THE DISTRIBUTION AND MOBILITY OF EFFECTIVE TEACHERS: EVIDENCE FROM A LARGE, URBAN SCHOOL DISTRICT

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Abstract

Using seven years of student achievement data from a large urban school district in the south, this study examines the sorting of teachers' value-added effectiveness estimates by student demographics and considers factors that may contribute to such sorting. We find that students in schools in the highest quartile of minority enrollments have teachers with value-added estimates that are about 0.11 of a student-level standard deviation lower than their peers in schools in the lowest minority quartile. However, neither teacher mobility patterns nor between-school differences in teacher qualifications seems responsible for this sorting. Though the highest minority schools face higher teacher turnover, they do not disproportionately lose their highest value-added teachers, nor are teachers with high value-added systematically migrating to lower-minority schools. Instead, teachers in the highest minority schools have lower value-added on average, regardless of experience. We find suggestive but inconclusive evidence that teachers' improvement rates differ by minority-enrollment quartile.

Introduction

It is well-established that low-income students and students of color are disproportionately taught by teachers with weak observable qualifications, including limited experience and low academic proficiency (Betts, Rueben, & Danenberg, 2000; Clotfelter, Ladd, & Vigdor, 2005; Lankford, Loeb, & Wyckoff, 2002). However, research has also repeatedly shown that observable teacher characteristics, including experience and academic proficiency, are poor predictors of teachers' impact on student learning (Aaronson, Barrow, & Sander, 2007; Clotfelter, Ladd, & Vigdor, 2007; Rivkin, Hanushek, & Kain, 2005). As a consequence, policy attention has turned toward addressing inequities in students' access to *effective* teachers. Spurred by federal initiatives like the Teacher Incentive Fund and Race to the Top grant competitions, states and districts are increasingly focused on improving disadvantaged students' access to teachers who demonstrate high value-added as measured by their students' achievement gains (Denison, 2010; Sawchuck, 2011; Zelinski, 2010). What is less well-understood, however, is the extent to which the distribution of teacher value-added mirrors that of teacher qualifications. In other words, are the teachers of disadvantaged students actually less effective at raising student achievement, on average, than the teachers of more-advantaged students? The *Vergara vs. State of California* (2014) ruling, for example, which overturned California's teacher tenure statutes, drew on evidence about the sorting of teacher qualifications, but did not discuss the mixed evidence about the sorting of teachers' effectiveness in terms of value-added.

As important as understanding the extent of teacher sorting is the question of how this sorting occurs. Existing evidence suggests several possible mechanisms, even within school districts that share a common salary schedule. Insofar as teachers prefer to teach students who receive more academic support outside of school, schools serving more-affluent or advantaged students may have a larger pool of teacher applicants and thus be able to select those who at least appear most qualified. Moreover, within-district transfer restrictions that favor teachers with more seniority may exacerbate this pattern (Boyd et al., 2010). Second, if more-advantaged schools have lower turnover, as numerous studies have suggested (Feng, 2010; Falch & Strom, 2005; Hanushek, Kain, & Rivkin, 2004; Scafidi, Sjoquist, & Stinebrickner, 2007), they may be able to identify hiring needs more quickly and thereby select teachers earlier in the year, again yielding greater access to the strongest applicants (Liu & Johnson, 2006). In addition, more-affluent or well-resourced schools may provide better opportunities for mentoring and professional growth (Johnson et al., 2005), creating an environment in which teachers improve more rapidly over time (Sass et al., 2012).

In this paper, we use seven years of teacher-student linked panel data from a large, urban district in the southern United States to examine not only the distribution of teacher value-added by school demographics, but also the relationship between teachers' value-added and their probability of leaving their current school, as a function of school demographics. In addition, we examine the extent to which higher-value-added teachers who change schools within the district move to schools with a smaller share of minority students. We find that teachers in schools with a higher share of minority students have lower value-added estimates than their counterparts, but that teacher mobility patterns do not seem to be driving this pattern. Moreover, among teachers who switch schools, we find little evidence that value-added is linked to characteristics of the destination school relative to the sending school. Cross-sectional comparisons within year suggest no differential experience effects by minority enrollment quartile, though longitudinal models suggest that improvement rates may differ among quartiles.

1.1. Background and context

1.1.1. <u>Evidence about the sorting of teacher value-added</u>

As noted above, studies in numerous settings have found that *teachers' qualifications*, such as their experience, standardized test scores, licensure test pass rates, preparation experiences, and college competitiveness, are not equally distributed among schools, and that schools serving a larger share of poor, minority, or low-performing students are often staffed by teachers with weaker qualifications along some or all of these dimensions (Betts et al., 2000; Clotfelter et al., 2005; Clotfelter, Ladd, Vigdor, and Wheeler, 2007; Lankford et al., 2002; Loeb & Reininger, 2004). Yet studies that have estimated the relationship between teachers' value-added have found sorting patterns that are less stark and more diverse than the qualifications literature might suggest.

In a study of elementary school teachers in the Los Angeles Unified School District, Buddin (2010) found that a difference of one standard deviation in school achievement levels corresponded to a difference of about 0.04 of a standard deviation in average teacher value-added, suggesting very small average differences among schools.

In a two-state study, Sass, Hannaway, Xu, Figlio, and Feng (2012) examined the sorting of teacher value-added among elementary schools in Florida and North Carolina. They found an average difference of 0.02 to 0.04 of a standard deviation of teacher value-added between high-poverty and low-poverty schools in North Carolina, favoring the low-poverty schools. They found a similar pattern in reading in Florida, though sorting in mathematics in Florida appeared to favor higher-poverty schools. Moreover, they found that these differences were driven by a higher concentration of the weakest teachers in high-poverty schools, and that effects of experience were more positive in high-poverty than in lower-poverty schools.

Focusing also on North Carolina, but on high schools, Mansfield (2010) found that teacher value-added was modestly higher in high-achieving than in low-achieving schools, though the differences accounted for less than one-percent of the variation in students' achievement levels. In a study of three districts and a charter management organization in four states, Steele, Baird, Engberg, and Hunter (2014) reported that teachers in grades 4 through 8 were sorted between schools in ways that slightly favored disadvantaged students, but within schools in ways that gave disadvantaged students less access to teachers with higher value-added. However, the particular sorting patterns varied considerably among districts.

Using data from ten large districts across seven states, Glazerman and Max (2011) found that students in higher-performing or higher-income middle schools had slightly better access to top-quintile teachers on average, but as in other multi-site studies, the pattern differed by district. In elementary schools, they found a similar overall sorting pattern in terms of school-level student performance, but not in terms of family income levels in the schools. An even larger study of 29 school districts across the nation showed small differences in teacher value-added favoring more-advantaged students, though patterns again varied among districts (Isenberg et al., 2013). In this case, access to high value-added teachers was found to be less equitable between than within schools, on average.

Taken together, these studies suggest that teacher sorting patterns may indeed restrict the access of students from disadvantaged backgrounds to high-value-added teachers, but perhaps less so that the evidence on the sorting of teacher qualifications would suggest. Moreover, the particularities of the sorting patterns appear to vary among districts.

1.1.2. Contributions to teacher sorting

Another set of studies has examined possible contributions to teacher sorting, including teachers' mobility patterns in relation to their value-added. Focusing primarily on teachers in the early years of their careers, these studies have generally found that teachers leaving their schools have lower value-added, on average, than those who stay. For example, using statewide data on North Carolina teachers in grades 4-6 who began teaching in the state between 1996 and 2006, Goldhaber, Gross, and Player (2011) found that higher-value-added teachers had higher probabilities than teachers with lower value-added of staying in the profession and in their schools, and that teachers with higher value-added were no more likely than their counterparts to leave schools with lower math performance or with higher percentages of low-income students.

Using student achievement data from a large Texas district linked to statewide personnel data for teachers in grades 4 through 8 in the academic years 1995-96 through 2001-01, Hanushek and Rivkin (2010) found, similarly, that teachers who left their schools had lower value-added than those who remained in their schools by a difference of about 0.06 of a teacher-level standard deviation. They reported that the difference between leavers and stayers was even larger in lower-performing schools and schools with higher percentages of black students. The authors further noted that those leaving the state public school system had lower value-added than those changing schools within the district, who in turn had lower value-added than those changing between districts or staying in their current schools. Finally, they found no evidence that teachers with higher value-added who changed schools systematically moved to higher-performing or lower-minority schools.

Boyd and colleagues (2008) used student achievement data from New York City linked to statewide personnel data for teachers who began teaching grades 4 through 8 in the 1999-2000 through 2005-06 academic years. They found that early-career teachers who left their initial schools—including those who transferred within the district or left the state system—had lower value-added in mathematics, on average, than those who remained, though these patterns were clearest for elementary school teachers (grades 4 and 5) and for first-year teachers. However, unlike the other studies, they found that higher-value-added teachers leaving low-performing schools were disproportionately likely to move to higher-performing schools. They also reported that teachers transferring within the district to middle- and low-performing schools had lower value-added than their peers with comparable experience at the new schools. Their findings suggest that within-district transfer patterns in New York City may exacerbate inequalities in students' access to high-value-added teachers.

These studies, too, present mixed evidence about the extent to which teacher mobility contributes to the systematic sorting of teacher value-added among schools. The present study contributes to our understanding of the variability in sorting and mobility patterns by focusing on a large, urban district in the south. It examines not only sorting patterns in terms of teacher qualifications and value-added, but also the role that teacher mobility may play in contributing to systematic sorting.

1.2. Research questions

The study focuses on teachers grades 4 through 8 because these are the teachers for whom we have annual student achievement data from which to estimate value-added. Students are tested annually in four subjects—mathematics, reading, science, and social studies, and our analysis incorporates available data from all of these subject areas. To understand how teacher value-added varies by school, and the extent to which teacher mobility contributes to any such sorting, we address the following research questions:

1. How are teachers sorted among schools in terms of their observable characteristics and in terms of their value-added estimates?
2. Are schools with a higher share of minority students more likely to lose teachers in a given year, and are they especially likely to lose teachers with higher value-added?
3. Is the share of minority students in a school differently related to the probability of changing schools within the district versus leaving the district, and do these relationships depend on teachers' value-added?
4. Among teachers who change schools within the district, do teachers with higher value-added move to schools with a lower minority composition, and vice versa?
5. Do the effects of teacher experience appear to differ by schools' minority composition?

The final question helps us distinguish between teacher sorting that is due to different experience levels of teachers in schools with different demographic profiles and between value-added differences that are independent of teachers' experience levels. It also allows us to examine whether the effects of teacher experience differ in schools with different demographic profiles. Together, these five questions address the extent to which movement of teachers among and out of schools in the district contributes to between-school differences in teacher value-added.

2. Material and Methods

2.1. Data sources and sample

Our data come from a large, urban school district in a mostly rural state in the southern United States. In the 2009-10 school year, the district included just over 130 schools, employed more than 5,000 teachers, and served about 75,000 students. [1] In 2009-10, the focal district

[1] This district has not been associated with any scandals related to systematic cheating on standardized tests.

served a student body that was 72 percent eligible for subsidized meals and 67 percent students of color. Schools in the district are residentially zoned, and choice options were limited during the years of the study. In addition, charter enrollments constituted a tiny fraction of public school enrollments—fewer than one percent—during the study years. According to the district's written agreement with the teacher's union, teacher transfers within the district are granted according to criteria that include seniority, and experienced teachers are given priority over new teachers in filling vacancies.

In thinking about teachers' propensity to leave the district, it's useful to understand the context in terms of nearby districts. The district is surrounded by ten smaller and more-affluent suburban districts, whose sizes ranged in 2009-10 from 3,400 to 38,000 students, with a district mean of 15,000 students.[2] The share of students eligible for subsidized meals in surrounding districts ranged from 12 to 67 percent, with a district mean of 45 percent, and the proportion of students of color ranged from 4 to 40 percent with a district mean of 21 percent. The mean math and reading scores in surrounding districts were about 10 Normal Curve Equivalents higher, on average, than in the focal district. Compared to other districts in the state, the surrounding districts are larger and more affluent in terms of the share of students eligible for subsidized meals. As such, the surrounding districts could plausibly have faced more applicants for available jobs than the focal district and thus have been more selective in hiring. We do not have data on teachers' applications to any districts, including to our focal district, but it is conceivable that the focal district would be a net exporter of experienced teachers to the surrounding districts.

Student achievement data. We use longitudinal student achievement data for students enrolled in grades 3 through 8 in the 2002-03 through 2008-09 academic years. Because third

[2] The number of schools in the ten surrounding districts ranged from 5 to 46, with a district mean of 22, and the number of teachers employed by those districts ranged from 230 to 2400, with a district mean of about 1000.

grade student test scores are used as lagged estimates of student achievement, our analysis of teacher value-added focuses on teachers in grades 4 through 8 teaching in years 2004-05 through 2008-09. It includes 59,553 unique students enrolled in those grades and years. Students' criterion referenced scores on the state are standardized in mathematics, English/Language Arts (ELA), science, and social studies to have a mean of zero and a standard deviation of one within each subject-grade-year record.

Teacher characteristics. The teacher-year data include information about teachers' gender, race, marital status, educational level, licensure status, salary, distance between home and work, and years of employment in the district. When a teacher's descriptive characteristics were missing in some years but not others, we impute missing data based on information provided in the non-missing years. Descriptive statistics for the 2,331 teachers of grades 4 through 8 in the sample are shown in Table 1.

<Insert Table 1 about here>

Teacher value-added. Value-added estimates for each teacher in a given year, grade, and subject area are generated using a multivariate ANCOVA method following McCaffrey, Han, and Lockwood (2008), as described more fully in section 1 of the online appendix. Students' scale scores on the state accountability are standardized within subject, grade, and year, and each teacher's value-added effect is estimated for each subject and year in which the teacher taught. The resulting dataset of teachers' value-added estimates includes 2,331 teachers, 6,180 teacher-year records, and 14,847 teacher-year-subject records.

The analytic dataset includes two estimates of teachers' value-added effects in each subject: a fixed effect and a best linear unbiased prediction (BLUP), which is a shrunken estimate adjusted for imprecision in the fixed effect. Throughout the analyses, when value-added is an independent variable, we use shrunken estimates, and when value-added is a dependent variable, we use unshrunken estimates (Kane & Staiger, 2008). Table 1 summarizes the shrunken estimates for teachers in each of the four subject areas in the first year each teacher is observed, as well as the teacher's student-weighted mean value-added across subjects in the same year.[3]

School characteristics. School-level characteristics in the analysis include the percentage of students in the school who are black or Hispanic, the percent who are English language learners (ELLs), and the percent who receive special education accommodations or services. Focusing on a 2004-05 snapshot of the 114 schools included in this analysis, the schoolwide percentage of black and Hispanic students ranged from 9.3 to 100 percent, with a mean of 61.4 percent. The schoolwide percentage of ELLs ranged from 0 to 27.6 percent, with a mean of 4.7 percent, and the schoolwide percentage of special education students ranged from 0 to 33.3 percent, with a mean of 7.0 percent.

For all analyses, we emphasize teacher sorting and mobility in terms of schools' minority quartiles—that is, the proportion of students who are black or Hispanic in a given year. The mean share of black and Hispanic students in 2005 was 30 percent in the lowest quartile; 55 percent in the second quartile; 69 percent in the third quartile; and 90 percent in the highest quartile. Minority enrollment quartile is merely one proxy for student disadvantage, and by no means a perfect one. In our data, this metric is related to a school's academic performance in terms of average test scores (another viable proxy, as in Goldhaber, Gross, & Player, 2011).[4] The correlation between the proportion of students in a school who are black and Hispanic and the

[3] The proportion of a subject-specific value-added BLUP that is stable across observed years ranges from 35 percent to 47 percent. The proportion of the cross-subject BLUP that is stables across years is 48 percent. Averaging the cross-subject BLUPs across all observed years in a given school raises the within-teacher stability to 91 percent, though as described below, our results are quite robust to the use of a single-year or multi-year estimate.

[4] Concurrent data on the share of students eligible for free and reduced-price lunch was less readily available in our data at the time of analysis.

school's academic performance (measured in school-by-year-level z-scores) ranges from -0.55 to -0.71 between the 2005 and 2009 testing years.

2.2. Analytic strategy

2.2.1. Examining the distribution of teacher qualifications and value-added

To address research question 1, which concerns the distribution of teacher characteristics among schools, we separately regress teachers' observable characteristics, including years of experience, novice status, education level, competitiveness of bachelor's degree institution, and undergraduate GPA, on a set of demographic quartile indicators to ascertain whether mean teacher qualifications differ among schools with different shares of minority students. The model includes school year fixed effects so that teachers are compared only to their counterparts teaching in the same academic year. We examine school demographic quartiles rather than a linear demographic measure (like percent of students who are black or Hispanic) so that we are able to observe nonlinearities in sorting patterns, such as distinct differences in teacher characteristics in the highest or lowest quartiles of black and Hispanic student composition. In doing so, we also follow the example of teacher mobility analyses described in Boyd et al. (2008) and Goldhaber et al. (2007).

The model is specified as follows:

$$c_{ijt} = \alpha + \boldsymbol{\lambda}'\mathbf{Q_{jt}} + \boldsymbol{\tau}'\mathbf{S_t} + \varepsilon_{ijt} \qquad (1)$$

where the dependent variable is c_{ijt}, an observable characteristic for teacher i in school j and year t. $\mathbf{Q_{jt}}$ is a vector of dichotomous indicators representing individual quartiles of school demographic composition, and $\boldsymbol{\lambda}$ is a parameter vector representing average differences in the dependent variable by school demographic quartile. $\mathbf{S_t}$ is a vector of school year indicators, with fixed effects given by parameter vector $\boldsymbol{\tau}$. The α parameter is an intercept term, and ε_{ijt} is a random, independently and identically distributed error term with mean 0 and standard deviation σ. We cluster the standard errors at the teacher level to avoid overstating the precision of the estimates (Wooldridge, 2002). For research question 2, the dependent variable is instead y_{ijt}, representing the value-added estimate of teacher *i* in school *j* in year *t*.

2.2.2. Teacher mobility as a function of value-added and school demographics

We address question 2 by fitting a multilevel logistic regression model that estimates teachers' probability of leaving their current school after the current year. We include school year fixed effects so that teachers are compared only to those teaching in the same school year, and we include a school-level random effect to adjust for the nesting of teacher-by-year observations within schools.

$$\ln\left(\frac{p\left(turn_{ijt}\right)}{1-p(turn_{ijt})}\right)=\alpha+\boldsymbol{\gamma}'\mathbf{Q_{jt}}+\kappa y_{ijt}+\boldsymbol{\theta}'(\mathbf{yQ_{ijt}})+\boldsymbol{\tau}'\mathbf{S_t}+\boldsymbol{\omega}'\mathbf{X_{ijt}}+u_{jt}+\varepsilon_{ijt} \quad (2)$$

where $turn_{ijt}$ is a dichotomous indicator of turnover coded 1 if the teacher did not return to the same school the following year and 0 otherwise, and $p(turn_{ijt})$ is the probability of turnover for teacher *i* in school *j* and year *t.* The intercept term is represented as α, and y_{ijt} represents the shrunken estimates of the teacher's value-added in year *t*. (In sensitivity tests, we replace y_{ijt} with $\overline{y}_{ijt}$, which is averaged from the first observation year through year *t*). For the first part of research question 2, about turnover rates at schools with different concentrations of minority students, the predictors of interest are given by $\mathbf{Q_{jt}}$. This is a vector of quartile indicators for the schools' percentage of black and Hispanic students, with effects given by parameter vector $\boldsymbol{\gamma}$. For the second part of research question 2, which concerns the relationship between teacher value-added and turnover, the κ parameter represents the difference in the log-odds of turnover at the end of year *t* associated with a unit difference in the teachers' value-added estimate in year *t*, conditional on the other terms in the model. To assess whether schools with different concentrations of black and Hispanic students lose teachers with higher value-added at different rates, some specifications include the two-way interactions between vector $\mathbf{Q_{jt}}$ and parameter κ, with effects given by parameter vector θ. Parameter $\boldsymbol{S_t}$ again represents a vector of year indicators, with fixed effects given by parameter $\boldsymbol{\tau}$. We also include a vector of time-varying teacher characteristics $\mathbf{X_{ijt}}$, whose effects are given by parameter vector $\boldsymbol{\omega}$. The X_{ijt} vector includes a linear years-of-experience term, as well as four categorical experience categories of roughly equal size (0-3 years, 4-10 years, 11-20 years, and 21-42 years) to capture any differences in the experience/turnover relationship by career phase. It also includes linear terms for the teacher's age, distance from home to work in miles (coded zero if miles are missing), and missingness indicator coded 1 for records with no information about miles to work and 0 otherwise. The error term has two components—a random school-by-year intercept denoted by u_{jt}, and a teacher-by-school-by-year error term, ε_{ijt}, both of which are assumed to have a binomial distribution under the logistic regression framework (Hosmer & Lemeshow, 2000).[5]

2.2.3. <u>Changing schools within the district versus leaving the district</u>

Beyond examining teachers' probabilities of leaving their current schools, we also examine their relative probabilities of changing schools within the district as opposed to leaving the dataset, where leaving the dataset means the teacher left the district or stayed in the district but left the tested grades (4 through 8). [6] To estimate the relative probability of moving to a

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[5] Multilevel models are estimated using the *xtreg* and *mixed* routines in Stata 13.1.

[6] When we examine teachers' year-to-year movement among just the tested grades, we find that about 10 percent of teachers entirely change grades from year to year, and the vast majority of these changes are within one grade level, so we are most concerned here about 8th grade teachers who begin teaching only 9th grade or higher, or 4th grade teachers who begin teaching only 3rd grade. Based on the pattern in the tested grade, we would approximate that the share of teachers appearing to leave the district who actually changed out of the tested grades is no more than 10 percent, an assumption we consider in a sensitivity analysis in section 3 of the online appendix.

different school in the district versus leaving the tested grades in the district, we fit a pair of multilevel, random effects logistic regression models in an approach similar to Boyd et al. (2008). In this approach, one of the possible outcome conditions (moving or leaving) is omitted from the estimation of each model. This two-step approach yields results very similar to that of a single-level multinomial logistic regression model, though it is modestly less efficient because the equations are fit in two steps rather than simultaneously (see, for instance, Boyd et al., 2008). Its advantage is that it allows us to include school random effects, thereby accounting for the nesting of teachers within schools. The model is specified as follows:

$$\ln\left(\frac{p\left(turn_{ijt}\right)}{1-p(turn_{ijt})}\right)=\alpha^{h}+\boldsymbol{\gamma}'\mathbf{Q}_{jt}^{h}+\kappa y_{ijt}^{h}+\boldsymbol{\theta}'(\mathbf{yQ}_{ijt}^{h})+\boldsymbol{\tau}'\mathbf{S}_{t}^{h}+\boldsymbol{\omega}'\mathbf{X}_{ijt}^{h}+u_{jt}^{h}+\varepsilon_{ijt}^{h}\text{, h=1, 2, 3} \qquad (3)$$

where h represents one of three outcomes of interest: staying in the same school after the current year (h=1), moving to a different school in the district after the current year (h=2), or leaving the tested grades in the district after the current year (h=3). Otherwise, the parameters are defined as in equation 2. We set staying in the current school (h=1) as the default category and first estimate the probability that h=2 as opposed to h=1, excluding observations in which h=3. We then separately model the probability that h=3 as opposed to h=1, excluding individuals for which h=2. The coefficients represent the relative relationships of the predictors to a teacher's probability of moving within the district, *or* of leaving the district, versus staying in the same school. An assumption of multinomial logistic regression is the independence of irrelevant alternatives, which implies that a teacher's decision about whether or not to transfer within the district is separate from the decision to leave the district.[7] In research question 4, we ask

[7] As noted by Hausman and McFadden (1984), this assumption is difficult to satisfy completely. In our case, it would hold insofar as the choice to leave the district were guided by geographic concerns and/or by the choice to stay employed as a teacher, rather than by the relative availability of jobs in each district. Because the analysis described in equation 2 captures the relationship between our predictors and the more inclusive turnover definition,

whether, among teachers who change schools, teachers' value-added predicts the characteristics of the schools they move to relative to the schools they left behind. For this analysis, which focuses exclusively on teachers who transfer between schools in the district (whom we call movers), we subtract the proportion of black and Hispanic students in a teacher's pre-move school from than of her post-move school, thus capturing the difference in the two schools' demographic composition in the years before and after the teacher's transfer. Thus, a positive difference in percent black/Hispanic indicates that the teacher moved to a school with a larger share of black and Hispanic students than attended her previous school.

2.2.4. Changes in school demographics among teachers who move between schools

To assess whether the differences between new and prior schools are related to teachers' prior value-added, we use ordinary least squares to regress these differences on teachers' shrunken value-added estimates in the pre-move year while controlling for various teacher characteristics and for a vector of school fixed effects, as in the following model:

$$(k_{ijt+1} - k_{ijt}) = \alpha + \kappa y_{ijt} + \boldsymbol{\tau}'\mathbf{S_t} + \upsilon'\mathbf{X}^*_{ijt} + \zeta_{ijt} \tag{4}$$

where (k_{ijt+1}-k_{ijt}) represents the difference in percent black/Hispanic between the teacher's post-move and pre-move school. $\mathbf{X}^*_{ijt}$ is a vector of teacher characteristics similar to the version in the previous equations, except that it now also includes a linear term for the change in miles to work between the new and previous schools, with effects given by parameter vector υ. The ζ_{ijt} parameter is a normally distributed random error term with mean 0 and standard deviation σ. As in estimation of equation 1, we cluster standard errors at the teacher level. The parameter of interest is κ, which expresses the relationship between a teacher's value-added in year *t* and the

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the estimation of equation 3 can be viewed as a descriptive effort to understand whether the predictors of interest have a different apparent relationship to each type of turnover we observe.

change in the share of black and Hispanic students in the new versus prior schools. If κ is negative and statistically significant, this would indicate that higher-value-added teachers had reduced the share of black and Hispanic students in their schools to a greater extent than teachers with lower value-added.

2.2.5. Effects of experience overall and by quartile of minority enrollment

To distinguish sorting of teacher value-added (y_{ijt}) that is due to the sorting of observed teacher characteristics (including experience) from sorting that is due to unobserved teacher attributes, skills, or practices, we modify equation 1 as follows:

$$y_{ijt} = \alpha + \boldsymbol{\lambda}'\mathbf{Q_{jt}} + \boldsymbol{\tau}'\mathbf{S_t} + \boldsymbol{\eta}'\mathbf{c_{ijt}} + \boldsymbol{\rho}'\mathbf{Q_{jt}} * \mathbf{c_{ijt}} + \varepsilon_{ijt} \quad (5)$$

so that $\mathbf{c_{ijt}}$ represents a vector of observable teacher characteristics, including years of experience, with effects given by parameter vector $\boldsymbol{\eta}$. In some specifications, we also interact some teacher characteristics with school quartiles, with effects interaction effects given by parameter vector $\boldsymbol{\rho}$. In section 4 of the appendix, we briefly discuss an alternative, longitudinal specification that omits year fixed effects, $\mathbf{S_t}$.

3. Results

3.1. Distribution of teacher qualifications and value-added by school demographics

We first consider the distribution of teachers' observable qualifications as a function of schools' demographic characteristics. As shown in Table 2, the focal district demonstrates a pattern similar to other school systems in the literature, in that schools with a larger share of black and Hispanic students are staffed by less experienced teachers on average. Schools in the highest quartile in terms of black and Hispanic enrollment have teachers with about 3.1 fewer years of experience than schools in the lowest quartile (the omitted category). Similarly, we find that the probability that a teacher is a novice (in the first three years of employment in the district) is about 10 percentage points higher in schools with the largest share of minority students, and increases steadily from the lowest to highest quartiles of minority composition. Teachers with advanced degrees become less common as one moves from the lowest to highest quartiles of minority composition. In the subset of teachers for which we have data on the college attended and the undergraduate grade point average, we find that the share who attended a competitive college is four to six percentage-points lower in schools in quartiles 2 through 4 as compared to the lowest-minority quartile, and teachers' undergraduate grade point averages are 0.11 to 0.16 lower in these quartiles than in the lowest minority quartile on a four-point scale. In short, there do appear to be notable differences among schools in terms of the observable qualifications of their teachers, such that schools with the lowest minority enrollment rates enjoy teachers with the highest qualifications.

<Insert Table 2 about here>

As noted, however, systematic sorting of teacher qualifications does not necessarily indicate systematic sorting in terms of teachers' value-added. A key question is how closely teachers' observable characteristics and their value-added are correlated in the district. To address that question, we regress teachers' unshrunken value-added estimates in a given year (specifically, their student-weighted cross-subject averages) on the aforementioned qualification indicators and a vector of school year fixed effects, which means that these are within-year estimates. Coefficients on the qualification variables are shown in Table 3.

<Insert Table 3 about here>

In this district, we find that teacher qualifications are related to value-added in the expected directions. In the model that includes both a linear and categorical experience terms and the other qualification variables (column 7), we find that the linear experience term is positively related to value-added at the 10-percent level though the linear experience categories are non-significant. The positive standalone effect of having an advanced degree (column 4) becomes non-significant when we account for other terms, though the effects of undergraduate GPA (measured on a four-point scale) and attending a competitive college are positive and significant.[8] It is nevertheless important to note that these characteristics together account for only a small portion—less than 2 percent—of the total variation in teachers' value-added estimates, meaning that they are correlated with teacher value-added but only weakly, as other literature has shown (Aaronson, Barrow, & Sander, 2007; Rivkin, Hanushek, & Kain, 2005; Rockoff, 2004).

Given that we do find a clear relationship between teacher qualifications and value-added, it is not surprising that when we examine systematic sorting of teachers' value-added by school demographics, we find teacher sorting patterns that are quite consistent with what we observe in the teacher characteristics data. First, we examine teacher density in 2004-05 by the share of black and Hispanic students in the school.

<Insert Figure 1 about here>

As shown in Figure 1, teachers in the highest value-added quintile are disproportionately sorted toward schools with a lower share of minority students, while those in the lowest value-added quintile are sorted toward schools with higher minority enrollment rates. Table 4 places this finding in a regression context, displaying the relationship between a school's quartile of black and Hispanic students in any given year and the average value-added estimates of its teachers in

[8] In models not shown, we find very similar relationships when we focus solely on value-added in a single subject (language arts, math, science, and social studies) and when we aggregate value-added across not only subjects but all observed years.

that year. In Table 4, we examine overall value-added, which is averaged across subjects for each teacher, as well as subject-specific estimates. As before, all regression models represented in Table 4 include school year fixed effects so that comparisons are within year.

<Insert Table 4 about here>

Focusing first on column 1, which concerns teachers' overall value-added in a given year, we find that the average teacher value-added in schools with the largest share of minority students is 11 percent of a student-level standard deviation lower than in schools with the fewest minority students—a striking difference. Columns 2 through 5 indicate that this finding is reasonably consistent when we focus only on teachers' value-added estimates in discrete subject areas, though the sorting of teacher value-added in science and social studies does appear much more pronounced than in language arts and math. Specifically, the difference in teachers' average value-added between a school in the lowest quartile of percent black and Hispanic and a school in the highest quartile is about 6 percent of a student-level standard deviation of language arts achievement and 4 percent of a standard deviation of mathematics achievement, but it is nearly 19 percent of a standard deviation in science and more than 16 percent of a standard deviation in social studies. Given that the number of teachers with tested students in each subject area is relatively stable and that the standard errors on the coefficients are similar in math, science, and social studies, the increased sorting in science and social studies does not seem to be driven by noisier estimates in those subjects. Another possible explanation is that schools with the highest shares of minority students are disproportionately emphasizing math and reading in response to federally mandated accountability. This explanation would be consistent with prior research showing that schools—especially those at greatest risk of not meeting accountability targets—have responded to high-stakes accountability under No Child Left Behind by reallocating instructional resources and time toward reading and math (Hamilton et al., 2007; Stecher et al., 2008). Though the state in question did test students annually in all four subjects, whether a school made Adequate Yearly Progress under No Child Left Behind was determined by students' scores in language arts and math (and by graduation rates for high schools). Of course, we cannot be certain that differential emphasis on science and social studies in higher- versus lower-minority schools is responsible for the greater degree of value-added sorting we see in science and social studies, but the observed pattern is consistent with that explanation.

To place these findings in context, we examine the extent to which teacher value-added varies between schools and between years. Using unconditional school-level and school-by-year level random effects models, we find that only about 13 percent of the variation in teachers' unshrunken mathematics value-added estimates is attributable to time-invariant differences among schools, and about 21 percent is attributable to time-varying differences among schools. Though this suggests that the majority of sorting is within rather than between schools, these systematic between-school differences are large enough to have meaningful consequences for children's opportunity to learn.

3.2. Teacher mobility as a function of value-added and school demographics

Having established that average teacher value-added does vary systematically between schools with higher versus lower shares of minority students, we now examine to what extent teachers' movement out of schools and between schools in the district appears to contribute to the problem. Here, for simplicity of presentation and to reduce the risk of false discovery, we focus on teachers' overall value-added estimates averaged across subject areas in a given year.

First we consider the frequency of teacher turnover in the district. Examining the years 2004-05 through 2007-08, we find that between 24 percent and 32 percent of teachers did not return to their schools the following year. However, only about 6 percent of teachers appeared to change schools within the district, while the other 18 to 26 percent appeared to leave the district, or at least the tested grades within it. In other words, moving between schools was relatively rare in comparison to the frequency with which teachers left the tested grades in the district.

Research question 2 asks whether the probability that teachers leave their schools at the end of a given year varies by the school's demographic quartile (in terms of the percent of black and Hispanic students in the school). To answer this question, we turn to the first column of Table 5, which presents coefficients from a multilevel logistic regression of teachers' turnover behavior (leaving versus staying the current school at the end of the current year) on school demographic quartiles and a variety of control variables, including experience, age, distance to work, and school year fixed effects. Bearing in mind that schools in the lowest quartile of percent of students who are black and Hispanic are the reference category, we find that the probability of leaving the current school is approximately consistent across the first three quartiles of schools' percentage of black and Hispanic students. However, for schools in the highest quartile of minority student composition, the estimated coefficient of 0.367 (corresponding to an odds ratio of 1.44) is statistically distinguishable from zero at the five-percent level. In substantive terms, if we assume a base annual turnover rate of 28 percent, which is the annual average across all years in the data, then students in schools with the highest minority compositions would have an expected turnover probability of 35.9 percent, which represents a predicted difference of 7.9 percentage points, all else being equal. Because this is logistic regression, the percentage point difference is obviously subject to the base rate, so a more generalizable way to state the finding is that the odds of leaving one of the highest-minority quartile schools in a given year are 44 percent greater than the odds of leaving a school in one of the other quartiles in the same year.

<Insert Table 5 about here>

Next, we ask whether teachers' turnover probability is related to their value-added, holding school demographics and other observed teacher characteristics constant. Based on prior literature, we would expect to find that teachers with lower value-added were more likely to leave their schools than those with higher value-added, all else being equal, and indeed, that is what we find in the second column of Table 5. The statistically significant coefficient of -1.125 on teachers' value-added in the current year ($p<0.001$) means that if we were to compare two similar teachers, one who had a value-added estimate at the sample mean, and the other with a value-added estimate a unit higher (representing one standard deviation of student achievement), the teacher with the higher value-added would have odds of leaving that were only 0.32 times those of the teacher whose value-added was at the sample mean. If the teacher at the sample mean had a 28 percent risk of turnover, the corresponding risk for the teacher with one unit higher value-added would be about 11 percent. This is a large effect that is consistent with the literature in suggesting that low value-added in a given year markedly increases the teachers' risk of not returning beyond that year.

Of course, whether it is the underperformance that drives the decision to leave or the decision to leave that drives underperformance is not clear. To consider this question, we run a sensitivity test in which we redefine a teacher's value-added as her average overall score across all years she is observed in the current school. In an analysis not shown, we find very little difference in the value-added coefficient using this definition. The negative relationship between value-added and turnover probability is, if anything, slightly stronger in that analysis, with a coefficient of -1.333 ($p<.001$). This suggests that the negative relationship isn't merely due to the kind of one-year dip that might occur if one is planning to leave at the end of the year.[9] Rather, it appears that teachers with lower value-added are simply more likely to leave than their counterparts, holding constant their other observable characteristics and the demographics quartiles of their schools.[10]

Returning to Table 5, in column 3 we examine whether the relationship between value-added and leaving the school differs by the schools' demographic quartile. If, for example, teachers with high value-added were inclined to stay in lower-minority schools and to leave higher-minority schools, that would, in time, increase the gap in teacher value-added between schools with lower and higher shares of minority students unless high-minority schools were able to replace teachers who leave with other high value-added teachers. However, we find very little indication of such patterns in our data. Coefficients on the terms that interact teachers' value-added estimates with school demographic quartiles are very noisy and do not approach statistical significance. As such, we conclude that schools with a high share of black and Hispanic students are not disproportionately losing high value-added teachers, though they do appear to be losing teachers in general at a faster rate than other schools.

<Insert Figure 2 about here>

Our preferred specification in Table 5 is thus column 2, which captures the effects of school demographics and teacher value-added but does not include terms for their interaction. Figure 2 depicts the column 2 estimates visually, showing the fitted effects of teacher value-added and of working in a school in the highest minority-composition quartile. (The latter has a

[9] In sensitivity analyses not shown, we find a similar pattern—that is, negative and substantial relationships between value-added and probability of turnover—when we disaggregate by teachers' primary content areas.

[10] In section 2 of the online appendix, we examine whether value-added for those who change schools improves in the year after the move. We do not find that teachers who transfer improve their value-added scores more than their counterparts who remain in the same schools, but we do find that prior-year value-added is less predictive of subsequent-year value-added if a teacher moves between years than if she remains in the same school.

coefficient of 0.3 that is significant at the 10-percent level.) The graph indicates that a teacher with a mean value-added score has a probability of turnover of about 20 percent in a school in the lowest quartile of percent black and Hispanic, and of about 25.2 percent in a school in the highest quartile. Though the gap between lowest and highest-quartile schools appears to shrink at higher levels of teacher value-added, this is due to the nonlinear fitted relationship between turnover and the predictor variables in a logistic model. In fact, the odds ratio of turnover between highest and lowest quartile schools remains constant at 1.35 (the exponentiation of the coefficient, 0.3). Meanwhile, the relationship between teachers' value-added and their probability of turnover is strongly negative and consistent across schools' demographic quartiles. The density plots on which the fitted trend lines are superimposed are represented to illustrate where most of the value-added estimates lie in each school quartile—in other words, they show the density of data points from which the fitted trend lines are estimated.

3.3. Changing schools within the district versus leaving the district

We now turn to research question 3, which examines whether schools' demographic compositions are similarly related to teachers' risk of changing schools within the district as compared to their risk of leaving the school district. Table 6 presents results of our multinomial logistic regression models.

<Insert Table 6 about here>

Columns 1 through 3 of Table 6 present coefficients estimating the probability of changing schools in the district relative to remaining in the same school as a function of the model predictors and school random effects. Columns 4 through 6 present comparable coefficients estimating the probability of leaving the district relative to remaining in the same school. What is immediately clear from comparing the two sets of columns is that the predictors for the two types of turnover decisions are distinct from one another. This is as we would expect if the decision processes are relatively independent, as assumed by the multinomial logit model (Hausman & McFadden, 1984). We find a strong relationship between schools' demographic quartiles and teachers' probability of moving between schools in the district. In column 1, which includes controls for teacher characteristics but not for value-added, we find that teachers whose schools are in the highest quartile of minority composition have about three times the odds of those in lowest-quartile schools of changing schools after their current year versus staying in the same school (β=1.119, p<.001). Moreover, this finding is reasonably robust to the inclusion of teachers' value-added estimates (column 2) and to the interaction of value-added by school demographics (column 3). What is also striking is that teachers in the second and third quartiles are also more likely to change schools in the district than those in the first quartile (the omitted category), such that teachers in third-quartile minority schools have similar probabilities to those in the highest quartile. Even those in the second quartile have odds of transferring that are 56 to 64 percent higher than those in the lowest quartile of minority composition, though the effects for second-quartile minority composition schools is significant at only the 10-percent level (see columns 1 and 2). In contrast, school demographics bear essentially no relationship to teachers' probability of leaving the tested grades and subjects in the district, as shown by the small and nonsigificant coefficients on schools' demographic quartiles in columns 4 through 6. The terms that *do* predict exit from the district are quite different from the terms that predict transfer within the district—namely, novice status, age, and miles to work—all of which are factors that might motivate exit from the profession (or in the case of miles to work, from a city-based job to a suburban job) more than they would drive transfer between schools in the city.[11]

[11] Estimates are are highly robust to the omission of both the miles-to-work and miles-missingness variables.

The variable that predicts transfer and exit similarly is teacher value-added, for which we find coefficients of -1.136 in column 2 and -1.182 in column 5, both statistically significant at the 0.1-percent level. There is a marginally significant interaction (p<.1) between schools' demographic quartiles and teachers' value-added in estimating the probability of moving between schools, such that the relationship between value-added and transfer probability is less negative in the second and third quartiles of minority composition than in the lowest quartile, but it remains negative all the same. What we might conclude from this is that teachers are very unlikely to transfer from schools with the lowest minority enrollment rates, and that those who do transfer from them have much lower value-added estimates than those who stay (consistent with the possibility that they are being excessed or counseled out), whereas teachers who leave schools in other quartiles have only modestly lower value-added estimates than those who stay. In predicting the probability of leaving the district, on the other hand, we find much less evidence that the effect of value-added differs by schools' demographic quartiles, as evidenced by the noisy and non-statistically significant coefficients on the interaction terms in column 6.[12]

3.4. Changes in school demographics for teachers who move between schools

Research question 4 asks whether teachers who change schools within the district tend to move to schools with lower or higher shares of minority students, and whether the answer depends on their value-added in the year preceding the move.[13] Focusing just on teachers who transfer between schools in the district, we examine the relationship between their value-added in the pre-move year and the characteristics of their destination schools. As described above, we do this by subtracting the school-level percentage of black and Hispanic students of a teacher's pre-

[12] In sensitivity analyses not shown, we find that these results are highly robust to redefining teacher value-added as an average across all years the teachers was observed at a given school.
[13] In a sensitivity analysis, we redefined value-added prior to the move as a multi-year average of all the years the teacher was observed in the pre-move school, and we found results that were nearly identical to those reported here.

move school from than of her post-move school. A positive difference in the minority enrollment percentage indicates that the teacher moved to a school with a larger share of black and Hispanic students than her previous school.

To examine whether the direction of the move is related to teachers' value-added estimates, we turn to Table 7, which presents results from models regressing the change in school demographics on teacher value-added. We first regress the difference in share of black and Hispanic students in the school just on teachers' linear value-added estimate in the pre-move year (column 1) and then on a quadratic value-added specification (column 2). Comparing the two suggests that the relationship is linear, so we drop the squared term in column 3, where we also add controls for observed teacher characteristics in the pre-move year, including not only the teacher-level controls from previous analyses, but also the teachers' change in miles to work between the post-move and pre-move year. We find no evidence of a statistically significant relationship between teacher turnover and teacher value-added in any model specification. In fact, all the coefficient estimates on value-added are slightly positive, indicating that higher value-added is linked to small increases in the fraction of minority students, though none of these estimates approaches statistical significance. In short, we find little evidence that movers with higher value-added differ from those with lower value-added in terms of the directions of their moves.

<Insert Table 7 about here>

3.5. Effects of experience overall and by quartile of minority enrollment

Given our finding above that less-experienced teachers and teachers with novice status were less effective than their peers at raising student achievement, turnover could still be hurting students' access to high-value-added teachers in high-minority schools if departing teachers are being replaced with lower-value-added counterparts. We do see a higher proportion of novice teachers in high-minority schools (Table 2). It seems possible that the comparatively high turnover these schools experience is undermining teacher quality simply by driving down the experience levels of their teachers. We wondered how much of the discrepancy in teacher value-added by minority enrollment quartile is attributable to the larger share of novice teachers in these schools. To address this question, we examine the differences in the average quality of the teachers in each experience bracket, by quartile of minority student enrollment.

Table 8 summarizes teachers' value-added estimates by experience category in each of the four quartiles for the 2004-05 academic year. What is striking about the table is that teacher value-added appears negatively related to quartile of minority enrollment in each experience category. (Tables for other years show similar patterns.) Of course, this table does not account for other teacher characteristics, nor does it formally test whether effects of experience differ by minority-enrollment quartile. We address these questions in Table 9.

Table 9 presents the relationship of teacher value-added to a teacher's years of experience in the district and the interactions of these terms with quartiles of minority enrollment.[14] Columns 1 through 3 show estimates from a regression of teacher value-added on experience and other teacher qualifications, with controls for school fixed effects (column 1) or for school demographic quartiles (columns 2 and 3). A few estimates are noteworthy. First, as suggested by the descriptive statistics in Table 8, we find that the relationship between experience and value-added remains negative and statistically significant even when we adjust for schools' demographic quartiles. Second, we find that the negative relationship shown in column 1 of Table 4 between schools' minority enrollment quartile and value-added is scarcely affected by

[14] When we fit these models using categorical rather than linear experience terms, the results are similar, but we present the linear experience term here for the sake of parsimony.

adjusting for teachers' experience and other characteristics, as shown in column 2 of Table 9. This, too, implies that neither experience nor other observable teacher attributes clearly account for between-quartile differences in teacher value-added. Third, the very small and non-significant coefficients on the interactions of experience with minority enrollment quartiles in column 3 suggest that, in any given school year, the effects of a teacher's years of experience are stable across minority enrollment quartiles.

When we omit year fixed effects and instead examine the effects of an additional year in the same school, we find that these effects may, in fact, vary by schools' minority enrollment quartile, such that improvement rates appear lower in the highest- and lowest-minority schools, and these differences are jointly significant at the one-percent level, as shown in appendix section 4. However, given that the mean number of years a teacher is observed in the same school is only 2.14 (with a range from 1 to 5), we view these results as somewhat inconclusive.

4. Discussion and Conclusion

Our analysis finds that teachers' qualifications and their estimated value-added are unequally distributed among schools in the district. Compared to a student whose school is in the lowest quartile of minority enrollment, a student who attends a school in the highest quartile has access to teachers with about three years less experience, about a 10 percentage-point higher chance of being a novice, about a 10 percentage-point lower chance of having an advanced degree, and about a 6 percentage-point lower chance of having attended a competitive college. Perhaps more importantly, the student has access to teachers whose value-added is about 11 percent of a student-level standard deviation lower than those of his peers in the lowest minority enrollment quartile. These are meaningful differences in that seem likely to exacerbate racial/ethnic achievement gaps.

When we examine the mechanisms by which this sorting occurs, we do find that schools with the highest share of minority students lose teachers at a faster rate than those with lower minority enrollment rates. However, we find little evidence that high-minority schools are losing their best teachers, or that the loss of their best teachers is disproportionately high compared to other schools. Also, the higher share of novice teachers in high-minority schools does little to explain the lower average teacher value-added estimates in these schools. Still, schools in the highest minority quartile may face particular difficulties in recruiting quality replacements for the teachers they lose. Any such difficulties may help account for the lower value-added of novice teachers in these schools relative to schools in the other three quartiles.

Teacher mobility within the district seems to occur largely among schools in the top three quartiles of minority enrollments. Schools in the lowest minority enrollment quartile are markedly less likely to lose teachers to other district schools. Much of the movement appears to be among teachers in the other three quartiles, such that the average change in minority enrollments for teachers who change schools is only -0.73 of a percentage point. The teachers who change schools also have lower value-added, on average, than the teachers who remain in the same schools, and this pattern does not appear to be driven by a short-term drop in value-added before changing schools.

The question facing policymakers in the district is how to improve average teacher value-added in high-minority schools given that these schools face higher levels of turnover but are not systematically losing their best teachers or ceding those teachers to schools with fewer minority students. The answer appears to lie in helping these schools replace the teachers they lose with teachers who will produce larger gains in student achievement, and also in helping these schools foster the conditions that allow teachers to improve. The former strategy might be carried out with incentives that reward high value-added teachers for choosing these schools. Such an approach would attempt to shift the neutral transfer patterns to ones that favor high-minority schools in order to equalize average teacher value-added across demographic quartiles. The latter strategy, of providing working conditions that foster teachers' professional growth, may be more challenging to accomplish. Evidence suggests that raising student achievement through quality teacher professional development is difficult, though possible (Garet et al., 2008; Marsh et al., 2008; Yoon et al., 2007). Moreover, the first strategy could conceivably catalyze the second. It may be, in other words, that recruiting high value-added teachers from across the district to fill vacancies in the highest-minority schools could strengthen teacher collaboration and school culture in ways that could feasibly improve teacher value-added (see, for instance, Chenoweth, 2007; Duncan & Murnane, 2014).

As in any study, our dataset presents certain limitations. Our data do not allow us to establish the destinations of teachers once they leave the tested grades and subjects in the district, but we estimate that no more than 10 percent of stayers are misclassified as leavers, and our results should be robust to that misclassification insofar as those misclassified are reasonably similar to actual leavers, an assumption we consider further in appendix section 3.

Finally, the present study is drawn from a single urban school district, which means that our findings of systematic school-level sorting of teacher value-added may or may not generalize broadly. Indeed, recent studies have found that the degree of systematic school-level sorting varies considerably among districts (Glazerman & Max, 2011; Isenberg et al., 2013; Steele et al., 2014). In light of this variability, there is value in studies that contribute to our understanding of teacher sorting in different contexts. The present study suggests that, at least in some urban contexts, between-school sorting of teacher value-added does indeed contribute to achievement gaps and to inequality of opportunity by school residential zoning. However, we find little evidence that teacher mobility contributes strongly to this pattern. Instead, the problem appears to lie in differences that begin in the early years of the career and *may* be exacerbated by differential teacher improvement rates across schools with different demographic profiles. Even though only 13 percent of sorting of teacher value-added in the district is between schools, these differences may have meaningful repercussions for students' long-term educational experiences and access to equal opportunity. Efforts to not only attract higher-value added teachers but also support teachers' growth in these schools could potentially mitigate these differences, helping to equalize educational opportunities for those in the least-advantaged schools.

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Tables

Table 1. Descriptive characteristics of teachers in the analytic sample (n=2331 teachers, 6180 teacher-by-year observations)

Variable	N	Mean	Std. Dev.	Min	Max
Gender					
Female	2331	0.757	0.429	0	1
Male	2331	0.219	0.414	0	1
Missing	2331	0.024	0.152	0	1
Race/Ethnicity					
Asian or Pacific Islander	2331	0.004	0.062	0	1
Black or African American	2331	0.313	0.464	0	1
Hispanic or Latino	2331	0.005	0.069	0	1
White	2331	0.641	0.480	0	1
Missing	2331	0.037	0.189	0	1
Bachelor's Degree Information					
Institution is competitive or better in Barron's	892	0.628	0.484	0	1
Bachelor's degree GPA	859	3.021	0.472	1.45	4
Time-Varying Characteristics in First Year Observed					
Master's degree or higher	2331	0.406	0.491	0	1
Three years of experience in the district or fewer	2182	0.381	0.486	0	1
Years of experience in the district	2189	7.994	8.809	0	41
Age	2238	39.406	11.562	22	70
Miles to work	1373	13.971	13.050	0.002	114
Miles to work missing	2331	0.411	0.492	0	1
Number of subjects taught	2331	2.428	1.277	1	4
Number of years teacher is observed in the dataset	2331	2.647	1.574	1	5
Left school at the end of the current year (2005 data)	1255	0.244	0.430	0	1
Value-Added (shrunken) in 2004-05					
All subjects (weighted by student n in each subject)	2331	0.000	0.155	-0.522	0.813
English Language Arts	1481	-0.002	0.124	-0.507	0.651
Math	1411	-0.003	0.216	-0.933	0.934
Science	1302	-0.010	0.177	-0.499	0.924
Social Studies	1465	-0.014	0.187	-0.677	0.801

Table 2. Linear regression coefficients (and standard errors) expressing the relationship between school demographic quartiles and various teacher qualifications

	(1) Years of experience	(2) Novice status	(3) Advanced degree	(4) Competitive college	(5) Undergrad GPA
Percentage of black and Hispanic students in school					
Second quartile	-1.393*	0.032~	-0.027	-0.039	-0.111**
	(0.592)	(0.018)	(0.028)	(0.041)	(0.039)
Third quartile	-2.675***	0.079***	-0.086**	-0.057	-0.155***
	(0.578)	(0.019)	(0.029)	(0.042)	(0.041)
Highest quartile	-3.085***	0.098***	-0.098**	-0.057	-0.149**
	(0.685)	(0.024)	(0.035)	(0.055)	(0.052)
Teacher-by-year observations	5,990	5,990	6,172	3,298	3,157
Teachers	2,183	2,183	2,331	892	859
R-squared	0.016	0.009	0.022	0.003	0.018
F	6.016	4.748	22.85	3.444	3.067

*** p<0.001, ** p<0.01, * p<0.05, ~ p<0.1

Note: Models include school year fixed effects (not shown). Standard errors are clustered at the teacher level.

Table 3. Coefficients (and standard errors) expressing the relationship between teacher characteristics and overall value-added

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Experience (linear term)	0.002***						0.003
	(0.000)						(0.002)
Experience: 0-3 years		-0.020*				-0.029*	-0.017
		(0.009)				(0.013)	(0.016)
Experience: 11-20 years		0.007				-0.001	-0.023
		(0.011)				(0.014)	(0.020)
Experience: 21-42 years		0.026*				0.018	-0.031
		(0.013)				(0.017)	(0.036)
Advanced degree			0.030***			-0.001	-0.002
			(0.008)			(0.012)	(0.012)
Competitive college				0.030**		0.033*	0.035**
				(0.012)		(0.013)	(0.013)
Undergrad GPA					0.045***	0.042**	0.043**
					(0.012)	(0.013)	(0.013)
Teacher-by-year observations	5,997	5,997	6,180	3,298	3,157	3,027	3,027
Teachers	2,190	2,190	2,339	892	859	818	818
R-squared	0.006	0.005	0.004	0.005	0.010	0.016	0.017
F	3.248	3.099	2.257	3.603	2.304	2.575	2.491

*** p<0.001, ** p<0.01, * p<0.05, ~ p<0.1

Note: Models include school year fixed effects (not shown). Standard errors are clustered at the teacher level.

Table 4. Coefficients and standard errors expressing the relationship between school demographic quartiles and teachers' value-added fixed-effect estimates

	(1)	(2)	(3)	(4)	(5)
	All VA	**ELA VA**	**Math VA**	**Science VA**	**Social Studies VA**
Percentage of black and Hispanic students in school					
Second quartile	-0.048***	-0.028*	-0.003	-0.085***	-0.070***
	(0.010)	(0.013)	(0.017)	(0.016)	(0.016)
Third quartile	-0.060***	-0.022~	-0.013	-0.080***	-0.081***
	(0.010)	(0.013)	(0.018)	(0.017)	(0.017)
Highest quartile	-0.111***	-0.062***	-0.044*	-0.188***	-0.163***
	(0.012)	(0.015)	(0.020)	(0.020)	(0.019)
Teacher-by-year observations	6,172	3,899	3,710	3,364	3,845
Teachers	2331	1620	1529	1459	1655
R-squared	0.023	0.006	0.002	0.038	0.030
F	12.96	2.564	0.859	12.74	11.15

*** p<0.001, ** p<0.01, * p<0.05, ~ p<0.1

Note: Models include school year fixed effects (not shown). Standard errors are clustered at the teacher level.

Table 5. Coefficients (and standard errors) from multilevel logistic regression estimating the probability of leaving the tested grades in the current school at the end of a given year

	(1)	(2)	(3)
Experience: 0-3 years	0.292*	0.283*	0.285*
	(0.114)	(0.114)	(0.114)
Experience: 11-20 years	-0.067	-0.078	-0.075
	(0.157)	(0.157)	(0.157)
Experience: 21-42 years	0.072	0.054	0.059
	(0.296)	(0.296)	(0.296)
Experience (Linear term)	-0.027~	-0.025~	-0.025~
	(0.014)	(0.015)	(0.015)
Age	0.006	0.004	0.004
	(0.004)	(0.004)	(0.004)
Miles to work	0.012***	0.012**	0.012**
	(0.004)	(0.004)	(0.004)
Miles missing	0.873***	0.848***	0.848***
	(0.112)	(0.113)	(0.113)
2nd quartile: % Black/Hispanic	-0.004	-0.044	-0.051
	(0.151)	(0.150)	(0.151)
3rd quartile: % Black/Hispanic	0.235	0.195	0.189
	(0.149)	(0.148)	(0.149)
Highest quartile: % Black/Hispanic	0.367*	0.300~	0.316~
	(0.169)	(0.169)	(0.171)
Year 2004-05	-0.730***	-0.713***	-0.712***
	(0.099)	(0.100)	(0.100)
Year 2005-06	-0.487***	-0.481***	-0.480***
	(0.096)	(0.096)	(0.096)
Year 2006-07	-0.373***	-0.370***	-0.371***
	(0.094)	(0.094)	(0.094)
Value-added (shrunken)		-1.125***	-1.340**
		(0.238)	(0.512)
Value-added * 2nd quartile			0.302
			(0.697)
Value-added * 3nd quartile			0.061
			(0.643)
Value-added * Highest quartile			0.750
			(0.785)
Constant	-1.148***	-1.055***	-1.047***
	(0.223)	(0.224)	(0.224)
Ln of variance in school-level error	-1.696***	-1.722***	-1.716***
	(0.281)	(0.286)	(0.286)
Teacher-by-year observations	4,738	4,738	4,738
Schools	112	112	112
Degrees of freedom in model	13	14	17
Chi-squared	202.4	220.8	221.4

*** p<0.001, ** p<0.01, * p<0.05, ~ p<0.1

Note: Omittted experience category is 4-10 years, and omitted school year is 2007-08. Models include school random effects.

Table 6. Coefficients (and standard errors) from multilevel logistic regression estimating the probability of changing schools within the district or leaving the district versus staying in the same school

	Probability of Transferring, Contingent on Staying in District			**Probability of Exiting District, Contingent on Not Transferring**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Experience: 0-3 years	-0.124	-0.131	-0.136	0.434***	0.427***	0.432***
	(0.204)	(0.205)	(0.205)	(0.127)	(0.127)	(0.127)
Experience: 11-20 years	0.246	0.228	0.239	-0.148	-0.160	-0.160
	(0.291)	(0.291)	(0.291)	(0.175)	(0.175)	(0.175)
Experience: 21-42 years	0.545	0.512	0.528	-0.064	-0.085	-0.083
	(0.554)	(0.555)	(0.555)	(0.329)	(0.329)	(0.330)
Experience (Linear term)	-0.046~	-0.043	-0.044	-0.022	-0.019	-0.019
	(0.028)	(0.028)	(0.028)	(0.016)	(0.016)	(0.016)
Age	-0.013	-0.014~	-0.014~	0.011*	0.010*	0.010*
	(0.008)	(0.008)	(0.008)	(0.005)	(0.005)	(0.005)
Miles to work	0.002	0.002	0.002	0.014***	0.014***	0.014***
	(0.007)	(0.007)	(0.007)	(0.004)	(0.004)	(0.004)
Miles missing	0.410*	0.390*	0.396*	0.986***	0.962***	0.960***
	(0.185)	(0.186)	(0.186)	(0.124)	(0.124)	(0.124)
2nd quartile: % Black/Hispanic	0.494~	0.447~	0.426	-0.073	-0.119	-0.119
	(0.263)	(0.263)	(0.263)	(0.164)	(0.164)	(0.165)
3rd quartile: % Black/Hispanic	1.011***	0.973***	0.951***	0.061	0.016	0.014
	(0.244)	(0.243)	(0.243)	(0.164)	(0.164)	(0.165)
Highest quartile: % Black/Hispanic	1.119***	1.034***	0.974***	0.198	0.127	0.172
	(0.271)	(0.272)	(0.278)	(0.186)	(0.186)	(0.188)
Year 2004-05	-0.296~	-0.268	-0.263	-0.888***	-0.873***	-0.876***
	(0.176)	(0.176)	(0.176)	(0.112)	(0.113)	(0.113)
Year 2005-06	-0.282	-0.262	-0.263	-0.554***	-0.547***	-0.546***
	(0.178)	(0.178)	(0.178)	(0.106)	(0.106)	(0.106)
Year 2006-07	-0.114	-0.099	-0.102	-0.460***	-0.459***	-0.460***
	(0.172)	(0.172)	(0.173)	(0.104)	(0.104)	(0.104)
Value-added (shrunken)		-1.136**	-3.167*		-1.182***	-1.101*
		(0.431)	(1.259)		(0.268)	(0.543)
Value-added * 2nd quartile			2.736~			-0.181
			(1.527)			(0.759)
Value-added * 3nd quartile			2.427~			-0.537
			(1.400)			(0.712)
Value-added * Highest quartile			1.403			0.914
			(1.637)			(0.850)
Constant	-2.348***	-2.265***	-2.247***	-1.579***	-1.487***	-1.488***
	(0.409)	(0.410)	(0.410)	(0.246)	(0.246)	(0.247)
Ln variance in school-level error	-1.695***	-1.708***	-1.691***	-1.483***	-1.503***	-1.490***
	(0.430)	(0.438)	(0.432)	(0.284)	(0.287)	(0.285)
Teacher-by-year observations	3,801	3,801	3,801	4,439	4,439	4,439
Schools	112	112	112	112	112	112
Degrees of freedom in model	13	14	17	13	14	17
Chi-squared	60.34	66.98	68.12	199.7	215.3	217.4

*** p<0.001, ** p<0.01, * p<0.05, ~ p<0.1

Note: Omittted experience category is 4-10 years, and omitted school year is 2007-08. Models include school random effects.

Table 7. Coefficients (and standard errors) from linear regression of the change in percent of black and Hispanic students on teacher value-added among teachers who changed schools

	(1)	**(2)**	**(3)**
Value-added (shrunken)	4.877	4.568	8.195
	(6.747)	(8.987)	(6.852)
Value-added squared		0.833	
		(8.811)	
Experience: 0-3 years			3.133
			(4.574)
Experience: 11-20 years			1.695
			(6.017)
Experience: 21-42 years			-0.827
			(11.966)
Experience (Linear term)			0.076
			(0.592)
Age			0.152
			(0.174)
Change in miles w/ transfer			-0.150
			(0.142)
Miles to work			-0.085
			(0.186)
Miles missing			2.349
			(3.435)
Year 2004-05			-6.671~
			(3.754)
Year 2005-06			-1.652
			(3.636)
Year 2006-07			-7.192~
			(3.775)
Constant	-0.743	-0.772	-5.040
	(1.230)	(1.331)	(7.857)
Teacher-by-year observations	299	299	299
Teachers	277	277	277
R-squared	0.001	0.001	0.039
Degrees of freedom in model	1	2	12
F	0.523	0.438	1.074

*** p<0.001, ** p<0.01, * p<0.05, ~ p<0.1
Note: Standard errors are clustered at the teacher level.

Table 8. Teachers' mean value-added in 2004-05, by experience level and minority enrollment quartile

		Minority enrollment quartile			
Experience Category		***Lowest***	***2nd***	***3rd***	***Highest***
0-3 years	μ_{VA}	0.085	-0.028	0.020	-0.057
	n	56	100	119	73
4-10 years	μ_{VA}	0.068	0.020	0.010	-0.058
	n	81	92	127	59
11-20 years	μ_{VA}	0.122	0.004	-0.008	-0.057
	n	78	67	79	35
21 years +	μ_{VA}	0.122	0.014	0.050	-0.007
	n	61	77	54	28

Table 9. Coefficients (and standard errors) from regressions estimating effects of experience by minority enrollment quartile

	(1)	(2)	(3)
Experience (linear term)	0.002*	0.001	0.001
	(0.001)	(0.001)	(0.001)
Experience * 2nd quartile			0.001
			(0.002)
Experience * 3rd quartile			-0.001
			(0.002)
Experience * Highest quartile			0.000
			(0.002)
Advanced degree	0.000	-0.004	-0.003
	(0.012)	(0.011)	(0.011)
Competitive college	0.036**	0.030*	0.030*
	(0.013)	(0.013)	(0.013)
Undergrad GPA	0.042**	0.032*	0.031*
	(0.013)	(0.013)	(0.013)
2nd quartile: % Black/Hispanic		-0.037*	-0.049*
		(0.015)	(0.024)
3rd quartile: % Black/Hispanic		-0.062***	-0.051*
		(0.014)	(0.021)
Highest quartile: % Black/Hispanic		-0.110***	-0.111***
		(0.018)	(0.028)
Year 2005-06	0.005	0.004	0.004
	(0.013)	(0.012)	(0.012)
Year 2006-07	-0.009	-0.011	-0.011
	(0.012)	(0.012)	(0.012)
Year 2007-08	-0.012	-0.017	-0.017
	(0.013)	(0.013)	(0.013)
Year 2008-09	-0.009	-0.011	-0.010
	(0.013)	(0.013)	(0.013)
Constant	-0.141**	-0.052	-0.052
	(0.043)	(0.045)	(0.047)
Teacher-by-year observations	3,027	3,027	3,027
Teachers	818	818	818
R-squared	0.015	0.038	0.039
Degrees of freedom in model	8	11	14

*** p<0.001, ** p<0.01, * p<0.05, ~ p<0.1

Note: Models include year fixed effects (not shown). Standard errors are clustered at the teacher level.

Figure 1. Density of the percentage of black and Hispanic students in the schools of all teachers in the analytic sample and of teachers in the top and bottom value-added quintiles in 2005

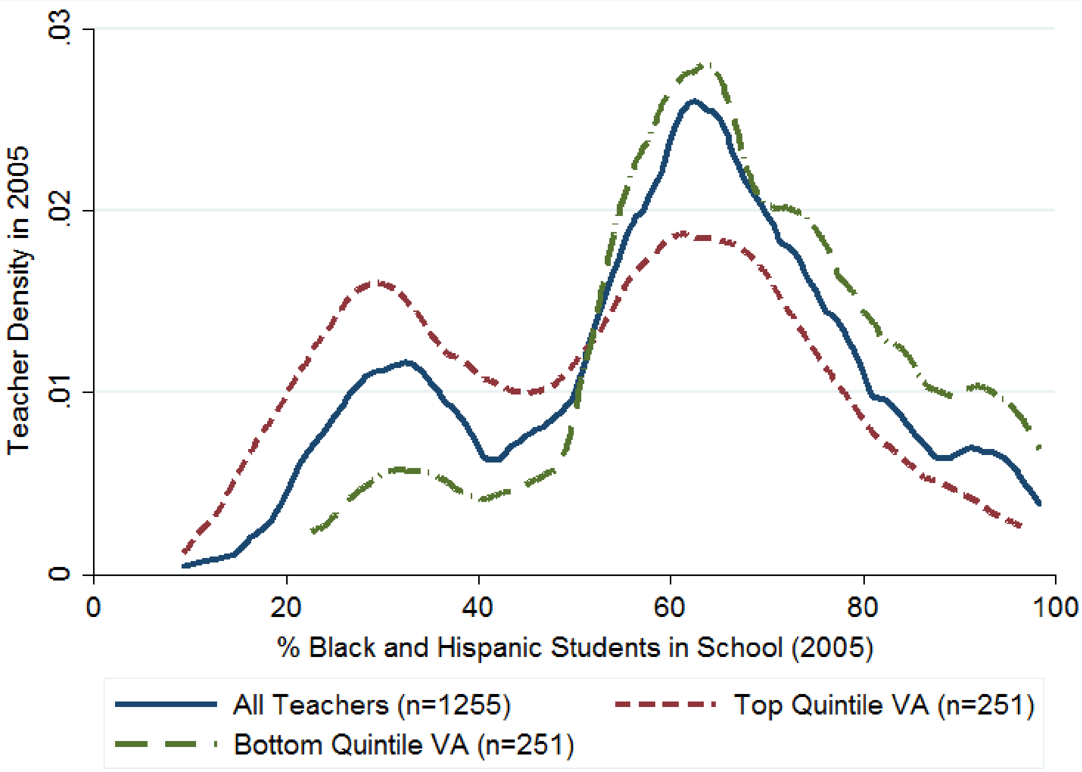
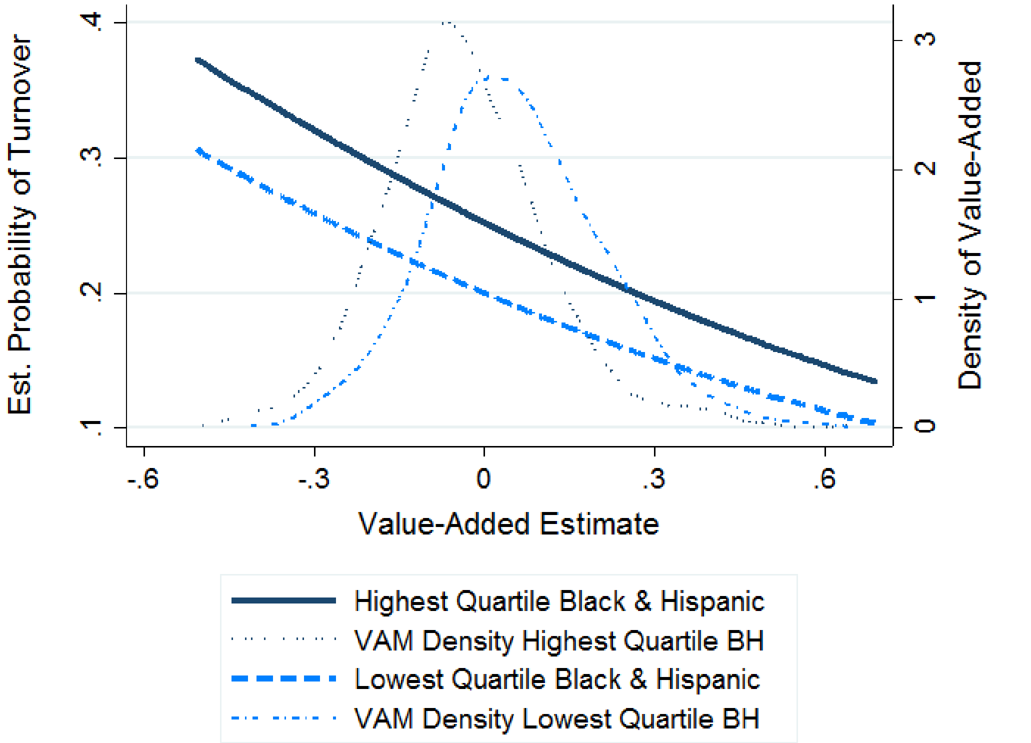


Figure 2. Estimated relationships among shrunken teacher value-added, minority enrollment quartile, and probability of teacher turnover (from Table 5, Column 2)



Note: Other terms in the estimation model are held constant at their sample means for the first year the teachers were observed in the sample. The difference between teachers in schools with the highest and lowest shares of black and Hispanic students is statistically significant at only the 10-percent level. Regression lines are superimposed on density plots showing the distribution of value-added estimates in schools in the highest and lowest minority enrollment quartiles.