THE QUALIFICATIONS AND CLASSROOM PERFORMANCE OF TEACHERS MOVING TO CHARTER SCHOOLS

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Abstract

Do charter schools draw good teachers from traditional, mainstream public schools? Using a thirteen-year panel of North Carolina public schoolteachers, I find that less qualified and less effective teachers move to charter schools, particularly if they move to urban schools, low-performing schools, or schools with higher shares of nonwhite students. It is unclear whether these findings reflect lower demand for teachers' credentials and value added or resource constraints unique to charter schools, but the inability to recruit teachers who are at least as effective as those in traditional public schools will likely hinder charter student achievement.

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1. INTRODUCTION

Charter schools, playing the role of competitive entrants in partially deregulated public education markets, can theoretically spur efficiency gains and improve the quality of education overall by introducing innovative teaching and leadership strategies, improving the match value between students and schools, and forcing incumbents (here, traditional public schools) to compete for limited resources. Critics of charter schools argue that they skim good students and remove much-needed funds from public schools without delivering unambiguously superior student achievement. While the effectiveness with which charter schools raise student achievement has been studied at length,[1] much less is known about the flow of resources between charter and mainstream schools. Public funding transfers to charter schools are typically proportionate to the number of students enrolled—that is, "the money follows the students." But might *teachers* follow the students as well? What can we learn from the teachers who opt out of traditional public schools in favor of the charter sector? In this study I use unprecedented detail on future charter teachers in North Carolina to describe the qualifications and value added of teachers moving out of traditional public schools and into charter schools. I show that North Carolina charter schools are drawing less qualified and less effective teachers from traditional, mainstream public schools. This pattern indicates that charters have lower demand for credentials and value added or that charters do not have the resources, broadly speaking, to attract good teachers from other schools.

Among North Carolina's charter teachers, 36.1 percent previously taught in a mainstream school. This subset of teachers represents a unique window on the competition between public schooling sectors for teaching talent. These "charter movers" are much more likely to have exercised revealed preference for charter schools than teachers who are recruited directly from college or nonteaching careers. The strength with which charters draw good teachers from mainstream schools is a signal of charters' workplace appeal but also a likely precursor to higher student achievement. Teacher quality is a profound factor in student achievement, and charters seeking to produce high achievement will value teachers who have succeeded in other schools. But good teachers tend to gravitate to good schools, and this tendency may work

1. See Dee 1998, Hoxby 2003, and Booker et al. 2008 for empirical evidence that mainstream student performance improves in light of competition from choice schools. Observational studies of administrative data find that enrolling in a new charter school has a negative impact on student achievement growth, more so in newer schools (see Bifulco and Bulkley 2008 and Gleason et al. 2010 for reviews). By contrast, recent studies of lottery-based admissions to urban, oversubscribed charter schools find large and positive impacts of charter attendance (Hoxby and Murarka 2009; Abdulkadiroglu et al. 2011; Dobbie and Fryer 2011).

against North Carolina's charters, which typically underperform traditional public schools (Bifulco and Ladd 2006; Carruthers 2012). Indeed, results suggest that North Carolina's charter schools attract less talented teachers from traditional public schools, a consequence and perhaps a cause of weaker performance throughout the state's charter sector. Teachers moving to charter schools are less experienced, less likely to be licensed, and less likely to hold graduate degrees than teachers who make similar shifts between mainstream schools. In this sense they resemble teachers who leave North Carolina public schools (and likely leave the profession) more than other teachers who switch schools. Furthermore, charter movers are less effective in terms of math and reading value added, and teachers moving to less effective charter schools, urban charter schools, or charters with higher shares of nonwhite students have even lower reading value added.

This article proceeds as follows. Section 2 outlines conceptual expectations for the relative qualifications and effectiveness of teachers moving to charter schools. Section 3 describes pertinent features of North Carolina's charter system and the data used in this study. Section 4 analyzes the credentials of teachers moving to charter schools. In section 5 I describe measures of classroom performance, evaluate charter movers' value added relative to other mobile teachers, and explore the possibility of observational bias from sampling error and nonrandom student sorting. Section 6 offers conclusions and open questions.

2. CONCEPTUAL FRAMEWORK

A founding purpose of North Carolina's charter legislation is to "create new professional opportunities for teachers."[2] It remains to be seen if charters capitalize on these opportunities to attract talented, effective teachers, nor is it clear if charters have enough advantages in the teacher labor market to do so. This section illustrates why expectations about the relative qualifications and value added of charter teachers are ambiguous a priori, which motivates the empirical exercises to follow and frames results within the broader policy implications of teacher quality in charter schools.

As a starting point, consider the motives of charter schools, which make up a small part of the demand for teachers. Broadly speaking, charters seek to optimize student enrollment (and proportionately budgets), subject to regulatory, financial, and physical constraints. Producing high student achievement supports this objective by meeting the accountability thresholds necessary to stay open and appealing to parents. Teachers are schools' primary resource

2. North Carolina General Statutes, § 115c-238.29a(4) (1996; see www.ncga.state.nc.us/enactedlegislation/statutes/html/bysection/chapter_115c/gs_115c-238.29a.html).

for producing tested achievement as well as myriad other student virtues that are less readily observable (e.g., maturity, an appreciation for the arts, or other outcomes unique to each charter school's mission). Since charter schools are subject to more oversight than traditional public schools (from authorizers, at least, if not parents and the public at large) as well as the credible threat of closure, charter administrators may place a higher value on teacher characteristics that help raise student achievement and otherwise retain the support of parents. Moreover, charters are typically free to deviate from step-lane pay scales that pay mainstream teachers according to strict functions of experience, education, and other credentials. Charter leaders can pay more or less for these credentials if they wish, and they can also pay more for less tangible elements of teacher quality, such as value added.

If we find that charter teachers exhibit more of a particular characteristic, this could be because charter schools have higher demand for that characteristic, because charters have more favorable endowments in the labor market for teachers with that characteristic, or both. Note that labor market endowments encompass pecuniary resources with which to pay salaries but also nonpecuniary workplace attributes that teachers may value. Hoxby (2002) develops this intuition further and, using a nationwide survey, finds that charter teachers tend to have taken more college math and science courses, are more likely to have graduated from a competitive college, but are no more or less likely to have earned a graduate degree. Lower levels of certain teacher aspects in the charter sector could reflect lower demand (perhaps because these aspects do not advance charters' objectives) or lower pecuniary and nonpecuniary resources. Financial resource constraints stem from charter finance models that allocate each school a per pupil rate roughly equal to the surrounding district's average per pupil cost. If a district enjoys substantial economies of scale, its per pupil expenses will be less than a charter school's average cost. Financial difficulties are common in North Carolina's charter schools. Twenty-four charters were relinquished or revoked between 1998 and 2006; of those, nine cited financial problems as a leading cause of failure.[3]

On the supply side, teachers have been shown to vote with their feet in favor of more effective schools and more socioeconomically advantaged student populations,[4] which works against charter schools that target urban or at-risk students. Charter schools, and choice schools in general, may induce sorting by race, income, or parental preferences for education (Hastings, Kane,

3. In a few cases, insolvency stemmed directly from embezzlement or negligent financial management. See, for example, Lanier 2008.
4. See, for instance, Hanushek, Kain, and Rivkin 2004; Falch and Strøm 2005; Scafidi, Sjoquist, and Stinebrickner 2007; and Loeb, Kalogrides, and Béteille 2012.

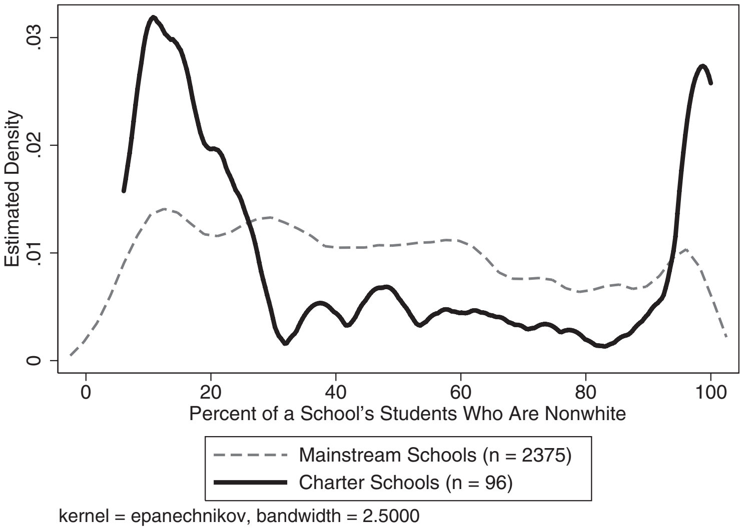

Figure 1. Density Estimates—Percent of Students Who Are Nonwhite in Charter and Mainstream Schools, Academic Year 2009

and Staiger 2009). Indeed, North Carolina's charter schools are racially segregated to a much starker degree than mainstream schools, as described by Bifulco and Ladd (2007) and illustrated in figure 1. Figure 1 plots kernel densities of nonwhite student shares for charter and mainstream schools in the 2009 school year.[5] Whether because of location, pedagogical foci, or other determinants of student sorting, North Carolina's charter schools are much more likely than mainstream schools to have very high or very low concentrations of nonwhite students. Stuit and Smith (2012) find that nonwhite student shares explain part of the fact that charter schools tend to have higher teacher turnover; therefore it would not be surprising to find that charters with more nonwhite students struggle to recruit mainstream teachers. Setting aside the relative draw of different student populations, teachers may be unwilling to accept lower pay in charter schools. Even though charters are free to exceed step-lane pay rates for teachers, charter teachers tend to earn no more than their mainstream counterparts, and unlike mainstream school districts, charters do not necessarily pay teachers more for experience, licensure, or education (Podgursky and Ballou 2001; Hoxby 2002; Taylor 2005). Even so, nonpecuniary benefits may offset disadvantaged student populations and lower pay in charter schools. Early advocates of the charter model stressed the professionalization and empowerment of teachers

5. I refer to school years by the year of their conclusion. For instance, 2009 references the 2008–9 school year.

as critical tenets of charter development (see, for example, Budde 1988 and Kolderie 1990), and modern charter schools often follow this course. In surveys, charter teachers cite collegiality, common instructional philosophies, and greater creative license as roots of job satisfaction (Malloy and Wohlstetter 2003).

To sum, charters' autonomy, limited resources, and diversity lead to uncertain expectations about the qualifications and effectiveness of teachers who choose to work in the charter sector over other options. Charters will value teacher characteristics that support school objectives, and in principle charters can offer teachers possessing those characteristics higher pay and higher job satisfaction. But in practice charters have limited salary funds, uncertain time horizons, and varied student challenges that may conflict with teacher preferences, and we cannot be certain that charters value the same qualifications that mainstream districts value, nor can we be certain where student achievement ranks among charter school objectives. The net, reduced-form outcome of all these factors is unclear; charter teachers may be more or less qualified than their mainstream counterparts, and charter teachers may have higher or lower value added in terms of student achievement.

In spite of ambiguous expectations overall, this conceptual framework has implications for different types of teachers and different types of charter schools. Nonpecuniary school conditions that teachers value should be positively associated with teacher characteristics that schools value. For instance, Loeb, Kalogrides, and Béteille (2012) show that more effective schools are better able to recruit good teachers from other schools. So within the charter sector, we would expect to see teachers with higher value added gravitating toward more effective charters. (Section 5 demonstrates this very pattern of positive matching between teacher and school quality.) Similarly, teacher preferences for more socioeconomically advantaged schools are consistent with teacher mobility patterns I describe, in that more effective teachers sort into less urban charter schools as well as charters with fewer nonwhite students.

I approach the question of charter teacher quality empirically, identifying relative qualifications and classroom performance for the subset of charter teachers who moved from the mainstream sector. These mobile teachers provide valuable insight about how well charter schools compete with mainstream schools for effective teachers who could likely work in either sector. Teachers who move from traditional public schools to charter schools (especially if they are regularly licensed) are more likely to exhibit revealed preference in favor of charter schools, in which case their mobility decisions involve demand-side charter *and* mainstream offerings, rather than charter alone. When assessing the qualifications and value added of charter movers, I compare them with other teachers changing schools but staying in the mainstream sector, controlling for sending and receiving school characteristics.[6] Results indicate that charter schools attract less qualified and less effective teachers, although it remains to be seen if these findings are due to resource constraints, lower demand for these qualities, or supply-side preferences. Regardless of which labor market factors dominate the sorting of teachers between charter and mainstream schools, the inability to recruit teachers who are at least as effective as those in traditional public schools likely hinders student achievement in charter schools.

3. CHARTER SCHOOLS IN NORTH CAROLINA

Background

The North Carolina legislature authorized the state's system of charter schools in 1996, and the first charters opened for the 1997–98 school year. By 2009 there were more than 35,000 students enrolled in charter schools, representing 2.4 percent of statewide enrollment. Charters are spread throughout urban, rural, and socioeconomically diverse regions of North Carolina. The state's charter legislation and oversight bear many features in common with other charter systems. North Carolina had a binding one hundred school cap on the charter sector throughout the window of time this analysis considers; accordingly, a very small percentage of teachers move to charter schools in any given year.[7] The comparison group—mainstream teachers moving to other mainstream schools—is large and varied, as are the schools they move to, so for any given mainstream-to-charter move, I can likely find another move between qualitatively similar mainstream schools. That is, charter and mainstream movers have common support for identification of their relative quality, controlling for sending and receiving school environments. Extensive data covering a thirteen-year period are available for all teachers in the state. These data allow me to characterize the qualifications of every teacher moving to the state's charter sector and to estimate the classroom performance of many elementary charter movers.

The application, approval, and evaluation of charter schools is closely regulated, but the schools are given wide latitude in their personnel management and daily operations. North Carolina charter schools are organized as private, nonprofit organizations. They are allotted funding from state and local boards of education on a per pupil rate, commensurate with district per pupil costs.

6. Evaluating charter movers against nonmobile teachers would impose an inappropriate benchmark if stayers had higher value added than leavers (Hanushek and Rivkin 2010) or if charter movers would have changed schools or left teaching regardless of charter opportunities (Jackson 2011). Results to follow support these ideas.
7. The one hundred school cap was lifted in the summer of 2011.

Public funds can be used toward "operational and financing leases for real property," but the state does not take responsibility for any charter indebtedness.[8] Charters can raise additional funds by winning grants or soliciting donations, but they cannot charge tuition.

Charter schools are allowed great flexibility in the recruitment, retention, and pay of their faculties. At least 75 percent of charter teachers in kindergarten through fifth-grade classrooms must hold teaching certificates. This number falls to 50 percent for charter teachers of grades 6–12. Only certified teachers are eligible for tenure after four consecutive years of teaching in a mainstream public school. Tenured mainstream teachers who wish to teach in a charter school are granted one year's leave, meaning that they can return to their original school after a year, space permitting.[9] Charters are not required to offer tenure, nor are they required to participate in the state retirement plan.

Data

I utilize a richly detailed panel describing teachers' credentials, work environments, and career paths over the years 1997–2009 within the universe of North Carolina public schools, students, and teachers.[10] Data are not uniform across charter and mainstream teachers. Gender, race, and school assignments are known for all teachers—including, importantly, charter teachers—but teacher credentials and student-teacher linkages necessary for value-added estimation are known only for mainstream teachers. Thus I cannot characterize the qualifications or classroom performance of charter teachers who are hired directly from college or other careers, and I cannot observe teacher qualifications or value added after teachers move to charter schools. These are irreconcilable limitations of the data. But I observe mainstream teachers who move to charter schools, allowing me to evaluate their credentials and, for the first time, to estimate the value added of individual (albeit future) charter teachers. I exclude teaching assistants, facilitators, and teachers simultaneously assigned to more than one school. I link each teacher's school assignment to campuswide statistics derived from the National Center for Education Statistics (NCES) Common Core of Data (grades served, urbanicity of locale, percentage of students who are nonwhite,

8. North Carolina General Statutes, § 115C-238.29H(a1). See www.ncga.state.nc.us/enactedlegislation/statutes/html/bysection/chapter_115c/gs_115c-238.29h.html.
9. North Carolina General Statutes, § 115C-238.29F(e3). See www.ncga.state.nc.us/enactedlegislation/statutes/html/bysection/chapter_115c/gs_115c-238.29f.html.
10. Data are managed by the North Carolina Education Research Data Center (NCERDC) at Duke University. See Muschkin, Bonneau, and Dodge (2009) for details.

Table 1. In-Sample Mobility Patterns of Charter Teachers

Teacher Mobility Pattern	Percent
Started and ended in the charter system (right censored)	18.8
Started and ended in the charter system (uncensored)	33.2
Mainstream to charter	27
Mainstream to charter to mainstream	9.1
Charter to mainstream	11.1
Other patterns	$<$1.0

Notes: $n = 6{,}823$ teachers. The first two mobility patterns apply to teachers who teach exclusively in charter schools. Right-censored charter teachers enter the sample in the charter system and are observed teaching there in 2009, the last year of the panel. Uncensored teaching spells end before 2009. The last four mobility patterns apply to teachers who teach in charter and mainstream schools. The percent of all charter participants who follow each pattern is indicated at right.

and total enrollment) as well as schoolwide proficiency rates calculated by the North Carolina Department of Public Instruction.[11]

4. THE QUALIFICATIONS OF TEACHERS MOVING TO CHARTER SCHOOLS

Table 1 describes teacher mobility patterns between charter and mainstream schools for the 6,823 teachers who are observed working in a charter school at some time between 1998 and 2009. The majority teach exclusively in charter schools. The results to follow focus on charter teachers who initially teach in a mainstream North Carolina school before moving to the charter sector, which accounted for 36.1 percent of all charter teachers. Table 2 lists summary statistics for the 1997–2008 panel of North Carolina's mainstream public schoolteachers with known following-year teaching assignments. It is important to emphasize that the qualifications listed in table 2 are at best weakly linked to student achievement.[12] Thus the relative frequency of these credentials among charter movers will do little to foreshadow student achievement

11. Common Core statistics and schoolwide proficiency data are available alongside teacher, student, and school microdata in the NCERDC data files. The percent of students performing at grade level, or the "performance composite," is determined by the state as part of annual accountability procedures.
12. Graduate degrees appear to have no robust impact on teacher quality (see Goldhaber 2008 for a review). Licensure has been linked with higher student achievement (Clotfelter, Ladd, and Vigdor 2007; Goldhaber 2007), although there tends to be much more variation in teacher quality within licensure classes than between (Boyd et al. 2006; Kane, Rockoff, and Staiger 2008). The returns to teacher experience are initially steep, with significant student achievement gains over the first three to five years of a teacher's career. Thereafter the impact of teacher experience plateaus (Murnane and Phillips 1981; Rockoff 2004; Clotfelter, Ladd, and Vigdor 2007).

Table 2. North Carolina Public School Teachers: Summary Statistics

Teacher Qualification	(1) All Teachers	(2) Mainstream Movers	(3) Charter Movers
Holds graduate degree (%)	30.7	28.4*	25.2*
	(46.1)	(45.1)	(43.4)
Attended competitive college (%)	76.3	74.8*	69.5*
	(42.5)	(43.4)	(46.0)
Mean licensure test score (∼N(0;1))	0.031	0.022*	0.039
	(0.851)	(0.828)	(0.895)
Regularly licensed (%)	90.5	87.6*	78.7*
	(29.4)	(32.9)	(41.0)
Teaching experience (years)	12.6	9.5*	8.3*
	(9.6)	(9.0)	(9.3)
Experience ≤ 3 years (%)	20.7	31.9*	39.4*
	(40.5)	(46.6)	(48.9)
Experience ≥ 25 years (%)	14.0	8.4*	9.4
	(34.7)	(27.8)	(29.2)
Days absent	11.7	13.1*	13.4
	(9.9)	(11.2)	(11.6)
Black (%)	14.3	15.9*	23.1*
	(35.0)	(36.6)	(42.1)
Hispanic (%)	0.9	1.3*	1.9*
	(9.2)	(11.4)	(13.5)
Other, nonwhite (%)	1.2	1.3	1.9*
	(10.9)	(11.1)	(13.5)
Female (%)	80.0	78.9*	78.3*
	(40.0)	(40.8)	(41.2)
n (teacher years)	867,019	84,222	1,926

Notes: The table lists summary statistics for all 1997–2008 North Carolina mainstream school teachers with known school assignments in the following year. Standard deviations are in parentheses below each mean. Data for moving teachers reference the year immediately preceding a school change. Mainstream movers (column 2) are mainstream teachers who are next observed in a different mainstream school, and asterisks in column 2 indicate a significant difference (at 95% confidence or greater) between mainstream movers and nonmobile teachers. Charter movers (column 3) are next observed in a charter school, and asterisks indicate significant differences between mainstream and charter movers.

in charter schools. This analysis will determine if charters are drawing well-qualified teachers from mainstream schools in terms of qualifications like graduate education, licensure, and experience that are valued by mainstream districts and rewarded in step-lane pay scales.

Teachers' experience and higher education data are drawn from detailed personnel records.[13] College competitiveness is inferred from the 1995

13. Experience is underestimated because personnel records do not necessarily account for accumulated teaching experience from outside North Carolina public schools.

edition of *Barron's Profiles of American Colleges*, which roughly corresponds to the graduation date of mobile teachers with six years (the median) of experience. North Carolina teachers take a variety of licensure exams, most of which are in the Praxis series. In order to include all available test information, I scale raw licensure test scores to have a standard normal distribution within each test code and test year. I calculate each teacher's mean standardized licensure test score, equal to the average of all his or her unique exam records. Regularly licensed teachers, who account for 90.5 percent of all teachers, have completed an approved teacher education and testing program or attained North Carolina licensing by reciprocal or interstate agreement. Teachers without regular licensure are uncertified teachers holding temporary, emergency, or provisional licenses. Absenteeism figures exclude vacation days and obvious data errors.[14]

Mobile teachers,[15] summarized in the second column of table 2, are on average less qualified than teachers who are not changing schools. Movers are earlier in their careers, less likely to have graduate degrees, and somewhat less likely to have graduated from a competitive college. Further, they have lower licensure test scores and are absent more often in the year prior to moving. Mainstream teachers moving to charter schools, summarized in the third column of table 2, are even less credentialed than other moving teachers in terms of higher education, licensure, and experience. Strikingly, charter movers are 8.9 percentage points less likely to be regularly licensed. North Carolina's policy of permitting more uncertified teachers in charter schools, which is intended to attract individuals from outside the traditional teacher education pipeline, may have the consequence of drawing untenured mainstream teachers nearing the expiration of temporary licenses. Additional descriptive evidence supports this notion. Tenure is typically granted to licensed teachers after four years. Among unlicensed school changers, the likelihood of moving to a charter school is 3.8 percent for first-year teachers, increasing to 5–6 percent for second- and third-year teachers, and back down to 3.1 percent for teachers completing their fourth year. Finally, table 2 shows that teachers moving to charter schools are much more likely to be black and modestly more likely to be Hispanic or otherwise nonwhite.

14. Vacation days, which include all mandatory holidays, are recorded inconsistently in the absenteeism data. I exclude records with negative days absent, more than 25 absences in a month, or more than 150 in a year.
15. Throughout the article, mobile teachers are defined as those who are next observed in a different school, with no more than a one-year gap between schools. Principal results are robust to more liberal definitions of mobility (allowing for longer gaps between schools) and to more conservative definitions (allowing for no gaps between schools).

Summary evidence suggests that charter movers are typically less credentialed than other mobile teachers, but it may be the case that charter movers are drawn from schools or districts with weaker qualifications throughout. I estimate a multinomial logit model of teacher mobility to assess how particular teacher and school factors relate to charter mobility.

$$P_{im} = \frac{\theta^{Z_i \beta_m}}{\sum_{l=1}^{S} \theta^{Z_i \beta_l}} \quad m = 1, \ldots, 5 \quad l = 1, \ldots, 5, \tag{1}$$

where P_{im} is the probability of choosing one of five mobility outcomes (m): move to a charter school, move to another mainstream school, temporarily leave the sample, leave the sample completely, or teach at the same school. Z_i is a matrix of teacher characteristics summarized in table 2 and several variables describing teachers' sending schools: the percent of students who are nonwhite, the percent who are proficient, total enrollment, grade level(s) served, urbanicity indicators,[16] and indicators for missing data. The baseline option—teach at the same school—is restricted to have $\beta_5 = 0$, so β_m estimates for other outcomes are interpreted as relative to β_5.

Relationships between control variables and the relative risk of making mobility choice m are listed in table 3. Significant coefficients greater than 1 indicate that a marginal increase in variable Z_i is associated with a higher risk of making that particular mobility choice. Teachers with graduate degrees or degrees from competitive colleges are not significantly more or less likely to move to a charter school relative to stayers. Teachers with higher licensure test scores are more likely to move to a charter school, as are unlicensed teachers, teachers with no more than three years' experience, and teachers with more absences. In terms of credentials, charter movers resemble teachers leaving North Carolina public schools more than teachers changing schools or temporarily exiting the sample. Unlicensed and inexperienced teachers are more likely to make any move, as are teachers with higher licensure test scores (which may correlate with skills valued in other schools and careers), but these patterns are pronounced for charter movers and leavers. Echoing Jackson (2011), these findings may shed light on why teachers leave for charter schools if doing so is a close substitute to leaving the profession. In contrast to descriptive statistics in table 2, multinomial logit results suggest that black teachers are not significantly more likely to move to charter schools, conditioning on teacher and school characteristics. In terms of school characteristics, teachers outside

16. Census Bureau classifications are used to classify schools as located in rural areas, towns, or urban areas. Rural areas generally include places with fewer than 2,500 inhabitants outside metropolitan statistical areas (MSAs). Large and small towns are incorporated places with at least 2,500 inhabitants outside any urban fringe or MSA. Urban areas encompass MSAs, including cities and urban fringes.

Table 3. Multinomial Logit Results: Teacher Mobility, Teacher Qualifications, and School Characteristics

Type of Move	(1) To a Charter School	(2) To a Mainstream School	(3) Temporarily Out of Sample	(4) Out of Sample
Teacher Qualifications				
Holds graduate degree	0.995	1.048	1.264	1.353
	(0.07)	(4.75)	(13.59)	(33.93)
Attended competitive college	1.050	1.035	1.075	1.097
	(0.67)	(3.03)	(3.50)	(8.39)
Mean licensure test score (∼N(0;1))	1.201	1.031	1.014	1.133
	(9.23)	(5.15)	(1.37)	(21.52)
Regularly licensed	0.449	0.776	0.672	0.457
	(9.45)	(15.59)	(14.37)	(56.42)
Experience $\leq$ 3 years	2.151	1.666	1.879	2.025
	(11.24)	(49.43)	(32.83)	(67.98)
Experience $\geq$ 25 years	0.909	0.565	1.055	2.306
	(0.93)	(36.63)	(2.24)	(78.20)
Days absent	1.019	1.015	1.031	1.031
	(8.66)	(41.07)	(62.70)	(93.54)
Teacher Characteristics				
Black, non-Hispanic	1.070	0.891	1.162	0.929
	(0.78)	(7.73)	(5.95)	(5.21)
Hispanic	1.426	1.436	1.880	1.477
	(1.27)	(7.96)	(8.63)	(9.06)
Other nonwhite, non-Hispanic	1.136	0.760	0.872	0.912
	(0.59)	(6.69)	(1.83)	(2.41)
Female	0.836	0.856	0.909	0.865
	(2.27)	(13.72)	(4.41)	(13.54)
School and Student Characteristics				
Located in a large or small town	1.018	0.969	0.788	0.800
	(0.20)	(2.49)	(9.85)	(17.81)
Located in a rural area	1.101	1.038	0.865	0.939
	(1.43)	(3.77)	(7.99)	(6.80)
Percent performing at grade level	0.982	0.980	0.988	0.983
	(6.37)	(49.34)	(16.57)	(41.90)
Percent nonwhite	1.012	1.005	1.004	1.003
	(8.70)	(22.30)	(9.31)	(14.48)
Wald2 = 129,752				
Pseudo $R^2 = 0.044$				

Notes: $n = 707{,}110$ teachers. The baseline category is no mobility—that is, staying at one's current school. Relative risk ratios (and robust z-scores, in parentheses) are estimated by multinomial logit. Additional control variables include indicators for schools with elementary, middle, and/or high school grades as well as a set of indicators for missing data.

urban areas are less likely to change schools or leave the sample (temporarily or otherwise), but no more or less likely to move to a charter school. Teachers in schools with more proficient students are less likely to make any move. In agreement with the teacher mobility literature, higher shares of nonwhite students are associated with a higher likelihood of making any move, and charter mobility is somewhat more sensitive to nonwhite student shares than other types of mobility.[17]

Multinomial logit results confirm many impressions from table 2 summary statistics but do not resolve the question of whether charter schools are attracting more or less qualified teachers than *similar* mainstream schools. The charter sector as a whole is attracting less qualified teachers, but receiving charters may have been drawing relatively well, controlling for their own locations and student populations. Toward that end I conduct further analyses of charter and mainstream movers' credentials (Q^{k}_{jslt}) by estimating equation 2 via ordinary least squares (OLS) for each North Carolina teacher *j* observed in year *t* (1997–2008), school *s*, and county *l*:

$$Q^{k}_{jslt} = \delta^{m}\mathbf{1}(moving)_{j} + \delta^{c}\mathbf{1}(tocharter)_{j} + \boldsymbol{C}^{r}_{sl(t+1)}\beta^{r} + \boldsymbol{C}^{s}_{slt}\beta^{s} + \boldsymbol{\alpha}_{l(t+1)} + v_{jslt}. \qquad (2)$$

All mobile teachers have the indicator $\mathbf{1}(moving)_{j}$ equal to one. Teachers moving to a charter school additionally have $\mathbf{1}(tocharter)_{j}$ equal to one. Equation 2 estimates regression-adjusted mean differences in qualification *k* between mainstream movers and nonmovers (δ^{m}) and between mainstream movers and charter movers (δ^{c}). This formulation evaluates charter movers against other mobile teachers, who are more likely to share some of the omitted variables that are correlated with teachers' mobility decisions as well as their credentials (e.g., job satisfaction). I estimate equation 2 separately for each of the credentials summarized in table 2: graduate degree, competitive college education, mean licensure test score, regular licensure, three measures of experience, and absenteeism. Controls include receiving and sending campus characteristics ($\boldsymbol{C}^{r}_{sl(t+1)}$, $\boldsymbol{C}^{s}_{slt}$) and receiving county-by-year effects ($\alpha_{l(t+1)}$). School characteristics include variables representing student body size and composition (percent nonwhite, percent proficient, and total enrollment), urbanicity indicators, range of grades served, and a set of dummy variables controlling for missing data. County-by-year effects control for unobserved heterogeneity in regional variables like nonteaching job opportunities. Robust

17. The 95 percent confidence interval for the relationship between percent nonwhite and charter mobility is (1.010, 1.015) versus (1.004, 1.005) for intra-mainstream mobility.

standard errors allow for clustering within each sending school and year. If charter schools have higher demand for some qualifications and if they are able to outbid mainstream schools by manipulating employment terms and working conditions, δ^c will be positive. If charters have lower demand or if they are unable to realize an advantage in the teachers' labor market, δ^c will be insignificant or negative.

More experienced teachers may seek graduate degrees or additional certifications to increase their pay, so I control for teacher experience categories (indicators for fewer than three years' experience or more than twenty-five years' experience) when estimating equation 2 for licensure and education variables. Licensed and unlicensed teachers may have different incentives to consider charter schools. Unlicensed teachers likely have smaller choice sets in the mainstream sector, particularly if they are near the end of their probationary period. We can infer more about the relative appeal of charter schools as workplaces from teachers who have the opportunity to work in either sector. As such, I produce separate estimates of δ^m and δ^c for the subsample of licensed teachers.

Table 4 lists estimates of δ^m and δ^c for each résumé qualification. Columns 1 and 2 present results from the full sample. Column 1 lists coefficient estimates for δ^m, the difference in qualification *k* between teachers moving to mainstream schools and nonmoving teachers. Estimates of δ^m serve as the baseline with which δ^c estimates are compared. Mobile teachers are modestly more likely to have graduate degrees and less likely to have graduated from a competitive college. They have lower licensure test scores than nonmovers, and they are 1.3 percentage points less likely to be licensed. Movers are much less experienced, by 3.2 years on average, than their nonmoving counterparts. They are 11.6 percentage points more likely to have three years' experience or less and 5.8 percentage points less likely to have at least twenty-five years' experience. Movers are absent an additional 1.7 days relative to nonmovers.

Column 2 coefficients in table 4 answer the question, "Are charter movers more or less qualified than teachers moving between comparable mainstream schools?" It is important, given the heterogeneity of mainstream opportunity costs and charter school environments, to control for sending and receiving school profiles. Nonetheless, results are robust to controls for receiving-school controls alone or to sending-school controls alone. With respect to graduate education, degrees from competitive colleges, licensure, and experience, charter movers are significantly less qualified. They are 3.4 percentage points less likely to hold a graduate degree, in agreement with findings by Hoxby (2002) and Taylor (2005). Charter movers are much less likely to be licensed than other mobile teachers, by 7.2 percentage points. Charter movers are less experienced than mainstream movers by 1.2 years, and they are 7.2 percentage points

Table 4. Regression Results: Qualifications of Teachers Changing Schools, by Mainstream/Charter Destination

Receiving School Type Sample (Equation 2 Coefficient)	(1) Mainstream All (δ^m)	(2) Charter All (δ^c)	(3) Mainstream Licensed (δ^m)	(4) Charter Licensed (δ^c)
Holds graduate degree	0.007 (4.47)	−0.034 (3.17)	0.012 (6.67)	−0.027 (2.13)
Attended competitive college	−0.005 (3.38)	−0.044 (4.11)	0.001 (0.53)	−0.026 (2.20)
Mean licensure test score (∼N(0;1))	−0.016 (4.99)	−0.020 (0.93)	−0.011 (3.22)	0.052 (2.31)
Regularly licensed	−0.013 (11.23)	−0.072 (7.58)		
Teaching experience (years)	−3.2 (82.86)	−1.2 (4.73)	−3.2 (76.08)	−0.5 (1.78)
Experience ≤ 3 years	0.116 (62.18)	0.072 (6.06)	0.106 (55.23)	0.049 (3.71)
Experience ≥ 25 years	−0.058 (51.00)	0.010 (1.40)	−0.061 (47.02)	0.028 (2.96)
Days absent	1.7 (37.78)	0.3 (1.16)	1.7 (36.31)	0.6 (1.61)

Notes: n = 867,019 teachers with known school assignments in the following year. Column 1 lists the regression-adjusted mean difference in each qualification between teachers moving to traditional, mainstream public schools and nonmovers (δ^m in equation 2). Column 2 lists the regression-adjusted mean difference in each qualification between charter and mainstream movers (δ^c). Columns 3 and 4 report δ^m and δ^c estimates when the analysis is limited to regularly licensed teachers. Control variables include receiving and sending school characteristics (percent nonwhite, performance composite, total enrollment, locale indicators, grade ranges served), a set of dummy variables for school missing data, and receiving county-by-year effects. The absolute values of t-statistics are reported in parentheses below each coefficient. Robust standard errors are clustered within each school and year.

more likely to have three or fewer years' experience. There is no significant gap in licensure test scores or absenteeism between charter and mainstream movers.

Columns 3 and 4 list results for the subsample of licensed teachers. Limiting the sample has little effect on results for mainstream movers; point estimates are not economically different between columns 1 and 3. But excluding unlicensed teachers from the analysis narrows or reverses the qualification gap between charter and mainstream movers, suggesting that uncertified mainstream teachers moving to charter schools attenuated the average qualifications of charter movers. The difference between the full and limited samples is particularly stark for licensure test scores and high levels of experience. Licensed teachers moving to charter schools have significantly higher licensure test scores than other moving teachers, by 5.2 percent of a standard deviation, and they are 2.8 percentage points more likely to have twenty-five years or more of experience.

These findings emphasize the possibility that teachers view the charter sector as a low-cost job change preceding retirement or permanent career changes. Sample attrition is high among new teachers, highly experienced teachers, uncertified teachers, and teachers with higher licensure test scores. These are the same groups I observe disproportionately flowing to charter schools. Nonetheless charter schools do not appear to be a quick precursor to attrition for mainstream teachers. Charter movers have a typical post-move duration (uncensored) that is just 12 percent shorter than that of teachers moving to mainstream schools (3.24 years versus 3.67).

5. CLASSROOM PERFORMANCE

As noted above, teacher credentials are limited proxies of teacher quality. Even if charter schools are drawing less *qualified* individuals, they may be attracting more *effective* teachers from traditional public schools, which could subsequently increase charter student achievement. North Carolina students in the third through eighth grades take end-of-grade (EOG) exams in math and reading each spring. I assess teachers' value added using grades 3–5 student EOG records for 2.3 million student-years spanning 1996 to 2008, omitting grade repeaters and test exemptions. To compare teachers across time and grade levels, raw EOG scores are scaled to have a mean of 0 and standard deviation equal to 1 within each year and grade.[18] North Carolina is one of the rare settings where teachers can be linked to their students over several years. I utilize this valuable feature of the data to describe the classroom performance of mainstream elementary teachers who ultimately move to charter schools.

Exam proctors are linked to each student's test scores and sociodemographic data. For test takers in elementary grades, exam proctors are usually—but not always—their classroom teachers. To minimize the likelihood of invalid teacher-student matches, I omit makeup tests, alternative tests, tests for severely disabled students, classrooms with fewer than five or more than thirty test takers, and tests that accommodate students' need for multiple sessions, dictation, home testing, or separation from the rest of the class. I also focus on self-contained classrooms whose proctor is found in the assembled panel of teachers. Self-contained classrooms embody the traditional structure of elementary education, where each class of students spends all or the majority of each day with one teacher. These limitations lend considerable validity to each

18. EOG exams are interval scaled across grades, but the range of raw scores shifts over time and tends to compress in higher grades.

allowed teacher-student match. Of the 146,282 EOG test-taking classrooms with a known teacher, 87.3 percent are considered valid matches. I explore the soundness of observed teacher-student matching by cross-referencing EOG records with course membership files for 2007–9, the only years for which students can be linked with certainty to their teachers of record. Within these years I find that 91.4 percent of student-teacher pairs in the analysis sample are matched to verified student-teacher pairs in course membership records, whereas a naive sample of all test records and all proctors yields just a 74.2 percent match rate.

Classroom Performance—Main Results

Consider the following model describing student *i*'s standardized, normalized test score A^k_{ijt} in subject *k* (math or reading) in teacher *j*'s classroom, school *s*, year *t*:

$$A^k_{ijt} = \lambda A^k_{it-1} + \boldsymbol{X}_{ijt}\beta^k_X + \bar{\boldsymbol{X}}_{-ijt}\beta^k_{\bar{X}} + T_{jt}\beta^k_T + \boldsymbol{C}_{st}\beta^k_C + \theta^k_j + \alpha^k_s + \varepsilon^k_{ijt}. \quad (3)$$

Equation 3 is an educational production function that controls for once-lagged student achievement (A^k_{it-1}) in place of prior inputs and endowed ability. The model assumes that effects of prior inputs and endowments decay uniformly and geometrically (Todd and Wolpin 2003). These are strong assumptions, but because of the students' short time series (three years at most), equation 3 is the best available value-added specification for the purposes of this study. Variables in $\boldsymbol{X}_{ijt}$ are student characteristics, including race, gender, parental education, and learning disability indicators. $\bar{\boldsymbol{X}}_{-ijt}$ is a vector controlling for class size and average student characteristics in *j*'s classroom, excluding student *i*. T_{jt} is an indicator equal to one if *j* is a new teacher. $\boldsymbol{C}_{st}$ contains campus-level variables, including urbanicity indicators and continuous variables for total enrollment, percent proficient, and percent nonwhite. The coefficients θ^k_j and α^k_s are teacher fixed effects and school fixed effects, respectively. The results to follow evaluate θ^k_j estimates under two variations of equation 3: (1) without school fixed effects (assumes α^k_s is a mean-zero component of the error term) and (2) with school fixed effects. Estimates of θ^k_j from each specification are centered at zero so they can be interpreted as each teacher's standing relative to the average instructor.

Teacher fixed effects from the specification of equation 3 without school fixed effects do not account for unobserved, inherent school quality, so any tendency of students experiencing steeper achievement growth to gravitate toward particular schools will bias teacher quality estimates. Teacher fixed effects from the specification controlling for school fixed effects reflect teachers' relative performance within their schools, which limits the scope of

Table 5. Teacher Fixed Effect Estimates: Summary Statistics

	(1) All Teachers	(2) Mainstream Movers	(3) Charter Movers
Teachers' math fixed effects			
Without school fixed effects	0.013	−0.007*	−0.037*
	(0.207)	(0.213)	(0.228)
	[8.52*]		
With school fixed effects	0.011	−0.002*	−0.024*
	(0.144)	(0.153)	(0.170)
	[7.56*]		
Teachers' reading fixed effects			
Without school fixed effects	0.018	−0.005*	−0.033*
	(0.240)	(0.237)	(0.263)
	[3.09*]		
With school fixed effects	0.014	−0.002*	−0.029*
	(0.171)	(0.173)	(0.200)
	[2.77*]		
n(teacher-years)	124,852	14,728	354

Notes: Teacher fixed effects are estimated by regressing student achievement against current teacher indicators and other inputs in the educational production function, equation 3. Cells list mean teacher fixed effects by subject, specification, and mobility status. Standard deviations are in parentheses below each mean, and F-statistics from Wald tests of the joint significance of teacher fixed effects are in brackets below each standard deviation. Data for moving teachers reference the year immediately preceding a school change. Mainstream movers (column 2) are mainstream teachers who are next observed in a different mainstream school, and asterisks in column 2 indicate a significant difference (at 95% confidence or greater) between mainstream movers and nonmobile teachers. Charter movers (column 3) are next observed in a charter school, and asterisks indicate significant differences between mainstream and charter movers.

interpretation and understates the variance in teacher quality across schools but adequately addresses between-school sorting. Both models control for students' prior place in their grade-cohort distribution, so teacher fixed effect estimates represent the degree to which teachers are responsible for advancing their students through the distribution, conditioning on baseline achievement. Controlling for prior achievement necessarily limits the analysis to fourth- and fifth-grade teachers.

Teacher fixed effects are estimated for 14,728 mobile individuals, 354 of whom are moving to a charter school. Table 5 summarizes the time-invariant teacher fixed effects generated by each specification of equation 3. Since student achievement (A^k_{ijt}) is normalized to a $\sim N(0,1)$ scale by grade and year, teacher fixed effects are in terms of student-level standard deviations. That is, a teacher with $\theta^k_j = 1$ would on average advance her students by 1 standard deviation in subject k relative to the rest of their cohort. The typical teacher in this panel advanced students by 0.011–0.018 standard deviations, as listed in the first column of table 5, and these positive values are explained by longer teaching spells for above-average teachers. Moving teachers have somewhat lower value added than nonmoving teachers, in agreement with recent work by Hanushek and Rivkin (2010). Relative to mainstream movers, charter movers have even lower value added, by 0.022–0.030 student-level standard deviations.

Simple mean differences do not control for the type of schools teachers are leaving or moving to, and charter schools may have attracted relatively high-performing teachers, compared with mainstream schools with similar student populations. In parallel to the analysis of résumé qualifications, I regress teacher fixed effect estimates against mobility indicators, sending and receiving school characteristics, and receiving county-by-year effects:

$$\hat{\theta}_j^k = \delta^{m,k}\mathbf{1}(moving)_j + \delta^{c,k}\mathbf{1}(tocharter)_j + \boldsymbol{C}^r_{sl(t+1)}\beta^k_{C^r} + \boldsymbol{C}^s_{slt}\beta^k_{C^s} + \alpha^k_{l(t+1)} + v^k_{jslt}. \quad (4)$$

Subjects (math and reading) are again indexed by k, teachers by j, schools by s, counties by l, and years by t. Table 6 presents estimates of $\delta^{m,k}$ and $\delta^{c,k}$. Column 1 lists the estimated difference in teacher fixed effects between mainstream movers and nonmovers ($\delta^{m,k}$ in equation 4), and column 2 lists conditional mean differences in teacher fixed effects between charter and mainstream movers ($\delta^{c,k}$). The rate of licensure is nearly 100 percent among elementary teachers with fixed effect estimates, and given the small number of charter movers for whom fixed effects can be estimated, I do not produce separate estimates for the subsample of regularly licensed teachers.

In agreement with unconditional mean differences in teacher fixed effects, charter movers have lower fixed effects than teachers moving between mainstream schools, and mainstream movers have lower fixed effects than nonmobile teachers. Point estimates are more precise for gaps in math value added and for gaps in teacher fixed effects estimated without controls for school fixed effects. Recall that without controls for school fixed effects, teacher fixed effects collectively represent that value-added distribution of teachers across schools. Table 6 results indicate that charter movers are on average drawn from the lower half of the teacher effectiveness distribution, by 2.6 percent of a student-level standard deviation in math and 1.8 percent in reading. Perhaps, however, charter schools tend to attract teachers from lower-performing schools, which could bias their value added down if equation 3 without school fixed effects fails to adequately control for student sorting across schools. Table 6 shows that even within sending schools, teachers moving to charter schools are 1.9 percent of a standard deviation less effective in reading

Table 6. Regression Results: Math and Reading Fixed Effects of Teachers Changing Schools, by Mainstream/Charter Destination

(Equation 4 coefficient)	(1) Mainstream Movers (δ^m)	(2) Charter Movers (δ^c)
Teachers' math fixed effects		
Without school fixed effects	−0.022	−0.026
	(11.13)	(2.08)
With school fixed effects	−0.023	−0.014
	(10.20)	(0.98)
Teachers' reading fixed effects		
Without school fixed effects	−0.012	−0.018
	(8.97)	(1.86)
With school fixed effects	−0.016	−0.019
	(9.62)	(1.67)

Notes: $n = 124{,}852$ teachers with known following year assignments, of whom 14,728 are changing schools and 354 are moving to a charter school. Column 1 lists regression-adjusted mean differences in teacher fixed effects between movers and nonmovers (δ^m in equation 4), and column 2 lists regression-adjusted mean differences in teacher fixed effects between charter and non-charter movers (δ^c). Control variables include receiving and sending school characteristics (percent nonwhite, performance composite, total enrollment, locale indicators, grade ranges served), a set of dummy variables for school missing data, and receiving county-by-year effects. The absolute values of *t*-statistics are reported in parentheses below each coefficient. Robust standard errors are clustered within each school and year.

instruction than other mobile teachers and are at best equivalent to other mobile teachers in terms of math value added.

A 0.018–0.026 gap between these two groups of mobile teachers has statistical and practical significance. Unreported coefficient estimates from equation 3 (without school fixed effects) suggest that first-year teachers are associated with significantly lower student achievement: 0.069 standard deviations in math and 0.038 standard deviations in reading. These are very similar to returns to teacher experience estimated by Clotfelter, Ladd, and Vigdor (2007). Thus the difference between a teacher moving to the charter sector and a teacher moving elsewhere is 38–47 percent of the effectiveness gap between new and more experienced teachers. Knowing that many charter movers are themselves new or inexperienced teachers, we can conclude that North Carolina's charter schools are not recruiting teachers with higher value added from traditional, mainstream public schools,[19] although the causal

19. These findings are robust to several corrections for observational biases in the estimated gap between charter and mainstream movers' value added. For instance, if mobile teachers tend to

mechanisms behind this finding remain to be seen. Charters may have lower demand for effective teachers, perhaps because of an emphasis on untested skills, or the schools may have insufficient resources to attract more effective teachers. It bears repeated emphasis that resources are not limited to salary funds. Nonpecuniary conditions like school quality, school location, institutional and administrative experience, student and parental engagement, and regulatory compliance burdens combine with salary to form the utility a teacher expects to enjoy in a new charter school. If this utility cannot dominate other options, charters will have difficulty recruiting good teachers. Results in the following subsection indicate that the effectiveness of mobile teachers varies by some of these nonpecuniary conditions—specifically, schoolwide effectiveness, urbanicity, and student racial composition.

Heterogeneous Teacher Flows between Mainstream and Charter Schools

Given the idiosyncratic nature of charter schools and their students, it may be the case that some charters draw more qualified or more effective teachers than others. Moreover, heterogeneous teacher flows have important policy implications if, for instance, more disadvantaged mainstream schools tend to lose more effective teachers to charters. To assess the relationships among teachers' qualifications, value added, and features of their sending and receiving schools, I estimate additional specifications of equations 2 and 4, adding an interaction between the charter mobility indicator $\mathbf{1}(tocharter)_j$ and one sending or receiving school characteristic. In order to compare teacher effectiveness gaps across schools, I use teacher fixed effect ($\hat{\theta}_j^k$) estimated by specifications of equation 3 without school fixed effect controls. School characteristics that are interacted with charter mobility include an indicator for urban locales, the share of students who are proficient, the share of students who are nonwhite, or schools' own math or reading value added. Schools' math and reading value added are time-varying school fixed effects estimated by the following:

$$A_{ijt}^k = \lambda A_{it-1}^k + \boldsymbol{X}_{ijt}\beta_X^k + \bar{\boldsymbol{X}}_{-ijt}\beta_{\bar{X}}^k + T_{jt}\beta_T^k + \alpha_{st}^k + \varepsilon_{ijt}^k. \quad (5)$$

be more effective in their new schools (Jackson 2010), the time-invariant fixed effects of charter movers could be biased downward, since their performance while in charter schools cannot be observed. I replicate the analysis after simulating these data limitations for all moving teachers. Specifically, I reestimate teacher fixed effects, neglecting to observe any classroom performance following a school change. Results are less precise but nonetheless suggest a 0.012–0.022 standard deviation gap in teacher fixed effects between mainstream movers and nonmovers (very similar to the first column of table 6), and a large and significant gap in math fixed effects between charter and mainstream movers. Another possibility is that the comparison group (mainstream movers statewide) is inadequate because some of them presumably do not have charter schools in their choice set. If, for instance, mainstream movers in districts without charter schools tend to have higher value added, their inclusion would widen estimates of the charter-mainstream mover gap reported in table 6. I address this possibility by estimating equation 4 for a limited sample of teachers with at least one charter elementary school in their sending county. Results indicate an even larger gap in value added between mainstream and charter movers.

Equation 5 is much like the educational production function represented by equation 3, with three differences. Most important for the current context, school fixed effects (α_{st}^{k}) vary intertemporally. Estimates of α_{st}^{k} represent each school's average value added in a given year. This allows me to compare each mobile teacher's value added with that of the current quality of her next school and further to preclude bias from any effect she may have on that school's average quality after moving there. Second, the sample of students is broader for equation 5, including students without self-contained classrooms or verified teachers. This allows me to estimate school fixed effects for charter students, who are rarely linked to classroom teachers in these data. Finally, teacher fixed effects are omitted from equation 5, in part because of weaker teacher-student linkages in this broader sample but also to identify variation in school quality across teachers.

Results are reported in table 7. Each coefficient represents the change in the gap between mainstream and charter movers' qualifications or value added associated with a marginal increase in urbanicity, student proficiency, percent of students who are nonwhite, or schoolwide effectiveness. For instance, the upper panel of table 7, column 1, indicates that teachers leaving urban mainstream schools for the charter sector are even less experienced than other charter movers, by a weakly significant 1.64 years. The lower panel shows that teachers moving *to* urban charter schools are not significantly different from other charter movers in terms of credentials or math value added, but they have lower value added in reading by 3.6 percent of a student-level standard deviation. The rate of student proficiency in sending schools (i.e., the share of students at grade level according to the state accountability system) has little relationship with the type of teachers leaving for charters, but more proficient charters draw teachers with higher licensure test scores and modestly less experience. Mainstream schools with more nonwhite students tend to lose more licensed teachers to the charter sector as well as teachers with higher licensure test scores, but they do not differentially lose more or less effective teachers. Charter schools with more nonwhite students tend to attract less qualified teachers in terms of selective college education, licensure, and licensure test scores.

Furthermore, the reading value added of teachers moving to charter schools with more nonwhite students is lower, by a weakly significant 0.004 student-level standard deviations per 10 percentage point increase in nonwhite students. Recalling the bimodal distribution of nonwhite student shares illustrated in figure 1, this means that teachers moving to a 90 percent nonwhite school are typically 0.032 standard deviations less effective in reading instruction than teachers moving to a 10 percent nonwhite school. The upper panel of table 7 shows that more effective mainstream schools tend to lose teachers with higher value added to the charter

Table 7. Regression Results: Qualifications and Classroom Performance of Teachers Moving to Charter Schools, by Characteristics of Sending and Receiving Schools

	(1) Urban[a]	(2) Proficient Students (%)	(3) Nonwhite Students (%)	(4) School Math Fixed Effect[b]	(5) School Reading Fixed Effect[b]
Teacher Credentials and Value Added by Characteristics of Sending Schools					
Holds graduate degree	0.008	6.0E-5	1.9E-4	0.017	0.101
	(0.20)	(0.06)	(0.29)	(0.14)	(0.88)
Attended competitive college	0.002	3.9E-4	−0.001	−0.218	−0.015
	(0.06)	(0.31)	(1.56)	(1.61)	(0.09)
Regularly licensed	0.009	0.001	−0.001	−0.016	0.125
	(0.32)	(1.72)	(2.32)	(0.16)	(1.03)
Mean licensure test score	0.125	0.004	−0.004	−0.438	0.351
	(1.67)	(1.56)	(2.86)	(1.85)	(1.45)
Experience (years)	−1.64	0.01	−0.01	−3.54	−3.16
	(1.85)	(0.32)	(0.37)	(1.20)	(0.97)
Days absent	−0.24	0.01	0.00	−4.16	−1.74
	(0.22)	(0.26)	(0.06)	(0.97)	(0.42)
Teacher math fixed effect[c]	0.004	−4.0E-5	1.3E-4	0.230	0.194
	(0.18)	(0.05)	(0.29)	(2.54)	(2.29)
Teacher reading fixed effect[c]	−0.010	1.4E-4	−2.9E-4	0.003	0.170
	(0.55)	(0.27)	(0.91)	(0.04)	(2.27)
Teacher Credentials and Value Added by Characteristics of Receiving Schools					
Holds graduate degree	−0.042	−0.001	2.2E-4	−0.159	−0.081
	(1.00)	(1.13)	(0.44)	(1.80)	(0.69)
Attended competitive college	0.004	0.001	−0.001	−0.091	0.053
	(0.08)	(1.48)	(2.15)	(0.92)	(0.35)
Regularly licensed	0.004	8.0E-5	−0.001	0.015	−0.048
	(0.15)	(0.17)	(2.43)	(0.28)	(0.54)
Mean licensure test score	0.067	0.003	−0.005	0.035	−0.019
	(0.77)	(2.04)	(4.60)	(0.18)	(0.07)
Experience (years)	−0.50	−0.04	0.01	−1.25	3.25
	(0.47)	(2.03)	(0.65)	(0.59)	(1.26)
Days absent	1.16	0.01	0.01	3.68	−3.78
	(0.84)	(0.39)	(0.84)	(1.28)	(0.95)
Teacher math fixed effect[c]	−0.035	−1.0E-4	−4.7E-4	0.280	0.112
	(1.47)	(0.19)	(1.37)	(2.98)	(0.90)
Teacher reading fixed effect[c]	−0.036	−2.5E-4	−4.4E-4	0.128	0.106
	(2.03)	(0.68)	(1.66)	(2.06)	(1.17)

Notes: The table lists estimated coefficients from regressions of teachers' credentials and value added on mobility indicators and characteristics of their sending or receiving schools (i.e., equations 2 and 4), including interactions between the charter mobility indicator and one sending or receiving school characteristic. The absolute values of *t*-statistics are reported in parentheses below each coefficient. Robust standard errors are clustered within each school and year.
[a]An urban area is defined as an incorporated place inside a metropolitan statistical area with a population of at least 250,000.
[b]School fixed effects are estimated by equation 5.
[c]Teacher fixed effects—limited to elementary teachers with self-contained classrooms—are estimated by equation 3, omitting school fixed effects.

sector.[20] The lower panel shows that charters with higher schoolwide value added in math tend to receive teachers with higher value added in both subjects. Charter school math fixed effects have a standard deviation of 0.262. Thus increasing the schoolwide quality of math instruction by 1 standard deviation (roughly the difference between a median charter school and a 90th percentile charter school) is associated with a 0.073 student-level standard deviation gain in recruited teachers' math value added and a 0.034 standard deviation gain in their reading value added, which more than compensates for the 0.018–0.026 standard deviation gap in charter movers' value added reported in table 7.

The positive relationship between teachers' value added and that of their receiving charter schools is illustrated in figure 2, where a mean-smoothing local polynomial plots the average value added of mobile teachers against the value added of receiving charters. The upward trend in matched teacher-school effectiveness is apparent for both subjects. Note, however, that even the most effective charter schools tend to draw teachers with below-average (i.e., below zero) value-added estimates.

The tendency of more effective teachers to move to more effective charter schools has important implications for the state's charter sector, chiefly because few North Carolina charters outperform traditional public schools. And given the well-documented importance of teacher quality in supporting student learning, recruiting less effective teachers from mainstream schools can reinforce the disadvantages charters face in raising student achievement.

Robustness Check—Biases from Student Sorting

Teacher fixed effects are interpreted as each individual's history of classroom performance relative to expectations, which should be important to schools looking to hire teachers with a record of success in raising student test scores, but nonrandom sorting of students between and within schools can lead to biased estimates of teacher effectiveness. School fixed effects control for the tendency of high-growth students to group within particular schools, but they do not control for any systematic sorting of students within schools. An example of such sorting is "teacher shopping" by parents, which has a wealth of anecdotal support. In general, there are abundant practical reasons why school leaders might not want to randomly assign students to classrooms. Rothstein (2010), using a subset of the North Carolina data employed here, shows that

20. This result is in part, but not wholly, due to the exclusion of school fixed effects in specifications estimating teacher fixed effects.

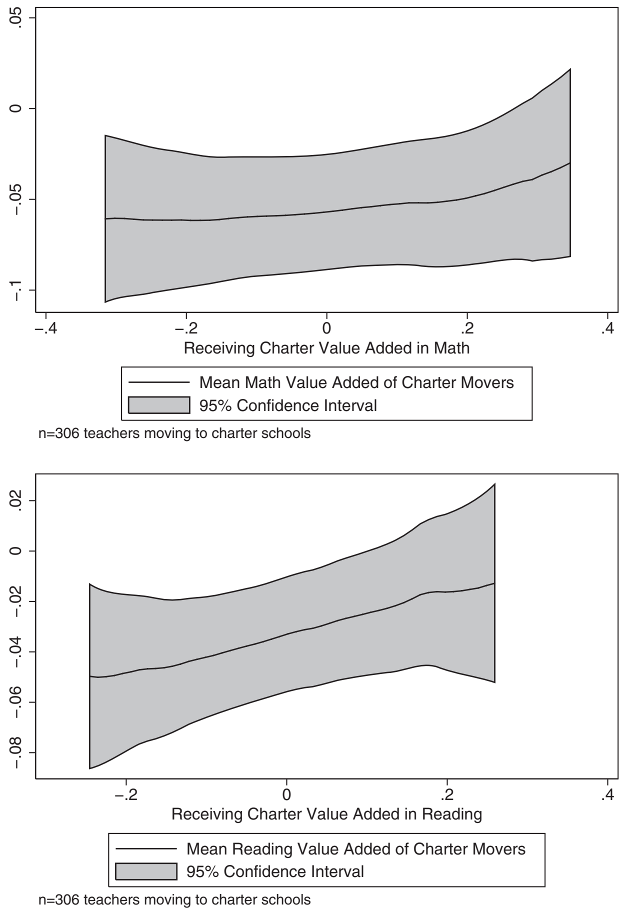

Figure 2. Panels 1 and 2 illustrate mean-smoothing estimates and confidence intervals for the relationship between charter movers' value added and the schoolwide value added of the charters they are moving to. School fixed effects are estimated by equation 5. Teacher fixed effects—limited to elementary teachers with self-contained classrooms—are estimated by equation 3, omitting school fixed effects.

common value-added methodologies falsely ascribe significant value to students' future teachers, which is symptomatic of sorting biases.[21]

Sorting biases would affect the analysis only to the degree that charter movers are more affected by nonrandom student sorting than other mobile

21. Much attention has been devoted to resolving this issue, and I apply some of the lessons learned to the evaluation of charter movers. Koedel and Betts (2011), for instance, show that teacher effect estimates derived from multiple years of data are less subject to sorting biases than single-year classroom effects. Kane and Staiger (2008) conclude that controls for a student's lagged achievement and observable characteristics of peers within his classroom are sufficient to drive the bias from nonrandom sorting to zero. Here equation 3 is estimated for a multicohort panel, generating teacher fixed effect estimates covering multiple school years. Lagged achievement and peer characteristics—at the classroom and school levels—are included in all specifications.

teachers. I investigate this possibility directly by substituting following year teacher indicators for current teacher indicators in equation 3 and then comparing the false "effects" of movers and nonmovers and of charter and mainstream movers. Summary statistics for false effects are listed in table 8. Charter movers are not significantly more connected to their students' prior achievement than are mainstream movers. Controls for school fixed effects and/or lagged achievement are not sufficient to drive the joint significance of false effects to zero (as indicated by small but significant F-statistics for false effects), but they are sufficient to eliminate any significant, spurious difference between mainstream movers and charter movers. It should be noted that these false effects reflect multiple years of sorting, not trends in sorting that may have led a teacher to change schools. In a related test, I supplement the educational production function described by equation 3 with indicators for the mobility of students' future teachers (i.e., indicating whether one's year $t + 1$ teacher moved to a mainstream or charter school in $t + 2$). If charter movers are systematically assigned more or less proficient students than other mobile teachers in the year immediately preceding a school change, the coefficient on leading charter mobility should be significantly different from that of leading mainstream mobility. Results are in agreement with those already discussed: lagged achievement and school fixed effects adequately control for significant pre-mobility differences in teachers' students.[22]

Robustness Check—Biases from Sampling Error

Sampling error from finite panel length and class size cause the variance of teacher fixed effects to overstate the variance of true value added. Furthermore, if sampling error disproportionately affects certain groups of teachers who are more likely to transition to charter schools (new teachers, for instance), comparing teacher fixed effects may put charter movers at a disadvantage. Following several recent studies, I partition the variance in persistent teacher quality from that of sampling error in students' residual achievement and construct estimates of teacher effectiveness that account for likely sampling error.[23] These variance components are used to approximate teachers' persistent value added. Drawing from Carrell and West (2008) and Kane and Staiger (2008), I construct teacher *j*'s value added by scaling her classes' residual performance toward zero according to an estimate of her signal-to-total variance ratio. This Bayesian shrinkage estimator disproportionately attenuates the value added

22. I thank an anonymous referee for suggesting this test.
23. See, e.g., Carrell and West 2008; Kane, Rockoff, and Staiger 2008; Kane and Staiger 2008; and Hanushek and Rivkin 2010.

Table 8. Future Teachers' False Effects: Summary Statistics

	(1) All Teachers	(2) Mainstream Movers	(3) Charter Movers
Teachers' false math fixed effects			
Without school fixed effects	0.002	−1.87E-04	−0.001
	(0.194)	(0.202)	(0.242)
	[2.97*]		
With school fixed effects	0.001	0.002	0.004
	(0.188)	(0.198)	(0.227)
	[1.85*]		
Teachers' false reading fixed effects			
Without school fixed effects	0.004	−0.001*	−0.005
	(0.179)	(0.192)	(0.242)
	[1.71*]		
With school fixed effects	0.005	0.003	−0.007
	(0.185)	(0.199)	(0.241)
	[1.35*]		
n(teacher-years)	66,478	8,073	184

Notes: Future teacher "effects" are estimated by regressing student achievement against leading teacher indicators and other inputs in the educational production function, equation 3. Column 1 lists average false fixed effects for all teachers. Standard deviations are in parentheses below each mean, and F-statistics from Wald tests of the joint significance of false teacher fixed effects are in brackets below each standard deviation. Data for moving teachers are evaluated in the year immediately preceding a school change. Column 2 lists mean false fixed effects for teachers moving to mainstream schools, with standard deviations in parentheses below each mean, and asterisks indicating statistically significant differences (at 95% confidence or greater) relative to nonmovers. Column 3 lists mean false fixed effects for teachers moving to charter schools, with standard deviations in parentheses below each mean, and asterisks indicating significant differences between mainstream and charter movers.

of less experienced teachers who are expected to have been more affected by sampling error. Computational details are provided in the appendix.

Figure 3 illustrates the effect of Bayesian scaling and affords a visual comparison of future charter teachers' value added versus that of their exclusively mainstream counterparts. Panel 1 plots comparative kernel densities of teachers' math fixed effects, controlling for students' lagged achievement but not school fixed effects. Panel 2 plots densities of teachers' mathematics value-added estimates from Bayesian shrinkage estimators, again controlling for lagged achievement but not school fixed effects.[24] The distribution of future charter teachers' value added is significantly left of the distribution of other mainstream teachers' value added, regardless of Bayesian scaling. Wilcoxon

24. Figures for reading value added are qualitatively equivalent to figure 3.

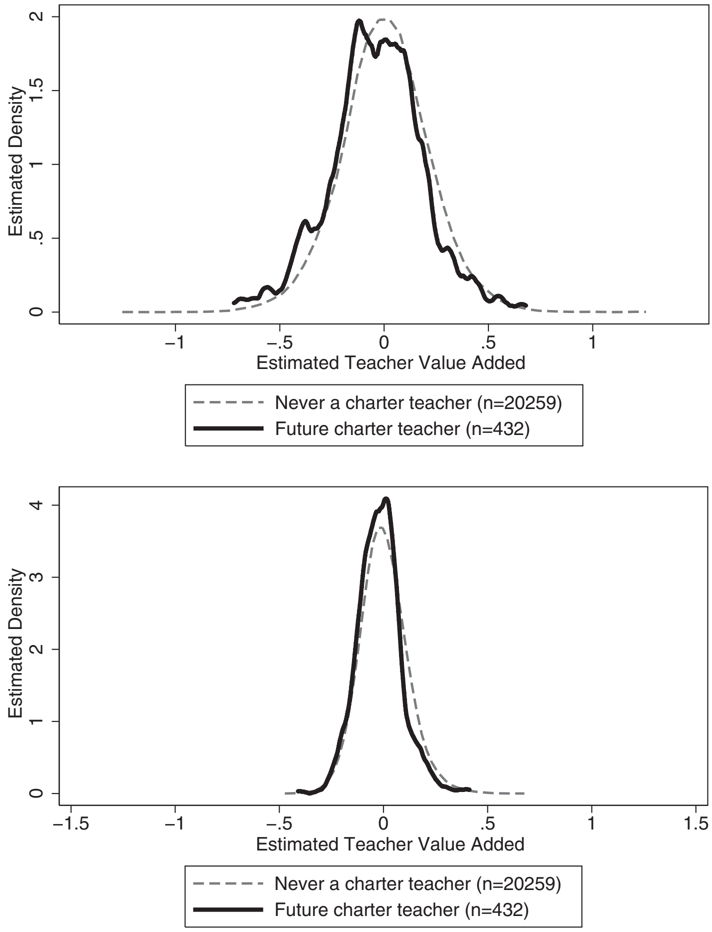

Figure 3. Panels 1 and 2 illustrate kernel density estimates of future charter teachers' math value added (solid line), relative to the same for exclusively mainstream teachers (dashed line). Panel 1: distribution of teacher fixed effects, controlling for lagged student achievement. Panel 2: distribution of persistent value added (via Bayesian shrinkage estimators), controlling for lagged achievement. Densities are estimated using Epanechnikov kernel functions and halfwidths of 0.025 standard deviations.

rank-sum tests reject the hypothesis that future charter teachers and exclusively mainstream teachers are drawn from the same distribution of value added. Figure 3 provides further evidence that teachers flowing to the charter sector typically have lower classroom performance than other mainstream teachers, but also demonstrates considerable overlap and variation in teacher quality across groups.

6. CONCLUSIONS, IMPLICATIONS, AND CAVEATS

In many ways, autonomous charter schools are well positioned to exploit any inefficiencies in monopsonistic markets for public teachers. Mainstream teachers in North Carolina, as in other systems, are paid according to rigid salary schedules that climb steadily with experience and graduate degrees, despite compelling evidence that the returns to experience are largely exhausted after the first few years of a teacher's career and that the returns to graduate degrees are insignificant. Charter administrators are free to hire, compensate, and fire according to merit and robust signals of teacher quality. They also have the flexibility to structure work environments that are more appealing to teachers, whereas many elements of mainstream employment (especially curricula) are centrally managed. But do charter schools have the resources to exploit these inefficiencies and attract good teachers from the mainstream? Tighter budgets, institutional inexperience, and challenging student populations may limit the appeal of working in a charter school.

I find that the North Carolina teachers who leave the mainstream public school sector for charter schools are less qualified and less effective than other mobile teachers, even in the presence of controls for sending and receiving school environments. These results suggest that charters have lower demand for these teacher qualities or that charters have insufficient resources to outbid competing mainstream schools, or both. The relative risk of charter mobility increased with nonwhite student shares in mainstream schools, so choice schools may exacerbate higher turnover in high-minority schools. It is important to note, however, that charters could reduce overall teacher turnover by offering a viable alternative to nonteaching careers. Charter movers resembled teachers leaving North Carolina public schools more so than other mobile teachers, but charter movers taught for another 3.24 years on average. Low-performing or high-minority mainstream schools do not lose substantially more effective or more qualified teachers to the charter sector, but among recipient charters better teachers gravitate to better schools, schools with fewer nonwhite students, and schools in less urban areas. These patterns will likely reinforce subpar achievement in North Carolina's charter schools.

Three important caveats and open questions must be emphasized alongside these results. First, charter teachers' value added *while in charter schools* remains an important but unexplored topic, largely because of data limitations. It may be the case that charter teachers recruited straight from college or other careers are much more effective than teachers who opt out of traditional public schools. Or it is possible that charter movers become much more effective upon entering a charter school. These two possibilities seem unlikely to reverse this study's implication that North Carolina's charter teachers have lower value added, given persistently low student achievement in the state's charter system. Second, although North Carolina's charter infrastructure resembles that of many other systems in terms of finance and regulation, results may not generalize to other settings. Charters may be better suited to attract talented teachers in settings where charter schools outperform traditional public schools (as in successful urban charter programs). Similarly, in areas with thicker choice markets (i.e., with more competitive choice systems or looser caps on the number of charter schools), the typical charter school may be more appealing to teachers with options in multiple sectors. Finally, this study joins many others in using "teacher quality" and econometric estimates of "value added" interchangeably. But rather than being below-average teachers, it is possible that charter movers are less devoted to standardized testing or that charters have lower relative demand for teachers who advance tested achievement rather than other school objectives. These possibilities are difficult to explore with administrative data but present an opportunity for observational or qualitative research. Nonetheless, if North Carolina's EOG exams reflect a set of appropriate cognitive standards, the relative ability of future charter teachers to raise student achievement has important implications for the successful application of school choice. Regarding this dimension of teacher quality, North Carolina charter teachers compare unfavorably to other teachers while they are teaching in mainstream schools.

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REFERENCES

Abdulkadiroglu, Atila, Joshua Angrist, Susan Dynarski, Thomas J. Kane, and Parag Pathak. 2011. Accountability and flexibility in public schools: Evidence from Boston's charters and pilots. *Quarterly Journal of Economics* 126(2): 699–748.

Bifulco, Robert, and Katina Bulkley. 2008. Charter schools. In *Handbook of research in education finance and policy*, edited by Helen F. Ladd and Edward B. Fiske, pp. 425–46. New York: Routledge.

Bifulco, Robert, and Helen F. Ladd. 2006. The impacts of charter schools on student achievement: Evidence from North Carolina. *Education Finance and Policy* 1(1): 50–90.

Bifulco, Robert, and Helen F. Ladd. 2007. School choice, racial segregation, and test-score gaps: Evidence from North Carolina's charter school program. *Journal of Policy Analysis and Management* 26(1): 31–56.

Booker, Kevin, Scott Gilpatric, Timothy Gronberg, and Dennis Jansen. 2008. The effect of charter schools on traditional public school students in Texas: Are children who stay behind left behind? *Journal of Urban Economics* 64(1): 123–45.

Boyd, Donald, Pamela Grossman, Hamilton Lankford, Susanna Loeb, and James Wyckoff. 2006. How changes in entry requirements alter the teacher workforce and affect student achievement. *Education Finance and Policy* 1(2): 176–216.

Budde, Ray. 1988. Education by charter: Restructuring school districts key to long-term continuing improvement in American education. Andover, MA: Regional Laboratory for Educational Improvement of the Northeast & Islands.

Carrell, Scott E., and James E. West. 2008. Does professor quality matter? Evidence from random assignment of students to professors. NBER Working Paper No. 14081.

Carruthers, Celeste K. 2012. New schools, new students, new teachers: Evaluating the effectiveness of charter schools. *Economics of Education Review* 31(2): 280–92.

Clotfelter, Charles T., Helen F. Ladd, and Jacob L. Vigdor. 2007. Teacher credentials and student achievement: Longitudinal analysis with student fixed effects. *Economics of Education Review* 26(6): 673–82.

Dee, Thomas S. 1998. Competition and the quality of public schools. *Economics of Education Review* 17(4): 419–27.

Dobbie, Will, and Roland G. Fryer. 2011. Are high-quality schools enough to increase achievement among the poor? Evidence from the Harlem children's zone. *American Economic Journal: Applied Economics* 3(3): 158–87.

Falch, Torberg, and Bjarne Strøm. 2005. Teacher turnover and non-pecuniary factors. *Economics of Education Review* 24(6): 611–31.

Gleason, Philip, Melissa Clark, Christina Clark Tuttle, and Emily Dwoyer. 2010. The evaluation of charter school impacts: Final report. NCEE 2010-4029. Washington, DC: U.S. Department of Education, Institute of Education Sciences.

Goldhaber, Dan. 2007. Everybody's doing it, but what does teacher testing tell us about teacher effectiveness? *Journal of Human Resources* 42(4): 765–94.

Goldhaber, Dan. 2008. Teachers matter, but effective teacher quality policies are elusive. In *Handbook of research in education finance and policy*, edited by Helen F. Ladd and Edward B. Fiske, pp. 146–65. New York: Routledge.

Hanushek, Eric A., John F. Kain, and Steven G. Rivkin. 2004. Disruption versus Tiebout improvement: The costs and benefits of switching schools. *Journal of Public Economics* 88(9–10): 1721–46.

Hanushek, Eric A., and Steven G. Rivkin. 2010. Constrained job matching: Does teacher job search harm disadvantaged urban schools? NBER Working Paper No. 15816.

Hastings, Justine S., Thomas J. Kane, and Douglas O. Staiger. 2009. Heterogeneous preferences and the efficacy of public school choice. NBER Working Paper No. 12145.

Hoxby, Carolyn M. 2002. Would school choice change the teaching profession? *Journal of Human Resources* 37(4): 846–91.

Hoxby, Carolyn M. 2003. School choice and school productivity: Could school choice be a tide that lifts all boats? In *The economics of school choice*, edited by Carolyn M. Hoxby, pp. 287–342. Chicago: University of Chicago Press.

Hoxby, Carolyn M., and Sonali Murarka. 2009. Charter schools in New York City: Who enrolls and how they affect their students' achievement. NBER Working Paper No. 14852.

Jackson, C. Kirabo. 2010. Match quality, worker productivity, and worker mobility: Direct evidence from teachers. NBER Working Paper No. 15990.

Jackson, C. Kirabo. 2011. School competition and teacher labor markets: Evidence from charter school entry in North Carolina. NBER Working Paper No. 17225.

Kane, Thomas J., Jonah E. Rockoff, and Douglas O. Staiger. 2008. What does certification tell us about teacher effectiveness? Evidence from New York City. *Economics of Education Review* 27(6): 615–31.

Kane, Thomas J., and Douglas O. Staiger. 2008. Estimating teacher impacts on student achievement: An experimental evaluation. NBER Working Paper No. 14607.

Koedel, Cory, and Julian R. Betts. 2011. Does student sorting invalidate value-added models of teacher effectiveness? An extended analysis of the Rothstein critique. *Education Finance and Policy* 6(1): 18–42.

Kolderie, Ted. 1990. Beyond choice to new public schools: Withdrawing the exclusive franchise in public education. Policy Report No. 8. Washington, DC: Progressive Policy Institute.

Lanier, Josh. 2008. Teachers' questions about pay unanswered: School's financial woes topic of meeting with faculty, parents. *Independent Tribune* (Concord, NC), 22 February.

Loeb, Susanna, Demetra Kalogrides, and Tara Béteille. 2012. Effective schools: Teacher hiring, assignment, development, and retention. *Education Finance and Policy* 7(3): 269–304.

Malloy, Courtney L., and Priscilla Wohlstetter. 2003. Working conditions in charter schools: What's the appeal for teachers? *Education and Urban Society* 35(2): 219–41.

Murnane, Richard J., and Barbara R. Phillips. 1981. Learning by doing, vintage, and selection: Three pieces of the puzzle relating to teaching experience and teaching performance. *Economics of Education Review* 1(4): 453–65.

Muschkin, Clara, Kara Bonneau, and Kenneth Dodge. 2009. North Carolina Education Research Data Center. Grant No. 200300138. Annual report to the Spencer Foundation. Available www.childandfamilypolicy.duke.edu/pdfs/projects/NCERDC_SpencerReport2009_final.pdf. Accessed 20 January 2012.

Podgursky, Michael, and Dale Ballou. 2001. *Personnel policy in charter schools*. Washington, DC: Thomas B. Fordham Foundation.

Rockoff, Jonah E. 2004. The impact of individual teachers on student achievement: Evidence from panel data. *American Economic Review* 94(2): 247–52.

Rothstein, Jesse. 2010. Teacher quality in educational production: Tracking, decay, and student achievement. *Quarterly Journal of Economics* 125(1): 175–214.

Scafidi, Benjamin, David L. Sjoquist, and Todd R. Stinebrickner. 2007. Race, poverty, and teacher mobility. *Economics of Education Review* 26(2): 145–59.

Stuit, David A., and Thomas M. Smith. 2012. Teacher turnover in charter schools. *Economics of Education Review* 31(2): 268–79.

Taylor, Lori L. 2005. Teacher cream skimming: Do charter schools attract the most effective teachers? Unpublished paper, Texas A&M University.

Todd, Petra E., and Kenneth I. Wolpin. 2003. On the specification and estimation of the production function for cognitive achievement. *Economic Journal* 113(485): F3–F33.

APPENDIX: CONSTRUCTION OF BAYESIAN SHRINKAGE ESTIMATORS

Consider equation 3, omitting teacher fixed effects (θ_j) and suppressing subject notation:

$$A_{ijt} = \lambda A_{it-1} + \boldsymbol{X}_{ijt}\beta_X + \bar{\boldsymbol{X}}_{-ijt}\beta_{\bar{X}} + T_{jt}\beta_T + \boldsymbol{C}_{st}\beta_C + \boldsymbol{\alpha}_s + \varepsilon_{ijt}. \quad \text{(A1)}$$

Residuals are $e_{ijt} = \theta_j + \eta_{jt} + \varepsilon_{ijt}$, where θ_j is the persistent effectiveness with which teacher j can advance students' place in their cohort distribution, η_{jt} represents nonpersistent classroom shocks, and ε_{ijt} represents nonpersistent student shocks. An example of η_{jt} would be the shared effect of a dog barking outside the classroom on test day, and ε_{ijt} could be driven by student i having a uniquely bad morning prior to taking his end-of-grade exam. I estimate equation A1 with and without school fixed effects (α_s) and decompose residual variance into the variance of each component: $\hat{\sigma}^2_\theta$, $\hat{\sigma}^2_\eta$, and $\hat{\sigma}^2_\varepsilon$. Of particular interest is $\hat{\sigma}^2_\theta$, the standard deviation of persistent teacher quality.

The average student residual for each class can be expressed as:

$$\hat{\bar{e}}_{jt} = \theta_j + \eta_{jt} + \frac{1}{N_{jt}}\sum\nolimits_{i=1}^{N_{jt}} \varepsilon_{ijt}, \quad \text{(A2)}$$

where N_{jt} is class size for year t. If θ_j, η_{jt}, and $\bar{\varepsilon}_{jt}$ are independent, the variance of $\hat{\bar{e}}_{jt}$ across teachers can be decomposed into the variance of persistent value added and the variance of nonpersistent error: $\mathbb{E}[\hat{\bar{e}}^2_{jct} = \sigma^2_\theta + \sigma^2_\eta + \sigma^2_s]$, where σ^2_θ is the variance of persistent teacher quality, σ^2_η is the variance of classroom-by-year residuals not attributable to teachers, and σ_s^2 is the variance of student-by-year residuals not attributable to teacher or classroom effects. Consider two average residuals from two different classes taught by the same teacher: $\hat{\bar{e}}_{jt}$ and $\hat{\bar{e}}_{jt'}$, where $t \neq t'$. If the three residual components are uncorrelated contemporaneously, and if nonpersistent shocks are uncorrelated intertemporally, then

$$\mathbb{E}[\hat{\bar{e}}_{jt}\hat{\bar{e}}_{jt'}] = \sigma_\theta^2. \tag{A3}$$

The assumption that θ_j, η_{jt}, and $\bar{\varepsilon}_{jt}$ are uncorrelated is nontrivial: in fact, it is one of the assumptions that must be met in order to interpret estimated teacher fixed effects as unbiased measures of teacher quality. Positive matching of better students with better teachers, for instance, will increase estimates of σ_θ^2. In addition, omitting teacher fixed effects in equation A1 may bias other coefficients if they are correlated with θ_j; this in turn will bias estimated residuals, $\hat{\bar{e}}_{jt}$. Controlling for school fixed effects in equation A1 limits biases from between-school sorting, but within-school assignment patterns may nonetheless affect σ_θ^2 estimates.

Following Carrell and West (2008), I estimate σ_θ^2 by computing the pairwise covariance of classroom-averaged residuals between teacher *j*'s class in year *t* and all *j* classes in years $t' \neq$ t:

$$\hat{\sigma}_\theta^2 = \left[\sum\nolimits_{j=1}^{J} \sum\nolimits_{t=1}^{C_j} \hat{\bar{e}}_{jt}\hat{\bar{e}}_{jt'}\right] / N, \tag{A4}$$

where *J* is the number of teachers in the sample, C_j is the number of classes taught by teacher *j*, and *N* is the number of same-teacher pairs.

The remaining steps follow Kane and Staiger (2008). The variance of student-by-year residuals is approximated by $\hat{\sigma}_\theta^2 = var(e_{ijt} - \bar{e}_{jt})$, the variance of deviations from class means. The variance of class-by-year residuals is taken to be the gap between the total variance of errors and the sum of teacher-induced and student-by-year residual variance: $\hat{\sigma}_\eta^2 = var(e_{ijt}) - (\hat{\sigma}_\theta^2 + \hat{\sigma}_\varepsilon^2)$. For each teacher *j*, I compute $\tilde{e}_j = \sum_{t=1}^{C_j} \omega_{jt}\bar{e}_{jt}$, a weighted average of her classroom-averaged residuals. Weights are as follows:

$$\omega_{jt} = \left(\frac{1}{\hat{\sigma}_\eta^2 + \frac{\hat{\sigma}_\varepsilon^2}{N_{jt}}}\right) * \left[\sum\nolimits_{s=1}^{T_j} \frac{1}{\hat{\sigma}_\eta^2 + \frac{\hat{\sigma}_\varepsilon^2}{N_{js}}}\right]^{-1}. \tag{A5}$$

Note that weights favor classes with more students. As class size grows, sampling error is expected to diminish. Class size per se is included as a control variable in educational production function regressions, so losses from attending larger classes are reflected in teachers' value-added estimates.

The empirical Bayes estimator of each teacher's value added is computed by scaling $\tilde{e}_j$ toward zero by the approximated signal-to-total variance ratio in residual classroom performance:

$$\hat{\theta}_j^{Bayes} = \tilde{e}_j * \left(\frac{\sigma_\theta^2}{var(\tilde{\theta}_j)} \right) \quad \text{(A6)}$$

$$var(\tilde{e}_j) = \hat{\sigma}_\theta^2 + \left[\sum_{s=1}^{C_j} \frac{1}{\hat{\sigma}_\eta^2 + \frac{\hat{\sigma}_\varepsilon^2}{N_{js}}} \right]^{-1}. \quad \text{(A7)}$$

Note that the only components of the scaling factor that are unique to teacher j are C_j, the number of classes she taught in the panel, and N_{jt}, the number of students in a particular class. The scaling factor multiplying $\hat{\theta}_j^{Bayes}$ is increasing in N_{jt} and C_j, so $\hat{\theta}_j^{Bayes}$ will be scaled by less for teachers with more students or more experience.