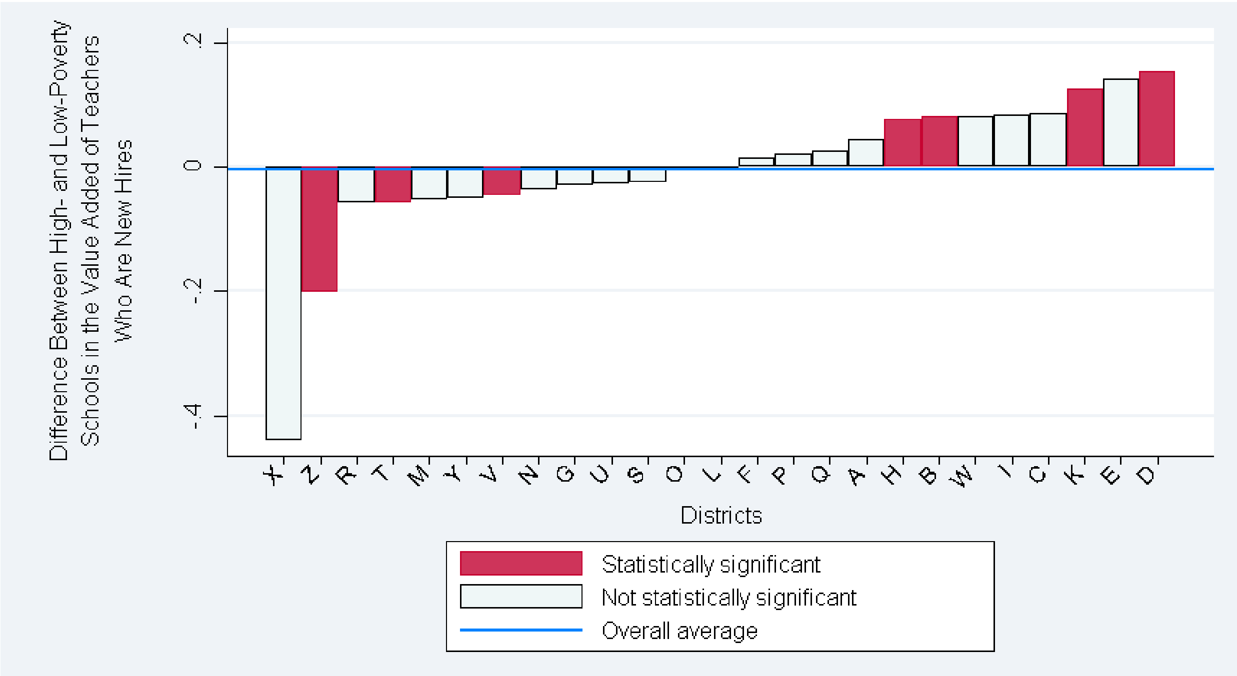
Figure D.7. Relationship between proportion of new hires and school poverty, by district



Source: Author calculations based on district administrative data.

Note: Positive values indicate that new hires are more prevalent at high-poverty schools. Results are for grades 4 through 8 and years 2 through 5, and include 25 districts. The cross-district average of 5.4 percentage points is shown by the solid blue line. Districts are ordered by the size of the difference between low- and high-poverty schools. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). The identifiers are consistent across figures. The dark red bars show differences between low- and high-poverty schools that are significantly different from zero at the 0.05 level; the light blue bars indicate differences that are not significantly different from zero. We reject the hypothesis that the differences are the same in all districts based on an f-test of joint significance, 0.05 level.

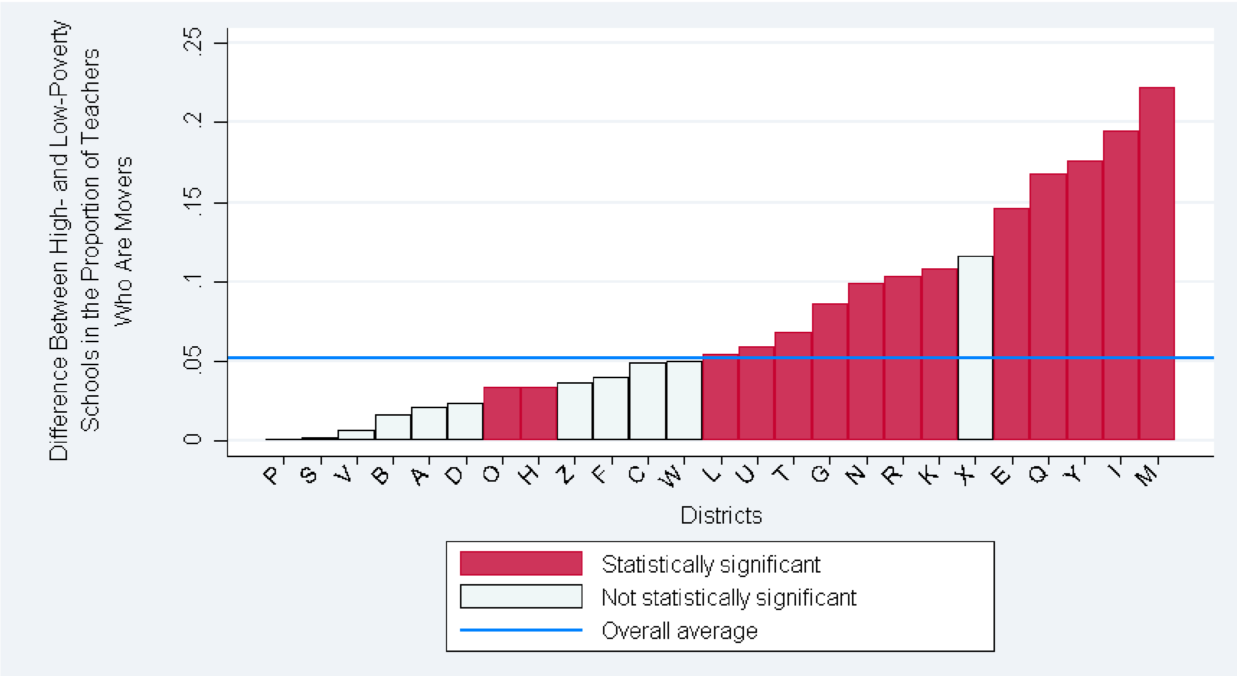
Figure D.8. Relationship between effectiveness of new hires and school poverty, by district



Source: Author calculations based on district administrative data.

Note: Positive values indicate that new hires are more effective at high-poverty schools. Results are for grades 4 through 8 and years 2 through 5, and include 25 districts. The cross-district average of -0.005 standard deviations is shown by the solid blue line. Districts are ordered by the size of the difference between low- and high-poverty schools. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). The identifiers are consistent across figures. The dark red bars show differences between low- and high-poverty schools that are significantly different from zero at the 0.05 level; the light blue bars indicate differences that are not significantly different from zero. We reject the hypothesis that the differences are the same in all districts based on an f-test of joint significance, 0.05 level.

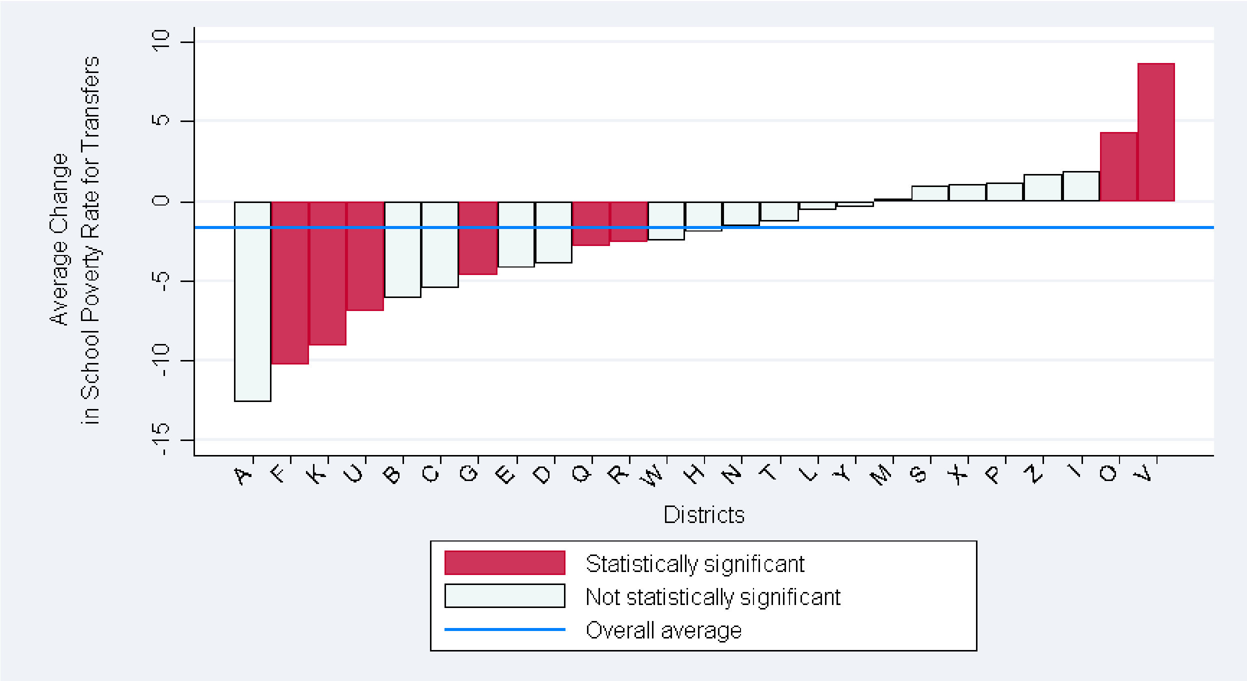
Figure D.9. Relationship between proportion of transfers and school poverty by district



Source: Author calculations based on district administrative data.

Note: Positive values indicate that teachers who transfer out of high-poverty schools are more prevalent than teachers who transfer out of low-poverty schools. Results are for grades 4 through 8 and years 1 through 4, and include 25 districts. The cross-district average of 5.2 percentage points is shown by the solid blue line. Districts are ordered by the size of the difference between low- and high-poverty schools. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). The identifiers are consistent across figures. The dark red bars show differences between low- and high-poverty schools that are significantly different from zero at the 0.05 level; the light blue bars indicate differences that are not significantly different from zero. We reject the hypothesis that the differences are the same in all districts based on an f-test of joint significance, 0.05 level.

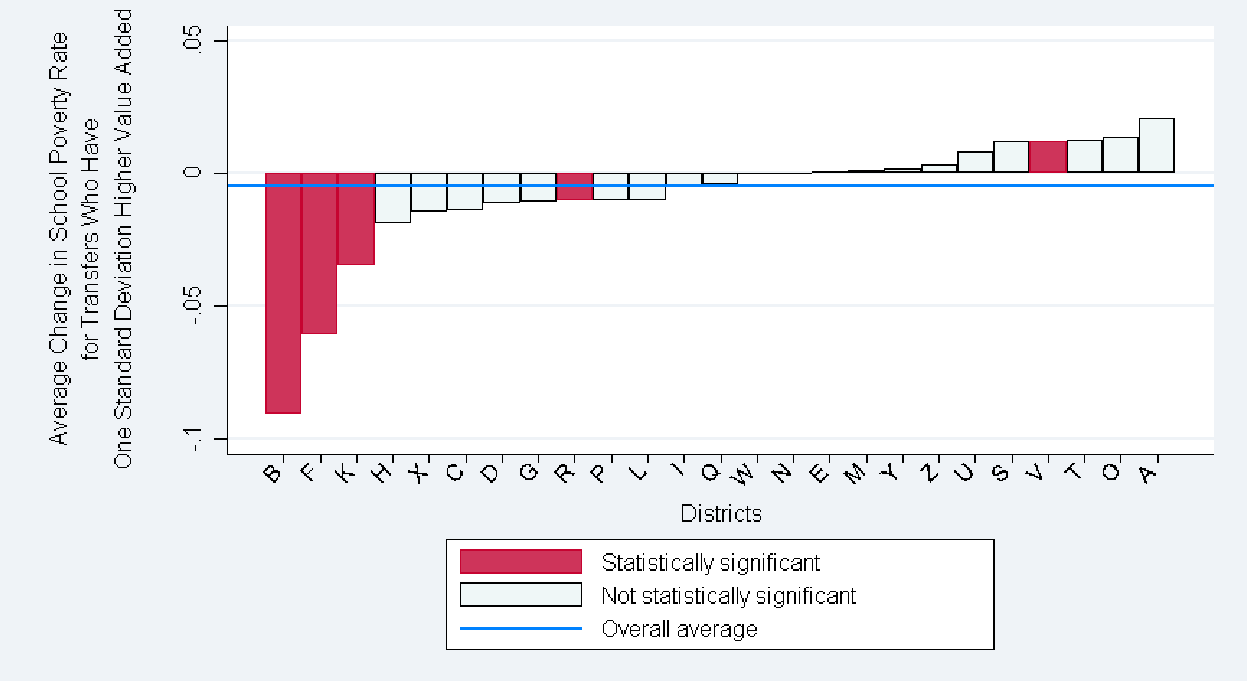
Figure D.10. Difference in poverty rates between the schools that teachers transfer to and from



Source: Author calculations based on district administrative data.

Note: Positive values indicate that transfers experience an increase in the school poverty rate. Results are for grades 4 through 8 and years 1 through 4, and include 25 districts. Two districts were excluded from this sample because there were fewer than 10 transfers with data on both the current-year and next-year school poverty rates. The cross-district average of -1.7 percentage points is shown by the solid blue line. Districts are ordered by the size of the change in poverty rates experienced by transfers. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). The identifiers are consistent across figures. The dark red bars show differences that are significantly different from zero at the 0.05 level; the light blue bars indicate differences that are not significantly different from zero. We reject the hypothesis that the differences are the same in all districts based on an f-test of joint significance, 0.05 level.

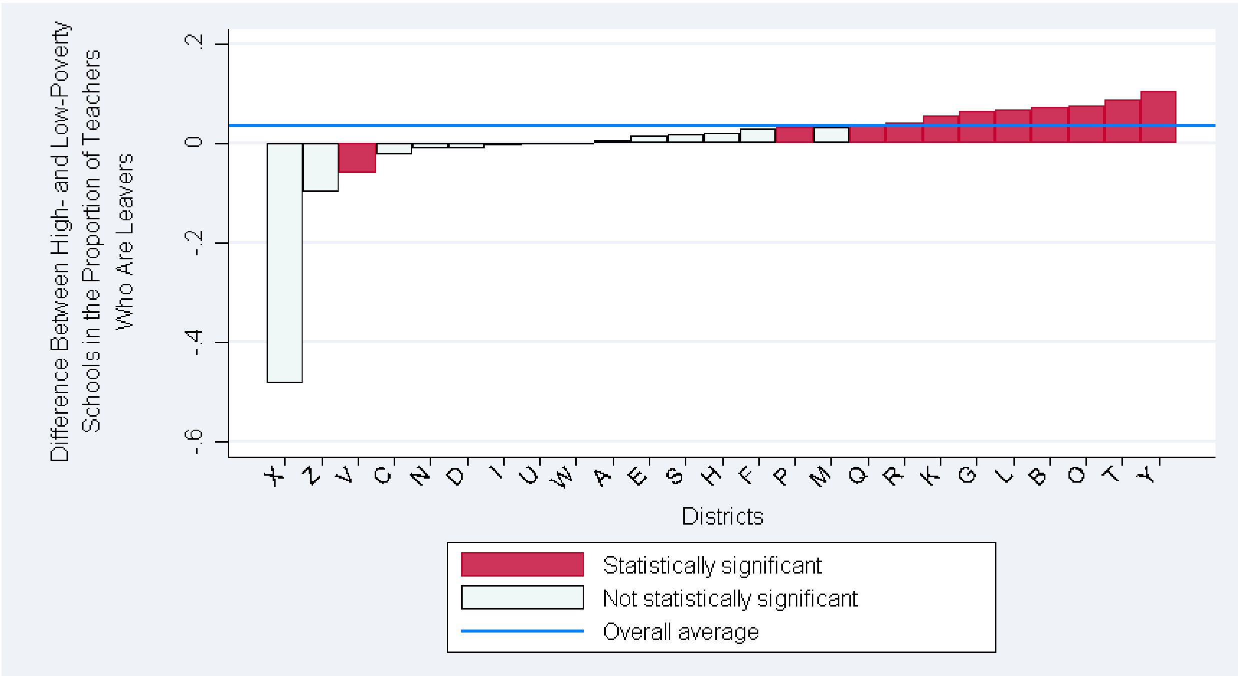
Figure D.11. Relationship between change in school poverty and effectiveness of transfers



Source: Author calculations based on district administrative data.

Note: Positive values indicate that transfers with higher value added experience an increase in the school poverty rate. Results are for grades 4 through 8 and years 1 through 4, and include 25 districts. The cross-district average of -0.008 percentage points is shown by the solid blue line. Districts are ordered by the size of the difference between low- and high-poverty schools. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). The identifiers are consistent across figures. The dark red bars show changes in school poverty rate that are significantly different from zero at the 0.05 level; the light blue bars indicate changes that are not significantly different from zero. We reject the hypothesis that the changes are the same in all districts based on an f-test of joint significance, 0.05 level.

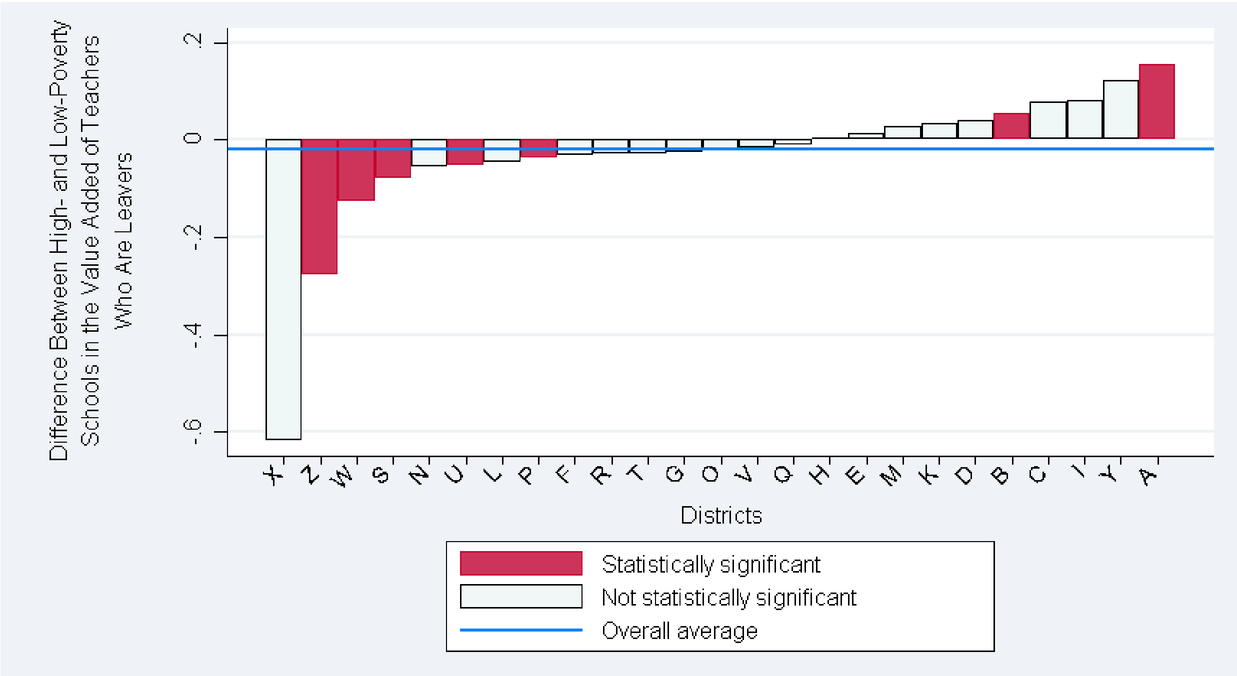
Figure D.12. Relationship between proportion of leavers and school poverty by district



Source: Author calculations based on district administrative data.

Note: Positive values indicate that leavers are more prevalent at high-poverty schools. Results are for grades 4 through 8 and years 1 through 4, and include 25 districts. The cross-district average of 3.5 percentage points is shown by the solid blue line. Districts are ordered by the size of the difference between low- and high-poverty schools. District identifiers A to Z are assigned according to the size of each district’s Effective Teaching Gap in ELA (with Z representing the largest positive gap). The identifiers are consistent across figures. The dark red bars show differences between low- and high-poverty schools that are significantly different from zero at the 0.05 level; the light blue bars indicate differences that are not significantly different from zero. We reject the hypothesis that the differences are the same in all districts based on an f-test of joint significance, 0.05 level.

Figure D.13. Relationship between effectiveness of leavers and school poverty by district



Source: Author calculations based on district administrative data.

Note: Positive values indicate that leavers are more effective at high-poverty schools. Results are for grades 4 through 8 and years 1 through 4, and include 25 districts. The cross-district average of -0.019 standard deviations is shown by the solid blue line. Districts are ordered by the size of the difference between low- and high-poverty schools. District identifiers A to Z are assigned according to the size of each district's Effective Teaching Gap in ELA (with Z representing the largest positive gap). The identifiers are consistent across figures. The dark red bars show differences between low- and high-poverty schools that are significantly different from zero at the 0.05 level; the light blue bars indicate differences that are not significantly different from zero. We reject the hypothesis that the differences are the same in all districts based on an f-test of joint significance, 0.05 level.

B. Effectiveness of new hires during their first year in the district

We examined whether new hires are less effective during their first year in a new district, separately from differences in the experience level of new hires relative to other teachers. This might occur if, for example, new teachers require some time to acclimate to teaching in their new district. To do this, we added an indicator variable to Equation B.18 for whether a teacher is a new hire in their first year. This is the regression equation designed to estimate the impact of a teacher's experience level on his or her effectiveness. The dependent variable of the equation is teacher value added, and the independent variables other than the new hire indicator are indicators for teacher experience, school poverty categories, the interaction between experience and school poverty, and teacher fixed effects. We interacted the new hire indicator with school poverty level to examine whether the experience of new hires differed across high- and low-poverty schools.

New hires at low poverty schools are significantly less effective than other teachers with similar levels of experience. In particular, the average value added of new hires is 0.032 less than that of similarly experienced teachers. However, there were no statistically significant differences across school poverty categories with respect to the effectiveness of new hires relative to other teachers with similar levels of experience (Table D.1).[52]

Table D.1. Difference between first-year value added of new hires and other teachers with similar experience

	Difference for new hires at low-poverty schools	Difference for new hires at medium-poverty schools	Difference for new hires at high-poverty schools	Overall average difference for new hires
ELA and Math Combined	-0.034*	-0.035*	-0.030*	-0.034*
ELA	-0.037*	-0.022	-0.014	-0.027*
Math	-0.028	-0.050*	-0.054*	-0.044*

Source: Author calculations based on district administrative data.

Note: *Indicates whether each value is significantly different from zero at the 0.05 level. The differences between high-, medium-, and low-poverty schools in the effect of being a new hire is not statistically significant for any of the three subject combinations.

C. Relationship between school poverty and teacher development

In addition to the ways that teachers are hired into schools, transfer across schools within a district, and leave teaching in a district, the pace at which teachers develop over time may contribute to inequitable access to effective teachers. If teachers at high-poverty schools develop more slowly than those at low-poverty schools, this would ultimately lead to low-income students being taught by less effective teachers. Teachers at high-poverty schools could improve more slowly, for example, because of weaker principals or fewer resources to support their development. So, as a supplementary analysis, we examine whether the pace of development differs for teachers in high-, medium-, and low-poverty schools.

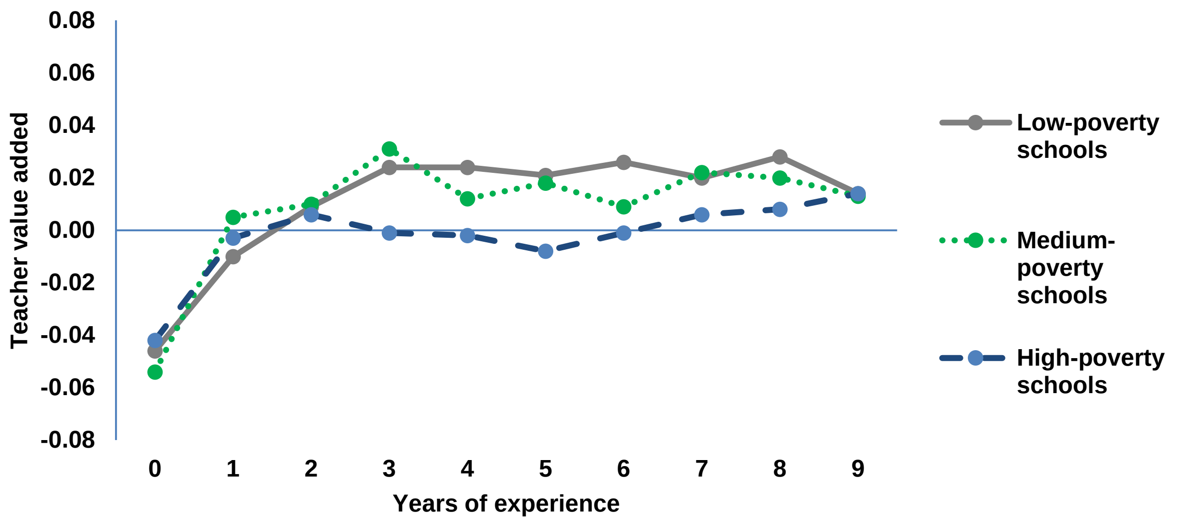
Teachers in our study improve rapidly during their first few years of teaching. Teachers' growth over a single year can be determined by examining the change in average value added between two consecutive years for a given group of teachers. The largest gain in teachers' effectiveness takes place between their first and second years of teaching, with an increase in value added of 0.05 standard deviations of student achievement. Teachers continue to improve after they have one to two years of experience, but at a slower rate. Teacher effectiveness flattens out once teachers have three to four years of experience, with no significant improvements in effectiveness during the years that follow.

On average, teachers improve at similar rates in schools with different levels of student poverty (Figure D.14). Although rates of growth for teachers in high- and low-poverty schools vary from year to year, there are no significant differences in teacher development across school poverty categories over the first 10 years of teachers' careers. We present estimates of average teacher value added in each of the first ten years of teachers' careers, in high-, medium-, and low-poverty schools (Table D.2). Examining overall growth between years 1 and 5 and between years 1 and 10 by school poverty category, we find that the difference in growth rates at

[52] The estimated effectiveness of new hires relative to other teachers with similar experience levels is based only on new hires with one or more years of experience teaching in other districts. Among new hires who are in their first year of teaching overall, we cannot distinguish between the effect of being a new hire and the effect of being a brand new novice teacher. This is because all teachers with no prior teaching experience elsewhere are new hires.

medium- and high-poverty schools are not significantly different from the growth rate at low-poverty schools, with one exception (Table D.3). Teachers with eight years of experience in medium-poverty schools are more effective than similarly experienced teachers in low-poverty schools. An earlier study also found no significant difference in the trajectories of teacher effectiveness in schools with different levels of poverty (Xu et al. 2015).

Figure D.14. Average value added by teacher's years of experience and school poverty level, ELA and math results combined



Source: Author's calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 10 districts and in grades 6 to 8 in 8 districts, for years 1 through 5. New hires are teachers who were not teaching in the district during the previous school year. The results are presented as an average across districts, weighted by the number of students taught by each teacher in the analysis. The sample contains 70,671 teacher-year observations.

The year-to-year changes in value added for teachers in low-poverty schools are not statistically different from the year-to-year changes for teachers in medium- or high-poverty schools, at the 0.05 level, two-tailed test.

Table D.2. Average value added by years of experience and school poverty: ELA and math combined

Years of experience	Low-poverty	Medium-poverty	High-poverty	All schools
1	-0.047	-0.053	-0.041	-0.047
2	-0.009	0.005	-0.002	-0.001
3	0.008	0.010	0.007	0.009
4	0.025	0.031	0.001	0.021
5	0.024	0.013	0.000	0.014
6	0.021	0.018	-0.008	0.013
7	0.026	0.010	0.000	0.014
8	0.019	0.023*	0.006	0.017
9	0.028	0.020	0.008	0.020
10	0.014	0.014	0.015	0.014

Source: Author calculations based on district administrative data.

Note: Asterisks in the medium and high poverty columns indicate that the growth in value added between the current and previous experience level differs significantly relative to the growth between those experience categories for low-poverty schools. The sample includes 68,309 teacher-year observations from 18 districts.

Table D.3. Average value added by years of experience and school poverty: ELA and math combined

Years of experience	Low-poverty	Medium-poverty	High-poverty	All schools
Growth Between 1-5	0.072	0.067	0.040	0.061
Growth Between 1-10	0.061	0.067	0.056	0.061

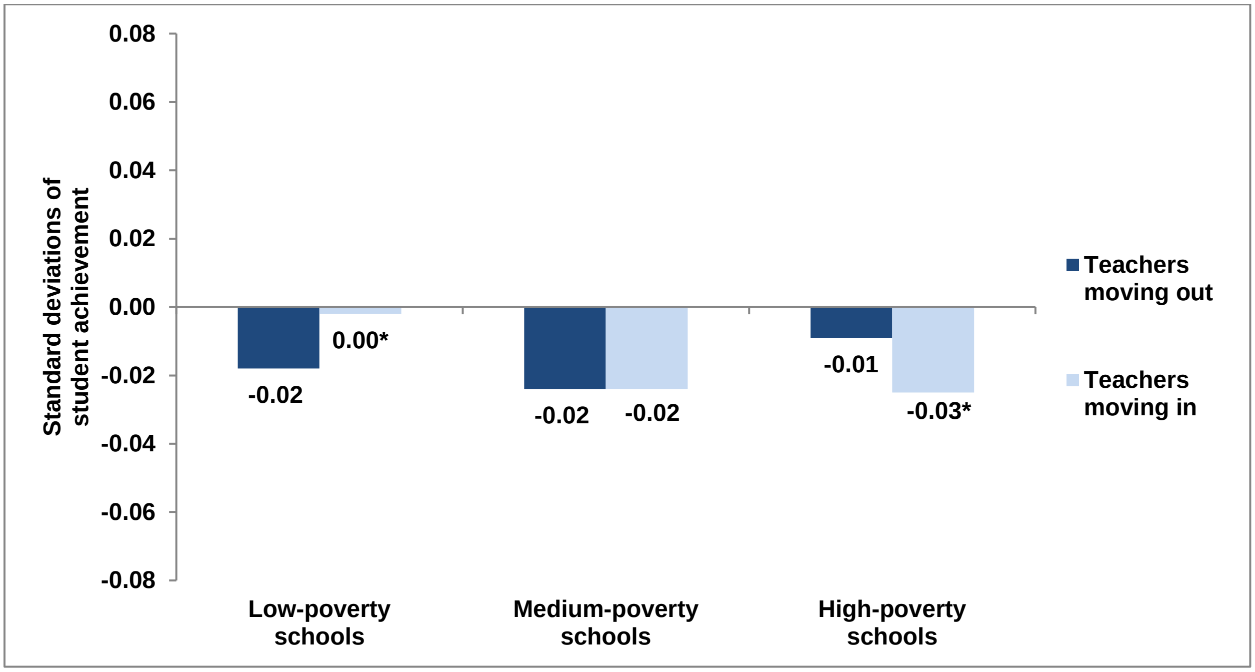
Source: Author calculations based on district administrative data.

Note: The sample includes 68,309 teacher-year observations from 18 districts

D. Effectiveness of teachers who transfer in and out of high- and low-poverty schools

In Chapter 5, we describe how teacher transfer patterns are consistent with small differences in access to effective teachers for high- and low-income students. The chapter described the prevalence and effectiveness of teachers who transfer to schools in a higher poverty category and to schools in a lower poverty category. Another way to examine how teacher transfers could lead to inequity is to compare the effectiveness of teachers who transfer in and out of high-, and low-poverty schools. At low-poverty schools, the teachers transferring in are significantly more effective than those transferring out, by 0.016 standard deviations of student achievement (Figure D.15). On average, teachers transferring in are at the 50th percentile of teacher effectiveness and teachers transferring out are at the 45th percentile. The opposite trend takes place at high-poverty schools, where teachers transferring in (43rd percentile) are significantly less effective than those transferring out (48th percentile). These patterns result in a small improvement in the average effectiveness of teachers at low-poverty schools and a small decline in the average effectiveness of teachers at high-poverty schools.

Figure D.15. Value added of teachers who transfer by school poverty categories



Source: Author's calculations based on district administrative data.

Note: The results are for teachers in grades 4 to 8 in 12 districts and in grades 6 to 8 in 13 districts, for years 1 through 4. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 7,385 teacher-year observations are included in the sample. There are 1,864 teacher-year observations in low-poverty schools, 2,899 teacher-year observations in medium-poverty schools, and 2,622 teacher-year observations in high-poverty schools (counting teachers moving out of each school poverty category).

* Differences in the value added of teachers moving in and out the school poverty category are significantly different at the 0.05 level, two-tailed test

E. Effectiveness of teachers who transfer in their new and former schools

We examined whether teachers who transfer to a new school become more or less effective as a result, and whether this differs across high- and low-poverty schools. Jackson (2013) finds that teachers who transfer schools tend to increase in effectiveness in their new school setting as a result of a better match between the teacher and his or her new school setting. To assess this possibility while isolating the effect of being in a new school from any general effect of gaining experience, we added to Equation B.18 a set of indicator variables for whether a teacher had previously transferred into their current school, and whether their current school is in a poverty category that is lower, the same, or higher than the poverty category of their former school.[53]

Overall, there are no significant differences in teacher value added when they transferred schools (Table D.4, last column). This was true regardless of whether the transfer was to a school that was in a poverty category that was lower, the same as, or higher than the teachers' starting

[53] This analysis includes only years in which we can observe the prior movement of each teacher. Because there are many teachers who transferred schools in years before we first observed them, this analysis may understate the change in value added teachers experience when transferring schools, because some previous transfers would not be captured and would be counted as teachers who have not transferred before.

schools. The results did not differ when we examined ELA and math teachers together and when we examined the two subjects separately.

Table D.4. Change in value added of transfers after move to a new school, by whether transfers to a school in lower, same, or higher poverty category

	After transfer to lower poverty category	After transfer to same poverty category	After transfer to higher poverty category	After any transfer
Math and ELA Combined	0.016	0.001	0.007	0.004
ELA	0.022	0.007	0.019	0.012
Math	0.010	-0.003	-0.002	-0.001

Source: Author calculations based on district administrative data.

Note: The average change in value added after a move is not significantly different from zero for any type of move or for any of the three subject combinations. The difference between the change in value added after a move to either a higher poverty category or to the same school poverty category are not significantly different from the change after a move to a lower poverty category for any of the three subject combinations.

F. Effectiveness of teachers who leave the district in their last year

We explored whether teachers who leave the district are less effective in their last year teaching in the district than expected, given their experience level and previous effectiveness. Hanushek et al. (2005) found evidence of a dip in teacher effectiveness in teachers' last year. To explore this issue, we added an indicator to Equation B.18 for whether a teacher was no longer teaching in the district the following year. We also interacted this indicator with the school poverty indicators.

There is evidence that teachers become less effective in their last year, as value added in this last year is 0.016 lower than expected, and this effect is statistically significant (Table D.5). Though the decline in value added for leavers from low- and medium-poverty schools is less than for teachers at high-poverty schools, these differences are not statistically significant. There are some differences in this pattern across subjects In ELA there is no statistically significant effect overall of being in the last year in the district. However, leavers from high-poverty schools in ELA experienced a statistically significant decline in value added. In math there is a statistically significant decline in value added of 0.030 for leavers during their last year in the district, and this magnitude is similar across school poverty categories. The magnitude of the decrease in value added does not significantly differ across school poverty categories in either subject.

Table D.5. Average change in value added of leavers during their last year in the district

	Leavers from low-poverty schools	Leavers from medium- poverty schools	Leavers from high-poverty schools	Leavers from any school
Math and ELA Combined	-0.009	-0.016	-0.032*	-0.015*
ELA	0.004	-0.009	-0.030*	-0.007
Math	-0.032*	-0.026	-0.031	-0.030*

Source: Author calculations based on district administrative data.

Note: Asterisks indicate whether each value is significantly different from zero. The difference between the change in value added for leavers at high- and medium-poverty schools was not significantly different from the difference for leavers at low-poverty schools in any of the three subject combinations.

G. Relationship between a continuous measure of school poverty and hiring, transfer, and attrition

In Chapter V, we present hiring and mobility results that focus on differences between the three school poverty categories, but we do not examine differences across schools within the poverty categories. Each category covers a wide range of school poverty levels. For example, the low-poverty category includes schools that range from having zero to 60 percent of students low-income.

We tested the robustness of our results by using a continuous measure of school poverty to capture differences in teacher hiring and mobility both within and between the categories. For this approach, we estimated the relationship between school poverty and teacher hiring and mobility status using a regression model similar to the one described in Equation B.18, but with the school poverty category indicators replaced by a continuous variable representing the percentage of low-income students at a teacher's school.

We then compared the results of our analysis based on the continuous poverty measure to those based on the categorical measure. The top panel of Table D.6 shows the average change in the percentage of new hires in a school that is associated with a 60 percentage point increase in a school's poverty rate. This 60 percentage point increase is approximately equal to the difference in rates between the average high-poverty school and the average low-poverty school in our sample. For comparison, we also present the difference in the proportion of new hires between high- and low-poverty schools, as calculated in Chapter V using the categorical approach. The top panel also compares differences in the effectiveness of new hires when using the two approaches. The bottom panel of Table D.6 shows an analogous set of results for transfers and leavers.

As with the original results based on the categorical poverty measure, the results based on a continuous poverty measure show that high-poverty schools hire a larger proportion of new teachers than low-poverty schools. The magnitude of this difference is similar across the two approaches—the prevalence of new hires is 5 to 6 percentage points higher in high-poverty schools than in low-poverty schools regardless of the approach (Table D.6). Similarly, there is little difference in the effectiveness of new hires in high-poverty schools versus low-poverty schools regardless of our approach for defining high- and low-poverty schools. The results of the analysis of the relationship between school poverty and transfer and attrition behavior are also similar whether we use a continuous or categorical measure of school poverty.

Table D.6. Hiring, transfer, and attrition results with continuous measure of school poverty, grades 4 to 5 (12 districts) and grades 6 to 8 (25 districts)

	Difference resulting from 60 percentage-point increase in school poverty rate (continuous measure)	Difference between high- and low-poverty schools (categories)	Difference between estimates
Hiring			
Percentage			
New Hires	5.4%	6.0%	0.6%
Value Added			
New Hires	-0.005	-0.001	0.004
Current Teachers	-0.008	-0.001	0.007
Transfer and Attrition			
Percentage			
Transfers	5.2%	5.8%	0.6%
Leavers	3.5%	3.0%	-0.5%
Value Added			
Stayers	-0.011	-0.002	0.009
Transfers	-0.008	0.004	0.012
Leavers	-0.019	-0.014	0.005

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 25 districts and in grades 4 and 5 in 12 of these districts, for years 2 through 5 (new hire results) and years 1 through 4 (transfer and leaver results). The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 116,072 teacher-year-grade-subject observations are included in the sample for new hires and 110,466 observations are included in the sample for stayers, transfers, and leavers.

H. Hiring, transfer, and attrition results by grade span and subject

To produce the results described in Chapter V, we combined three groups of teachers: middle school math, middle school English/language arts (ELA), and upper elementary school teachers. To ensure that these combined results did not mask a more nuanced story, we examined these three groups separately. We also examined the results for two additional subgroups—middle school math and ELA teachers in the 12 districts included in the upper elementary school analysis. We compared these results to the results for middle school math and ELA teachers in the full set of 25 districts. Thus, we examined five different subsamples of teachers overall. In general, the results were similar for all five subsamples we examined.

1. New hire results by grade span and subject

The percentage of new hires overall is 7.8 percent, and it ranges from 7.1 to 9.9 percent across the five subgroups (Table D.7). In Chapter V, we describe how new hires are more common in medium- and high-poverty schools than in low-poverty schools. This finding is true for all five subgroups we examined: the proportion of new hires in medium- and high-poverty schools is always significantly higher than in low-poverty schools.

In terms of effectiveness, teachers at medium- and high-poverty schools have similar value added estimates as teachers in low-poverty schools overall (Table D.8). However, in middle school math in both the 25-district and 12-district samples, new hires in high-poverty schools are significantly more effective than teachers in low-poverty schools. In the upper elementary grades, new hires in medium-poverty schools are significantly less effective than new hires in low-poverty schools.

Table D.7. Amount of new teacher hiring by school poverty level, subject, and grade span, grades 4 to 5 (12 districts) and grades 6 to 8 (25 districts)

	Low-poverty schools	Medium-poverty schools	High-poverty schools	Overall average
Combined Sample	**4.9%**	**8.6%***	**10.9%***	**7.8%**
Middle School, ELA	5.3%	8.6%*	10.1%*	7.8%
Middle School, Math	4.5%	8.8%*	11.9%*	8.1%
Upper Elementary, ELA and Math	4.8%	8.0%*	10.6%*	7.1%
12 Districts with Upper Elementary Results				
Middle School, ELA	6.8%	10.2%*	14.2%*	9.1%
Middle School, Math	6.8%	11.2%*	16.9%*	9.9%

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 25 districts and in grades 4 and 5 in 12 of these districts, for years 2 through 5. New hires are teachers who were not teaching in the district during the prior school year. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 116,072 teacher-year-grade-subject observations are included in the combined sample. The sample for middle school ELA includes 43,538 observations, middle school math includes 34,197 observations, and upper elementary grades includes 38,337 observations.

*Indicates whether medium- or high-poverty schools are significantly different from low-poverty schools at the 0.05 level.

Table D.8. Value added of new hires, by school poverty level, subject, and grade span, grades 4 to 5 (12 districts) and grades 6 to 8 (25 districts)

	Low-poverty schools	Medium-poverty schools	High-poverty schools	Overall average
	(A)	(B)	(C)	(D)
Combined Sample	**-0.049**	**-0.047**	**-0.050**	**-0.048**
Middle School, ELA	-0.026	-0.025	-0.043	-0.031
Middle School, Math	-0.084	-0.066	-0.047*	-0.064
Upper Elementary, ELA and Math	-0.047	-0.076*	-0.074	-0.065
12 Districts with Upper Elementary Results				
Middle School, ELA	-0.034	-0.010	-0.047	-0.028
Middle School, Math	-0.105	-0.067	-0.046*	-0.075

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 25 districts and in grades 4 and 5 in 12 of these districts, for years 2 through 5. New hires are teachers who were not teaching in the district during the prior school year. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 116,072 teacher-year-grade-subject observations are included in the combined sample. The sample for middle school ELA includes 43,538 observations, middle school math includes 34,197 observations, and upper elementary grades includes 38,337 observations.

*In columns B and C, indicates whether medium- or high-poverty schools are significantly different from low-poverty schools at the 0.05 level.

2. Transfer results by grade span and subject

In Chapter V, we show that high-poverty schools have more transfers than low-poverty schools, that transfers tend to move into schools in the same poverty category but slightly lower poverty levels, and that transfers are less effective than stayers. The results for each of the five subgroups of interest are similar, though do not always match the overall sample results in terms of their statistical significance. These results showing patterns of transfer behavior are shown in Tables D.9 through D.13.

3. Attrition results by grade span and subject

In Chapter V, we show that leavers are more common at high-poverty schools than at low-poverty schools, and that leavers are less effective than stayers at schools in each poverty category. We reached the same conclusions when examining the five subsamples of teachers separately. In every case except the 12-district sample for middle school math, teachers are significantly more likely to exit high-poverty schools than low-poverty schools (Table D.9). In addition, for each school poverty category across all subgroups, leavers are less effective than stayers, though the difference in effectiveness between leavers and stayers is not always statistically significant (Table D.12).

Table D.9. Rate of transfers and attrition, by school poverty level, subject, and grade span, grades 4 to 5 (12 districts) and grades 6 to 8 (25 districts)

	Low-Poverty Schools			Medium-Poverty Schools			High-Poverty Schools			Overall Average		
	Stayers	Transfers	Leavers	Stayers	Transfers	Leavers	Stayers	Transfers	Leavers	Stayers	Transfers	Leavers
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
Combined Sample	**88.2%**	**5.2%**	**6.6%**	**82.9%***	**8.3%***	**8.7%***	**79.4%***	**11.0%***	**9.6%***	**84.1%**	**7.8%**	**8.1%**
Middle School, ELA	87.5%	5.3%	7.2%	81.9%*	8.8%*	9.3%*	78.4%*	11.2%*	10.4%*	83.1%	8.1%	8.8%
Middle School, Math	88.9%	4.7%	6.4%	82.9%*	8.4%*	8.6%*	79.4%*	11.4%*	9.2%*	84.2%	7.8%	7.9%
Upper Elementary, ELA and Math	88.6%	5.8%	5.7%	85.4%*	6.9%*	7.7%*	81.5%*	9.6%*	8.9%*	86.1%	6.9%	6.9%
12 Districts with Upper Elementary Results												
Middle School, ELA	85.1%	6.1%	8.8%	82.0%*	7.6%*	10.4%	74.7%*	13.6%*	11.7%*	82.6%	7.7%	9.7%
Middle School, Math	85.1%	6.1%	8.8%	81.4%*	8.4%*	10.3%	76.7%*	12.7%*	10.6%	82.7%	7.8%	9.6%

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 25 districts and in grades 4 and 5 in 12 of these districts, for years 1 through 4. Teachers in the “Stayers” category continue teaching at the same school; “Transfers” moved to schools within the district; and “Leavers” left teaching in the district. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 110,466 teacher-year-grade-subject observations are included in the combined sample. The sample for middle school ELA included 42,091 observations, for middle school math included 32,296 observations, and for upper elementary grades included 36,079 observations.

*In columns D through I, indicates whether medium- or high-poverty schools are significantly different from low-poverty schools at the 0.05 level.

Table D.10. Percentage of teachers moving to higher, lower, and similar poverty categories, by subject and grade span, grades 4 to 5 (12 districts) and grades 6 to 8 (25 districts)

Percentage of teachers	To much lower School poverty category	To lower school poverty category	To same school poverty category	To higher school poverty category	To much higher school poverty category
Combined Sample	**4.3%**	**18.8%**	**57.3%**	**16.9%**	**2.7%**
Middle School, ELA	4.0%	18.1%	58.6%	16.8%	2.5%
Middle School, Math	4.5%	19.6%	57.1%	16.8%	2.0%
Upper Elementary, ELA and Math	4.7%	18.6%	54.7%	17.4%	4.6%
12 Districts with Upper Elementary Results					
Middle School, ELA	2.2%	15.9%	63.2%	16.7%	1.9%
Middle School, Math	3.1%	17.8%	62.4%	14.7%	2.0%

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 25 districts and in grades 4 and 5 in 12 of these districts, for years 1 through 4. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 7,385 teacher-year-grade-subject observations are included in the combined sample. The sample for middle school ELA included 2,918 observations, middle school math included 2,196 observations, and upper elementary grades included 2,271 observations.

Table D.11. Changes in poverty rates for transfers by teacher value added, subject, and grade span grades 4 to 5 (12 districts) and grades 6 to 8 (25 districts)

	Low value added	Average value added	High value added	Overall average
Combined Sample	**-0.2%**	**-1.8%**	**-3.4%***	**-1.7%***
Middle School, ELA	-1.0%	-2.4%	-2.3%	-2.1% *
Middle School, Math	-0.1%	-3.0%	-7.2% *	-3.0% *
Upper Elementary, ELA and Math	1.2%	2.5%	0.9%	2.0%*
12 Districts with Upper Elementary Results				
Middle School, ELA	1.1%	1.6%	-0.3%	1.2%
Middle School, Math	0.9%	0.0%	-4.0%	-0.6%

Source: District administrative data

Note: The results are for teachers in grades 6 through 8 in 25 districts and for grades 4 through 5 in 12 of these districts. This Table contains data on the change in school characteristics experienced by teachers who transfer schools within the same district. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. Low and high value added teachers are teachers in the bottom and top quintile of each district's value added distribution. Average value added teachers are teachers in the middle three quintiles of each district's value added distribution. A total of 7,385 teacher-year-grade-subject observations are included in the sample.

* For the average- and high-value added columns, the asterisk indicates whether the change in the percentage of low-income students for these teachers is significantly different relative to low-value added teachers at the 0.05 level. In the overall column, the asterisk indicates that the average change in school FRL for transfers overall is significantly different from zero at the 0.05 level.

Table D.12. Value added of stayers, transfers, and leavers, by school poverty level, subject, and grade span, grades 4 to 5 (12 districts) and grades 6 to 8 (25 districts)

	Low-Poverty Schools			Medium-Poverty Schools			High-Poverty Schools			Overall Average		
	Stayers	Transfers	Leavers	Stayers	Transfers	Leavers	Stayers	Transfers	Leavers	Stayers	Transfers	Leavers
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
Combined Sample	**0.008**	**-0.015+**	**-0.018+**	**0.000***	**-0.027 +**	**-0.030*+**	**0.006**	**-0.011 +**	**-0.032 +**	**0.004**	**-0.019+**	**-0.026+**
Middle School, ELA	0.007	-0.005	-0.001	0.001	-0.014 +	-0.016*	-0.002*	-0.012 +	-0.024*+	0.002	-0.011+	-0.013+
Middle School, Math	0.009	-0.035+	-0.047+	-0.003	-0.048 +	-0.050+	0.023	0.002*+	-0.038+	0.007	-0.030+	-0.046+
Upper Elementary, ELA and Math	0.009	-0.010+	-0.014	0.000	-0.024 +	-0.041*+	-0.003	-0.035+	-0.040 +	0.004	-0.022+	-0.030+
12 Districts with Upper Elementary Results												
Middle School, ELA	0.005	0.008	-0.005	0.004	-0.014	-0.014	-0.014*	-0.013	-0.046*+	0.002	-0.006	-0.015+
Middle School, Math	0.012	-0.026+	-0.036+	-0.001	-0.058 +	-0.056+	0.013	0.032	-0.071+	0.008	-0.024+	-0.049+

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 25 districts and in grades 4 and 5 in 12 of these districts, for years 1 through 4. Teachers in the “Stayers” category continue teaching at the same school; “Transfers” moved to schools within the district; and “Leavers” left teaching in the district. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 110,466 teacher-year-grade-subject observations are included in the combined sample. The sample for middle school ELA includes 42,091 observations, middle school math includes 32,296 observations, and upper elementary grades includes 36,079 observations.

*In columns D through I, indicates whether low-poverty schools are significantly different from medium- or high-poverty schools at the 0.05 level.

+In columns B, C, E, F, H, I, K, and L, indicates whether transfers’ or leavers’ average value added is significantly different from that of stayers at the 0.05 level.

Table D.13. Value added of teachers moving to higher, lower, and similar poverty categories, by subject and grade span, grades 4 to 5 (12 districts) and grades 6 to 8 (25 districts)

Average value added	To lower or much lower school poverty category	To same school poverty category	To higher or much higher school poverty category
Combined Sample	**-0.007**	**-0.017**	**-0.032***
Middle School, ELA	-0.010	-0.010	-0.011
Middle School, Math	0.004	-0.027*	-0.068*
Upper Elementary, ELA and Math	-0.023	-0.020	-0.022
12 Districts with Upper Elementary Results			
Middle School, ELA	-0.002	-0.008	-0.005
Middle School, Math	-0.001	-0.009	-0.096*

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 25 districts and in grades 4 and 5 in 12 of these districts, for years 1 through 4. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 7,385 teacher-year-grade-subject observations are included in the combined sample. The sample for middle school ELA included 2,918 observations, middle school math included 2,196 observations, and upper elementary grades included 2,271 observations.

*Indicates whether teachers moving to the same poverty category or to a higher or much higher school poverty category have value added that significantly differs from that of teachers moving to a lower or much lower school poverty category at the 0.05 level.

I. Teacher hiring, transfer, and attrition by experience level

We examined results separately by experience level to understand whether the overall results might be the product of contradictory patterns for novice and veteran teachers. For example, while the overall results suggest that there are no differences in the effectiveness of new hires at high- and low-poverty schools, we explored whether there might be contradictory patterns in the effectiveness of veteran and novice new hires that offset one another.[54]

We divided our sample into three categories based on teacher experience: novice teachers (zero to two years of prior teaching experience), mid-career veteran teachers (three to eight years of prior teaching experience), and late-career veteran teachers (nine or more years of prior teaching experience). Overall, 13 percent of teachers are novices, 34 percent are mid-career veterans, and 53 percent are late-career veterans. The overall patterns of hiring and mobility are similar for the three groups of teachers.

- **Hiring**. Sixty percent of all new hires are novices, twenty percent are mid-career veterans, and twenty percent are late-career veterans. There are significantly larger proportions of new hires at high- and medium-poverty schools than at low-poverty schools within each experience category (Table D.14, top panel). Novice new hires make up 6.6 percent of all teachers in high-poverty schools, compared with 2.7 percent in low-poverty schools, in part because high-poverty schools hire more teachers than low-poverty schools. In addition, a

[54] There are fewer teachers included in this analysis relative to the main analysis because we exclude 7 districts that could not provide data on teachers' total teaching experience and teachers with missing experience data in this analysis The sample size decreases by 10,704 teacher-year-grade-subject observations for the new hire analysis and by 9,110 observations for the transfer and attrition analysis.

larger proportion of the new hires at high-poverty schools than at low-poverty schools are novice teachers rather than veteran teachers. These patterns lead there to be a larger proportion of novices among all teachers in high-poverty schools than in low-poverty schools. In particular, 16.2 percent of all teachers in high-poverty schools are novices compared with 8.1 percent in low-poverty schools. For both novices and mid-career veterans, the average effectiveness of new hires is not significantly different at high- and medium-poverty schools relative to low-poverty schools (Table D.14, bottom panel). Late-career veteran new hires at high-poverty schools have value added that is significantly lower than that of late-career veteran new hires at low-poverty schools.

- **Transfer**. Overall, 19 percent of all transfers are novices, 40 percent are mid-career veterans, and 40 percent are late-career veterans. There are more transfers from high-poverty schools than from low-poverty schools, and transfers from high-poverty schools are about as effective as those from low-poverty schools. For both novices and veterans, these patterns hold true. Within each group, more teachers transfer out of high- and medium-poverty schools than out of low-poverty schools (Table D.15, top panel). The average effectiveness of novices and veterans transferring out of high-poverty schools is not significantly different than their novice and veteran counterparts transferring out of low-poverty schools (Table D.15, bottom panel).

Table D.14. Rates of new teacher hiring and value added of new hires, by school poverty level, grades 4 to 5 (10 districts) and grades 6 to 8 (18 districts)

	Low-poverty schools	Medium-poverty schools	High-poverty schools	Overall average
Percentage				
Overall	4.6%	8.2%*	10.7%*	7.5%
0–2 years experience	2.7%	4.8%*	6.6%*	4.5%
3–8 years experience	1.1%	1.7%*	2.0%*	1.5%
9 or more years experience	0.9%	1.7%*	2.1%*	1.5%
Average Value Added				
Overall	-0.048	-0.046	-0.050	-0.048
0–2 years experience	-0.065	-0.054	-0.052	-0.057
3–8 years experience	-0.025	-0.033	-0.014	-0.025
9 or more years experience	-0.029	-0.041	-0.070*	-0.045

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 18 districts and in grades 4 and 5 in 10 of these districts, for years 2 through 5. The sample excludes teachers with missing experience data and 7 districts that could not provide data on teachers' total teaching experience. New hires are teachers who were not teaching in the district during the prior school year. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 105,369 teacher-year-grade-subject observations are included in the sample. The sample for low-poverty schools includes 37,271 observations, medium-poverty schools includes 37,186 observations, and high-poverty schools includes 30,912 observations.

*Indicates whether medium- or high-poverty schools are significantly different from low-poverty schools at the 0.05 level.

- **Attrition.** Overall, 25 percent of all leavers are novices, 32 percent are mid-career veterans, and 43 percent are late-career veterans. Novice teachers and mid-career veteran teachers are more likely to leave the district from high- and medium-poverty schools than from low-poverty schools (Table D.15). Late-career veteran teachers, by contrast, are similarly likely to leave the district from high-, medium-, and low-poverty schools. For each group, however, leavers are less effective than stayers, on average.

Table D.15. Rates of teacher turnover and value added of teachers by mobility category and school poverty, grades 4 to 5 (10 districts) and grades 6 to 8 (18 districts)

	Low-poverty schools	Medium-poverty schools	High-poverty schools	Overall average
Percentage				
Stayers	**88.6%**	**83.4%***	**79.6%***	**84.6%**
0–2 years experience	7.0%	11.0%*	13.0%*	9.9%
3–8 years experience	26.9%	30.0%*	29.1%*	28.6%
9 or more years experience	54.8%	42.5%*	37.5%*	46.1%
Transfers	**5.2%**	**8.3%***	**11.0%***	**7.8%**
0–2 years experience	1.0%	1.5%*	2.2%*	1.5%
3–8 years experience	2.0%	3.5%*	4.3%*	3.1%
9 or more years experience	2.2%	3.3%*	4.3%*	3.1%
Leavers	**6.6%**	**8.7%***	**9.6%***	**8.1%**
0–2 years experience	0.9%	2.2%*	3.1%*	1.9%
3–8 years experience	1.9%	2.7%*	3.2%*	2.5%
9 or more years experience	3.4%	3.4%	3.2%	3.3%
Average Value Added				
Stayers	**0.009**	**-0.001***	**0.005**	**0.004**
0–2 years experience	-0.029	-0.018	0.002 *	-0.016
3–8 years experience	0.012	0.008	0.013	0.011
9 or more years experience	0.012	-0.002*	0.000 *	0.004
Transfers	**-0.013+**	**-0.028 +**	**-0.013 +**	**-0.035+**
0–2 years experience	-0.034	-0.039	-0.032 +	-0.035+
3–8 years experience	-0.006	-0.014 +	-0.003 +	-0.009+
9 or more years experience	-0.011	-0.034 +	-0.016	-0.022+
Leavers	**-0.018+**	**-0.029 +**	**-0.036*+**	**-0.026+**
0–2 years experience	-0.054+	-0.046 +	-0.016*	-0.040+
3–8 years experience	-0.005+	-0.017 +	-0.044*+	-0.018+
9 or more years experience	-0.013+	-0.026 +	-0.045*+	-0.024+

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 18 districts and in grades 4 and 5 in 10 of these districts, for years 1 through 4. The sample excludes teachers with missing experience data and 5 districts that could not provide data on teachers' total teaching experience. Teachers in the "Stayers" category continue teaching at the same school; "Transfers" moved to schools within the district; and "Leavers" left teaching in the district. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 101,355 teacher-year-grade-subject observations are included in the sample. The sample for low-poverty schools includes 37,462 observations, medium-poverty schools includes 37,418 observations, and high-poverty schools includes 26,475 observations.

*Indicates whether medium- or high-poverty schools are significantly different from low-poverty schools at the 0.05 level.

+For value added, indicates whether transfers or leavers are significantly different from stayers at the 0.05 level.

We have shown that high-poverty schools have a larger proportion of novice teachers than low-poverty schools for two reasons. First, high-poverty schools do more hiring in any given year, on average, and so a larger proportion of their teachers are new hires. Second, among these new hires, those at high-poverty schools are more likely than those at low-poverty schools to be novice teachers. These differences at the school level translate to the student level, with low-income students more likely than high-income students to be taught by novice teachers.

J. Novice teachers and access to effective teachers

Due to concerns about the disproportionate placement of novice teachers in high-poverty schools, we investigated whether this could lead to greater inequity for low-income students. Across the study districts, in high-poverty schools, 16 percent of the teachers are novices—defined as teachers in their first three years—compared with 13 percent at medium-poverty schools and 8 percent at low-poverty schools. In addition, novices in the study districts are less effective than veteran teachers. This suggests that the higher proportion of novice teachers in high-poverty schools could contribute to inequitable access to effective teachers. However, we find that the presence of more novice teachers in high-poverty schools does not create substantial inequity for two reasons.

First, the substantial difference between high- and low-poverty schools in the prevalence of novice teachers translates into a smaller difference between high- and low-income students in the likelihood of having a novice teacher. Although there are more low-income students in high-poverty schools than in low-poverty schools, both types of students attend each type of school. In low-poverty schools, for example, up to 60 percent of students can be low-income. When calculated at the student level, the difference between the likelihood of being taught by a novice teacher is modest, with 14 percent of low-income students and 10 percent of high-income students taught by novices (Table D.16). In other words, 86 percent of low-income students and 90 percent of high-income students are taught by veteran teachers.

Second, the average difference in the effectiveness of novices and veteran teachers is also modest, at about 0.03 standard deviations of student achievement across both subjects. Thus, even if all low-income students were taught by novices and all high-income students were taught by veteran teachers, the Effective Teaching Gap would be 0.03. The actual difference in the proportion of students taught by a novice teacher is only 4 percentage points. So the component of the Effective Teaching Gap resulting from low-income students being taught more frequently by novice teachers is approximately 4 percent of 0.03 standard deviations, or 0.001 standard deviations of student achievement.

More formally, this calculation is derived from the decomposition of the Effective Teaching Gap presented in Section D of Appendix B. As shown in Equation B.26 (reproduced below), the amount of the Effective Teaching Gap derived from differences in the likelihood of being taught by a novice teacher depends on four factors: the proportion of high-income and low-income students taught by novices, and the average value added of novices and veteran teachers for low-income students.

$$\text{(B.26)}\quad \begin{aligned} ETG = &\left[(P_{nov}^{LI} - P_{nov}^{HI})(\overline{VA}_{vet}^{LI} - \overline{VA}_{nov}^{LI}) \right] \\ &+ \left[(P_{nov}^{HI})(\overline{VA}_{nov}^{HI} - \overline{VA}_{nov}^{LI}) + (P_{vet}^{HI})(\overline{VA}_{vet}^{HI} - \overline{VA}_{vet}^{LI}) \right] \end{aligned}$$

= Difference in Likelihood of Being Taught By a Novice Teacher +

Difference in Teacher Effectiveness, Accounting for Experience

Inserting the values from Table D.16 into the first part of this expression, we find that [(0.140 – 0.102)(0.000 – (-0.021))] = 0.001.

Table D.16. Novice and veteran components of the effective teaching gap, grades 4 to 5 (9 districts) and grades 6 to 8 (21 districts)

	Low-income students	High-income students
Percentage of Students Taught		
By veteran teachers	86.0%	89.8%
By novice teachers	14.0%	10.2%
Average Value Added		
Veteran Teachers	0.000	0.010
Novice Teachers	-0.021	-0.023

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 18 districts and in grades 4 and 5 in 10 of these districts. The sample excludes teachers with missing experience data and 5 districts that could not provide data on teachers' total teaching experience. Novice teachers have one to three years of experience and veteran teachers have four or more years of experience. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis.

K. Patterns of teacher hiring, transfer, and attrition using a value-added model that excludes classroom characteristics

In our main analysis of teacher hiring, transfer, and attrition, we measured teacher effectiveness using a value-added model that includes classroom characteristics. This section presents these results based on a value-added model that excludes classroom characteristics. In this analysis, we found that new hires at high-poverty schools are significantly less effective than new hires at low-poverty schools, with a value-added of -0.080 among new hires and high-poverty schools and -0.025 among those at low-poverty schools (Table D.17). These findings are consistent with the larger Effective Teaching Gap found using this model (see Section G of Appendix C). Similar to the results found using the main model, under the alternative model new hires improve significantly during their second year in the district, though those at high-poverty schools remained less effective than those at low-poverty schools (Table D.18).

Table D.17. Value added of new hires, by school poverty level and type of value-added model grades 4 to 5 (10 districts) and grades 6 to 8 (18 districts)

	Low-poverty schools	Medium-poverty schools	High-poverty schools	Overall average
	(A)	(B)	(C)	(D)
Main model (with classroom characteristics)	-0.049	-0.047	-0.050	-0.048
Alternative model without classroom characteristics	-0.025	-0.060 *	-0.080 *	-0.056

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 18 districts and in grades 4 and 5 in 10 of these districts, for years 2 through 5. New hires are teachers who were not teaching in the district during the prior school year. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 116,072 teacher-year-grade-subject observations are included in the combined sample. The sample for middle school ELA includes 43,538 observations, for middle school math includes 34,197 observations, and for upper elementary grades includes 38,337 observations.

*In columns B and C, indicates whether medium- or high-poverty schools are significantly different from low-poverty schools at the 0.05 level.

Table D.18 Value added of new hires, by school poverty level and type of value-added model- restricted to teachers with next-year value added, grades 4 to 5 (10 districts) and grades 6 to 8 (18 districts)

	Low-poverty schools	Medium-poverty schools	High-poverty schools	Overall average
Main model (with classroom characteristics)				
Average value added, current year	-0.051	-0.048	-0.034	-0.045
Average value added, next year	-0.020	-0.002	0.006*	-0.005*
Alternative model without classroom characteristics				
Average value added, current year	-0.026	-0.065*	-0.066*	-0.053
Average value added, next year	0.001	-0.021*	-0.024*	-0.015*

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 18 districts and in grades 4 and 5 in 10 of these districts. The sample is restricted to teachers in years 2 through 4 who continued to teach in the following year. The sample also excludes teachers with missing experience data and 5 districts that could not provide data on teachers' total teaching experience. New hires are teachers who were not teaching in the district during the prior school year. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 48,241 teacher-year-grade-subject observations are included in the sample. The sample for low-poverty schools includes 19,208 observations, for medium-poverty schools includes 16,728 observations, and for high-poverty schools includes 12,305 observations.

*Indicates whether medium- or high-poverty schools are significantly different from low-poverty schools at the 0.05 level. In the overall column an asterisk in the next-year row indicates that the next-year values are significantly different from the current year values at the 0.05 level.

Stayers, transfers, and leavers all have significantly lower value added at medium- and high-poverty schools compared to those at low-poverty schools when the estimates are based on the alternative value-added model that excludes classroom characteristics (Table D.19). Under the main model stayers, transfers, and leavers do not have significantly different value added at medium- or high-poverty schools relative to low-poverty schools. The differences across value-added models are consistent with the findings reported in Section G of Appendix C that there is a larger Effective Teaching Gap under the alternative model. Under both value-added models, the value added of transfers and leavers is significantly lower than the value added of stayers.

Table D.19. Value added of stayers, transfers, and leavers, by school poverty level, subject, and grade span, grades 4 to 5 (10 districts) and grades 6 to 8 (18 districts)

	Low-poverty schools			Medium-poverty schools			High-poverty schools			Overall average		
	Stayers	Transfers	Leavers	Stayers	Transfers	Leavers	Stayers	Transfers	Leavers	Stayers	Transfers	Leavers
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
Main model (with classroom characteristics)	0.008	-0.015+	-0.018+	0.000*	-0.027 +	-0.030*+	0.006	-0.011 +	-0.032 +	0.004	-0.019+	-0.026+
Alternative model without classroom characteristics	0.034	0.006+	0.004+	-0.009*	-0.040*+	-0.043*+	-0.020*	-0.036*+	-0.064*+	0.006	-0.027+	-0.031+

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 18 districts and in grades 4 and 5 in 10 of these districts, for years 1 and 2. Teachers in the "Stayers" category continue teaching at the same school; "Transfers" moved to schools within the district; and "Leavers" left teaching in the district. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 110,466 teacher-year-grade-subject observations are included in the combined sample. The sample for middle school ELA includes 42,091 observations, for middle school math includes 32,296 observations, and for upper elementary grades includes 36,079 observations.

*In columns D through I, indicates whether low-poverty schools are significantly different from medium- or high-poverty schools at the 0.05 level.

+In columns B, C, E, F, H, I, K, and L, indicates whether transfers' or leavers' average value added is significantly different from that of stayers at the 0.05 level.

Finally, under the main value-added model, teachers who transfer to higher-poverty schools have value added that is lower than teachers who transfer to lower-poverty schools (Table D.20). Under the alternative model, there are no significant differences between the value-added of teachers transferring to higher- and lower-poverty schools.

Table D.20. Value added of teachers moving to higher, lower, and similar poverty categories, by subject and grade span, grades 4 to 5 (10 districts) and grades 6 to 8 (18 districts)

Average value added	To lower or much lower school poverty category	To same school poverty category	To higher or much higher school poverty category
Main model (with classroom characteristics)	-0.007	-0.017	-0.032 *
Alternative model without classroom characteristics	-0.024	-0.025	-0.034

Source: Author calculations based on district administrative data.

Note: Results are for teachers in grades 6 through 8 in 18 districts and in grades 4 and 5 in 10 of these districts, for years 1 and 2. The results are presented as an average across districts weighted by the number of students taught by each teacher in the analysis. A total of 7,385 teacher-year-grade-subject observations are included in the combined sample. The sample for middle school ELA includes 2,918 observations, for middle school math includes 2,196 observations, and for upper elementary grades includes 2,271 36,079observations.

*Indicates whether teachers moving to the same poverty category or to a higher or much higher school poverty category have value added that significantly differs from that of teachers moving to a lower or much lower school poverty category at the 0.05 level.

L. Relationship between a district's Effective Teaching Gap and district-level patterns of hiring, transfer, and attrition

We examined whether patterns of hiring, transfer, and attrition at the district level are related to a district's Effective Teaching Gap. In particular, we examined the relationship of the between-school Effective Teaching Gap at the middle school level to district-level measures of 1) the percentage of teachers who made each type of career transition in the district and 2) the relative effectiveness of teachers making each career transition. See Section F of Appendix B for methodological details.

Our analysis found that districts with larger Effective Teaching Gaps are those in which:

- There are greater differences between high- and low-poverty schools in the value added of new hires; that is, where new hires in high-poverty schools are less effective to a greater extent.

The following teaching hiring, transfer, and attrition are not related to the Effective Teaching Gap, including:

- Differences between high- and low-poverty schools in the prevalence of new hires, transfers, or leavers.
- The change in school poverty rate for transfer teachers with above-average effectiveness and for those with below-average effectiveness
- Differences between high- and low-poverty schools in the effectiveness of leavers (compared to stayers).

Table D.21 shows the full set of estimated relationships between the Effective Teaching Gap and measures of hiring, transfer, and attrition for ELA and math. These estimates are based on regressions of the Effective Teaching Gap on each measure of a difference between high- and low-poverty schools in a particular pattern. We also experimented with combining multiple measures together in the same regression model, but found qualitatively similar results as when the regression models were estimated separately.

Table D.21. Relationship between the between-school Effective Teaching Gap and hiring, transfer, and attrition patterns

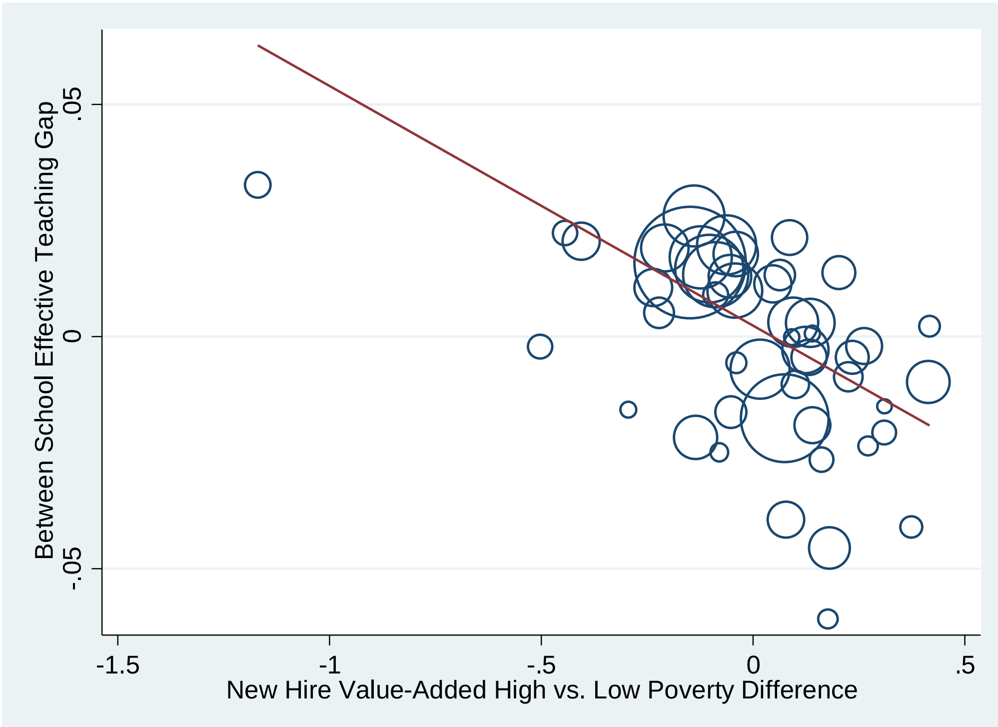
Mobility measure	Math and ELA combined	Math	ELA
Prevalence of new hires	-0.008	-0.005	-0.011
Prevalence of transfers	-0.002	-0.052	0.018
Prevalence of leavers	-0.016	-0.009	-0.014
Effectiveness of new hires	-0.052*	-0.050*	-0.048*
Effectiveness of transfers: Above-average transfer teachers move to higher-poverty schools	0.051	0.062	0.028
Effectiveness of transfers: Below-average transfer teachers move to higher-poverty schools	0.028	0.074	-0.009
Leaver value-added difference	-0.007	-0.040	0.016

Source: Author calculations based on district administrative data.

Note: Asterisks indicate whether each coefficient is significantly different from zero at the 0.05 level. The sample size for main results consists of 25 districts. Observations are weighted by the number of teacher-year observations in the district that contribute to each summary measure. Districts are excluded if there are fewer than 10 teacher-year observations contributing to the analysis. Two districts are excluded from the analysis of transfer effectiveness, 1 district is excluded from the prevalence of transfers analysis for math, 1 district is excluded from the ELA new hire analysis, and 2 districts are excluded from the ELA leaver analysis for this reason.

We depict the relationship between the Effective Teaching Gap and new hire value-added differences graphically (Figure D.16). Each circle represents the weight each district receives in the analysis, which is proportional to the number of teacher-year observations contributing to the analysis. The trend line in Figure D.16 shows a negative relationship between the difference in the value added of new hires (with larger positive differences indicating that new hires at high-poverty schools are more effective than those at low-poverty schools) and the between-school Effective Teaching Gap (with a larger positive gap indicating less effective teachers and high poverty schools relative to low-poverty schools).

Figure D.16. Relationship between the Effective Teaching Gap and new hire value-added differences



Source: Author calculations based on district administrative data.

Note: The size of the circles represents the number of new hires in each district, the weight used in the regression analysis.

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