The Determinants and Consequences of Within-Year Teacher Turnover

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CHAPTER 1

INTRODUCTION

A substantial literature has emerged to describe teachers' systematic labor patterns. A fundamental assumption of this literature has been that teacher turnover occurs between school years. I examine the tenability of this assumption using rich administrative data from North Carolina that enable me to measure teacher turnover not only as an annual event but as occurring at any month throughout the school year. Documenting the teacher turnover that occurs within school year allows for a more complete and accurate picture of how this instability occurs not just between school years, but during the school year as well. If within-year turnover is a low-frequency event and evenly spread among all types of schools, then, it may not be necessary to do more than document when, where, by whom, and the extent to which it occurs. Yet, if within-year turnover is a frequent occurrence or occurs disproportionately at underserved schools, within-year turnover may adversely affect students as well as their administrators who are forced to find a replacement teacher in the middle of the school year.

Each of the studies in this dissertation, demarcated as chapters, address a different element of within-year teacher turnover. In the first study, I begin by describing the frequency with which within-year teacher turnover occurs, including measuring the extent to which other measures of teacher turnover misidentify the true frequency with which teachers turn over by overlooking within-year turnover. I then consider the teacher and school characteristics associated with higher levels of within-year turnover. I also identify the ways in which within-year turnover patterns resemble or differ from end-of-year turnover.

Unlike this first study that focuses on all public school teachers in North Carolina, the second study attends to novice teacher turnover. In this paper, I argue that an increasingly less

experienced teacher labor force who have entered teaching from more varied entry pathways appear to be feeding a new dynamic whereby novice teachers begin their career in schools with higher concentrations of economically disadvantaged and racial/ethnic minority students. As these schools tend to have more challenging working conditions, teachers new to the profession risk becoming demoralized, leading to higher turnover, even during the school year. The unique contribution of this study is the use of survival analysis to model turnover monthly throughout the year, rather than as a single annual event occurring at one point in time. This approach allows me to understand how differences in the timing of novice teacher turnover across teacher entry pathway and school characteristics.

The final study shifts the focus from the teacher and school characteristics that predict within-year turnover to the impact that such turnover has on students. This study conceptualizes teacher turnover as harming student achievement through three distinct mechanisms: (1) staff instability; (2) classroom disruption; (3) differences in quality of replacement and replaced teacher. The destabilizing effect of teacher turnover is likely greater when turnover occurs during the school year than at the end of the year. Yet, within-year teacher turnover is likely to be most detrimental for the students assigned to the teacher who leaves midyear. In addition to the disruptive effect of losing their teacher, the replacement teacher may be a long-term substitute or be hired from a pool of less qualified teachers. This paper relies on a variety of fixed effects models to identify differences in the effect of turnover depending on the timing in the school year and organizational unit in which it occurs.

Taken together, the three studies in this dissertation add breadth to the policy discourse surrounding teacher turnover. In the literature, teacher turnover is treated as occurring between the end of one school year and the beginning of the next. Yet, if the underlying factors which

predict within- versus end-of-year turnover differ, policy levers to address this problem may also differ, depending on the timing of turnover. For instance, compared to teacher incentive programs that reward teachers in the subsequent school year, loss aversion may be exploited by asking teachers to give back money if they do not remain in their school. Examining teachers' employment status every month increases our understanding of turnover as an ongoing management problem that schools, their leaders, and staff must contend with, rather than an annual recruitment and hiring activity.

CHAPTER 2

NEW EVIDENCE ON THE FREQUENCY OF TEACHER TURNOVER: CONSIDERING WITHIN-YEAR TURNOVER

Introduction

Despite the overwhelming impact of teachers on student learning (Chetty, Friedman, & Rockoff, 2013; Rivkin, Hanushek, & Kain, 2005; Rockoff, 2004), more qualified and effective teachers are less likely to teach the students most in need (Goldhaber, Lavery, & Theobald, 2015; Steele, Pepper, Springer, & Lockwood, 2015). To understand the factors that contribute to this entrenched pattern in the teacher labor market, a substantial research base describes the factors most strongly related to teacher turnover. Research has shown that teachers are more likely to move from high-poverty schools with high concentrations of low-income students and traditionally underserved racial/ethnic groups, which also tend to have more challenging working conditions at the classroom and school level (Borman & Dowling, 2008; Guarino, Santibañez, & Daley, 2006; Ingersoll, 2001). This positive sorting, whereby the most effective teachers are matched with higher performing students, leaves the students most in need strong instructional support with less exposure to high quality teachers (Clotfelter, Ladd, & Vigdor, 2007; Goldhaber et al., 2015; Kalogrides, Loeb, & Beteille, 2013).

A limitation of this research base is that it assumes teacher turnover only occurs between school years. Researchers have operationalized the measurement of teacher turnover with little direct attention to the turnover that occurs during the school year. Some researchers count teachers in the spring of one year who are not present the following fall (e.g. Clotfelter, Glennie, Ladd, & Vigdor, 2008). Others identify whether and where a teacher is employed based on their active employment in October or November, compared to their employment status in the same month in the previous year (Allensworth, Ponisciak, & Mazzeo, 2009; Ronfeldt, Loeb, &

Wyckoff, 2013). While examination of year-to-year turnover has produced several important findings, turnover within the school year, for example when beginning teachers find teaching too stressful or when teachers transfer to other schools, may have even greater effects on student outcomes. Anecdotal information about within-year teacher turnover based on principal reports and teachers' comments has become more common, but the magnitude and nature of this phenomena have yet to be quantified. We begin to address this gap in the study presented in this manuscript.

Within-year teacher turnover has five potential consequences that make it important to quantify it generally and then to examine the extent to which it disproportionally affects high poverty, low achieving schools. First, turnover during the school year may be particularly disruptive to students, as this turnover undermines instructional continuity and student-teacher relationships within the classroom. Second, when teachers leave mid-year, their students may be assigned long-term substitutes while the school hires a replacement. Also, the supply of mid-year hires may leave less qualified teachers to replace the teacher who left. Third, in addition to the direct impact on the students who face this disruption, turnover undermines amassed social capital, which forms the basis of collegiality between school staff (Johnson, Kraft, & Papay, 2012; Simon & Johnson, 2015). Fourth, current measures of teacher turnover may substantially underestimate teacher turnover by not addressing within-year turnover and any bias seems likely to be greater in the schools that experience the highest within-year turnover. Fifth, if within-year teacher turnover occurs disproportionately at schools with high concentrations of low-income students and underrepresented minorities, administrators at these schools may be forced to dedicate their time and effort to staff teacher vacancies in classrooms that may have been better spent on instructional improvements. The literature describes a segment of high turnover schools

plagued by instability, the erosion of professional norms, and the absence of mentors for new teachers, which may be distracted from improvement efforts by the need to recruit and fill mid-year teacher vacancies (Ingersoll, 2001; Loeb, Darling-Hammond, & Luczak, 2005) and depress student outcomes. Documenting the teacher turnover that occurs within school year allows for a more complete and accurate picture of how this instability occurs not just between school years, but during the school year as well.

However, if within-year turnover is a low-frequency event and evenly spread among all types of schools, then, it may not be necessary to do more than document when, where, by whom, and the extent to which it occurs. During the school year, teacher transfer may relate primarily to districts' needs to ensure that all schools are adequately staffed based on shifting student enrollments. In contrast, research on end-of-year teacher sorting has shown how teachers are more likely to move from schools with high concentrations of students of color and weak leadership (Ingersoll, 2001; Ladd, 2011; Schweig, 2014).

In this paper, we describe the frequency with which within-year teacher turnover occurs and the types of teacher and school characteristics associated with higher levels of this type of turnover that has not been addressed in prior research. Building off of the substantial research on the dynamics of teacher labor markets, we also seek to identify the ways in which within-year turnover patterns resemble or differ from end-of -year turnover. We address three main research questions:

1) To what extent do teachers turn over during the school year? How does this within-year turnover rate compare to end-of -year turnover?

2) What are the teacher background characteristics, school demographic characteristics, and working conditions of teachers who leave during the school year? How do these characteristics compare to end-of-year turnover?
3) To what extent do the background characteristics of the teachers or the characteristics of their schools predict within-year turnover? How do the predictors of within- and end-of-year turnover compare?

The following section summarizes previous research on teacher turnover and discusses the ways in which this body of research may apply to within-year turnover. In doing so, we focus on teacher background characteristics and school demographic characteristics and working conditions. We then describe the sample of teachers used for this study, the data, and the methods.

Literature Review

Characterizing Within-Year Turnover

One of the first challenges in understanding within-year turnover is describing the ways in which it is similar to and different from the turnover that occurs between school years. Similar to end-of-year turnover, within-year turnover consists of teachers moving between schools ("movers") and leaving teaching ("leavers"). However, it is different from between year turnover in that teachers may leave and return to the same school during the year ("returners").

Also, teacher turnover may be voluntary or involuntary. In contrast to moving schools at the end of the school year, moving schools within the year may be more likely to be involuntary, particularly when it occurs in the same district. Involuntary within-year transfers may be primarily in response to shifting student enrollment patterns that require a teacher hired at one school to transfer to another school in the district. These staffing decisions tend to be seniority-

based, although there is variation across district policy within states (Koski & Horng, 2007), with some districts able to make more strategic transfers (Grissom, Loeb, & Nakashima, 2013). Among the three largest districts in North Carolina, the site of the current study, data from the National Council on Teacher Quality (2013) show that Charlotte-Mecklenburg and Guilford County Schools place more of an emphasis on seniority whereas Wake County Schools assigns teachers in the "best interests" of the district, although Charlotte-Mecklenburg adopted a discretionary layoff policy during layoffs following the Great Recession (Kraft, 2015). With most within-year, within-district moving attributable to involuntary transfer, most voluntary moves occur when teachers move to different districts within the state.

In contrast to switching schools mid-year, leaving the teaching profession during the school year would appear to be primarily voluntary as the most common involuntary reason for leaving teaching—contract nonrenewal—tends to occur at the end of the school year. An additional exception to this pattern may be staff reductions following the Great Recession, which may have occurred during the school year or non-renewals at the end of the school year. When teachers voluntarily leave during the school year, it is likely rooted in intense dissatisfaction with teaching. Research suggests teacher dissatisfaction and exit of the teacher workforce is linked to working conditions, to the extent that school conditions inhibit teachers' ability to develop professionally (Horng, 2009; Johnson, Kraft, & Papay, 2012; Kraft & Papay, 2014). Early career teachers may be particularly sensitive to the influence of classroom and school working conditions when making their decision to leave their school and the profession (Smith & Ingersoll, 2004).

The final type of teacher turnover analyzed in this paper includes teachers who temporarily leave their school for a part of the year and return to the same school either in the

current year or next. The turnover patterns of these returners has generally been overlooked in studies of the teacher labor market. One exception is Grissom and Reininger's (2012) study of the personnel, work, and family factors associated with teachers' return to teaching. Drawing on the National Longitudinal Survey of Youth, 1979 cohort, they find approximately half of teachers who left teaching to re-enter the profession within ten years of their exit. Of teachers who leave and return, 48 percent of these teachers return after one-year outside the profession, with another 19 percent returning after the second year. In survival analysis, they find female, younger, better paid, and more experienced teachers are more likely to reenter when controlling for a range of teacher characteristics. Whereas these authors examined teachers who exit the profession for at least one year, we focus on teachers who returned after a minimum of a month-long spell out of the classroom. With no information on school characteristics, they were not able to document the types of schools in which these returners work. Studies on teacher absences, which may be related to leaving and returning within a year, find higher absentee rates in schools with higher concentrations of low-income students (Clotfelter, Ladd, & Vigdor, 2009; Miller, Murnane, & Willett, 2007). We now turn to the broader teacher turnover literature to link within-year turnover with the body of literature on the factors predictive of end-of-year turnover.

Teacher Turnover Literature

The teacher turnover literature has coalesced on a set of central findings related to the teacher and school characteristics most predictive of turnover (Borman & Dowling, 2008; Guarino et al., 2006). The literature distinguishes between teacher background characteristics, school demographic characteristics, and school working conditions as all having an important influence on teachers' decision to remain in their current school, move schools, or leave teaching. We review findings from this literature to develop reasonable working hypotheses of

how teacher, classroom, and school characteristics may predict within-year teacher turnover. Recognizing that this literature is built around understanding end-of-year turnover, we note areas in which teacher and school characteristics may predict within-year teacher turnover differently than end-of-year turnover.

Among teacher demographic characteristics, research on end-of-year turnover has found that men are more likely to leave teaching (Borman & Dowling, 2008), although women may be more likely to temporarily leave and re-enter following child rearing (Grissom and Reininger, 2012). White teachers have generally been found to turnover at higher rates (Ingersoll, 2001, Kirby, Berend, & Naftel, 1999; Hanushek, Kain, & Rivkin, 2004), although more recent research suggests a reversal of the pattern with higher turnover rates among teachers of color, particularly Black teachers (Ingersoll, 2015). Regarding teacher age, researchers have come to identify a U-shaped distribution of attrition and age and experience, with both the youngest and oldest teachers most likely to turnover (Borman & Dowling, 2008; Guarino, et al., 2006). Of this set of teacher characteristics, there is no indication that systematic differences would exist when comparing end-of-year and within-year turnover.

Outside of teacher retirements, end-of-year teacher turnover is most likely to occur at the beginning of teachers' careers (Ingersoll, Merrill, & Stuckey, 2014). There are reasons to believe that within-year teacher turnover occurs at similarly higher rates among new teachers. Through inverse-seniority policies—so called "Last in, First Out"—new teachers are most likely to be laid off as part of staffing cuts (Goldhaber & Theobald, 2013), which may occur over the summer or, perhaps with less frequency, during the school year. Seniority policies may also shape the transfer for teachers within a district, with novice teachers more likely to be transferred mid-year to meet staffing needs within the district. New teachers may also be more likely to leave teaching

during the school year in comparison to their more experienced colleagues. With less time invested in their careers, when faced with the demands of acculturation into the teaching profession, demoralization or burnout may lead to premature exit. New alternate entry and out-of-state prepared teachers may be at a particular risk to this within-year turnover as the opportunity costs associated with entry into teaching are much lower than teachers from traditional pathways, especially within the same state (Bastian & Henry, 2014; Redding & Smith, 2016).

Among school characteristics, researchers have described systematic patterns in the teacher labor market where teachers more frequently transfer out of under-resourced urban schools with high concentrations of low-income students and traditionally underserved racial/ethnic groups (Lankford, Loeb, & Wyckoff, 2002). For instance, Hanushek and colleagues' (2004) observe a strong relationship between schools with higher rates of free or reduced price lunch (FRPL), lower achievement levels, and higher minority student enrollments and higher turnover rates in public schools in Texas.[1] However, this study and others drawing on administrative data tend not to include measures of school working conditions. Without controlling for school working conditions, these estimates would likely be upwardly biased to the extent to which working conditions are negatively correlated with greater poverty, lower performance and minority student enrollment. Several papers offer a corrective, controlling for a range of teacher-reported working conditions.

Leadership—either at the administrative level or distributed among teachers—tends to be particularly important in teachers' retention decisions. Using data from the Schools and Staffing

[1] The notable exception to this pattern is that for Black teachers, as the percentage of black students increases, black teachers are increasingly more likely to stay. (Kirby, Berends, & Nattel, 1999). Congruence between teacher and principal race is also associated with lower turnover rates (Grissom & Keiser, 2011).

Survey, Grissom (2011) finds a positive association between principal effectiveness and teacher retention, particularly for schools in the highest quartile of Black or Hispanic students or economically disadvantaged students. Similarly, in New York City, Boyd and colleagues (2011) report that administrator support is the most influential school characteristic in retaining teachers. In North Carolina, Ladd (2011) also finds principal leadership to be predictive of planned and actual movement between schools. Yet, when Schweig (2014) re-estimates teacher survey responses using multilevel exploratory factor analysis to account for shared variance in the error term associated with multiple respondents in the same school, he finds distributed leadership to be a stronger predictor of intended departure than school leadership. Other studies have affirmed the importance of distributed leadership, finding that teacher influence over school decisions (Allensworth, Ponisciak, & Mazzeo, 2009; Ingersoll, 2001) and more opportunities for teacher collaboration (Smith & Ingersoll, 2004) are associated with lower turnover rates, particularly among novice teachers. In addition to these social conditions, student conflict is predictive of higher turnover rates (Boyd et al., 2011; Ingersoll, 2001).

From this literature, we identify a series of hypotheses that we believe are related to within-year turnover. Among teacher background characteristics, we expect younger and older, white, male, alternate entry teachers, out-of-state, and teachers with less experience to turnover during the school year at higher rates. We also predict that teachers most likely to leave within the school year work in schools with higher concentrations of economically disadvantaged students and traditionally underserved racial/ethnic groups as well as schools with more difficult working conditions. Among within-year movers, we expect that they will be more likely to work in large, urban districts and will be most responsive to difficult school working conditions.

Finally, we predict that returners are more likely to be female and work in low-income, high minority schools.

Study Sample

This study aims to characterize the frequency of within-year teacher turnover and describe the teacher and school characteristics associated with within-year turnover. We draw on administrative data from the state of North Carolina from the 2008-2009 to the 2014-2015 school years. The analytic sample includes all full-time teachers in traditional public schools from kindergarten through twelfth grades. From this sample, we exclude teachers assigned to multiple schools. After limiting the sample to full-time teachers assigned to one school who are not missing data on teacher, classroom, or school characteristics, the total sample includes 145,441 unique teacher observations and 445,641 teacher-year observations.

Study Data

Outcome Variables

For each of these teachers, we create variables for six types of turnover: (1) stayer, (2) within-year mover, (3) end-of-year mover, (4) returner, (5) within-year leaver, and (6) end-of-year leaver. Stayers remained in their school throughout the year and return the following year. Within-year movers changed schools before the end of the school year. End-of-year movers changed schools between the end of one school year and the beginning of the next. Returners temporarily exited teaching for at least one month before returning to their current school. While we would ideally define within-year leavers as those who left the profession, due to data limitations, we define them as those who left teaching in the public schools of North Carolina during the school year. Because of the same data limitation, the inability to follow teachers who leave North Carolina for positions in other states, we define end-of-year leavers as those who left

teaching in North Carolina after the end of one school year and prior to the beginning of the next. To construct these different categories, we draw on monthly teacher pay files, which give detailed information on where a teacher is paid for working in a given month. This data allows us to identify when in the school year a teacher moved, returned, or left their school. To ensure that this measure of teacher turnover is mutually exclusive, we code a teacher's first transition. For instance, if a teacher moved schools and then left teaching at the end of the school year, this variable would code a teacher as a within-year mover. A limitation of this approach is that it overlooks any teachers who turned over at multiple points within the same year.

To understand differences in the predictors of within- and end-of-year turnover, we also create more general measures of within-year and end-of-year turnover. These two measures include moving and leaving. In these analyses, teachers who temporarily leave and return are excluded from the analysis.

Independent Variables of Interest

This analysis utilizes a range of teacher, classroom, and school variables to better understand the factors associated with these various types of teacher turnover. These variables are listed in Table A1. They include teacher background characteristics, school demographic characteristics, and school working conditions. These variables help us to understand the types of teacher and school characteristics predictive of higher probabilities of within-year teacher turnover.

We draw on a variety of teacher background characteristics, including teacher experience, gender, race/ethnicity (Black, Hispanic, and other non-White teachers), age, and indicators of teachers' entry pathway into teaching (alternate entry, Teacher For America (TFA), out-of-state prepared, and Other, including Visiting International Faculty and teachers from

unclassifiable entry pathways). To account for nonlinearities in the relationship between teacher experience and turnover, is separated into five categories: 0-2 years of experience, 3-5 years, 6-10 years, 11-20 year, and more than 20 years. We also create a categorical variable of teacher age: 25 years old and younger, 26 to 30 years old, 31-40 years old, 41-50 years old, 51-60 years old, and over 60 years old.

School-level variables include indicators for the school level (elementary, middle, or high school) and urbancity (city, suburb, rural, and town). Additional variables are the average student enrollment, total per-pupil expenditures, the percent of students receiving free lunch, and the percent of Black and Hispanic students. We examine differences in school quality with an overall performance composite measure (the number of state accountability tests passed divided by the number of tests taken). The final measures of school climate include the reported violent rates per 1,000 students, the short-term suspension per 100 students, and the percentage of teachers with 3 years of experience or less. We also add a variable for the local education agency (LEA) teacher salary supplement, the main district-to-district source of variation in teachers' salaries in the data given North Carolina's statewide teacher salary schedule.

In addition to these school demographic characteristics, we also add descriptive variables compiled from teacher responses to the biennial Teacher Working Conditions (TWC) survey measuring leadership characteristics, distribution of decision-making, teacher empowerment, and facilities and resources. In years the survey was conducted, we use confirmatory factor analysis to generate these four factors that have been used previously in the literature (e.g. Ladd, 2011; Schweig, 2014). Each factor had moderate to high internal consistency, with Cronbach's alpha ranging from 0.79 to 0.93, depending on the year (see Table A1). As the survey was conducted every other year, for off years, we impute the school-level average from the previous year.

Methods

This study seeks to answer three research questions. The first research question aims to understand the frequency of within-year turnover. We describe the annual frequency of within-year turnover, contrasting it to between-year turnover. In answering this question, we provide evidence of the extent to which conventional measures of teacher turnover attenuate the overall turnover rate by overlooking the prevalence of teacher turnover during the school year. To investigate the issue of attenuation, we report on annual teacher turnover rates, breaking down the frequency of overall school turnover into teachers who turn over during the school year and at the end of the school year. For comparison to other studies, we also construct another annual turnover measure used in earlier studies based on a teacher's active employment in October in year t compared to their employment status in the same month in year $t+1$. We then calculate the percentage of teachers who were identified as moving or leaving schools with the end-of-year and October-to-October turnover measures to document the extent to which conventional estimates of moving schools or leaving teaching have attenuated these types of teacher mobility by overlooking within-year turnover.

The second research question looks at descriptive evidence of the differences in the teacher, classroom, and school characteristics between teachers who remain in their school, move, leave or return during the school year, and move or leave at the end of the school year.

The third research question asks about the extent to which teacher, classroom, and school characteristics predict within-year turnover. To contrast the predictors of within- and end-of-year turnover, we first run a series of logistic regression models predicting within-year turnover and end-of-year turnover compared to staying in the same school. This models take the simplified form:

$$\Pr(turnover)_{ijk} = \frac{e^f}{1 + e^f} \quad (1)$$

where

$$f = \beta_0 + \beta_1 T_i + + \beta_2 S_j + \delta_k$$

is the odds that teacher *i* turned over from school *j* in year *k* as a function of their background characteristics (T_i) and a vector including school context and working conditions (S_j). Models include year fixed effects (δ_k) to account time-specific correlates of turnover. In the first series of models, $turnover$ is coded as a binary variable where one indicates within-year movers and leavers and zero indicates teachers who remained in their school during their school and at the end of the school year. The second series of models code $turnover$ equal to one for end-of-year movers and leavers and zero for teachers who remained in their school throughout the year and returned the following year. Standard errors are clustered at the teacher level to account for repeated observations of the same teacher.

We extend these models by comparing within-year movers, end-of-year movers, returners, within-year leavers, and end-of-year leavers to the teachers who stay in their school in a given school year. We estimate this model using multinomial logistic regression, with estimates reported in reference to teachers who remained in their school.

Results

Frequency of Within-Year Turnover

We find that slightly less than four percent of teachers turn over during each school year, which compares with 13.4% of teachers turning over at the end-of-year, as we report in Table 1. As the average North Carolina school employs approximately forty teachers, this means that, on average, each school loses at least one teacher during the year. Within-year turnover may result from demoralized novice teachers leaving teaching before the end of the year, involuntarily transfer or dismissal, maternity or other health leave of absence, and retirements, all of which,

Table 1. Attenuation in Annual Measures of Teacher Mobility

Overall teacher turnover			
Overall	Within-year	End-of-year	October-to-October
17.09	3.84	13.41	15.89

Movers			
Overall	Within-year	End-of-year	October-to-October
8.80	1.72	7.24	7.60

Leavers			
Overall	Within-year	End-of-year	October-to-October
8.29	2.12	6.17	8.29

Notes. Observations = 436,945

we suspect, significantly disrupt students' learning opportunities. In addition to the negative effect on students, within-year turnover leads to a non-trivial attenuation of the magnitude of teacher turnover and minimize attention to within-year teacher turnover, which may have more significant consequences than end-of-year turnover. First, the 3.84% of teachers to turn over during the school year accounts for 22.47% of total turnover, with traditional measures of turnover attenuated to 77.53 percent of their true value. Second, when within-year turnover is overlooked, as is the case when turnover is measured at the end of the school year, it underestimates the true frequency of turnover. We find that comparing teachers' employment status from the end of one school year to the beginning of the next underestimates the true frequency of turnover by 17.7%. The October-to-October measure of turnover more accurately represents annual teacher mobility, as it does not miss within-year turnover to the same extent that end-of-year turnover measures do. October-to-October measures of moving capture the

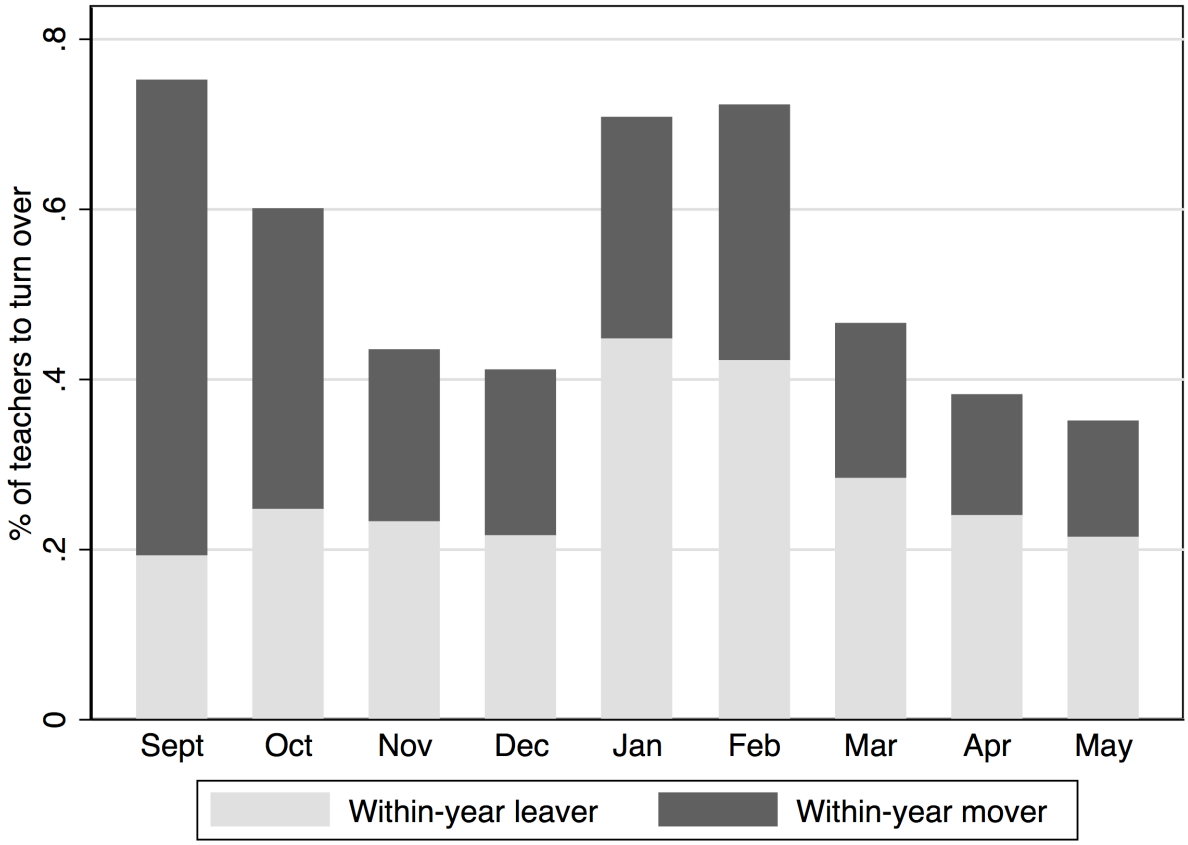
mobility that occurs in year *t* as well as the first couple of months of *t+1*. However, this measure under-estimates moving by 7.02%, attenuating turnover to 92.98% of its true value.

When within-year movers are omitted, the movement of teachers between schools risks being overlooked by conventional measures of teacher turnover. By comparing teacher's employment status at the end of one school year to the beginning of the next, we find that 7.24% of teachers moved schools, as shown in the second panel of Table 1. This overlooks the 1.72% of teachers to move during the school year, attenuating the true frequency of moving by 17.73% to 82.27% of its true value. October-to-October measures of teachers' movement to other schools better capture this within-year dynamic, only attenuating turnover to 86.36% of its true value.

Omitting within-year teacher turnover attenuates measures of leaving teaching less than measures of moving. The source of mismeasurement for leaving is in terms of the timing. By observing leaving during the school year, we demonstrate that a quarter of leaving occurs during the school year. Whereas 6.17% of teachers leave teaching at the end of the year, 2.12% leave before the end of the academic year. As conventional end-of-year measures of leaving still identify that a teacher had left, the timing would be incorrectly attributed to between year leaving rather than including within-year leaving, which is likely more detrimental to the students, teachers and administrators who lost a teacher midyear.

To further probe the issue of timing, we present monthly turnover frequencies in Figure 1. Figure 1 plots the percentage of teachers to move schools or leave teacher in a given month during the school year. Teachers are most likely to move schools at the beginning of the school year. 0.56% of teachers move schools during the first month of the school year and 0.35% move in the second month. In other periods, only approximately 0.2% of teachers move schools, with a slight jump in January and February. These months in the middle of the school year are

Figure 1. Monthly Frequency of Within-Year Teacher Turnover



the period when the most teachers leave teaching during the school year, with 0.45% and 0.42% leaving in January and February, respectively. Besides the higher rates of moving schools at the start of the school year, teachers leave teaching during the year more often than they move between schools. As turnover is not evenly distributed across teachers or schools, in the next section, we characterize the teacher and school characteristics most strongly related to within- and end-of-year turnover.

Characterizing Within- and End-of-Year Turnover

In this section we present the descriptive and associational evidence and the analysis of turnover patterns from our second and third research questions. First we describe the results for teacher race/ethnicity, gender, experience and age, and entry pathway. We then report on the following school characteristics: minority student enrollment, economically disadvantaged

Table 2. Conditional Means and Frequencies, by Turnover Status

	Stayer	Within-year mover	Within-year leaver	End-of-year mover	End-of-year leaver	Temporary Exit and Return
Teaching experience (years)	12.47	11.02	13.41	9.67	13.43	10.79
0-2 years experience	71.77	2.37	3.27	11.99	9.93	0.67
3-5 years experience	77.09	2.17	2.85	9.39	7.45	1.05
6-10 years experience	81.15	2.13	2.24	8.39	5.12	0.97
11-20 years experience	86.31	1.70	1.56	6.55	3.49	0.39
20+ years experience	78.40	1.66	3.78	5.15	10.44	0.56
Male	79.74	2.06	2.89	8.06	6.96	0.28
Female	79.79	1.80	2.74	7.93	7.03	0.72
White	80.50	1.67	2.73	7.55	6.93	0.62
Black	76.47	2.82	2.88	10.10	7.07	0.64
Hispanic	74.62	2.30	3.57	9.59	9.07	0.86
Other race	77.05	2.19	3.16	8.78	8.10	0.73
In-state, traditional preparation	81.86	1.80	2.26	7.63	5.79	0.66
Alternate entry	78.51	2.64	2.41	9.71	6.04	0.69
Teacher For America	55.37	1.37	3.64	8.69	30.62	0.31
Out-of-state prepared	78.02	1.89	3.28	7.64	8.41	0.76
Other	80.14	1.92	3.03	6.55	7.81	0.55
Age (years)	40.73	39.54	43.71	37.76	42.33	38.42
< 26 years old	73.22	2.04	2.17	12.64	9.50	0.43
26-30 years old	75.50	2.08	3.10	9.76	8.52	1.04
31-40 years old	81.40	2.02	2.26	8.37	5.13	0.82
41-50 years old	85.88	1.65	1.60	7.07	3.51	0.30
51-60 years old	80.39	1.63	3.59	5.70	8.21	0.48
60+ years of age	62.37	1.63	8.52	4.47	22.13	0.63
School size (100s)	7.91	7.75	8.05	7.39	7.89	7.88
City	77.91	2.14	3.08	8.34	7.78	0.75
Rural	80.91	1.85	2.43	7.79	6.41	0.61
Town	80.13	2.06	2.48	8.16	6.52	0.65
Suburb	82.34	1.75	2.25	6.71	6.14	0.81
Elementary school	80.87	1.68	2.21	7.88	6.60	0.76
Middle School	78.84	2.12	2.82	8.57	7.06	0.59
High School	76.83	2.98	4.41	7.81	7.16	0.81
% economically disadvantaged	56.15	61.42	59.13	61.69	58.50	55.66
% White students	51.99	42.42	45.40	44.46	46.97	49.11
% Black students	26.46	34.93	31.93	32.90	30.72	28.47
% Hispanic students	13.64	14.86	14.62	14.83	14.40	14.53
% other race	7.91	7.79	8.05	7.81	7.91	7.88
Violent acts rate	7.98	10.51	9.70	9.53	8.94	7.95
Suspension rate	17.51	25.26	22.47	23.16	20.40	17.36
Teachers with 3 yrs experience or less	19.82	22.80	22.51	22.34	21.91	21.08
Overall performance composite	66.21	63.38	60.93	62.31	62.47	67.62

Per pupil expenditures	8.50	9.17	8.73	8.80	8.64	8.75
Teacher salary supplement	3.35	3.44	3.49	3.34	3.46	3.58
Facilities and Resources (std)	-0.08	-0.24	-0.20	-0.19	-0.16	-0.12
Distributed leadership (std)	-0.13	-0.28	-0.24	-0.26	-0.22	-0.17
Principal leadership (std)	-0.14	-0.33	-0.30	-0.32	-0.25	-0.19
Professional development (std)	-0.10	-0.15	-0.14	-0.15	-0.14	-0.09

Notes. Observations = 445,641. Conditional means presented for continuous variables. Conditional frequencies presented for categorical and binary variables.

student enrollment, overall school performance, school working conditions, and other notable school characteristics. For each teacher and school characteristic, we first describe overall differences between within- and end-of-year turnover before reporting differences in terms of within-year and end-of-year turnover before decomposing turnover into the five types listed above.

Teacher Race/Ethnicity

In Table 2, we find that Black and Hispanic teachers are more likely to turnover than White teachers. 19.50% of White teachers turn over annually compared to 23.53% of Black teachers, and 25.38% of Hispanic teachers. In Table 3, before controlling for school characteristics, the odds of within-year and end-of-year turnover for Black teachers are considerably greater compared to white teachers (1.34 and 1.26, respectively). When school controls are added, we find no evidence of a difference in within- or end-of-year turnover between Black and White teachers. We see a similar story for Hispanic teachers in terms of within-year turnover but not end-of-year turnover. Even when controlling for school characteristics, the odds of end-of-year turnover for Hispanic teachers are 17% greater than White teachers.

Table 2 also shows that the descriptively higher turnover rates for Black teachers are driven by moving schools, both during and at the end of the school year. 2.82% of Black teachers move midyear compared to only 1.67% of White teacher. At the end of the school year, 10.10%

Table 3. Logistic Regression Estimates of Within- and End-of-Year Teacher Turnover

	Within-year turnover		End-of-year turnover	
0-2 years experience	2.05***	1.79***	1.78***	1.62***
	(25.23)	(19.65)	(32.84)	(27.13)
3-5 years experience	1.37***	1.34***	1.34***	1.30***
	(11.75)	(10.75)	(18.47)	(16.43)
11-20 years experience	0.65***	0.64***	0.71***	0.72***
	(-17.59)	(-18.01)	(-23.41)	(-22.31)
20+ years experience	0.87***	0.79***	0.92***	0.94***
	(-4.98)	(-8.05)	(-4.46)	(-3.43)
Female	0.97	1.11***	1.02*	1.04**
	(-1.86)	(5.27)	(1.97)	(3.26)
Black	1.33***	0.97	1.26***	1.00
	(13.32)	(-1.10)	(17.22)	(0.15)
Hispanic	1.27***	1.02	1.28***	1.17***
	(4.35)	(0.41)	(7.29)	(4.58)
Other race	1.16***	1.00	1.10***	1.02
	(3.40)	(-0.04)	(3.62)	(0.69)
Alternate entry	1.20***	0.96	1.24***	1.17***
	(7.80)	(-1.70)	(15.50)	(10.98)
Teacher For America	1.55***	0.85	2.88***	1.95***
	(4.40)	(-1.56)	(27.48)	(16.84)
Out-of-state prepared	1.29***	1.27***	1.30***	1.28***
	(14.40)	(12.98)	(25.20)	(22.89)
Other	1.16***	1.04	1.20***	1.16***
	(4.17)	(1.00)	(8.44)	(7.00)
< 26 years old	1.62***	1.60***	1.04	1.03
	(13.86)	(13.26)	(1.89)	(1.72)
26-30 years old	1.80***	1.83***	0.97	0.97
	(16.09)	(16.06)	(-1.50)	(-1.36)
31-40 years old	1.49***	1.52***	0.80***	0.80***
	(9.90)	(10.30)	(-9.68)	(-9.71)
51-60 years old	2.60***	2.51***	1.14***	1.11***
	(23.16)	(21.80)	(5.41)	(4.30)
60+ years of age	6.35***	5.64***	2.75***	2.66***
	(39.37)	(35.74)	(35.26)	(33.77)
School size (100s)		0.95***		0.97***
		(-22.22)		(-19.08)
City		1.04		0.99
		(1.20)		(-0.50)
Rural		1.04		1.01
		(1.28)		(0.75)
Town		0.97		0.99
		(-0.84)		(-0.70)

Middle school		2.39***		1.12***
		(38.60)		(9.31)
High school		5.34***		1.16***
		(77.65)		(13.46)
% economically disadvantaged		0.999		0.998***
		(-1.48)		(-6.45)
% Black students		1.006***		1.006***
		(11.50)		(17.66)
% Hispanic students		1.004***		1.002***
		(4.66)		(4.85)
% Other race students		1.006***		1.001
		(6.17)		(1.39)
Violent acts rate		0.997***		1.000
		(-3.52)		(1.20)
Suspension rate		0.999***		1.001***
		(-3.65)		(3.55)
Teachers with 3 yrs experience or less		3.832***		2.207***
		(16.29)		(16.54)
Overall performance composite		0.995***		0.996***
		(-5.01)		(-6.86)
Per pupil expenditures		0.996**		0.998**
		(-3.28)		(-2.91)
Teacher salary supplement		1.04***		0.99
		(5.60)		(-1.37)
Facilities and Resources (std)		0.95***		1.00
		(-4.45)		(-0.02)
Distributed leadership (std)		0.95***		0.97***
		(-3.50)		(-4.16)
Principal leadership (std)		0.95***		0.93***
		(-4.07)		(-9.47)
Professional development (std)		1.07***		1.01
		(5.09)		(1.32)
Constant	0.02***	0.01***	0.12***	0.15***
	(-84.97)	(-41.69)	(-83.43)	(-28.03)
Observations	378882	378882	425158	425158
Deviance	154717.08	144381.40	357761.67	354468.47

Notes. Estimates reported as odds ratios. Estimates include wave fixed effects. *t*-statistics reported in parentheses. * p<0.05; ** p<0.01; *** p<0.001.

of Black teachers move schools compared to 7.55% of White teachers. Although Hispanic teachers are less likely to move schools within and at the end of the school year than Black teachers, they are less likely to move schools than White teachers. In Table 4, controlling for

school characteristics, the risk of moving schools within the year for Black teachers are 19% greater than White teachers. The risk of moving at the end of the school year are 6% greater for Black teachers than White teachers. For Hispanic teachers, we find no evidence of differences in moving during the year compared to White teachers. Instead, Hispanic teachers have greater odds of moving schools at the end of the year compared to white teachers, with relative risk ratio of 1.13.

Table 2 shows no practically significant differences in the rates at which Black teachers leave teaching compared to White teachers. Hispanic teachers are more likely to leave teaching than White teachers. During the school year, Hispanic teachers' turnover rate is 3.57% compared to 2.73% for White teachers. At the end of the school year, their turnover rate is 9.07% compared to 6.93% for White teachers. Table 4 reveals that after controlling for school characteristics, Black teachers are much less likely to leave teaching than White teachers, particularly within the school year. Compared to White teachers, the risk of leaving are lower within the year compared to the end of the year (0.83 versus 0.93). Hispanic teachers are no more likely to leave during the school year compared to White teachers, but, counter to our hypothesis, are more likely leave teaching at the end of the school year (1.23).

Teacher Gender

There is virtually no difference in the overall turnover rate of male versus female teachers, except in regards to female teachers' higher rates of temporarily exiting teaching (Table 2). 0.28% of male temporarily exit and return compared to 0.72% of female teachers. When controlling for school characteristics in Table 3, female teachers have slightly greater odds of turnover than male teachers, particularly during the school year (1.11 versus 1.04).

When separating these results between moving schools and leaving teaching in Table 4,

Table 4. Multinomial Logistic Regression Estimates of Within- and End-of-Year Teacher Moving, Leaving, and Temporary Exit and Return

	Within-year mover	Within-year leaver	End-of-year mover	End-of-year leaver	Temporary Exit and Return
0-2 years experience	1.33***	2.20***	1.40***	1.97***	0.97
	(6.10)	(21.93)	(14.74)	(26.98)	(-0.37)
3-5 years experience	1.10*	1.56***	1.16***	1.51***	1.03
	(2.30)	(12.83)	(7.39)	(17.81)	(0.53)
11-20 years experience	0.75***	0.54***	0.79***	0.61***	0.46***
	(-8.00)	(-18.65)	(-13.05)	(-22.46)	(-12.68)
20+ years experience	0.72***	0.80***	0.68***	1.18***	0.65***
	(-6.76)	(-6.39)	(-15.02)	(6.79)	(-5.65)
Female	1.01	1.19***	0.997	1.11***	2.71***
	(0.40)	(7.21)	(-0.16)	(6.21)	(14.14)
Black	1.19***	0.83***	1.06**	0.93***	1.003
	(4.93)	(-6.22)	(3.27)	(-3.68)	(0.05)
Hispanic	1.06	1.03	1.13**	1.23***	1.29
	(0.73)	(0.46)	(2.81)	(4.70)	(1.90)
Other race	1.05	0.97	0.95	1.12**	1.16
	(0.72)	(-0.54)	(-1.52)	(3.04)	(1.29)
Alternate entry	1.02	0.90***	1.12***	1.20***	0.96
	(0.67)	(-3.33)	(6.33)	(9.18)	(-0.72)
Teacher For America	0.42***	1.32*	0.65***	4.34***	0.68
	(-4.61)	(2.35)	(-5.82)	(31.50)	(-1.00)
Out-of-state prepared	1.07*	1.45***	1.07***	1.54***	1.16**
	(2.19)	(16.76)	(4.94)	(30.00)	(3.21)
Other	0.85**	1.22***	0.93*	1.48***	0.87
	(-2.89)	(4.59)	(-2.46)	(14.12)	(-1.29)
< 26 years old	1.15**	2.07***	0.90***	1.25***	2.29***
	(2.74)	(15.97)	(-4.35)	(8.52)	(8.42)
26-30 years old	1.28***	2.33***	0.89***	1.09**	2.25***
	(4.50)	(17.66)	(-4.31)	(3.03)	(7.59)
31-40 years old	1.15*	1.81***	0.83***	0.76***	0.96
	(2.27)	(11.34)	(-6.78)	(-8.30)	(-0.38)
51-60 years old	1.18*	4.30***	0.78***	1.75***	1.54***
	(2.57)	(27.95)	(-7.87)	(16.84)	(3.48)
60+ years of age	1.45***	11.95***	0.81***	5.70***	3.67***
	(4.29)	(42.83)	(-4.31)	(46.83)	(9.18)
School size (100s)	0.95***	0.96***	0.96***	0.99***	0.97***
	(-15.04)	(-17.17)	(-19.98)	(-8.16)	(-6.34)
City	1.00	1.06	0.99	0.998	1.02

	(-0.05)	(1.57)	(-0.58)	(-0.09)	(0.21)
Rural	1.10*	0.99	1.05*	0.97	0.93
	(2.30)	(-0.18)	(2.40)	(-1.42)	(-1.11)
Town	1.001	0.94	1.04	0.93*	1.01
	(0.03)	(-1.30)	(1.43)	(-2.55)	(0.10)
Middle school	2.21***	2.54***	1.17***	1.07***	1.20**
	(22.80)	(33.42)	(10.10)	(4.10)	(2.97)
High school	4.53***	6.13***	1.21***	1.13***	2.14***
	(46.56)	(66.19)	(13.46)	(8.19)	(15.46)
% economically disadvantaged	1.001	0.998**	0.997***	0.998***	0.995**
	(0.85)	(-2.71)	(-5.60)	(-4.53)	(-3.13)
% Black students	1.008***	1.005***	1.007***	1.005***	1.002
	(10.07)	(7.23)	(15.92)	(10.60)	(1.19)
% Hispanic students	1.007***	1.002*	1.004***	1.001	1.005*
	(5.21)	(2.07)	(5.82)	(1.82)	(2.19)
% Other race students	1.005**	1.007***	1.002*	1.000	0.997
	(3.28)	(5.54)	(2.47)	(-0.49)	(-1.07)
Violent acts rate	0.998	0.997***	1.000	1.000	0.997
	(-1.54)	(-3.34)	(0.43)	(0.89)	(-1.13)
Suspension rate	0.999**	0.999*	1.001**	1.000	0.998
	(-3.00)	(-2.41)	(2.66)	(1.65)	(-1.40)
Teachers with 3 yrs experience or less	3.88***	4.03***	2.25***	2.23***	1.99**
	(10.72)	(13.62)	(13.20)	(12.00)	(3.27)
Overall performance composite	0.999**	0.999*	1.001**	1.000	0.998
	(-3.00)	(-2.41)	(2.66)	(1.65)	(-1.40)
Per pupil expenditures	0.999	0.994**	0.997**	0.999	1.000
	(-0.50)	(-3.12)	(-3.28)	(-1.26)	(-0.04)
Teacher salary supplement	1.06***	1.02*	1.00	0.99*	1.06**
	(6.45)	(2.04)	(0.48)	(-2.57)	(3.25)
Facilities and Resources (std)	0.93***	0.97*	1.00	1.00	0.93*
	(-4.00)	(-2.23)	(0.19)	(-0.52)	(-2.33)
Distributed leadership (std)	0.93***	0.97	0.96***	0.97*	0.95
	(-3.42)	(-1.77)	(-3.63)	(-2.55)	(-1.65)
Principal leadership (std)	0.97	0.92***	0.90***	0.96***	0.98
	(-1.28)	(-4.68)	(-9.87)	(-3.77)	(-0.70)
Professional development (std)	1.07**	1.07***	1.01	1.01	1.10**
	(3.07)	(4.17)	(1.36)	(0.84)	(2.68)
Constant	0.01***	0.00***	0.16***	0.03***	0.00***
	(-28.83)	(-40.62)	(-20.93)	(-36.60)	(-19.87)
Observations	445641	445641	445641	445641	445641

Notes. Estimates reported as relative risk ratios. Estimates include wave fixed effects. *t*-statistics reported in parentheses. * p<0.05; ** p<0.01; *** p<0.001.

we find that the higher turnover rates among female teachers are driven by leaving teaching. Also, we find a stronger relationship between gender and leaving within the school year than at the end of the year. The odds a female teacher will leave teaching during the school year are 19% greater than a male teacher. The odds a female teacher will leave teaching at the end of the school year are 11% greater than a male teacher. There is an even larger gender gap in terms of temporary exit and return. The odds a female teacher will temporarily exit teaching are 171% greater than a male teacher.

To examine the extent to which the higher rates of leaving teaching are related to childbearing, in Table A7, we add to the model an interaction between female and the age categories. Female teachers are predicted to leave teaching at higher rates than male teachers beginning in their mid-20s and continuing into their 30s. The odds of within-year turnover are 16% greater for female teachers in their late 20s compared to male teachers of the same age. After these prime childbearing years, the odds of within-year leaving for male and female teachers converge. That being said, the difference in predicted probabilities is small. The predicted probability of within-year turnover is 5% for a female teacher between 26 and 30 years old and 4.1% for a male teacher in the same age group. For teachers in their 30s, the predicted probability of within-year turnover is 5.5% for female teachers compared to 4.8% for male teachers.[2] We find no corresponding gender difference for end-of-year turnover for females in their late 20s or 30s. We do, however, find evidence that when female teachers exit the classroom temporarily it tends to be concentrated around these traditional childbearing ages

[2] In Table A8 we run the multinomial logistic regression model with the interaction between gender and the categories. We find even stronger evidence of a gender gap between men and women in terms of leaving within the school year. The relative risk ratio on the interaction between Female Teacher and 26-30 years old is 1.43. The relative risk ratio on the interaction between Female Teacher and 30-40 years old is 1.19. We find no significant evidence of a differential effect outside this period.

(Table A8). With temporary exit and return being a rare event—0.9% of teachers exit and return in a year—young female teachers are much more likely than male teachers to display this behavior. The predicted probability of temporary exit is 1.2% for 26 to 40 year-old female teachers and 0.2% for 26 to 40 year-old male teachers, a difference that also disappears in teachers' 40s.

Teacher Experience

Descriptively, Table 2 shows the least experienced teachers are most likely to turnover. 28.23% of teachers in their first three years in the profession turn over each year. 5.64% of novice teachers turn over during the school year with an additional 21.92% turning over at the end of the school year. In other words, a fifth of all novice teachers who turn over during their first three years on the job leave before the end of the school year. The rates of within- and end-of-year turnover decrease until teachers reach 20 or more years of experience. Among teachers with over 20 years of experience, 5.44% turn over during the school year with an additional 15.59 turning over at the end of the school year, which means that a fourth of the veteran teachers who turnover do so during the school year.

The regression analysis in Table 3 confirms the significance of these differences. When controlling for school characteristics, the odds of within-year turnover among teachers with zero to two years of experience are 79% greater compared to teachers with six to ten years of experience. Compared to teachers with six to ten years of experience, novice teachers are more likely to turn over during the school year than at the end of the year when controlling for school characteristics (1.79 versus 1.62). Although teachers with three to five years of experience are more likely to turn over than teachers with six to ten years of experience, the magnitude of the turnover have diminished and differences between within- and end-of-year turnover have

narrowed (1.34 versus 1.30). Midcareer teachers, those with 11 to 20 years of experience and veteran teachers are less likely to turnover than teachers with six to ten years of experience, both within and at the end of the school year.

In Table 2, we find that as teachers gain experience, they are less likely to move schools within and at the end of the year. 2.37% of novice teachers move within the year compared to only 1.66% of the most experienced teachers. 11.99% of novice teachers move at the end of the school year compared to 5.15% of the most experienced teachers. This pattern is consistent when controls are added for teacher background and school characteristics (Table 4). Compared to teachers with six to ten years of experience, the risk of within-year moving for novice teachers is 33% greater and the risk of end-of-year moving are 40% greater. The risk of within- and end-of-year moving are lowest for veteran teachers with over 20 years of experience.

The most and least experienced teachers leave teaching at the highest rates, both within and at the end of the school year. On average, in Table 2 we see that 3.27% of teachers in their first three years in the profession leave teaching during the school year and 9.93% leave at the end of the school year. In other words, a quarter of all teachers to leave teaching during their first three years on the job leave before the end of the school year. Among teachers with more than 20 years of experience, 3.78% leave midyear and 10.44% leave at the end of the year, likely for retirement, which we discuss below in greater detail. When we control for teacher and school characteristics, novice teachers are more than twice as likely to leave teaching within the year compared to teachers with six to ten years of experience. Veteran teachers are less likely to leave teaching during the school year but more likely to leave at the end of the year compared to teachers with six to ten years of experience (0.80 versus 1.18).

Teacher Age

Within- and end-of-year turnover rates differ greatly across different teacher age groups. In Table 2, we find that, on average, 4.21% of teachers younger than 26 turn over during the school year. 5.18% of teachers between 26 and 30 years old turn over during each school year. The within-year turnover drops to 3.25% for 41-50 year-old teachers before jumping to 10.15% for teachers over 60 years old. An additional 26.6% of teachers over 60 years old turn over at the end of the school year. In other words, when teachers over 60 turn over, over a quarter do so during the school year.

In the regression analysis in Table 3, we find a stronger relationship between age and within-year turnover than end-of-year turnover. For instance, we find no evidence that teachers in their 20s are more or less likely to turnover at the end of the school year compared to 41 to 50 year-old teachers. In terms of within-year turnover, the odds ratio for teachers who are less than 26 years old is 1.62, controlling for experience and other covariates. For teachers between 26 and 30 years old, the odds ratio for within-year turnover is 1.80. Results from Table 3 confirm also the strong relationship between within-year turnover and age among the oldest teachers. The odds of within-year turnover for teachers over 60 is 464% greater compared to 41 to 50 year-old teachers. Although there is also a strong relationship between age and end-of-year turnover, it is much smaller in magnitude, with an odds ratio of 2.66 for teachers over 60 compared to those between 41 and 50, when controlling for teacher and school characteristics.

Older teachers are much less likely to move schools, particularly at the end of the school year. On average, 12.64% of teachers under 26 years old move schools compared to only 4.47% of teachers over 60 years old (Table 2). In regression analysis in Table 4, compared to 41-50 teachers, teachers at every other age group are more likely to move schools during the school

year and less likely to move schools at the end of the school year.

Older teachers are the most likely to leave teaching, both within and at the end of the year. Descriptive results in Table 2 indicate that 8.52% of teachers over 60 leave teaching during the school year every year. An additional 22.13% leave at the end of the school year. In contrast, 3.1% of 26 to 30 year olds leave within the year and 8.52% leave at the end of the year. Table 4 shows that, when controlling for teacher and school characteristics, teachers over 60 years old are nearly 12 times as likely to leave within the school year compared to teachers between 41 and 50 years old and almost 6 times as likely to leave at the end of the year.

To examine the extent to which the comparatively high rates of within-year leaving for the oldest and most experienced teachers are driven by teachers retiring midyear, we create two indicator variables, one if a teacher is eligible for full benefits and another if a teacher is eligible for reduced but not full retirement benefits.[3] Table A3 reports the turnover rates for teachers with over 20 years of experience, separated by whether the teacher is not yet eligible for retirement benefits, is eligible for full benefits, or only eligible for reduced benefits. We find suggestive evidence that teachers eligible for retirement are leaving midyear. Among the most experienced teachers not eligible for retirement, 2.41% leave teaching within the school year compared to 5.11% of fully eligible teachers and 8.71% of teachers eligible for reduced benefits. This pattern is even stronger for leaving at the end of the school year.

To further test the extent to which this relationship between teacher age and within-year

[3] Teachers are qualified for full retirement benefits under three conditions: (1) 65 years old and over 5 years of experience, 60 years old and over 25 years of experience, or over 30 years of experience. Teachers are eligible for reduced benefits if they are over 50 years old and have 20 years of experience or over 60 years old and have 5 years of experience. It is worth noting that the state distinguishes creditable service and membership service, whereby teachers contribute to the Teachers' and State Employees' Retirement Program. As we cannot distinguish between these two type of service, we create this measure the general retirement eligibility standards. Although this measure risks overstating the number of teachers eligible for retirement, in regression analysis, it would understate the effect of retirement eligibility.

turnover is driven by teachers retiring during the school year, in supplementary models in Table A7, we add the indicator for a teacher's eligibility for retirement benefits. We find strong evidence of a relationship between retirement eligibility and within- and end-of-year turnover. Compared to teachers not eligible for retirement benefits, the odds of within-year turnover are 55% greater for teachers eligible for full benefits. There is an even stronger relationship between retirement eligibility and end-of-year turnover. Compared to teachers not eligible for retirement benefits, the odds of within-year turnover are 111% greater for those eligible for full benefits. Controlling for retirement eligibility changes the relationship between teacher age and within-year turnover among older teachers. In Table 3, the odds ratio was 2.51 for teachers between 51 and 60 years old and 5.64 for teachers over 60 years old. When controlling for retirement eligibility, the odds ratio shrinks to 1.56 for teachers between 51 and 60 years and 2.79 for teachers over 60. In other words, the retirement eligibility partially mediates the effect of age on retirement.

Among teachers over 60 years old, the predicted probability of within-year turnover is 11.2% for teachers' ineligible for retirement benefits, 15.8% for teachers' eligible for full benefits, and 12.8% for teachers' eligible for reduced benefits. The relationship is even stronger for end-of-year turnover. Among teachers over 60 years old, the predicted probability of end-of-year turnover is 22.2% for teachers' ineligible for retirement benefits, 36.9% for teachers' eligible for full benefits, and 28.8% for teachers' eligible for reduced benefits.

In summary, we find that retirement eligibility partially mediates the relationship between age and teacher turnover, both within and at the end of the school year. Further, although there is a stronger relationship between end-of-year than within-year turnover, we still find strong evidence that teachers retiring during the academic year comprise a noteworthy share of teacher

retirements.

Entry Pathway

Descriptively, in-state, traditionally prepared teachers are the least likely to turnover of all entry pathways. In Table 2, we see that, on average, 18.14% of traditionally prepared teachers turn over each year. In contrast, 21.49% of alternate entry, 44.63% of TFA, and 21.98% of out-of-state prepared teachers turn over annually. These higher turnover rates are comprised of higher within- and end-of-year turnover. While 4.06% in-state, traditionally prepared teachers turn over during every school year, over 5% of alternate entry, TFA, and out-of-state prepared teachers turn over within the year. At the end of the school year, 13.42% of in-state, traditionally prepared teachers turn over annually, compared to 15.75% of alternate entry, 39.31% of TFA teachers, and 16.05% of out-of-state prepared teachers. In Table 3, we find that, compared to in-state, traditionally prepared teachers, alternate entry teachers are more likely to turnover during the school year until school controls are added, when we find that they are neither more nor less likely to turnover within the year. The odds of end-of-year turnover are 17% greater for alternate entry teachers compared to traditionally prepared teachers, when controlling for school characteristics. When controlling for school characteristics, we find no evidence of differences in within-year turnover for Teach For America compared to traditionally prepared teachers. TFA teachers are twice as likely to turn over at the end of the year. The odds of turnover for out-of-state prepared teachers are nearly 30% greater than in-state prepared teachers, both within and at the end of the school year.

The frequency with which teachers from different entry pathways move schools is less consistent. Alternate entry teachers move schools within and at the end of the school year at the highest rate. Out-of-state and teachers prepared through traditional routes in North Carolina

move schools at similar rates within and at the end of the school year. TFA teachers have the lowest rates of moving schools within the school year. In the regression analysis in Table 4, we find no evidence of differences between teachers prepared through traditional and alternate routes in terms of moving within the year when controlling for teacher and school characteristics. The risk of end-of-year moving is 12% greater for alternate entry teachers compared to traditionally prepared teachers. TFA teachers have much lower risk of moving schools, both within and at the end of the school year (0.40 an 0.67, respectively). The risk of moving for out-of-state prepared teachers are 7% greater than teachers prepared in North Carolina, both within and at the end of the year.

Descriptive evidence in Table 2 indicate that TFA teachers have the largest descriptive differences between leaving teaching within and at the end of the year. 3.64% of TFA teachers leave teaching during each school year with an additional 30.62% leaving at the end of the school year. Out-of-state prepared teachers also leave at higher rates than in-state, traditionally prepared teachers. 3.28% of out-of-state prepared teachers leave during the school year; 8.41% leave at the end of the year. In contrast, 2.26% of in-state, traditionally prepared teachers leave during the year and 5.79% leave at the end of the year. Alternate entry teachers also leave teaching at higher rates than traditionally prepared teachers, with a larger difference for leaving at the end of the year than within the school year. Table 4 provides additional evidence for these descriptive differences. Controlling for teacher and school characteristics, the risk of within-year leaving is 32% greater for TFA teachers compared to traditionally prepared teachers. The risk of end-of-year leaving is 334% greater for TFA. Out-of-state prepared teachers are much more likely to leave both within and at the end of the year compared to in-state prepared teachers (1.49

and 1.57, respectively). In addition, compared to traditionally prepared teachers, alternate entry teachers' risk of leaving within the year are 10% lower but 20% greater at the end of the year.

Across the teacher characteristics examined in this study, we find evidence both consistent and counter to our hypotheses about the relationship between teacher characteristics and teacher turnover, with important differences based on the timing and type of teacher turnover. Consistent with our hypothesis, Black teachers are less likely than White teachers to leave teaching. Yet, counter to our hypothesis, Black teachers move schools more frequently than White teachers and Hispanic teachers move schools and leave teaching at the end of the school year at higher rates than White teachers, even when controlling for school characteristics. The odds of leaving teaching—either permanently or temporarily—are greater for female teachers compared to male teachers, which is driven by higher departure rates during child-rearing ages. We predicted the highest turnover rates among the least and most experienced teachers. Early career teachers move schools at the highest rates while teachers with over 20 years of experience are least likely to move. Consistent with our hypothesis, the least and most experienced teachers are most likely to leave teaching, both during and at the end of year. Among veteran teachers, we found evidence that suggests eligibility for retirement benefits is a strong predictor of within-year turnover as it is also for end-of-year turnover. The findings least consistent with our initial hypothesis are in regards to entry pathway. When controlling for school characteristics, alternate entry teachers were less likely to leave during the school year compared to traditionally prepared teachers, although they are predicted to move schools and leave teaching at higher rates. Teacher For America teachers move schools at lower rates but leave teaching at higher rates, both during and at the end of the school year. Most consistent with our hypothesis, the odds of turnover are consistently greater for out-of-state prepared teachers

compared to in-state, traditionally prepared teachers, with no strong differences in the timing of turnover.

School Characteristics

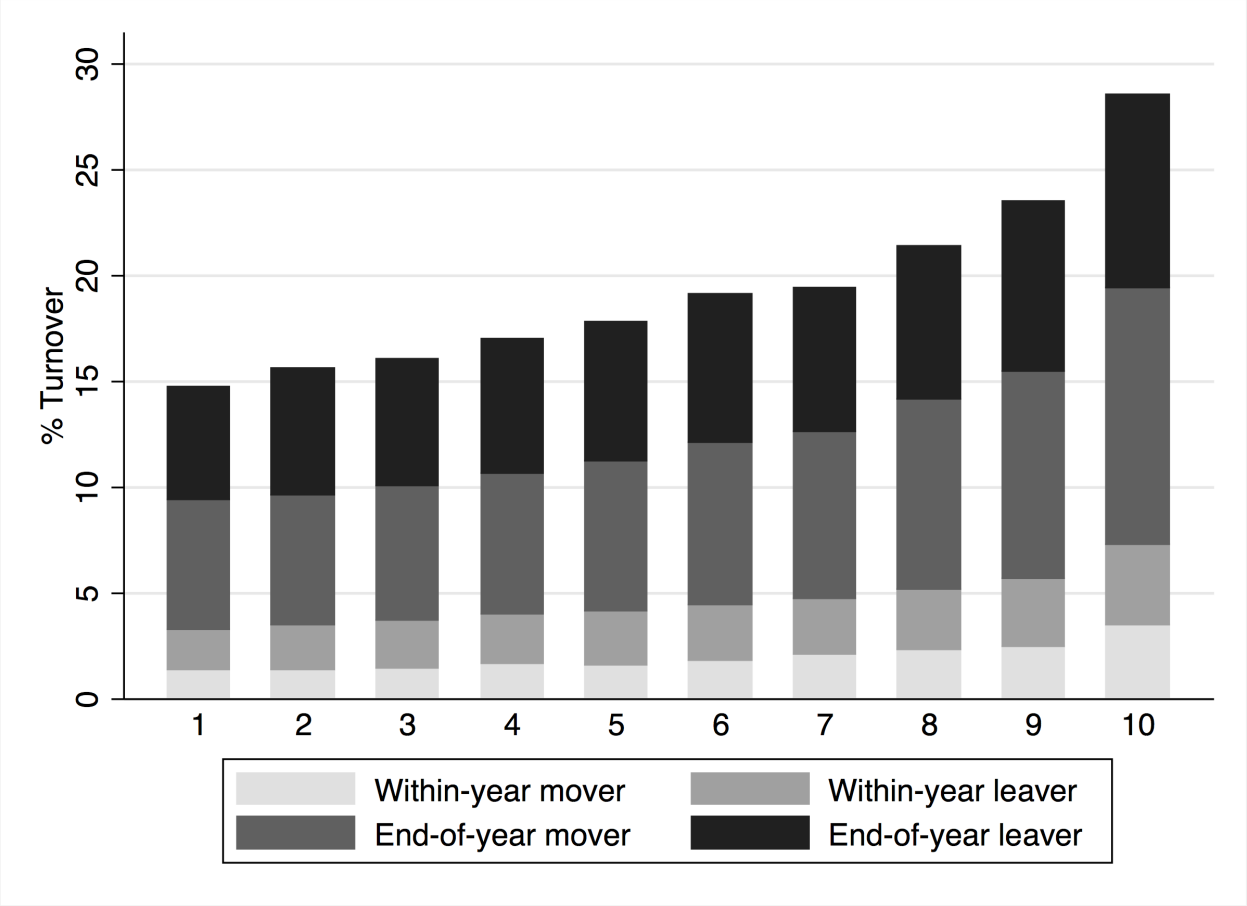
Previous research has linked the school demographic characteristics—including minority student enrollment, economically disadvantaged student enrollment, and overall school performance—and working conditions such as school leadership or facilities and resources to higher levels of turnover. In this section, we test the hypothesis that these characteristics are more predictive of within-year turnover than end-of-year turnover. In addition to the variables with which we had prior hypotheses, we also highlight key school characteristics with marked differences between within- and end-of-year turnover.

Minority Student Enrollment

Descriptive differences reported in Table 2 suggest that teachers who turnover are more likely to work in schools with a greater proportion of Black students, with slightly higher Black student enrollment in schools where teachers move or leave during the school year compared to the end-of-year movers and leavers, respectively. Stayers worked in schools with an average of 26% Black students compared to 35% for within-year movers, 33% for end-of-year movers, 32% for within-year leavers, and 31% for end-of-year leavers. No similar differences are observed for Hispanic student enrollment. To better characterize teacher turnover across the distribution of minority student enrollment, we separate this variable into deciles.[4] In Figure 2 and Table A4, schools in the bottom decile of minority student enrollment, that is, schools with 15% or fewer minority students, had 14.74% teachers turn over within and at the end of the school year. The

[4] In unreported results, we tabulated the results for Black and Hispanic student enrollment, respectively. The patterns were generally consistent for Black student enrollment. There is less stark of a distinction for Hispanic student enrollment. Schools in the bottom decile of Hispanic student enrollment had an annual turnover rate of 19.87% compared to 23.02% in schools in the top decile.

Figure 2. Frequency of Turnover by Minority Student Enrollment Deciles



annual turnover rate in schools in the top decile, schools with 89% minority student enrollment and higher, is nearly double, with an average of 28.56% of teachers turning over each year.

When comparing schools with the lowest and highest concentrations of minority students, the within-year turnover rate is relatively higher than end-of-year turnover. In schools with the lowest minority concentrations, the within-year turnover rate is 3.25%, where it is 7.3% in the schools with the highest minority enrollment. In contrast, in the schools with the fewest minorities, the end-of-year turnover rate is 11.49%, while in the schools with the largest minority enrollments have an end-of-year turnover rate is 21.25%. In other words, the within-year turnover rate is 2.25 times greater in schools in the top decile of minority student enrollment compared to the bottom decile. The end-of-year turnover rate is 1.85 times greater in schools in the top decile of minority student enrollment compared to the bottom decile. Regression analysis

in Table 3 confirm the strength of this relationship between within-year turnover and the concentration of Black, Hispanic, and other race students. We find a similar relationship between Black, Hispanic student enrollment percentages and within-year and end-of-year teacher turnover but no relationship between other race enrollment rates and end-of-year turnover.

When we examine the relationship between minority student enrollment and moving schools, we find a similar pattern. In Figure 2, we see that 1.4% of teachers move within the school year from schools in the bottom decile of minority student enrollment compared to 3.45% of teachers in the top decile. Regression analysis in Table 4 confirms this relationship. A one percentage point increase in Black student enrollment is associated with a 0.8% increase in the risk of moving schools within the school year. To get a better sense of the practical significance of these differences, we present the predicted probabilities at the 10^{th} and 90^{th} deciles, holding all other variables in the model at their mean. For a teacher in a school at the 10^{th} decile of Black student enrollment, that is, schools with 2.9% Black students, the predicted probability of moving within the school year is 1.5%. In schools at the 90^{th} decile or with 60.5% Black students, the predicted probability of moving schools within the year is 2.2%. The odds of moving schools within the school year increase by 0.7% with a percentage increase in Hispanic student enrollment. This translates into a marginal effect of 0.3% when comparing schools at the 10^{th} and 90^{th} deciles of Hispanic student enrollment. Although the strength of the relationship is similar for within- and end-of-year turnover for Black students, there is only a slight relationship between Hispanic student enrollment and moving at the end of the school year (1.004).

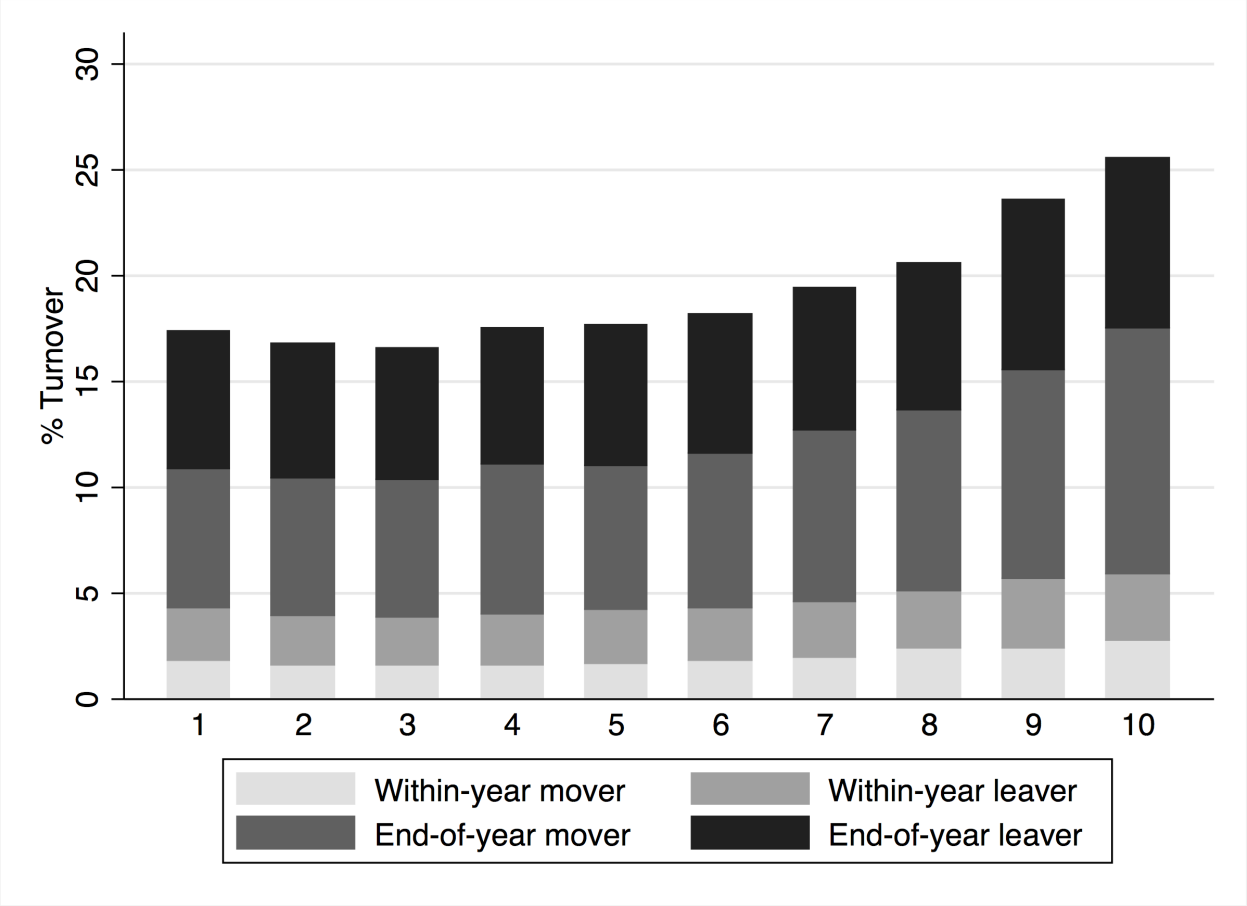
Consistent with moving schools, we find that teachers are disproportionately more likely to leave teaching within the year from schools enrolling the greatest share of minority students compared to those enrolling the fewest. Figure 2 shows that 3.85% of teachers in high minority

schools leave teaching during the school year compared to 1.85% of teachers in low minority schools. In regression analysis in Table 4, the magnitude of the relationship between Black student enrollment is consistent for within- and end-of-year turnover, with a relative risk ratio of 1.005. A one percentage point increase in Hispanic student enrollment is associated with a 0.2% increase in the risk of within-year leaving. A one percentage point increase in other non-White student enrollment is associated with a 0.7% increase in the risk of within-year turnover. We don't find any evidence of a relationship between Hispanic and other non-White student enrollment and end-of-year turnover.

Economically Disadvantaged Student Enrollment

Compared to teachers who stay in their school, teachers who turnover do so from schools enrolling a greater proportion of economically disadvantaged students. In Table 2, we find that stayers worked in schools with an average of 56% economically disadvantaged students compared to 61% and 62% for within- and end-of-year movers, respectively, and 59% for within- and end-of-year leavers. When looking at deciles of economically disadvantaged students in Figure 3 and Table A5, we find a similar pattern as was observed for minority student enrollment, although less of a difference is observed between schools with the least and greatest concentration of poverty. Schools in the bottom decile of economically disadvantaged student enrollment, on average, had 17.33% teachers turn over within and at the end of the school year. The annual turnover rate in schools in the top decile is nearly half again as large, with an average of 25.55%. Yet, when controlling for teacher and school characteristics, including minority student enrollment, we find no evidence of a relationship between a greater share of

Figure 3. Frequency of Turnover by Economically Disadvantaged Student Enrollment Deciles



economically disadvantaged students in a school and higher levels of within-year teacher turnover.[5]

When looking at moving schools, we do not find as large of descriptive differences between the least and most economically disadvantaged schools (Figure 3 and Table A5). 1.83% of teachers in schools in the bottom decile move within the year compared to 2.72% in the top decile. 6.59% move schools at the end of the school year in schools in the bottom decile compared to 11.61% in the top decile. In regression analysis in Table 4, we find no evidence of a

[5] When we drop the minority student enrollment variables from the model, we still find little evidence of a relationship between economically disadvantaged student enrollment and within- and end-of-year turnover. The odds ratio for economically disadvantaged in the model predicting on within-year turnover is 1.002 ($p = 0.003$). The odds ratio for the model predicting end-of-year turnover is 0.9996 and not significant ($p = 0.211$).

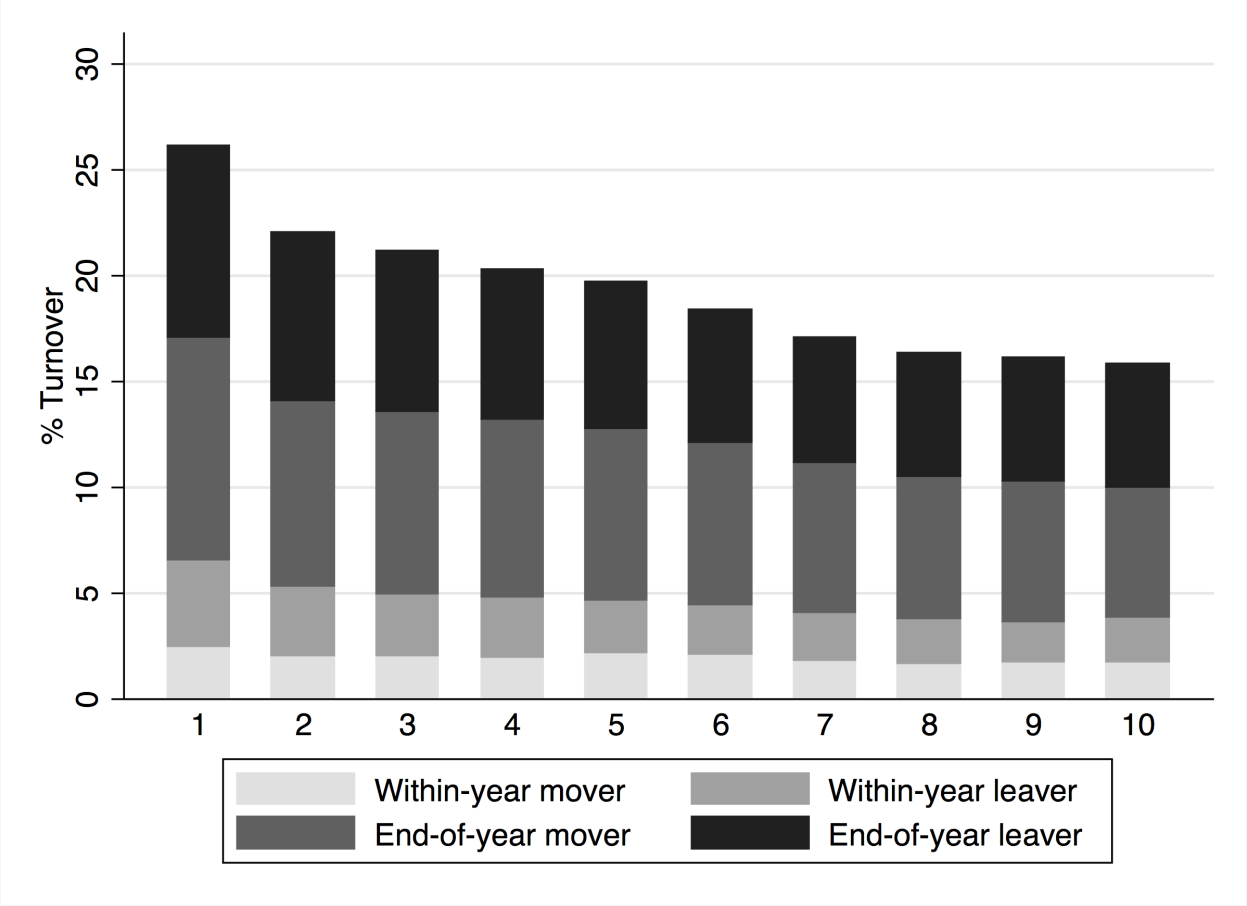
relationship between economically disadvantaged student enrollment and moving schools within the year and only a small, negative relationship with end-of-year turnover, with a relative risk ratio of 0.997.

The results are similar for leaving. Although teachers in schools with a greatest share of economically disadvantaged students are more likely to leave during the year, the gap is not large compared to schools in the bottom decile (Figure 3). 2.46% of teachers in the bottom decile leave teaching annually compared to 3.21% of teachers in the top decile. The proportional differences are similar when comparing end-of-year turnover. 6.45% of teachers leave teaching at the end of the year from schools in the bottom deciles compared to 8.01% of teachers in schools in the top decile. In Table 4, we find a small, but negative relationship between economically disadvantaged student enrollment and teachers leaving within and at the end of the school year. A percentage point increase in economically disadvantaged student enrollment is associated with a 0.2% decrease in the risk of moving within and at the end of the school year.

Overall School Performance

The measure of school performance—the overall performance composite—is a fraction of the number of tests passed over the number of tests taken. As a result, we would expect lower performing schools, that is, schools at the bottom decile of student performance, to have the highest turnover rates. Descriptively, we find this pattern in Figure 4 and Table A6. Over a quarter of teachers turn over from schools in the bottom decile of student performance, including 6.52% turning over within the academic year and an additional 19.58% turning over at the end of the year. Less than 15% of teachers turn over from the highest performing schools, with only 3.85% turning over during the year and 11.95% at the end of the year. In the regression analysis (Table 3), we expect a greater share of students in a school who achieve proficiency to be

Figure 4. Frequency of Turnover by School Performance Deciles



associated with lower odds of turnover. We find this to be the case, with evidence of a slight relationship between increased school performance and lower turnover. A unit increase in school performance is associated with a 0.5% decrease in the odds of within-year turnover and a 0.4% decrease in the odds of end-of-year turnover.

Although teachers are more likely to move during the school year from the lowest performing schools compared to the highest performing schools, the gap is not as large as compared to minority or economically disadvantaged student enrollment (Figure 4). On average, 1.71% of teachers move from the highest performing schools during each school year compared to 2.45% in the lowest performing schools. The gap is proportionally larger for end-of-year turnover. 6.11% of teachers move from the highest performing schools at the end of each year compared to 10.53% in the lowest performing schools. In regression analysis in Table 4, we find

a small, negative relationship between school performance and moving within the school year and a small positive relationship with moving at the end of the year. A one-unit increase in school performance is associated with a 0.1% decrease in the risk of within-year moving and a 0.1% increase in the risk of end-of-year moving.

Instead, the turnover gaps by school performance are driven by teachers leaving within the year at higher rates from the lowest performing schools. In Figure 4, we see that roughly two-thirds of within-year turnover in the lowest performing schools is teachers leaving the profession. Teachers are also nearly twice as likely to leave during the school year in low performing compared to high performing schools (4.07% versus 2.14%). In terms of leaving teaching at the end of the school year, we still observe a gap between the lowest and highest performing schools is, although proportionately, it is not as large as seen for leaving within the year (9.05% versus 5.84%). This descriptive anticipates the estimates from the regression analysis, where we find evidence of a slight relationship between leaving within the year but not at the end of the year. A one-unit increase in overall school performance is associated with a 0.1% reduction in the risk of leaving teaching during the school year.

School Working Conditions

Descriptively, the teacher-reported levels of the quality of facilities and resources, distributed leadership, and principal leadership are all lower among teachers who turn over compared to teachers who stayed in the same school. In Table 2, when combining the within-and end-of-year, we see that teachers who turn over during the year do so from schools with slightly worse working conditions. In Table 3, better distributed leadership and principal leadership scores are each related to lower odds of turnover, with no large differences in the timing of turnover. The quality of facilities and resources are related to within-year turnover but not end-

of-year turnover. A standard deviation increase in this variable is associated with a 5% decrease in the odds of turnover. Somewhat surprisingly, when controlling for other covariates in the model, teacher reports of the quality of professional development are positively related to within-year turnover. A standard deviation increase in professional development are associated with a 7% increase in the odds of within-year turnover.

When examining descriptive differences in terms of moving, we find facilities and resources are reported to be 0.05 standard deviations lower for teachers who move during the school year compared to those who move at the end of the year (Table 2). For the other measures, within-year movers left schools with 0.02 lower reported distributed leadership and 0.01 lower principal leadership. In Table 4, we find no evidence of a relationship between principal leadership and moving within the school year, although better principal leadership is associated with a reduced risk of end-of-year moving (0.90). A standard deviation increase in distributed leadership is associated with a 7% decrease in the risk of within-year moving and a 4% decrease in the risk of end-of-year moving. A standard deviation increase in teacher reports of the quality of facilities and resources are associated with a 7% decrease in the risk of moving schools during the year. We find no similar evidence of a relationship between facilities and resources and moving at the end of the school year.

Returning to Table 2, within-year leavers worked in schools with slightly worse conditions than end-of-year leavers. Facilities and resources, principal leadership, and distributed leadership are reported to be between 0.05 and 0.02 standard deviations lower in the within-year leavers' schools compared to end-of-year leavers. In regression analysis in Table 4, a standard deviation increase in facilities and resources is associated with a 3% decrease in the risk of leaving during the school year. No similar evidence for a relationship between facilities and

resources and leaving at the end of the year is found. A standard deviation increase in principal leadership is associated with a 8% decrease in the risk of leaving within the school year and a 4% decrease in the risk of leaving at the end of the year.

Other School Characteristics

Two descriptive differences in school characteristics emerge between teachers to turn over within and at the end of the school year (see Table 2). First, teachers in high schools are much more likely to move and leave schools within the year compared to elementary and middle schools. In high schools, 2.98% of teachers move schools within the year and 4.41% leave teaching within the year. In elementary schools, only 1.68% of teachers move and 2.21% leave teaching within the year. This corresponding gap is not observed for end-of-year turnover. Second, in comparison to stayers, within-year movers and leavers work in schools with more violent acts, higher suspension rates, and more novice teachers. There are few practical difference between turnover categories across these variables.

The regression analysis in Table 3 shows additional differences between the predictors of within-year and end-of-year turnover. The odds of within-year turnover for middle and high school teachers are much greater than elementary school teachers. While middle and high school teachers also have greater odds of turning over at the end of the school year, the magnitude is much smaller for these estimates. For instance, compared to elementary school teachers, the odds of within-year turnover are 434% greater for high school teachers and, for end-of-year turnover, only 16% greater for high school teachers.[6] A greater share of teachers in their first three years is associated with high turnover, particularly within-year turnover. Counter to our hypothesis that within-year turnover would occur in schools with fewer disciplinary incidents, we find evidence

[6] With evidence of differences by school level, we report on the results from the fully specified model in Table 4 separately for elementary, middle, and high schools (see Table A9).

of a small relationship between the number of violent rates and the suspension rate and within-year turnover, when controlling for teacher and school characteristics. At the same time, we find a small, positive relationship between the suspension rate and end-of-year turnover. An increase in per pupil expenditures are associated with slightly lower odds of within- and end-of-year turnover. We find no evidence that the district teacher salary supplement is related to end-of-year turnover, but an increase in the salary supplement is predictive of higher within-year turnover. A thousand-dollar increase in the teacher salary supplement is associated with a 4% increase in the odds of within-year turnover.

We find evidence that school size is related to within- and end-of-year turnover through two mechanisms. First, an increase in the number of students enrolled in a school is associated with lower odds of within- and end-of-year turnover. The other mechanisms by which student enrollments changes in the number of students enrolled in a school from one year to the next predict turnover, as shifting enrollment patterns may influence involuntary teacher transfer. In Table A7, we consider the extent to which a change in school size from the previous school year to the current year is related to higher levels turnover, particularly during the school year. If shifts in student enrollment drive this pattern, we would expect an increase in student enrollment to be associated with lower odds of turnover, both during and at the end of the school year, particularly within in regards to teachers moving schools within the same district. We find evidence of this hypothesis, with a 100 student change in student enrollment associated with a 4% decrease in the odds of within-year turnover and a 3% decrease in the odds of end-of-year turnover. Table A8 provides further evidence of this hypothesis, with a 100 student change in student enrollment associated with a 18% decrease in the odds of within-district mobility.

To summarize, although the school characteristics in our regression analysis did not consistently predict greater odds of within-year compared to end-of-year turnover, we still found notable differences. Black student enrollment is consistently related to higher turnover rates, with a stronger relationship to within-year turnover compared to end-of-year turnover but a weaker relationship to leaving within the school year than at the end of the year. Opposite our hypothesis, when controlling for school characteristics, an increase in the percentage of economically disadvantaged students has no observable relationship with within-year turnover and a negative relationship with within- and end-of-year turnover. Overall school performance predicts slightly lower rates of moving and leaving schools within the year and slightly higher rates of moving teaching at the end of the school year. Among working conditions, better distributed leadership and principal leadership were consistently related to reductions in within- and end-of-year turnover. Teacher reports of the quality of facilities and resources are only predictive of within-year turnover, including both moving and leaving schools. Among the other school characteristics, compared to elementary school teachers, we found much greater odds of within- and end-of-year turnover for middle and high school teachers.

Discussion

A significant research base has described the characteristics most predictive of end-of-year turnover. We add to this research by characterizing within-year teacher turnover, including its frequency and the school and teacher characteristics associated with within- and end-of-year turnover. Although a small segment of teachers turn over in a given month during the school year—less than 0.75%—throughout the course of a school year, over 4% of teachers either move schools or leave teaching within the school year, which comprises a non-negligible share of the 17% of teachers to turn over annually.

By overlooking this within-year teacher turnover, conventional measures of teacher turnover have either underestimated the actual frequency with which teachers turn over or incorrectly attributed the timing of turnover. The two most common approaches to operationalize teacher turnover—comparing end-of-year turnover rates and fall-to-fall employment status—each have their shortcomings. The former overlooks within-year turnover entirely, underestimating the true frequency with which teachers move schools by 17.6% and the true frequency for leaving schools by 25.6%. Fall-to-fall measures of turnover misattribute the timing of turnover, by including within-in year teacher turnover for a segment of the previous school year as well as teacher turnover at the beginning of the subsequent school year, the period in the school year when teachers are most likely to move schools. In the absence of within-year turnover data, our results suggest these measures are better than end-of-year turnover measures.

Just like end-of-year turnover, within-year turnover is not evenly distributed across schools. Teachers working in schools with the highest concentrations of minority, low-income, and low-performing students have the highest within- and end-of-year turnover rates. For instance, in the schools with the lowest concentrations of minority students the within-year turnover rate is 3.25% compared to 7.3% in the schools with the highest percentages of minority students. The end-of-year turnover rate is 11.49% in the least racially diverse schools and 21.25% in the most diverse schools. In regression analysis, this relationship was most consistent for teachers in schools with higher Black student enrollment, which was associated with consistently higher levels of within- and end-of-year teacher turnover. Notably, when controlling for teacher and school characteristics, we find no evidence of a relationship between a greater share of economically disadvantaged students in a school and higher levels of within-year teacher turnover. Among school working conditions, higher levels of teacher-reported principal

and distributed leadership were associated with lower within- and end-of-year turnover. Only the quality of resources and facilities was consistently related to within-year turnover.

For teacher characteristics, early career teachers move schools at the highest rates while teachers with over 20 years of experience are least likely to move. Consistent with our hypothesis, the least and most experienced teachers are most likely to leave teaching, both during and at the end of year. Among veteran teachers, we found evidence that suggests eligibility for retirement benefits strongly predicted both within- and end-of year turnover. While 22.13% of teachers over 60 leave teaching at the end of each school year, an additional 8.52% leave during the year. Also in terms of teacher age, we also found evidence of an interactive effect with teacher gender. We found higher within- and, to a lesser degree, end-of-year turnover rates among female teachers to be driven by higher rates of leaving teaching and temporarily exiting teaching and returning during the period traditionally associated with child-rearing.

We also identified important differences in the timing of turnover across entry pathways. When controlling for school and other teacher characteristics, alternate entry teachers were less likely to leave during the school year compared to traditionally prepared teachers, although they are predicted to move schools and leave teaching at higher rates at the end of the year. Teacher For America teachers move schools at lower rates, but leave teaching at higher rates, at the end of the school year. Most consistent with our hypothesis, the odds of turnover are consistently greater for out-of-state prepared teachers compared to in-state, traditionally prepared teachers, with no strong differences in the timing of turnover.

From these findings come a number of policy and research considerations. The literature describes how a segment of schools are confronted by high annual turnover so that there is a constant churn of new teachers. We better document this phenomenon by showing the extent to

which certain schools are also faced with more within-year staffing disruptions. Focusing on within-year turnover gives a more accurate picture of the level of turnover in these schools, which has implications on the presence of a supportive and stable work environment with sufficient instructional resources to mentor new teachers across different grades and subjects (Simon & Johnson, 2015). With a more accurate understanding of when teacher turnover occurs, more targeted organizational supports and financial incentives could be employed in high turnover schools to help retain teachers. Notably, we found evidence suggesting that a higher district teacher salary supplement reduces the likelihood that a teacher moves to a new district, while being associated with greater within-district mobility.

Evidence of within-year turnover situates turnover as an ongoing management problem that schools and their leaders must contend with, rather than a once a year recruitment and hiring commitment for school leaders and staff. When within-year turnover is concentrated within a school, administrators may be forced to dedicate time and effort to staff teacher vacancies in classrooms that may have been better spent on instructional improvements. Evidence of differences in the timing of turnover across entry pathways has broader implications for teacher hiring. Previous studies have found alternate entry, Teach For America, and out-of-state prepared teachers to turnover at higher rates than teachers prepared through in-state education programs. We found evidence of higher end-of-year turnover rates for alternate entry and TFA teachers than traditionally prepared teachers but no evidence of differences in within-year turnover. Out-of-state prepared teachers had consistently higher within- and end-of-year turnover rates than teachers prepared in traditional, in-state programs. Evidence of these differences in within-year turnover by entry pathway could be useful to administrators faced with hiring inexperienced teachers from a number of educational backgrounds.

Regarding teacher experience, we found evidence that within-year turnover is concentrated among early career and veteran teachers suggests. For novice teachers, this highlights the continued need to direct high quality induction supports from the district, preparation program, and colleagues within the school. For veteran teachers who are eligible for retirement benefits and retire during the year suggests that retirement eligibility should be restructured around end-of-year, especially if end of year turnover has less of an impact on students than within-year turnover.

Finally, a broader contribution from this paper comes from the unique use of administrative data. Imbedded within the development and use of district and state administrative data systems has been an assumed school production function that yields annual outcomes. Using the example of teacher turnover, researchers have assumed that turnover occurs between school years leading researchers to overlook within-year turnover. We encourage researchers to examine other student, teacher, and school outcomes in a similar fashion. For instance, linking measures of student and teacher attendance to mobility could yield a measure of the length of time a student is assigned to a particular teacher to be more accurately identify teacher effects within a school year. Within a survival analytic framework, researchers could study patterns in the timing of student and teacher absences and student assignment, with a particular eye towards how students are moved between teachers during the school year in the face of accountability pressures. Additionally, similar to the way in which we studied teacher labor markets, administrators may be just as mobile, if not more mobile, than teachers during the school year. Finally, previous studies have assumed that within-year and end-of-year turnover equally affect student outcomes. Researchers should examine the possibility of differential effects of teacher turnover depending on its timing in the school year. Further, they could test differences in the

effect of turnover for individual students who lose a teacher compared to students in schools with higher levels of turnover.

References

Allensworth, E., Ponisciak, S., & Mazzeo, C. (2009). *The schools teachers leave: Teacher mobility in Chicago Public Schools*. Chicago, IL: Consortium on Chicago School Research—University of Chicago.

Bastian, K. B. & Henry, G. T. (2014) Teachers without borders: Consequences of teacher labor force mobility. *Educational Evaluation and Policy Analysis*, *37*(2), 163-183.

Borman, G. D., & Dowling, N. M. (2008). Teacher Attrition and Retention: A Meta-Analytic and Narrative Review of the Research. *Review of Educational Research*, *78*(3), 367–409.

Boyd, D., Grossman, P. L., Ing, M., Lankford, R. H., Loeb, S., & Wyckoff, J. (2011). The influence of school administrators on teacher retention decisions. *American Educational Research Journal*, *48*(2), 303–333.

Chetty, R., Friedman, J. N., & Rockoff, J. R. (2014). Measuring the impacts of teachers II: Teacher value-added and student outcomes in adulthood. *American Economic Review, 104*(9), 2633–2679.

Clotfelter, C., Glennie, E., Ladd, H., & Vigdor, J. (2008). Would higher salaries keep teachers in high-poverty schools? Evidence from a policy intervention in North Carolina. *Journal of Public Economics, 92*(5-6), 1352-1370.

Clotfelter, C.T., Ladd, H.F. & Vigdor, J.L. (2007). Teacher credentials and student achievement: Longitudinal analysis with student fixed effects. *Economics of Education*, *26*(6), 673-682.

Clotfelter, C. T., Ladd, H.F., Vigdor, J.L. (2009). Are teacher absences worth worrying about in the United States? *Education Finance and Policy, 4*(2), 115-149.

Goldhaber, D., Lavery, L., & Theobald, R. (2015). Uneven playing field? Assessing the teacher quality gap between advantaged and disadvantaged students. *Educational Researcher*, *44*(5), 293-307.

Goldhaber, D. and Theobald, R. (2013). Managing the teacher workforce in austere times: The determinants and implications of teacher layoffs. *Education Finance and Policy, 8*(4), 494-527.

Grissom, J. A. (2011). Can good principals keep teachers in disadvantaged schools? Linking principal effectiveness to teacher satisfaction and turnover in hard-to-staff environments. *Teachers College Record*, *113*(11), 2552–2585.

Grissom, J. A. & Keiser, L. R. (2011). A supervisor like me: Race, representation, and the satisfaction and turnover decisions of public sector employees. *Journal of Policy Analysis and Management, 30*(3), 557-580.

Grissom, J. A., Loeb, S., & Nakashima, N. A. (2013). Strategic involuntary teacher transfers and teacher performance: Examining equity and efficiency, *Journal of Policy Analysis and Management*, *33*(1), 112-140.

Grissom, J. A., & Reininger, M. (2012). Who comes back? A longitudinal analysis of the re-entry behavior of exiting teachers. *Education Finance and Policy*, *7*(4) 425-454.

Guarino, C., Santibañez, L., & Daley, G. A. (2006). Teacher recruitment and retention: A review of the recent empirical literature. *Review of Educational Research*, *76*(2), 173–208.

Hanushek, E., Kain, J., & Rivkin, S. (2004). Why public schools lose teachers. *Journal of Human Resources*, *39*(2), 326–254.

Horng, E. L. (2009). Teacher tradeoffs: Disentangling teachers' preferences for working conditions and student demographics. *American Educational Research Journal*, *46*(3), 690–717.

Ingersoll, R. (2001). Teacher turnover and teacher shortages: An organizational analysis. *American Education Research Journal*, *38*(3), 499–534.

Ingersoll, R. M., Merrill, L., & Stuckey, D. (2014). *Seven trends: The transformation of the teaching force.* CPRE Research Report # RR-80. Philadelphia: Consortium for Policy Research in Education.

Johnson, S. M., Kraft, M., & Papay, J. P. (2012). How context matters in high-need schools: The effects of teachers' working conditions on their professional satisfaction and their students' achievement. *Teachers College Record*, *114*(10), 1–39.

Kalogrides, D., Loeb, S., & Beteille, T. (2013). Systematic sorting: Teacher characteristics and class assignments. *Sociology of Education, 86*(2), 103-123.

Kirby, S. N., Berends, M., Naftel, S. (1999). Supply and demand of minority teachers in Texas: Problems and prospects. *Educational Evaluation and Policy Analysis, 21*(1), 47-66.

Koski, W. S., & Horng, E. (2007). Facilitating the teacher quality gap? Collective bargaining agreements, teacher hiring and transfer rules, and teacher assignment among schools in California. *Education Finance and Policy*, *2*(3), 262–300.

Kraft, M. (2015). Teacher layoffs, teacher quality, and student achievement. Evidence from a discretionary layoff policy. *Education Finance and Policy*, *11*(4), 1-41.

Kraft, M. & Papay, J. P. (2014). Can professional environments in schools promote teacher development? Explaining heterogeneity in returns to teaching experience. *Educational Evaluation and Policy Analysis, 36*(4), 476-500.

Ladd, H. F. (2011). Teachers' perceptions of their working conditions: How predictive of planned and actual teacher movement? *Educational Evaluation and Policy Analysis*, *33*(2), 235–261.

Lankford, H., Loeb, S., & Wyckoff, J. (2002). Teacher sorting and the plight of urban schools: A descriptive analysis. *Educational Evaluation and Policy Analysis*, *24*(1), 37–62.

Loeb, S., Darling-Hammond, L., & Luczak, J. (2005). How teaching conditions predict teacher turnover in California schools. *Peabody Journal of Education*, *80*(3), 44–70.

Miller, R. T., Murnane, R. J., & Willett, J. B. (2008). Do teacher absences impact student achievement? Longitudinal evidence from one urban school district. *Educational Evaluation and Policy Analysis*, *30*(2), 181–200.

National Council on Teacher Quality (2013). NCTQ District Policy. Retrieved from www.nctq.org

Redding, C. & Smith, T. M. (2016). Easy in, easy out—Are alternatively certified teachers turning over at increased rates? *American Educational Research Journal, 53*(4), 1086-1125.

Rivkin, S. G., Hanushek, E. A., & Kain, J. F. (2005). Teachers, schools, and academic achievement. *Econometrica*, *73*(2), 417–458.

Rockoff, J. (2004). The impact of individual teachers on student achievement: Evidence from panel data. *American Economic Review, 94*(2), 247–252.

Ronfeldt, M., Loeb, S., & Wyckoff, J. (2013). How teacher turnover harms student achievement. *American Educational Research Journal*, *50*(1), 4-36.

Schweig, J. (2014). Cross-level measurement invariance in school and classroom environment surveys: Implications for policy and practice. *Educational Evaluation and Policy*

Analysis, *36*(3), 259-280.

Simon, N. S. & Johnson, S. M. (2015) Teacher turnover in high-poverty schools: What we know and can do. *Teachers College Record*, *117*(3), 1-36.

Smith, T. M., & Ingersoll, R. M. (2004). What are the effects of induction and mentoring on beginning teacher turnover? *American Educational Research Journal*, *41*(3), 681–714.

Steele, J. L., Pepper, M. J., Springer, M. G., & Lockwood, J. R. (2015). The distribution and mobility of effective teachers: Evidence from a large urban school district. *Economics of Education Review, 48*, 86-101.

CHAPTER 3

LEAVING SCHOOL EARLY: A SURVIVAL ANALYSIS OF NOVICE TEACHERS' WITHIN- AND END-OF-YEAR TURNOVER

Introduction

Filling vacancies for classroom teachers is no longer a springtime activity for school administrators. Anecdotal evidence, stories that principals tell about filling vacancies after school starts in the fall and indeed throughout the school year, is beginning to be backed up by empirical research (Camburn, Spillane, & Sebastian, 2010; Horng, Klasik, & Loeb, 2010). For example in North Carolina from 2008-09 through 2013-14, the rate at which teachers turned over at the end of the school year averaged 13.4% for all teachers. When within-year turnover is included, the total rate is actually 17.09%, which suggests the actual annual turnover rate with which school personnel and students contend is 22.4% higher than previous measures of teacher turnover would indicate. This research suggests that teacher turnover is an even larger problem than has been acknowledged and investigated in prior research. While end-of-year turnover has been the subject of extensive examination (Borman & Dowling, 2008; Guarino, Santibañez, & Daley, 2006; Ingersoll, 2001), the additional turnover that occurs during the school year, which we will refer to as within-year turnover, has yet to be examined and the teacher- and school-level factors that are driving it have yet to be explained.

Research on end-of-year turnover suggests that both individual and school-level variables affect teachers' decisions to turnover. Among teacher background characteristics, younger, alternate entry, out-of-state prepared teachers, and teachers with less experience turnover at higher rates (Borman & Dowling, 2008; Bastian & Henry, 2015). At the school level, teacher turnover is highest in schools with high concentrations of economically disadvantaged and

racial/ethnic minority students, schools that also tend to have the most difficult working conditions (Ingersoll, 2001; Ladd, 2011). The turnover levels in these challenging schools are likely exacerbated by the disproportionate number of novice, alternate entry, and out-of-state prepared teachers employed in them.

Amidst these persistent patterns of teacher turnover, an increasingly less experienced teacher labor force who have entered teaching from more varied entry pathways appear to be feeding a new dynamic (Ingersoll, Merrill, & Stuckey, 2014; Henry et al., 2014). The opportunities to teach, especially for novice teachers, occur with greater frequency in schools with high concentrations of economically disadvantaged and racial/ethnic minority students. In North Carolina elementary schools, Clotfelter and colleagues (2007) find schools in the highest poverty quartile had 18.7% of teachers in their first three years of their career compared to 13.3% in the lowest poverty quartile. These novice teachers enter into challenging conditions that their preparation may not prepared them to manage effectively. As early career teachers are most likely to draw on school personnel and resources to support their professional development, they may be particularly sensitive to the influence of school working conditions when making their decision to remain in their school and the profession (Smith & Ingersoll, 2004). Moreover, alternate entry and out-of-state prepared teachers may be even more dependent on a supportive environment in their school than teachers from in-state traditional education programs. Alternate entry teachers likely require additional mentoring to compensate for the lack of pre-service training. Out-of-state prepared teachers may need additional support to learn a new curriculum and state instructional context. If these supports are not available for new teachers, challenging working conditions are likely to increase demoralization and reduce their commitment to the profession, making the decision to leave, even during the school year, easier.

To describe the systematic variation in the early career trajectories of teachers across various entry pathways, we engage in a comprehensive examination of teacher turnover longitudinally that includes both within- and end-of-year turnover. We believe that a unique contribution to the teacher turnover literature comes from modeling turnover monthly throughout the year rather than as a single annual event occurring at one point in time. Examining teachers' employment status every month more accurately captures the current dynamics of teachers' labor markets. Examining turnover in this way also increases our understanding of turnover as an ongoing management problem that schools, their leaders, and staff must contend with, rather than an annual recruitment and hiring activity. In addition, within-year turnover significantly disrupts student learning when replacements, including short- and long-term substitutes, force students to adjust midyear to different instructional pace and practices, and disturb professional relationships and collaborations (Ronfeldt, Loeb & Wyckoff, 2013; Ronfeldt, Farmer, McQueen, & Grissom, 2015). Finally, the paper raises an important measurement issue for the teacher labor market literature. This literature commonly measures teacher turnover as a single event occurring between school years, with researchers measuring the proportion of teachers working at the end of the school year but not employed in the same school at the beginning of the next. We demonstrate how this operationalization attentuates the overall frequency of teacher turnover by excluding within-year turnover, which may occur more now than in the past if the trends that we hypothesize to have affected this phenomenon continue to hold.

In this paper, we seek to better understand the patterns of early career teacher turnover, focusing particularly on the turnover rates across teacher entry pathways and school characteristics. At times, we also distinguish between moving schools and leaving teaching in North Carolina, although the focus is on how overall turnover is consequential at the school

level. We conduct survival analysis of teachers' monthly turnover patterns using detailed teacher employment data files from North Carolina. We ask the following questions:

(1) To what extent does the timing of novice turnover differ by teacher entry pathway and school characteristics?

(2) To what extent do teacher and school characteristics reduce or increase the risk of turnover among novice teachers from different pathways?

(3) To what extent do teacher and school characteristics differentially predict end-of-year versus within-year novice teacher turnover?

(4) In what ways do novice teacher qualifications and effectiveness predict a greater or lower risk of turnover?

We begin with a theoretical framework describing differences in the commitment to teaching across different entry pathways. Then, we detail the sample of new teachers used for this analysis, the data used to generate monthly measures of teacher turnover, and the modeling approaches used for this study.

Novice Teacher Commitment and Turnover

Organizational commitment theory suggests that the perceived costs, affective attachment, and normative commitment all shape the duration of teachers' careers (Becker, 1960; Firestone & Pennell, 1993; Lee, Carswell, & Allen, 2000; Meyer & Allen, 1991; Meyer, Allen, & Smith, 1993). Perceived costs are defined as something valued by a teacher (e.g., salary, pension, seniority) that are contingent on employment in a particular organization and would be lost upon exit (Meyer and Allen, 1991). Affective attachment relates to a teacher's involvement in a school and identification with its goals and values. Also, teachers enter the profession with personal norms or values that shape their commitment to teaching. Normative commitments arise

from internalized values and normative pressure, both of which can shape teachers' decision to remain in their school or the profession. We describe how these three dimensions of organizational commitment differ across early career teachers' years of experience in teaching, entry pathway, and school context and affect the amount of time they remain in their original school or the teaching profession. Drawing on empirical literature and organizational commitment theory, in the next section and in Table 1, we develop a series of hypotheses related to the timing and type of turnover (moving or leaving). While any teacher turnover risks disrupting a school, the distinction between moving and leaving highlights the high rate with which novice teachers leave the profession.

Experience

Previous research indicates that novice teachers are the most likely to turnover, with the highest turnover rates following a teachers' first year (Borman & Dowling, 2008; Gray & Taie, 2015). Data from the nationally representative Beginning Teacher Longitudinal Study indicate that 26% of teachers had turned over from their initial school after the first year, with lower turnover rates in subsequent years (Gray & Taie, 2015). We predict that the high rates of first-year teacher turnover not only occur at the end of the school year but during their first school year as well. A description of the perceived costs faced by new teachers and affective attachments at their first school help explain why we would expect this decline in turnover with gains in experience.

Novice teachers face a unique set of costs compared to more experienced teachers, which predict their high turnover levels. Increasingly in recent years, new teachers have relatively low salaries within a single-salary schedule, which may discourage some teachers from remaining in teaching due to the income loss from other positions for which they could qualify (Allegretto &

Table 1. Hypotheses Related to Teacher and School Characteristics

Teacher Characteristic	Hypothesis	Rationale
Experience	• *Decline in moving and leaving, both within and at the end of the school year, with gains in experience*	• High perceived costs for new teachers, including relatively low starting salaries and pension plans that incur costs but accumulate little wealth in their first several years • Seniority-based norms leave less experienced teachers with more difficult teaching assignments, increasing the need for support from their school staff to integrate new teachers into the pre-existing professional and social culture of a school to increase their affective attachment
Entry Pathway		
In-state, traditional certification	• *More likely than other entry pathways to move schools* • *Less likely than other entry pathways to leave teaching*	• High costs associated with completion of licensure requirements increase human capital in ways specific to teaching, likely reduce transfer to other professions but increase employment opportunities at other schools
Alternate entry	• *Less likely than traditionally certified teachers to move schools* • *More likely to leave teaching within and at the end of the school year than traditionally certified teachers*	• Lack of full credential limits employment opportunities at other schools • Fewer real and opportunity costs when entering teaching result in less commitment to remain in teaching • More likely to work in underserved schools with less supportive social conditions, which may result in less affective attachment
Teach For America	• *Unlikely to move between schools* • *Most likely to leave teaching, both within and at the end of the school year*	• Normative commitment to work in underserved schools suggests they would remain in their initial school placement • Fewer real and opportunity costs when entering teaching result in less commitment to remain in teaching
Out-of-state prepared	• *No difference from in-state prepared teachers in terms of moving between schools.* • *More likely to leave teaching within and at the end of the school year than traditionally certified teachers*	• If an early career teacher knows they will not spend their career in the state, it would be most beneficial to transfer to their home state before investing additional time acquiring benefits that would not transfer to their home state.
School Context	• *Teachers in schools with greater concentrations of minority, economically disadvantaged, and low-performing students will be most likely to move schools and leave teaching, both during and at the end of the school year.*	• Move into schools with more positive working conditions and equivalent salary and benefits. • When early career teachers work in underserved schools without positive working conditions, they likely experience lower quality induction supports, become more demoralized, and lack commitment to remain in the profession.

Notes. School context refers to minority, economically disadvantaged, and low-performing student enrollment

Mishel, 2016). Defined-benefit pension plans incur significant costs for new teachers but accumulate little wealth in their first several years (Costrell & Podgursky, 2009). If a novice teacher feels they will not remain a teacher for their entire career, within the current pension system, they would be best served by a quick exit from the profession. Finally, seniority-based norms leave more experienced teachers with non-pecuniary benefits such as assignment to more preferable students or a classroom with better facilities (Clotfelter, Ladd, and Vigdor 2007). More difficult teaching assignments for novice teachers may also increase their likelihood of turnover (Henry, Smith and Bastian 2012).

Challenging teaching assignments are especially problematic when new teachers are forced to negotiate the new classroom environment and do not receive the support from their school staff and fail to be integrated into the pre-existing professional and social culture of a school thereby reducing their affective attachment. Kardos and Johnson (2007) argue that developing affective attachment to their school is likely to be most important among novice teachers as they are placed in a high stress environment, often without the supports to negotiate it successfully (Kardos & Johnson, 2007). Research suggests that the social conditions of schools may be particularly important for the retention of novice teachers. For instance, among novice teachers, more opportunities for teacher collaboration are associated with lower turnover rates (Smith & Ingersoll, 2004).

The least experienced teachers are also most likely to be moved involuntarily prior to earning tenure protections (Guarino et al., 2006). Involuntary within-year transfers may be primarily in response to shifting student enrollment patterns that require a teacher hired at one school to transfer to another school in the district. These staffing decisions tend to seniority-based, although there is variation across district policy within states (Koski & Horng, 2007), with

some districts able to make more strategic transfers (Grissom, Loeb, & Nakashima, 2013). In North Carolina—the site of the current study—data from the National Council on Teacher Quality show that among the three largest districts, Charlotte-Mecklenburg and Guilford County Schools place more of an emphasis on seniority whereas Wake County Schools assigns teachers in the "best interests" of the district (2013). However, Charlotte-Mecklenburg adopted a discretionary layoff policy during the Great Recession (Kraft, 2015).

In-State, Traditional Certification

In-state, traditionally certified teachers are the least likely to turnover compared to other entry pathways (Bastian & Henry, 2014; Borman and Dowling 2008; Darling-Hammond, 2000). These higher rates of persistence are attributed to the high costs associated with completion of licensure requirements and the values that shape teachers' decisions to enter teaching and their normative commitment to remain in the profession.

While licensure requirements drive up costs of entering teaching, which may limit those who decide to enter teaching, they could also ensure greater stability in the teacher labor market. By establishing requirements for entry into the teaching profession—pedagogical training, student teaching, and content knowledge—traditional education programs attempt to equip teachers who enter the classroom with the knowledge and skills deemed to be essential. The high costs associated with completion of licensure requirements through a traditional, in-state university-based program that increase human capital in ways specific to teaching, likely reduce transfer to other professions. In comparison to other early career teachers who enter the profession from a variety of pathways, this traditional certification may also serve as a signal of quality, increasing employment opportunities at other schools. As a result, we predict that

teachers who enter the profession through in-state, traditional university-based programs leave teaching at the lowest rate of all entry pathways but move schools at the highest rate.

The lower turnover rates for traditionally certified teachers can also be explained by the schools in which they teach. Previous research indicates that traditionally certified teachers tend to work in more affluent schools that also tend to have more positive working conditions. In the 2011-2012 school year, compared to early career traditionally certified teachers, novice alternate entry teachers worked in schools with on average of 9% more students on Free or Reduced Price Lunch and a quarter standard deviation lower teacher reported staff collegiality (Redding & Smith, 2016). As traditionally certified teachers are more likely to work in schools with more positive social conditions, the development of affective attachments to their school may also result in lower turnover rates.

Finally, by the time traditionally certified teachers enter the profession, they have already spent time as a student teacher, an experience which allows them to preview the job and determine whether the work of teaching and the district are a good fit (Ronfeldt, Reininger, & Kwok, 2013). Unlike alternate entry teachers who would make such a decision while serving as the instructor of record, those who enter teaching establish a normative commitment to the profession prior to entry.

Alternate Entry

Evidence suggests that alternate entry teachers turn over at higher rates than traditionally certified teachers, although differences exist between alternate entry programs. Drawing on four waves of the Schools and Staffing Survey, Redding and Smith (2016) find evidence of a growing turnover gap between alternate entry and traditionally certified teachers. In 2007-2008, 27 percent of early career alternate entry teachers turned over annually, compared to only 17 percent

of traditionally certified teachers. Evidence from New York City and North Carolina suggests that teachers from more selective programs leave teaching at higher rates. In New York City, Kane and colleagues (2008) found much lower persistence rates among Teach For America (TFA) teachers with only 18 percent teaching in the district after five years. Given the unique program design of TFA, which recruits high performing college graduates to two years of public service, this steep turnover rate may be expected. Kane et al. (2008) maintain that the value-added gains for TFA members offset the differential attrition rates for this group of teachers. While the evidence suggests that TFA teachers consistently turnover at higher rates, the turnover rates of teachers from less selective programs is inconsistent. Kane and colleagues (2008) observe no differences in turnover between traditionally certified teachers and participants in New York City Teaching Fellows. An earlier study using earlier data contradicts this finding of higher turnover rates among NYC Teaching Fellows. Boyd and colleagues (2006) find a 10.1 percentage point higher attrition rates among Teaching Fellows than traditional pathways after four years of experience when conditioning on school fixed effects (Boyd et al., 2006). In North Carolina, Bastian and Henry (2015) also find higher turnover rates among alternate entry teachers compared to any other entry portal. Differences in the perceived costs, affective attachment, and normative commitment seem to explain their higher turnover rates.

By reducing the barriers into teaching, alternate entry programs aim to recruit candidates with higher levels of human capital and a variety of job prospects both inside and outside education. As these teachers incur fewer real and opportunity costs when entering teaching and possibly have higher paying employment opportunities outside of education, they may be more likely to leave than their peers who entered teaching through a university-based teacher education program and have invested in human capital specific to teaching. Alternate entry

teachers' lack of prior investment could result in less commitment to remain in teaching and higher turnover rates, even during the school year. The elevated likelihood of turnover may be exacerbated by the time demands placed on new alternate entry teachers who have to teach as well as meet frequently with mentor teachers and complete coursework required for permanent certification during weekends, weekday evenings, and in the summer.

Alternate entry teachers who do not receive extensive training prior to entering the classroom may be less productive when they enter the classroom, which has implications for their normative commitment to remain in the profession. Evidence from New York City provides evidence for this scenario. The students of early career alternate entry teachers have smaller test score gains compared to teachers who completed a traditional teacher education program, although these differences disappear with experience (Kane, Rockoff, & Staiger, 2008). However, data from North Carolina suggest a more complex pattern, with alternate entry teachers, other than TFA corps members, less effective in middle grade mathematics, secondary mathematics and secondary science but TFA more effective in nearly every grade level and subject (Henry et al., 2014). Given the evidence of higher turnover rates among less effective teachers (Boyd, Grossman, Lankford, Loeb, & Wyckoff, 2009; Boyd, Lankford, Loeb, & Wyckoff, 2005; Goldhaber, Gross, & Player, 2011; Henry, Bastian, & Fortner, 2011; Henry, Fortner, & Bastian, 2012), it is plausible that feeling performing worse with their students and feeling less efficacious as a teacher leads to feelings of demoralization and higher turnover rates, reducing teachers' normative commitment (Johnson & Birkeland, 2003).

Because of the dearth of pre-service training, developing an affective attachment to their school may be particularly important for early career alternate entry teachers as they receive the bulk of their training once they begin teaching. As a result of the outsized role of inductive

supports, alternate entry teachers may be particularly sensitive to the social conditions of the school, possibly resulting in lower turnover rates when working in schools with positive social conditions. Yet, as alternate entry teachers tend to work in underserved schools with less supportive social conditions, they may not receive these supports.

At the same time, alternate entry teachers may bring a social justice or public service orientation to teaching that emphasizes their role in enhancing students' life chances (Cochran-Smith 1999; Darling-Hammond et al. 2002; Oakes, Lipton, Andersen, & Stillman 2012; Ronfeldt, Kwok, & Reininger, forthcoming). This motivation may enhance teachers' commitment to work in under-resourced schools with difficult working conditions and with students from traditionally underserved racial/ethnic groups, resulting in low rates of moving between schools during a two- or three-year period as part of a programmatic commitment. Their commitment to remain in their school may also arise because of feelings of obligation that arise once they have entered teaching. For alternate entry teachers, schools may incur additional costs in providing employment for these teachers. Administrators provide them with induction supports and teachers dedicate time to mentor them. A teacher's recognition of these investments may create feelings of obligation among alternate entry teachers, leading them to commit themselves to the schools until they "repay" these perceived debts (Meyer and Allen, 1991). Besides their normative commitment, the low rates of moving schools which we predict may also be explained by alternate entry teachers' lack of full teaching credential, which could serve to limit employment opportunities in different schools.

Out-of-State Prepared

Compared to other entry pathways, there is less evidence of turnover among out-of-state prepared teachers, although the existing research indicates that they turnover at higher rates than

in-state prepared teachers (Bastian & Henry, 2015; Goldhaber & Cowan, 2014). Bastian and Henry (2015) find that 25 percent of the early career teachers from out-of-state programs exited North Carolina public schools within five years of beginning teaching, compared to only 13 percent of in-state prepared teachers. In Washington State, Goldhaber and Cowan (2014) report that teachers from out-of-state prepared teachers are even more likely to exit the school system with 44 percent of out-of-state prepared teachers leaving by the end of their fifth year. Goldhaber and colleagues (2015) hypothesize that less experienced teachers will be the most likely to switch states because they face lower costs associated with interstate moves. These costs include additional seniority-benefits that bring job protection and greater returns from pension plans. If an early career teacher knows they will not spend their career in the state, it would be most beneficial to transfer to their home state before investing additional time acquiring benefits that would not transfer to their home state. It is also possible that these teachers emigrate from states that prepare more teachers than there are employment opportunities and that they may be more competitive for positions in the teacher surplus-producing states after they gain experience (Bastian & Henry, 2015).

Given the research that shown teachers' preference to work close to home (Boyd et al., 2005; Reininger, 2012), we suspect out-of-state prepared teachers have less of a normative commitment to remain in the out-of-state schools in which they begin teaching than in-state prepared teachers. Further, teachers from out-of-state are likely to be unfamiliar the state's educational environment, increasing the challenges faced by early career teachers and elevating their risk of turning over. Finally, similar to alternate entry teachers, out-of-state prepared teachers increasingly fill shortages in in high poverty schools with high concentrations of

students of color, which may strain the formation of affective attachments if these schools also lack strong social conditions.

School Context

One of the best established patterns in the teacher labor market is that teachers disproportionately leave under-resourced urban schools with high concentrations of economically disadvantaged students and traditionally underserved racial/ethnic groups (Lankford, Loeb, & Wyckoff, 2002). For instance, data from the nationally representative Schools and Staffing Survey (SASS) shows an annual turnover rate of 10.5% in low poverty schools compared to 15.2% in high poverty schools (Ingersoll, 2001). We expect this asymmetric sorting to be particularly strong for the early career teachers in this study, who increasingly fill roles in these underserved schools. We predict that early career teachers working in schools with the greatest concentrations of minority, economically disadvantaged, and low-performing students will have the highest turnover rates, both during and at the end of the school year. Given the evidence of teachers sorting into schools, we expect this turnover will be driven by moving to new schools rather than leaving teaching.

Underserved schools also tend to have more difficult working conditions (Borman & Dowling, 2008; Guarino, Santibañez, & Daley, 2006; Ingersoll, 2001). Research on working conditions has focused on social conditions such as school leadership or distributed leadership, the availability of adequate facilities and resources and high-quality professional development opportunities, and student discipline problems (Buckley, Schneider, & Shang, 2005; Feng, 2010; Ingersoll, 2001; Johnson, Kraft, & Papay, 2012; Ladd, 2011). Given the influence of school demographic characteristics and working conditions on early career teacher turnover, when these conditions do not exist, they likely increase demoralization and lack of commitment to remain in

the profession, leading to higher levels of turnover, both during and at the end of the school year. When new teachers are placed in a high stress environment and not provided the induction supports to negotiate classroom challenges, these teachers may become demoralized, leaving teaching before the school year even ends.

Yet, positive social conditions may be linked to teachers' affective attachment, job satisfaction, and retention (Johnson, Kraft, & Papay, 2012; Simon & Johnson, 2015). For instance, in Chicago, Allensworth, Ponisciak, and Mazzeo (2009) explain that teacher stability is higher in schools where teachers reported positive relationships with their peers and the administrators. Teachers were less likely to turnover from schools with higher levels of teacher-reported collective responsibility, teacher influence, teacher-teacher trust, and teacher-principal trust, even after controlling for teacher and student characteristics. In other studies, lower levels of teacher-reported school administrator quality (Boyd et al., 2011; Grissom, 2011; Ladd, 2011) and distributed leadership (Schweig, 2014) have been found to be strong predictors of retention.

Research Design

In this study, we examine the extent to which turnover among early career teachers is related to their entry pathway and school conditions. We conduct survival analysis to estimate the conditional probability that a teacher would turnover in a given month, given that they still remain in their school in the previous month. More specifically, we test three main hypotheses: (1) novice teachers' within-year and end-of-year turnover is expected to decrease with each year of experience, (2) novice out-of-state prepared and alternate entry teachers turnover at higher rates within the year and from year to year, and (3) teachers in schools with higher concentrations of racial/ethnic minorities, economically disadvantaged, and low-performing students will have higher levels of turnover, both during and at the end of the school year.

Similar to other studies using administrative data, turnover is defined as moving to a new school or leaving teaching in the state of North Carolina for this study. This analysis of teacher turnover is distinctive for two reasons. First, most research on teacher turnover tends to predict one-year turnover rates, particularly the research from the cross-sectional SASS. By only examining one year of data at a time, these models fail to predict the length of teachers' stays in their current school or the teaching profession. We follow three cohorts of early career teachers for three years, beginning with their entry into the profession. This sample and longitudinal data allow us to not only understand differences in turnover by certification status but also more adequately explain the employment trajectories of early career teachers. It also allows us to examine differences in timing and overall conditional probabilities of teachers from different entry portals leaving schools with high concentrations of poor or students from underserved racial/ethnic student subgroups before moving to more affluent schools.

Second, unlike other studies on teacher turnover that treat turnover as a single annual event occurring between school years, we measure turnover during any month and model it throughout three years using survival analysis. An assumption in any survival analysis is that there is an underlying continuous time model (Allison, 1982; 2014). By examining turnover as occurring annually, researchers have made an implicit assumption that teachers have an equivalent risk of turning over at any point in the year. As Willett and Singer (1991) argue, this type of dichotomization "eliminates potentially meaningful variation by clustering together everyone" (p. 408) at the end of the school year. For these reasons, we argue that the frequency of within-year mobility leaves this assumption untenable. We are able to better model turnover as we come closer than previous studies to approximating the underlying continuous time model. Still, in comparison to daily observations, it must be noted that the data study are interval

censored. In some of the models described below, we treat time as discrete and estimate models using discrete time hazard analysis. In others, we ignore this discreteness and treat monthly data as continuously measured using Cox proportional and Royston-Parmar hazard models.

Study Sample

The main objectives for this study are to compare differences in novice teachers' risk of turning over across different entry pathways into teaching and school characteristics. The sample is drawn from three cohorts of new teachers in the state of North Carolina who entered teaching in the 2009-2010, 2010-2011, and 2011-2012 school years. We follow teachers each month of the school year for their first three years of teaching. To determine end-of-year turnover, we draw on teacher salary files in the subsequent school year to determine if the teacher has remained in the same school year, moved schools, or left teaching. We focus on teachers' in their first three years for four reasons. First, first year teachers are the modal year of teacher experience in the profession and the largest share of teachers in the profession are in their first three years. Second, in previous work, we show that within- and end-of-year turnover is generally highest during teachers' first three years on the job. Third, as the timing of this study overlaps with a period of flux in the entry and exit of novice teachers following the Great Recession, we adopt a multiple-cohort approach to adequately account for differences in the exit and entry of new teachers during and after the recession. An alternative approach would follow each cohort for all years with available data. This approach risks inappropriately weighting the influence of an entry pathway, particularly in the first two cohorts who were most likely to be influenced by their entry during a period of flux in the teacher labor market. As a sensitivity analysis described in greater detail below, we follow the first cohort for five years to test if the differences in turnover persist following teachers' first three years. Fourth, as alternate entry is

one focal pathway of this study, limiting the sample to three years covers the maximum length alternate entry teachers in North Carolina have to transition from their lateral entry provisional educator's license to the professional educator's license.

To build this longitudinal analysis file we draw on monthly teacher pay files, which include detailed information about whether or not a teacher was employed in a given month and, if so, the school in which they were employed. Across these cohorts, the analytic sample includes 13,784 unique teachers and 35,536 teacher-year observations. The sample size varies across years, as the number of new teachers to enter the profession dipped during the Great Recession. Cohorts one through three consist of 3,837, 4,936, and 5,011, first-year teachers, respectively.

Study Data

Outcome Variables

For this analysis, the outcome variable is a teacher's employment status in a given month. These variables document a teacher's exit from their school, either (a) moving to a new school[7] and (b) leaving teaching in the state of North Carolina. In supplementary analysis in the appendix, we consider an additional outcome: temporarily leaving before returning to the same school in the current year or the next. These dichotomous variables are coded as 1 if the event was experienced in a particular month, given that it had not occurred earlier and 0 if the event had not been experienced in that month. It is important to note that we observe teachers for the length of a traditional school year, that is, for 10 months each year. So, if a teacher remained in the same school for the first three years of teaching, they would be observed for a maximum of 30 months. It is also important to note that these outcomes are not mutually exclusive. Before estimating the risk of moving and leaving schools separately, to understand the overall churn of

[7] In supplementary analysis in the appendix, we estimate separate models for within-district and within-state movers, to understand any differences in the predictors of these two types of mobility.

new teachers, we combine these turnover measures to predict a teachers' exit from their first school. Estimating separate models for movers and leavers allows us to better estimate the rate at which early career teachers leave the profession, some of whom have moved schools before leaving.

Main Independent Variables of Interest

We draw on data from North Carolina that distinguishes between teacher entry pathways (Henry et al., 2014). Alternatively certified teachers are separated between alternate entry and Teacher For America teachers. Out-of-state prepared teachers could have been undergraduate prepared, graduate prepared, or only earned their licensure. The out-of-state licensure only group earned a Bachelor's degree at a North Carolina university but completed the requirements for a teacher licensure at an out-of-state institution. We also include an indicator that includes other institutions that were either unclassifiable or the teacher was a Visiting International Faculty (VIF). The reference group includes teachers who attended a traditional, university-based preparation program, either at the undergraduate or graduate level or earned their teaching license in-state.

Other Independent Variables of Interest

In addition to differences by entry pathway, this study also seeks to understand differences in early career teachers' turnover patterns across schools with different characteristics. We examine differences across the percentage of economically disadvantaged students, the percentage of minority students (Black, Hispanic, and other non-white students), and a measure of school-wide student performance. This final measure is an overall performance composite, which is the number of tests passed divided by the number of tests taken. While these

variables serve as independent variables of interest in some models, in others, they are used as covariates to adjust differences in the turnover patterns across different entry pathways.

For the third research question, we demonstrate the extent to which teacher qualifications and effectiveness vary predict teacher turnover. Regarding qualifications, we examine differences on the performance of college entrance and teacher licensure exams. We created this measure by first standardizing all exams observed in the data by exam then taking each teachers' average across the tests s/he has taken. Additional measures of teacher performance include their annual evaluation from their principal (which was introduced in the state in the 2010-2011 school year) and their EVAAS teacher value-added score for those teachers in tested subjects or grades. We operationalize teacher evaluation in two ways. First, we take the median evaluation score across the five standards on which teachers in North Carolina are evaluated. Second, with the overwhelming majority of teachers receiving rated proficient or above, we create a variable to indicate whether or not a teacher received any score below proficient. All measures are lagged to the previous school year to avoid endogeneity concerns.

Covariates

The second research question seeks to understand the teacher and school conditions that reduce or increase the risk of turnover among early career teachers from different pathways. As teacher and school characteristics are not balanced across entry pathways, we control for a range of variables that have been used previously in the turnover literature to adjust the risk of early career teachers' moving schools or leaving the teaching profession. These variables include teacher background characteristics, school demographic characteristics, and school working conditions. A full list of variables is in Table A1.

At the teacher level, we control for a teacher's gender, race/ethnicity (Black, Hispanic, Asian, American Indian, and multiracial), and age. To adjust for differences across schools, we control for indicators of the school level (elementary, middle, or high schools), urbancity (city, suburb, rural, and town), average student enrollment total, and per-pupil expenditures. The final measures of school climate include the reported violent rates per 1,000 students, the short-term suspension per 100 students, and the percentage of teachers with 3 years of experience or less. We also control for the local education agency (LEA) teacher salary supplement. North Carolina has a statewide salary schedule, with the only source of variation occurring between districts due to salary supplements. All continuous variables are mean-centered to allow for making predictions from the hazard models for a teacher in an "average" school.

Previous research suggests that controlling only for observable school characteristics does not fully account for the school-level factors that shape teachers' turnover decision (Ladd, 2011). We draw on several scales from the Teacher Working Conditions (TWC) survey to also control for teacher-reported school conditions. These measures include Facilities and Resources ($\alpha = 0.84 - 0.85$), Distributed Leadership ($\alpha = 0.86 - 0.88$), School Leadership ($\alpha = 0.87 - 0.93$), and Professional Development ($\alpha = 0.79 - 0.86$). Table A2 provides additional information on the specific survey items that comprise these measures.

Methods

Studies of teacher turnover tend to analyze annual year-to-year turnover. Numerous problems have been described with this approach, namely, that it does not allow account for censored observations, prohibits longitudinal analysis, and, as a result, does not help identify particularly "risky" times for turnover (Willett & Singer, 1991). Given that the data includes monthly observations of teachers, a survival analytic framework allows us to predict when early

career teachers move schools and leave teaching. By accounting for these temporal patterns of occurrence, we are able to better model the complexities in the early career teacher labor market, which involves not only movement between schools and out of the profession at the end of the school year, but at all points during the school year as well.

We adopt three estimation strategies to answer the first two research question of differences in the timing of turnover by teacher entry pathway and school characteristics. Each approach offers distinct advantages, which we will discuss in turn. The initial approach involves estimating a discrete time survival analysis model. Discrete hazard models are most appropriate when the observed time in the data fails to sufficiently represent the underlying continuous time model. They also may be more appropriate in cases of interval censoring, when the event is not observed at the exact time it occurs. This model can be estimated as follows:

$$logit\ h(t) = \beta_o(t) + \beta_i X_i \quad (1)$$

where X_i is a vector of teacher and school characteristics. We estimate *(t)* as a discrete variable, to allow for separate hazard function in each time period a teacher is observed. In these models, $\beta_o(t)$ represents the baseline hazard and values β_i, representing the difference from the baseline hazard. Standard errors are clustered at the teacher level. This, and all models described below also include a cohort fixed effect to allow for cohort differences in the risk of turnover.

Unlike the discrete time models that predict a baseline hazard rate, the Cox proportional hazard model makes no assumptions of the baseline hazard rate. Without estimating a baseline hazard rate, the Cox model is best used for describing hazard ratios in survival data. Compared to the discrete time models, which allows the possibility to model for non-proportional hazard rates, the Cox model assumes that the hazard rate is continuous and proportional. This model can be estimated:

$$h(t, \boldsymbol{X}) = h_o(t)\exp(\beta_i X_i) \quad (2)$$

where $\boldsymbol{X}$ equals a vector teacher, classroom, and school predictors. An often violated assumption of the Cox model—the proportional relative hazard—can be tested by examining if there is a relationship between the Schoenfeld residuals and time (Schoenfeld, 1982).

In cases where this assumption is not met, Royston-Parmar models offer a flexible, parametric model with which to model time dependent effects. These models estimate a baseline hazard function parametrically, using a spline function of time (Royston & Lambert, 2011). They are more flexible than the Cox model as they allow for the effect of regression coefficients to vary over time. By estimating a baseline hazard function, these models enable us to predict a covariate-adjusted survival curve, including out-of-sample predictions. Yet, in both the Cox and Royston-Parmar models, concerns remain around for challenges in modeling patterns in teacher turnover where small numbers of teachers turn over each month, with most teachers turning over at the end of the school year.

The second research question examines the extent to which teacher and school characteristics reduce or increase the risk of turnover among early career teachers. We estimate a series of models with teacher characteristics, school demographic characteristics, and school working conditions. These models help document variation in the risk of turnover across teacher and school characteristics, as well as balance the difference in teacher and school characteristics across the main independent variable—teacher entry pathways. For instance, to the extent that alternatively certified or out-of-state prepared teachers work in schools with more racial/ethnic minorities or more difficult working conditions, controlling for these school demographic characteristics and working conditions would reduce the risk bias in estimates of the turnover associated with early career teachers from different pathways. At the same time, these variables

provide evidence of variation in early career teacher turnover across various types of schools. It is important to note that to the extent to which additional variables are correlated with teachers' decision to turnover and vary systematically by entry pathway or any of the other covariates being examined, the results should not be interpreted as the causal influence of any one of those variables.

The third research question aims to understand the extent to which measures teacher qualifications and effectiveness predict a greater or lower risk of turnover. For this final analysis, we re-estimate the discrete time hazard model described above with full controls, running separate models for each teacher quality measure.

Results

Frequency of Early Career Turnover

We begin by documenting the overall frequency with which early career teachers turn over, move schools, and leave teaching in North Carolina public schools. Table 2 reports the annual frequency of within-year turnover, end-of-year turnover, total turnover, and the percentage by which end-of-year turnover measures misidentify the true frequency of turnover, calculated by dividing within-year turnover by the total turnover. During teachers' first three years in the profession, an average of 28.73% turnover. This turnover consists of 6.76% of novice teachers who turn over during the school year and 20.43% who turn over at the end of the year. By not including within-year turnover, measures of turnover that only identify teacher departures at the end of the school are attenuated by 23.53%. Although novice teachers consistently turn over at high rates, they are most likely to turn over their first year. 8.36% of first year teachers turn over before the end of their first year with an additional 24.46% turning over at the end of the school year.

Table 2. Frequency and Bias in Annual Measures of Teacher Turnover, by Year in Profession

% of Teachers to Turn Over				
	Within-Year	End-of-Year	All Turnover	% Misidentified
Year 1	8.36	24.46	32.82	25.47
Year 2	6.32	21.00	27.32	23.13
Year 3	5.61	20.43	26.04	21.54
Overall	6.76	21.96	28.73	23.53

% of Teachers to Move				
	Within-Year	End-of-Year	All Movers	% Misidentified
Year 1	4.84	15.83	20.68	23.4
Year 2	3.24	10.80	14.04	23.08
Year 3	2.35	11.25	13.77	17.07
Overall	3.59	12.86	16.50	21.76

% of Teachers to Leave				
	Within-Year	End-of-Year	All Leavers	% Misidentified
Year 1	3.52	8.63	12.15	28.97
Year 2	3.08	10.20	13.28	23.19
Year 3	3.26	9.18	12.44	26.21
Overall	3.30	9.30	12.60	26.19

While these high turnover rates are cause for concern for the schools that hire numerous first year teachers, the high rates with which novice teachers leave teaching is of concern for the overall supply of teachers. Over their first three years, 3.3% of teachers leave teaching during the school year and 9.3% leave teaching at the end of the school year, totaling 12.6%. In other words, one out of every eight novice teachers leaves teaching every year. It is also noteworthy that end-of-year measures of teacher turnover misidentify the timing with which teachers leave by 12.19%. Although first year teachers are most likely to leave, the rate at which novice teachers turn over does not consistently decrease with experience. 3.52% of first year teachers

leave before the end of their first year, but that declines to 3.08% for second year teachers before increasing to 3.26% for third year teachers.

In terms of moving, we find that throughout teachers first three years, on average, 16.5% of teachers move schools annually. This turnover consists of 3.59% of teachers who moved schools during the school year and 12.86% who moved at the end of the year.[8] It is important to note that the within-year and end-of-year measures of the percentage of teachers to move schools in a given year are not mutually exclusive, as a teacher may have moved schools during the school year, only to change schools again at the end of the year. Teachers are most likely to move schools during their first year with 4.84% moving during the year and 15.83% at the end of the school year, compared with 3.24% for second year teachers and 2.35% for third year teachers.

Separating teacher turnover based on whether it occurred during or at the end of the school year also allows us to document the extent to which conventional measures of end-of-year teacher turnover misidentify either the timing or full extent of teacher turnover. Better understanding of the timing of turnover is important for two main reasons. First, the disruptive effect of turnover may be more detrimental to students or the instructional culture of a school when it occurs during versus the end of the school year. Second, overlooking the percentage of teachers who move schools during the year attenuates measures of turnover by not counting within-year turnover.

[8] Among within-year movers, 57% moved within the same district. This frequency is in contrast to teachers moving at the end of the school year, where only 25% of teachers moved within the same district.

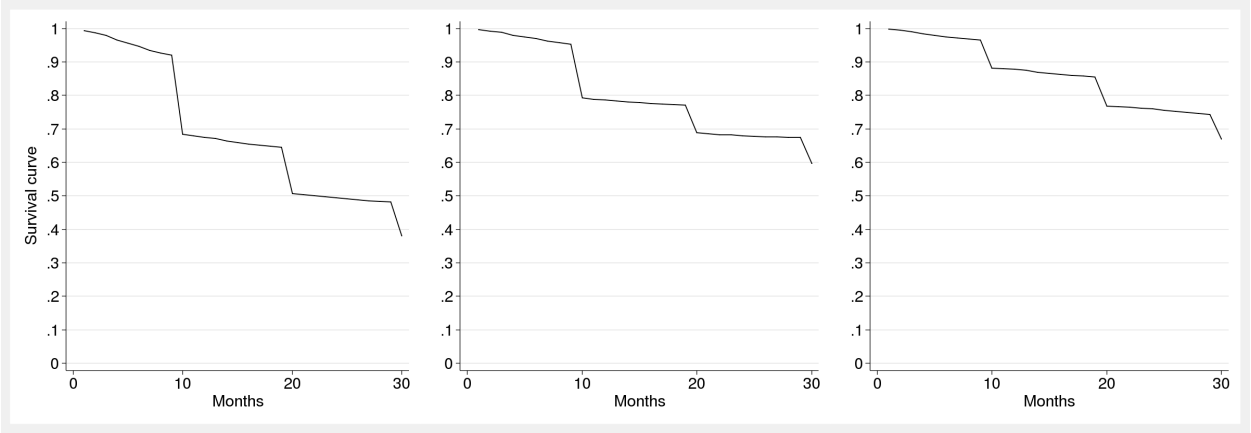
Timing of Early Career Teacher Turnover

To better understand the timing of early career teacher turnover and how it is distributed across teacher entry pathways and school types, Figure 1 plots of Kaplan-Meier survival curves for turnover (left), moving schools (center), and leaving teaching (right) for all early career teachers and by teacher entry pathways, minority student enrollment, economically disadvantaged student enrollment, and school academic performance. Figure 1a shows that by the end of their third year in the profession, only 38% of early career teachers remain in the same school. This turnover rate includes 40% of teachers who have moved schools by the end of their third year and 33% who have left teaching. It is important to note that as moving and leaving are treated as separate outcomes, they are not mutually exclusive, as a segment of teachers move schools and then later leave teaching.

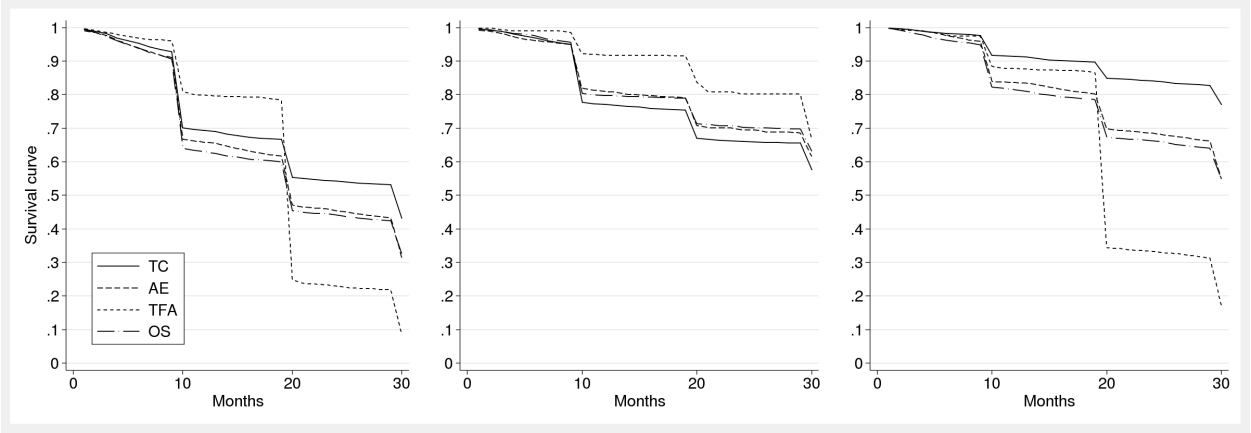
In addition to the cumulative turnover rates, a couple other patterns regarding the timing of turnover standout. First, while the largest share of teacher turnover occurs at the end of the school year, teachers are turning over during the school year, particularly in their first year, when 8% turned over. Second, the rate of within- and end-of-year turnover decreases with experience, which is driven by a large drop in the rate at which teachers move schools after their first year. Third, in contrast with moving schools, the rate at which early career teachers leave the profession decreased only slightly during their first three years, with 12% having left by the end of their first year, an additional 11% in their second year, and an additional 10% in their third year.

Consist with our hypothesis, Figure 1b shows notable differences in the turnover rates across entry pathways. By the end of their third year, while 43% of teachers from traditional, in-

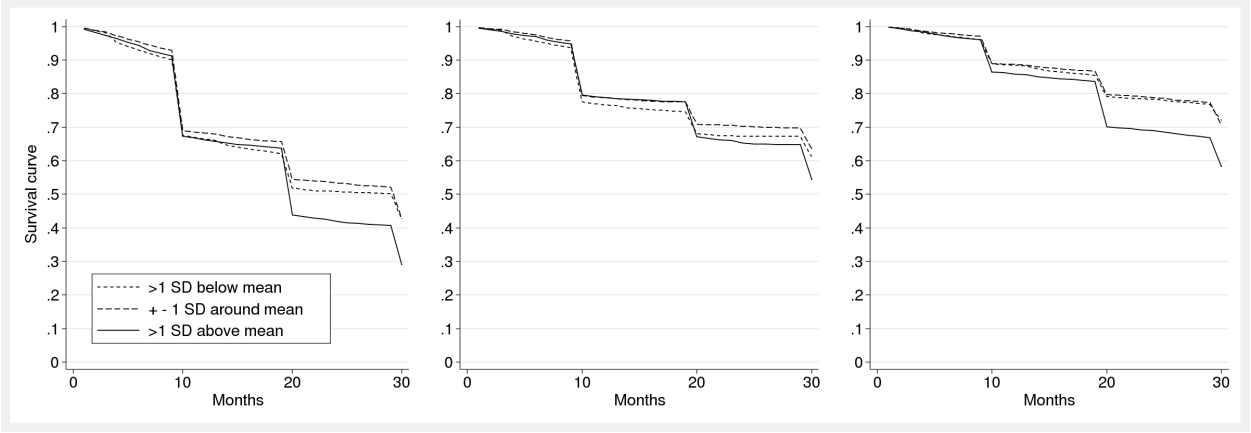
Figure 1. Kaplan-Meier Survival Curves for Turnover (right), Moving Schools (center), and Leaving (right), by Teacher and School Characteristics



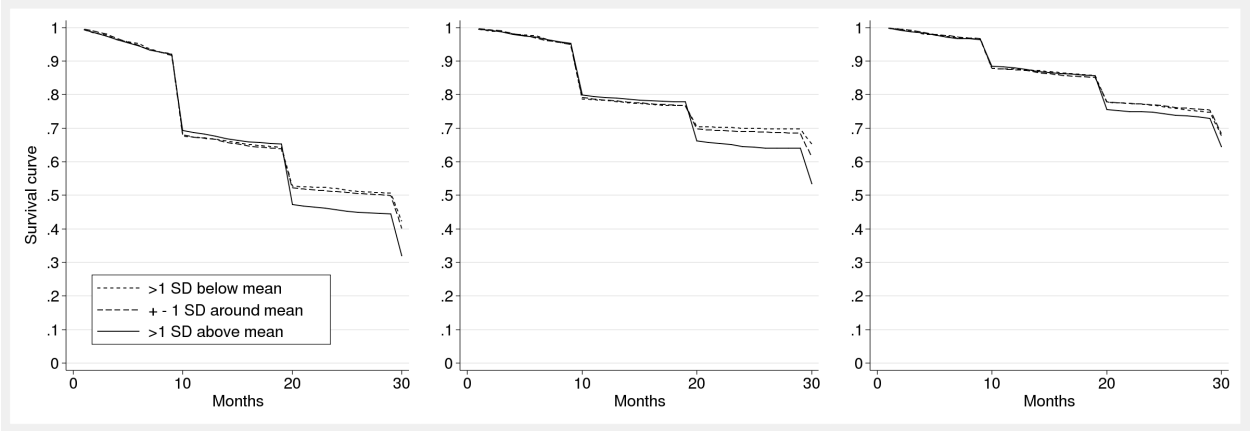
(a) All teachers



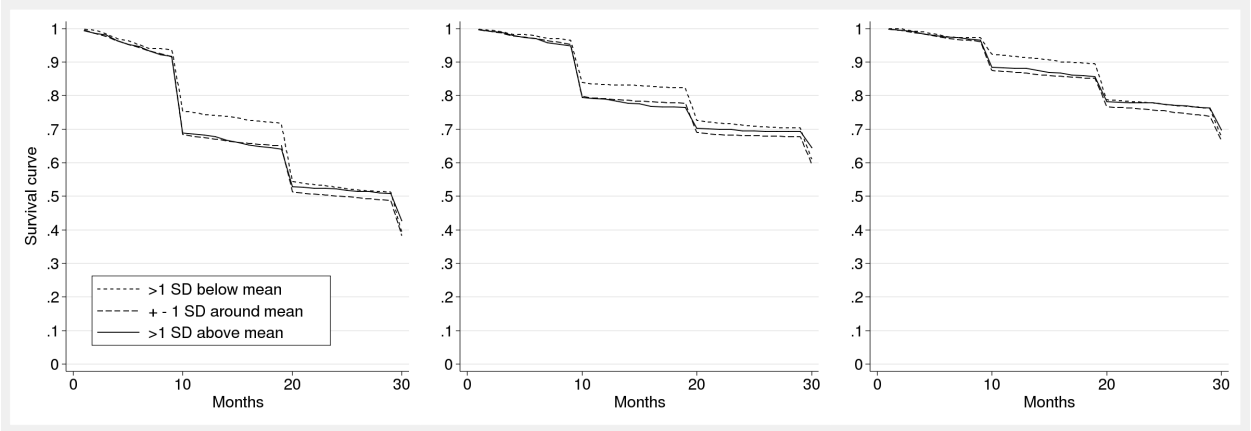
(b) Teacher entry pathway



(c) Minority student enrollment



(d) Economically disadvantaged student enrollment



(e) School academic performance

Notes. Each school year is coded as having 10 months. TC = In-state, traditional preparation; AE = Alternate entry; TFA = Teacher For America; OS = Out-of-state prepared.

state preparation programs remain in their original school compared to 31% of alternate entry, 9% of TFA teachers, and 32% of out-of-state prepared teachers. This overall turnover rate masks important differences in the type of turnover. Teachers from in-state, university-based teacher education programs are slightly more likely to move schools than alternate entry or out-of-state prepared teachers. TFA teachers are the least likely to move schools. The largest differences between entry pathway are related to the higher rate of leaving teaching for alternate entry, TFA, and out-of-state prepared teachers. By the end of their third year, 23% of in-state, traditionally prepared teachers have exited the profession compared to 45% of alternate entry and out-of-state

prepared teachers and 82% of TFA teachers. Higher turnover rates are not only driven by end-of-year turnover but within-year turnover as well. During their first year, only 2% of traditionally prepared teachers left teaching compared to 4% of alternate entry teachers, and 5% of out-of-state prepared teachers, a pattern of within-year turnover that continues into teachers' second and third years.

Differences in the timing of teacher turnover also occur across school characteristics. Figures 1c examines the relationship between minority student enrollment and the timing of turnover, with separate lines for schools one standard deviation below the average racial/ethnic minority enrollment (below 28%, one standard deviation on either side of the mean, and one standard deviation above the mean, or above 81%. With few differences following the first two years, a turnover gap emerges at the end of the second year. 52% of teachers in schools with the fewest minority students remain in their school after their second year compared to only 44% in the schools with the highest concentration of minority students. By the end of three years, 42% of teachers in schools with low minority student enrollment remain in the same school compared to 29% of teachers in schools with the highest minority student enrollments. This turnover is driven by high rates of leaving the profession following the second year, with a 10 percentage point gap between teachers in high minority schools compared to all other schools that increases to 13 percentage points by the end of the third year.

To a lesser degree, early career teachers also turnover from schools with greater concentrations of student poverty (Figure 1d). By the end of their third year, 35% of teachers in schools with more than one standard deviation above the average FRPL— that is, schools with more than 85% students on free or reduced lunch—have left their initial school. Teachers in schools with less concentrated poverty turnover at slightly lower rates, with 68% having left their

initial school by the end of the third year. Counter to the hypothesis that early career teachers would turnover from low performing schools at higher rates, we find no notable differences in relation to early career turnover and overall school performance (Figure 1e).[9]

Survival Analysis of Early Career Teacher Turnover

Through the survival analysis, we examine the risk of turnover by entry pathway and school characteristics, controlling for teacher background characteristics and school demographic characteristics and working conditions. In this first set of models presented in Table 3, we ignore the proportionality assumption of hazard modeling to estimate a "rough average of the effects" (Allison, 2014, p. 44) of entry pathway and school characteristics for teachers' first three years in the profession. In the section "Examining Differences in the Timing of Early Career Teacher Turnover", we test for violation of this assumption, and re-specify the models in Table 3 to include an interaction between time and teacher entry pathways. When interpreting the results, we focus on the discrete time hazard models (columns 1, 2, 5, 6, 9, & 10), although the results are generally consistent with the Royston-Parmar models columns 3, 4, 7. 8. 11, & 12).[10]

Consistent with the general pattern presented in Figure 1, we find evidence that alternate entry, Teach For America, and out-of-state prepared teachers are at greater risk of turning over than their peers who entered teaching through in-state, traditional education programs. Adding school-level controls in columns 2 and 4 reduces the strength of the relationship between teacher

[9] In addition to predicting moving school and leaving teaching in the appendix (Table A9), we also estimate a series of models that predict teachers' temporary exit and return. There is no significant relationship between any entry pathway variables. The two strongest teacher-level predictors of this turnover are gender and age, with female and older teachers more likely to temporarily exit and return, possibly for child-rearing or medical leave.

[10] In appendix table A4, we also estimate the model using the Cox proportional hazard model. Results are consistent in terms of level of significance. Although the direction of the estimates never changes, there are instances where the Cox model has an even higher or lower magnitude. For instance, in the turnover model with full controls, the odds ratio on alternate entry is 1.17 while the hazard ratio from the Cox model is 1.12. The odds ratio for Teacher For America is 1.63 versus a 1.45 hazard ratio. In general, the estimates from the Royston-Parmar model falls between the discrete time and Cox models.

Table 3. Survival Analysis of Turnover, Moving Schools, and Leaving Teaching in North Carolina

	Turnover				Moving				Leaving			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Alternate entry	1.32***	1.17***	1.25***	1.13**	0.87*	0.80***	0.89*	0.82***	2.12***	1.83***	2.05***	1.77***
Teacher For America	2.14***	1.63***	1.85***	1.31***	0.51***	0.40***	0.54***	0.39***	5.95***	4.45***	5.44***	3.71***
Out-of-state prepared	1.38***	1.36***	1.32***	1.29***	0.87***	0.86***	0.90**	0.89**	2.28***	2.22***	2.20***	2.12***
Other	1.43***	1.39***	1.35***	1.30***	0.97	0.95	0.99	0.96	2.15***	2.08***	2.06***	1.96***
Female	0.92**	0.97	0.90***	0.95	1.00	1.03	0.97	1.00	0.85***	0.91*	0.85***	0.91**
Black	1.02	0.90*	1.01	0.92*	1.08	0.95	1.07	0.95	0.98	0.88*	0.97	0.89*
Hispanic	0.91	0.87	0.94	0.89	0.79	0.76*	0.82	0.78*	1.08	1.03	1.09	1.04
Other race	0.88*	0.85*	0.94	0.91	0.94	0.92	0.98	0.95	0.87	0.82*	0.92	0.87
Age	1.02***	1.02***	1.01***	1.00**	1.01***	1.01*	1.00	1.00*	1.02***	1.02***	1.01***	1.01***
City		0.93		0.84***		0.84**		0.77***		1.11		0.98
Rural		0.95		0.89**		0.89*		0.85**		1.01		0.93
Town		0.86*		0.88*		0.84*		0.85*		0.96		0.97
School size (100s)		0.97***		0.97***		0.97***		0.97***		0.99**		0.98***
Overall performance composite		1.00		1.02***		1.00		1.02***		1.00		1.02***
% economically disadvantaged		1.00**		1.00***		1.00**		1.01***		1.00		1.00*
% Black students		1.00***		1.01***		1.00***		1.01***		1.00*		1.01***
% Hispanic students		1.00		1.00		1.00		1.00		1.00*		1.00
% Other race		1.00		1.00*		1.00		1.00		1.00		1.00
Teachers with 3 yrs experience or less		0.99		0.88		0.74		0.73*		1.38*		1.10
Suspension rate		1.00		1.00***		1.00		1.00**		1.00*		1.00*
Violent acts rate		1.00		1.00*		1.00		1.00*		1.00		1.00
Per pupil expenditures		1.00		1.00***		1.00		1.00		1.00		1.00***
Teacher salary supplement		1.00		1.00		1.00		1.00		1.00		1.00***
Middle School		1.35***		1.24***		1.29***		1.23***		1.34***		1.25***
High School		1.88***		1.51***		1.58***		1.39***		2.00***		1.65***

Facilities and Resources (std)		1.01		0.98		1.00		0.98		1.01		0.97
Distributed leadership (std)		0.98		0.97		0.98		0.97		1.00		0.99
Principal leadership (std)		0.93***		0.91***		0.96		0.93**		0.90***		0.88***
Professional development (std)		0.99		1.01		0.98		1.00		1.01		1.03
Observations	251421	251421	253267	253267	251921	251421	253683	253173	306954	305822	306954	305822
Deviance	50892.0	50286.4	30119.73	29186.10	34253.3	33899.1	23070.05	22499.80	34345.5	33756.4	20754.19	20127.65

Notes. Discrete time models (columns 1-2; 5-6; 9-10) estimated using logistic regression. Coefficients reported as odds ratios. Standard errors clustered at the teacher level. Royston-Parmar models (columns 3-4; 7-8; 11-12) estimated with 2 knots. * p<0.05; ** p <0.01; *** p <.001. All models include cohort fixed effects.

entry pathway and early career turnover, which can be attributed, in part, to these teachers' sorting into schools with more underserved students of color and more difficult working conditions.[11] The odds are 1.17 greater that an alternate entry teacher will turnover than a traditionally certified teacher, controlling for school characteristics. The odds of turnover are 1.63 greater for TFA teachers and 1.36 greater for out-of-state prepared teachers. Although these differences in the risk of turnover should not be interpreted causally, even when conditioning on a rich set of teacher- and school-level controls, we find a turnover gap that results in substantive differences in the predicted survival rates.

To calculate the predicted survival rate for different pathways, all mean-centered covariates are held constant. 56% of in-state traditionally prepared teachers have left their first school by the end of their third year, 66% of alternate entry teachers, 76% of TFA teachers, and 66% of out-of-state prepared teachers. Compared to the survival rates observed in Figure 1, teacher and school controls reduce the turnover gap between in-state traditionally prepared teachers and all other teacher entry pathways, although a sizable gap still remains.

The overall turnover measure overlooks important differences in terms of moving schools and leaving teaching. When controlling for school characteristics, alternate entry and out-of-state prepared teachers are at less of a risk of moving schools than in-state traditionally prepared teachers. TFA teachers have much lower odds of moving schools (0.51, $p < .001$). In terms of the predicted survival at the end of three years, 41% of in-state traditionally prepared teachers are predicted to have moved schools, 37% of alternate entry teachers, 23% of TFA teachers, and

[11] Conditional means across entry pathways reported in Table A3 indicate that alternate entry, Teacher For America, and out-of-state prepared teachers work in schools enrolling more Black students but not necessarily more Hispanic or other non-White students. Besides TFA teachers, there are no practical differences in the enrollment of economically disadvantaged students. Alternate entry and TFA teachers work in schools with a lower overall performance composite.

36% of out-of-state prepared teachers. Table A5 examines differences in terms of moving within the same district and to another district in the same state. We observe no relationship between teacher entry pathways and moving to a school in the same district. The overall lower odds of moving schools is driven by moving across district borders. Controlling for teacher and school characteristics, the odds of moving to a school in a new district are 26% lower for alternate teachers than in-state traditionally prepared teachers, 75% lower for TFA teachers, and 18% lower for out-of-state prepared teachers.

With in-state traditionally prepared teachers most likely to move schools, particularly across district lines, the turnover gap is driven by a greater risk of leaving teaching among teachers who entered teaching outside traditional education programs. When controlling for school characteristics, the odds of leaving teaching are 1.83 greater for alternate entry teachers, 4.45 for TFA teachers, and 2.22 for out-of-state prepared teachers compared to teachers from in-state, traditional preparation programs. Over their first three years, the model predicts that 78% of in-state traditionally prepared teachers remain in teaching compared to 57% of alternate entry teachers, 33% of TFA teachers, and 56% of out-of-state prepared teachers. In other words, alternate entry and out-of-state prepared teachers were twice as likely than in-state, traditionally prepared teachers to leave teaching.[12]

In terms of school characteristics, results indicate that an increase in Black students in a school and, to a lesser degree, economically disadvantaged students are associated with a greater risk of turnover. For Black student percentages, the odds of turnover from a school a standard deviation below the mean is 0.93. The odds of turnover from a school a standard deviation above

[12] In results not presented, we estimated a series of models that tested for the additive effect of working in schools with more economically disadvantaged, minority, or under-performing students for early career teachers from the various pathways. The only evidence of this hypothesis was a significant, positive interaction between alternate entry and Black student enrollment.

the mean is 1.08. For economically disadvantaged students, the odds of turnover from a school a standard deviation below the mean is 0.94. The odds of turnover from a school a standard deviation above the mean is 1.06. Counter to the hypothesis that teachers would be less likely to turnover from higher performing schools, we find that a one-unit increase in a school's overall performance composite increase the odds of turnover by 1.02 after conditioning on other school characteristics. These results were generally consistent across moving schools and leaving teaching.

Among other teacher and school characteristics, male and older teachers are at greater risk of leaving teaching. Urbanicity is related to moving schools but not leaving teaching. An increase in school size is associated with decreased odds of turnover. Teachers in middle and high schools are at greater risk of turning over.[13] A higher rate of suspensions and violent acts are related to a greater risk of moving schools, while increase in the fraction of teachers with three years of experience or less is associated with reduced risk of moving schools. Of the school working conditions, teacher reports of principal leadership is the only significant working condition, with an increase in principal leadership associated with decreased odds of turnover. Finally, in results not presented, the odds ratios for the month indicator that fall at the end of each school year (months 10, 20, and 30), are of much greater magnitude than any of the within-year estimates, confirming that the end of school years are the time when teachers are most at risk of turning over.

[13] With strong evidence of differences in turnover between elementary, middle, and high schools, we estimated a series of models to examine differences in turnover by school type (see Table A6-A8). When controlling for school characteristics, we find that alternate entry teachers are no more likely to turnover or move schools from elementary schools than traditionally prepared teachers. Among school characteristics, the percentage of Black students predicted higher levels of turnover and moving schools in elementary and middle schools but not high schools whereas the percentage of economically disadvantaged students only predicted higher levels of turnover in high schools. There was no relationship with overall school performance. There is consistent evidence that nontraditionally prepared teachers leave teaching from all school types. TFA teachers are most likely to turnover from elementary schools. The odds of leaving are comparatively lower in high schools than other types of schools.

To this point in the paper, we have described differences in the timing of teacher turnover by teacher entry pathway and school characteristics. A limitation of the survival analysis is that it fails to definitively separate the predictors of within- and end-of-year turnover. To address this concern in greater detail, we temporarily suspend the survival analysis to offer a more definitive test of differences in the predictors of within-year and end-of-year turnover. Table 4 presents four logistic regression models: (1) predicting overall turnover at any point during a teacher's first three years, (2) within-year turnover, (3) end-of-year turnover, and, (4) to test for significant differences in the predictors or within- and end-of-year turnover, a model where zero is coded to end-of-year turnover and one is coded to within-year turnover. When the estimate for this final model is significant and greater than one, it provides evidence that the within-year turnover rate is greater than end-of-year turnover. When the estimate is significant and less than one, it indicates that the end-of-year turnover rate is greater than within-year turnover. We present the results separately for turnover, moving, and leaving.

For comparison with Table 3, column 1 of Table 4 begins with a model predicting overall turnover. Overall, the level of significance is consistent across the survival analysis and logistic regression. The magnitude of the odds ratios is generally consistent across these specifications, although they tend to be somewhat smaller in the survival analysis. When the results are separated by within-year and end-of-year turnover in columns 2 and 3, we find some differences by entry pathway. Among alternate entry and TFA teachers, we find that the higher turnover rates compared to traditionally prepared teachers is driven by end-of-year turnover. However, results from column 4 indicate that only in the case of TFA teachers do we find evidence that the difference between within-year and end-of-year turnover is significantly different. In contrast, for out-of-state prepared teachers, the odds of turnover are consistent, regardless of the timing.

Table 4. Logistic Regression Estimates Comparing Within-Year and End-of-Year Turnover, Moving, and Leaving

	Turnover				Moving				Leaving			
	Overall	Within-year	End-of-year	End-of-year vs. Within-year	Overall	Within-year	End-of-year	End-of-year vs. Within-year	Overall	Within-year	End-of-year	End-of-year vs. Within-year
Alternate entry	1.24***	1.11	1.28***	0.95	0.84**	0.96	0.81***	1.09	1.94***	1.29*	2.27***	0.72**
Teacher For America	2.03***	0.81	2.23***	0.44***	0.37***	0.34***	0.40***	0.66	5.78***	1.45	6.83***	0.29***
Out-of-state prepared	1.40***	1.36***	1.36***	1.05	0.88**	0.94	0.87**	1.03	2.26***	1.89***	2.30***	0.97
Other	1.33***	1.65***	1.13	1.37*	0.89	1.09	0.80*	1.32	2.01***	2.16***	1.77***	1.26
Female	0.96	1.06	0.92**	1.16*	0.97	0.93	0.97	0.97	0.89**	1.02	0.83***	1.22*
Black	0.90**	0.89	0.92*	0.98	0.97	1.03	0.97	1.08	0.87*	0.76**	0.93	0.83
Hispanic	0.91	1.08	0.86	1.26	0.81	0.83	0.82	0.97	1.04	1.26	0.94	1.41
Other race	0.89*	0.66**	1.00	0.69*	0.95	0.88	0.97	0.87	0.84*	0.60**	0.96	0.67*
Age	1.01***	1.03***	0.99***	1.03***	1.00	1.01***	0.99***	1.02***	1.02***	1.04***	1.00	1.03***
City	0.86**	1.13	0.79***	1.36**	0.80***	0.95	0.77***	1.24	1.11	1.43**	0.98	1.40*
Rural	0.93	1.28**	0.85**	1.47***	0.90*	1.10	0.85**	1.38**	1.00	1.29*	0.91	1.32
Town	0.89	1.11	0.85**	1.21	0.84*	0.82	0.86*	0.94	0.96	1.29	0.86	1.36
School size (100s)	0.97***	0.95***	0.99*	0.96***	0.97***	0.94***	0.98***	0.96***	0.99*	0.97***	1.01	0.96***
Overall performance composite	1.01***	1.01***	1.01***	1.00	1.01***	1.01***	1.01***	1.00	1.00**	1.00	1.00**	1.00
% economically disadvantaged	1.00***	1.01***	1.00	1.01**	1.00***	1.00*	1.00**	1.00	1.00	1.01**	1.00**	1.01**
% Black students	1.01***	1.00	1.01***	1.00*	1.01***	1.00*	1.01***	1.00	1.00*	1.00	1.00***	0.99*
% Hispanic students	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00*	0.99*	1.00	1.00
% Other race	1.00	1.01	1.00	1.01	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.01
Teachers with 3 yrs experience or less	1.28*	0.63	1.59***	0.57*	0.96	0.65	1.07	0.72	1.55**	0.87	1.89***	0.66
Suspension rate	1.00*	1.00	1.00**	1.00	1.00*	1.00	1.00**	1.00	1.00	1.00	1.00	1.00
Violent acts rate	1.00	1.00	1.00*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99*
Per pupil expenditures	1.00*	1.00	1.00*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Teacher salary supplement	1.00	1.00	1.00	1.00	1.00	1.01*	1.00	1.00	1.00	1.00	1.00	1.00
Middle School	1.22***	1.79***	1.03	1.61***	1.18***	1.27**	1.14**	1.07	1.25***	2.50***	0.93	2.75***

High School	1.58***	4.63***	1.00	4.02***	1.31***	2.86***	1.00	2.77***	1.76***	7.15***	0.98	6.69***
Facilities and Resources (std)	0.98	0.96	0.99	0.95	0.99	0.99	0.99	0.97	1.01	0.99	1.02	0.95
Distributed leadership (std)	0.97	0.97	0.98	0.99	0.97	0.94	0.98	0.94	1.00	1.01	1.00	1.04
Principal leadership (std)	0.89***	0.87***	0.92***	0.94	0.95	0.95	0.96	1.00	0.90***	0.84**	0.94*	0.89
Professional development (std)	1.02	1.07	1.00	1.08	0.97	1.02	0.96	1.05	1.00	1.08	0.96	1.14*
Observations	34520	34520	34520	8393	34520	34520	34520	5702	34520	34520	34520	4336
Deviance	37163.3	13772.5	32513.5	8293.3	30480.2	10361.1	26511.0	5700.2	24514.8	8878.8	20150.8	4301.3

Notes. The End-of-year vs. Within-year variable is coded as 0 when a teacher turned over, moved schools, or left teaching at the end of the school year and 1 when a teacher turned over, moved schools, or left teaching within the school year. Coefficients reported as odds ratios. Standard errors clustered at the teacher level. * p<0.05; ** p <0.01; *** p <.001. All models include cohort fixed effects.

In terms of moving schools, teachers to enter teaching through an in-state, university based program move schools at the end of the school year at the highest rates. TFA teachers have much lower odds of moving schools within the school year compared to traditionally prepared teachers, although this difference is not significantly different from their low rates of end-of-year turnover.

Consistent with Table 3, we find much greater odds of leaving teaching for alternate entry, TFA, and out-of-state prepared teachers in comparison to in-state, traditionally prepared teachers. Although the magnitude of the odds ratios is greater for leaving at the end-of-year versus leaving within the year for out-of-state prepared teachers, we find no evidence that this difference is significant. In other words, the high rates of leaving for these teachers is driven by both within-year and end-of-year turnover. Alternate entry and TFA teachers, in contrast, are no more likely than traditionally certified teachers to leave during the year, but have high odds of turnover at the end of the school year.

Among school characteristics, we find no difference in the relationship between within-year and end-of-year turnover and a school's overall academic performance. We find differences in the relationship between the economically disadvantaged and Black student enrollment. A one percentage point increase in economically disadvantaged student enrollment is associated with a one percent increase in the odds of within-year turnover. We find no similar relationship with end-of-year turnover. Results from column 4 suggest that this difference between within- and end-of-year turnover is significant, suggesting that the slightly higher turnover rates among novice teachers from high poverty schools are driven by teachers leaving during the school year. In contrast, we find that the relationship between Black student enrollment and teacher turnover is concentrated among teachers leaving at the end of the school year.

With no evidence of differences in the relationship between these school characteristics and moving schools, we find the end-of-year versus within-year turnover gap is driven by differences in when teachers leave schools. Among novice teachers, we find a positive and significant relationship between the percentage of economically disadvantaged students in the school and within-year turnover. A one percentage point increase in economically disadvantaged student enrollment is associated with a 1% increase in the odds of leaving school within the year. In contrast, a one percentage point increase in economically disadvantaged student enrollment is associated with a 0.5% decrease in the odds of leaving school within the year. We find no evidence of a relationship between Black student enrollment and leaving within the year but a small and significant relationship with leaving at the end of the year.

Teacher Quality and Early Career Turnover

We extend the above analysis to examine the extent to which various measures of teacher quality predict early career teacher turnover. We run four separate models predicting overall turnover, moving schools, and leaving teaching, respectively. Each model includes a lagged measure of teacher quality: average teacher test score, TVAAS score, median evaluation score, and an indicator of whether or not they scored below proficient on any of the five standards that comprise a teacher evaluation score. A limitation of this approach is that we are only able to predict the relationship between teacher quality and turnover in teachers' second and third years.

Of the measures of teacher quality, in Table 5, we see a relationship between teacher turnover and the two measures related to a teachers' evaluation from their principal. First, a teacher who received at least one below proficient rating on any of the five standards is at greater risk of turning over. The next column provides further evidence that teachers who received proficient or accomplished ratings were at less risk of turning over compared to teachers rated

Table 5. Survival Analysis of Turnover, By Measures of Teacher Quality

			Principal Evaluation	
Panel A. Turnover	Average teacher test	TVAAS	Any score below proficient	Median Score
Lagged quality measure	0.99	1.00	1.26***	
Proficient Rating				0.78*
Accomplished Rating				0.75**
Distinguished Rating				1.28
Observations	104401	20286	106041	106041
Panel B. Moving Schools				
Lagged quality measure	0.96	0.97	1.20*	
Proficient Rating				0.84
Accomplished Rating				0.71**
Distinguished Rating				1.25
Observations	142680	25036	141158	141158
Panel C. Leaving Teaching in North Carolina				
Lagged quality measure	1.03	1.02	1.27**	
Proficient Rating				0.79*
Accomplished Rating				0.78*
Distinguished Rating				1.18
Observations	142680	27337	141158	141158

Notes. Odds ratios from separate discrete time hazard models. Models include teacher and student controls. Standard errors clustered at the teacher level. * p<0.05; ** p <0.01; *** p <.001. All models include cohort fixed effects.

below proficient. Although the estimate on distinguished, the highest rating in the state, is imprecisely measured and statistically insignificant, the direction on the odds ratio suggests that the highest rated teachers may be at risk of turning over at higher rates than the lowest rated teachers. We find no evidence of a relationship between the average teacher test or a teachers' value-added score. Without this evidence, these models are unable to separate whether it is the relationship between the evaluation score and teacher turnover is driven by the signal from an administrator of receiving a low evaluation or lower performance on behalf of the teacher.

Examining Differences in the Timing of Early Career Teacher Turnover

The results presented in Table 3 indicate differences in the average risk of turning over during teachers first three years across entry pathway and school characteristics. They give no indication of how this relationship varies over time. To test if there is evidence of the violation of the proportionality assumption, we test that the Schoenfeld residuals for each covariate are uncorrelated with time (Schoenfeld, 1982). Of the independent variables of interest, we find strong evidence of a time dependent effect of alternate entry ($\chi^2 = 28.75, p < .001$), TFA ($\chi^2 = 19.96, p < .001$), and out-of-state prepared teachers ($\chi^2 = 2.55, p = 0.1101$).[14] In regards to moving, we find little evidence of violation of the proportionality assumption. The χ^2 for alternate entry teachers is 0.21 (p = 0.64), 2.55 for TFA (p = 0.1105), and 1.20 for out-of-state prepared teachers (0.27). The magnitude of the χ^2 for leaving are even larger, suggesting a strong relationship between entry pathway and the timing of leaving teaching. Overall, we find no evidence that the percentage of economically disadvantaged, minority students, or overall school performance have a time dependent effect on turnover. Although the Royston-Parmar model is our preferred specification to model time dependent effects, for comparison, we also present the results from the district time hazard model that includes an interaction between each entry pathway and a continuous measure of time.

While the results are presented in Table 6, because of the difficulty interpreting time dependent Royston-Parmar models, we follow Royston and Lambert (2011) and plot the hazard ratio for alternate entry (left panel of Figure 2), TFA (middle), and out-of-state prepared teachers (right) compared to in-state traditionally prepared teachers. Across each graph, when the estimate or its confidence interval overlaps 1, there is no evidence of differences in the risk of turnover

[14] In regards to moving, we find less evidence of violation of the proportionality assumption. The χ^2 for alternate entry teachers is 0.21 (p = 0.64), 2.55 for TFA (p = 0.1105), and 1.20 for out-of-state prepared teachers (0.27).

Table 6. Time-Dependent Survival Analysis of Turnover, Moving Schools, and Leaving Teaching in North Carolina

	Turnover				Moving				Leaving			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Alternate entry	0.10	-0.05	0.24***	0.14*	-0.05	-0.17	0.12	0.04	0.57***	0.37**	0.49***	0.35***
Teacher For America	-1.18***	-1.56***	0.12	-0.23	-1.84***	-2.18***	-0.72***	-1.05***	0.04	-0.41**	0.91***	0.56***
Out-of-state prepared	0.30***	0.26***	0.28***	0.25***	0.01	-0.03	-0.09	-0.12	0.92***	-0.86***	0.76***	0.72***
Other	0.86***	0.79***	0.55***	0.50***	0.34*	0.29	-0.02	-0.05	1.62***	-1.52***	1.08***	0.99***
Time (in months)	0.02***	0.03***			0.01***	0.03***			0.04***	0.05***		
Time*Alternate entry	0.01**	0.01**			-0.00	-0.00			0.01	0.01*		
Time*Teacher For America	0.12***	0.12***			0.08***	0.08***			0.10***	0.10***		
Time*Out-of-state prepared	0.00	0.00			-0.01	-0.00			-0.01	-0.00		
Time*Other	-0.04***	-0.03***			-0.02*	-0.02*			-0.05***	-0.05***		
Female	-0.10***	-0.04	-0.11***	-0.06*	-0.02	0.02	-0.04	-0.00	-0.17***	-0.10**	-0.17***	-0.10**
Black	0.03	-0.07	0.00	-0.09*	0.08	-0.03	0.06	-0.05	-0.02	-0.11*	-0.04	-0.13*
Hispanic	-0.08	-0.13	-0.06	-0.11	-0.21	-0.27*	-0.20	-0.24*	0.09	0.04	0.09	0.05
Other race	-0.07	-0.09	-0.05	-0.08	-0.02	-0.04	-0.02	-0.05	-0.10	-0.15	-0.08	-0.13
Age	0.01***	0.01***	0.01***	0.00***	0.00	-0.00	-0.00	-0.00*	0.02***	0.02***	0.01***	0.01***
City		-0.17***		-0.16***		-0.28***		-0.26***		0.01		0.01
Rural		-0.13**		-0.12**		-0.18***		-0.17**		-0.08		-0.08
Town		-0.17**		-0.13*		-0.20**		-0.16*		-0.06		-0.03
School size (100s)		-0.03***		-0.03***		-0.04***		-0.04***		-0.02***		-0.02***
Overall performance composite		0.02***		0.02***		0.02***		0.02***		0.01***		0.02***
% economically disadvantaged		0.00***		0.00***		0.01***		0.01***		0.00*		0.00
% Black students		0.01***		0.01***		0.01***		0.01***		0.01***		0.01***
% Hispanic students		0.00		0.00		0.00		0.00		-0.00		0.00
% Other race		0.00*		0.00*		0.00		0.00		0.00*		0.00*

Teachers with 3 yrs experience or less		-0.25*		-0.16		-0.44**		-0.32*		0.05		0.07
Suspension rate		0.00*		0.00***		0.00*		0.00**		0.00		0.00*
Violent acts rate		0.00**		0.00*		0.00**		0.00*		0.00		0.00
Per pupil expenditures		0.00*		0.00***		0.00		0.00		0.00**		0.00***
Teacher salary supplement		-0.00		-0.00*		-0.00		-0.00		-0.00***		-0.01***
Middle School		0.23***		0.21***		0.22***		0.20***		0.25***		0.22***
High School		0.49***		0.41***		0.39***		0.33***		0.58***		0.49***
Facilities and Resources (std)		-0.03		-0.03		-0.03		-0.03		-0.03		-0.03
Distributed leadership (std)		-0.03		-0.03		-0.03		-0.03		-0.01		-0.02
Principal leadership (std)		-0.09***		-0.08***		-0.07**		-0.07**		-0.12***		-0.11***
Professional development (std)		0.01		0.01		0.00		-0.00		0.03		0.03
Constant	-3.62***	-4.22***			-3.94***	-4.43***			-5.16***	-5.86***		
Observations	251421	251421	253267	253267	251921	251421	253683	253173	306954	305822	306954	305822
Deviance	72542.2	71592.7	29761.1	28836.8	47365.2	46734.0	22997.0	22429.5	43929.1	43140	20509.5	19885.4

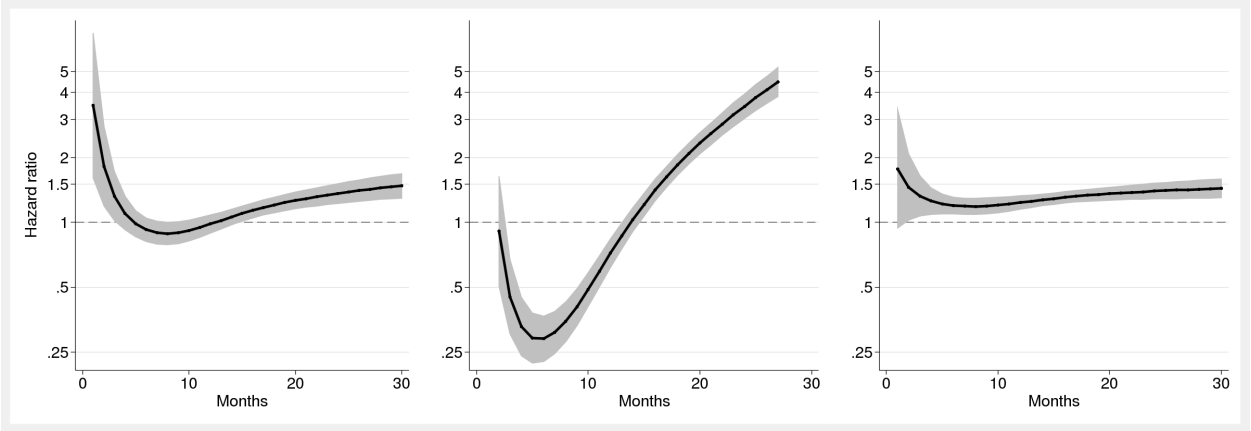
Notes. Discrete time models (columns 1-2; 5-6; 9-10) estimated using logistic regression. Coefficients reported as odds ratios. Standard errors clustered at the teacher level. Royston-Parmar models (columns 3-4; 7-8; 11-12) estimated with 2 knots. Models include a time-varying component for the entry pathway variables. * p<0.05; ** p <0.01; *** p <.001. All models include cohort fixed effects.

between traditionally prepared and the comparison teacher pathway at that point in their early career trajectory. Compared to traditionally prepared teachers, alternate entry teachers are at greater risk of moving schools for the first few months of their career and then have nearly twice the risk of leaving teaching. Teacher For America teachers have a much lower risk of moving schools until their third year, but have an increasing risk of leaving teaching after their first year. Out-of-state prepared teachers are no more at risk of moving schools, but consistently have twice the risk of leaving compared to in-state prepared teachers.

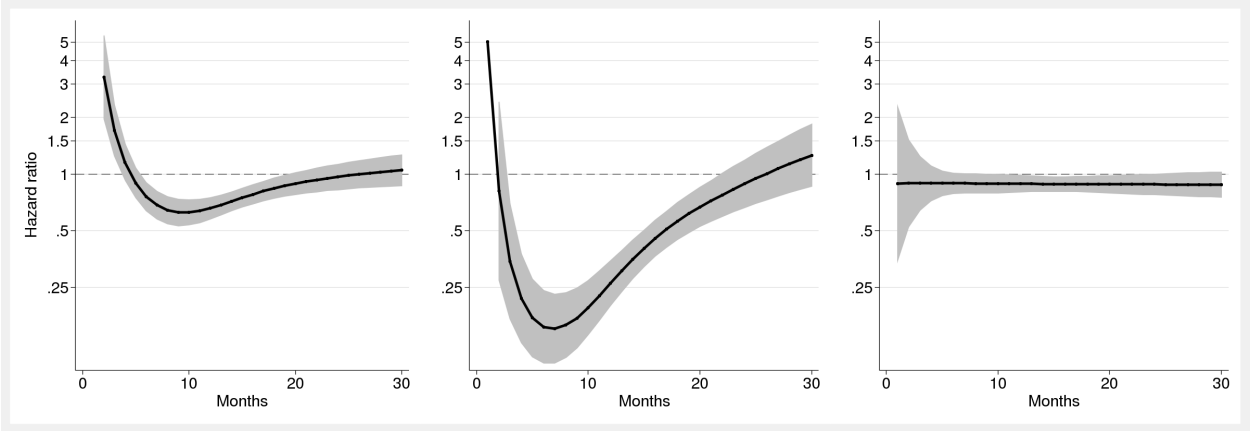
With evidence that the timing of turnover varies across pathways, Figure 3 plots the survival curves for turnover (right), moving schools (middle), and leaving teaching (right) from the Royston-Parmar model that models the time dependent effect of teacher entry pathway. Compared to the Kaplan-Meier survival curves in Figure 1, adding controls for teacher and school characteristics and modeling the time dependency of entry pathway reduces the turnover gap between in-state, traditionally prepared teachers and alternate entry and out-of-state prepared teachers. Whereas there was a 12 percentage point difference in the three-year survival rate between traditional and alternatively prepared teachers, the predicted difference is 6 percentage points. For out-of-state teachers, the descriptive difference is 11 percentage points, with a 10 percentage point predicted difference.

Compared to the results in Table 3 that only allow for the interpretation of the cumulative survival rates, allowing for the time dependent effect of entry pathways allows for the interpretation of the survival rates at any month in a novice teachers' career. Figure 3a shows that a significant difference in the percentage of teachers to remain in their original school emerges at the end of the first year for out-of-state prepared teachers and the end of the second year for alternate entry teachers. TFA teachers are shown to turnover at lower rates for the first

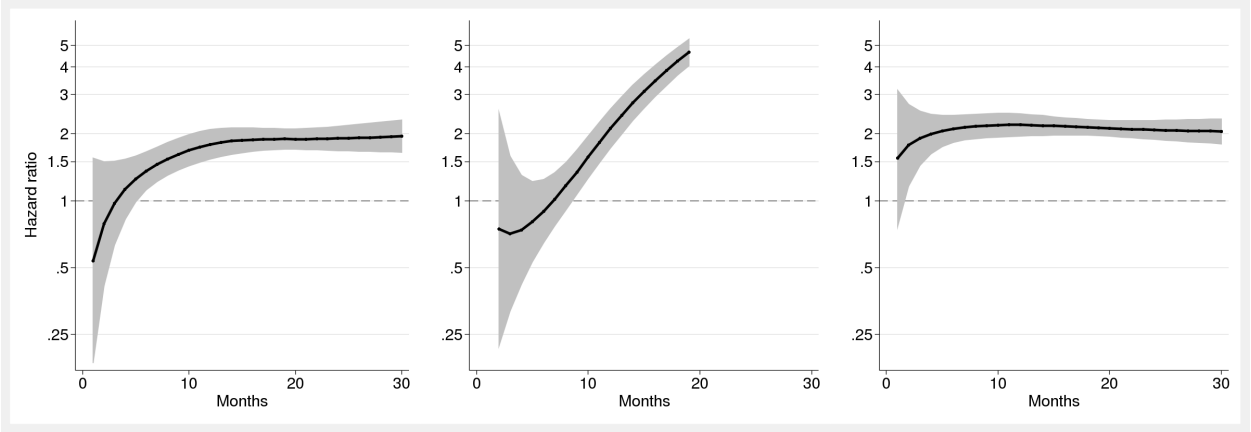
Figure 2. Hazard Ratios Comparing In-State, Traditionally Prepared Teachers to Alternate Entry (left), Teacher For America (center), and Out-of-State Prepared Teachers (right) from Time Dependent Royston-Parmar Model



(a) Turnover



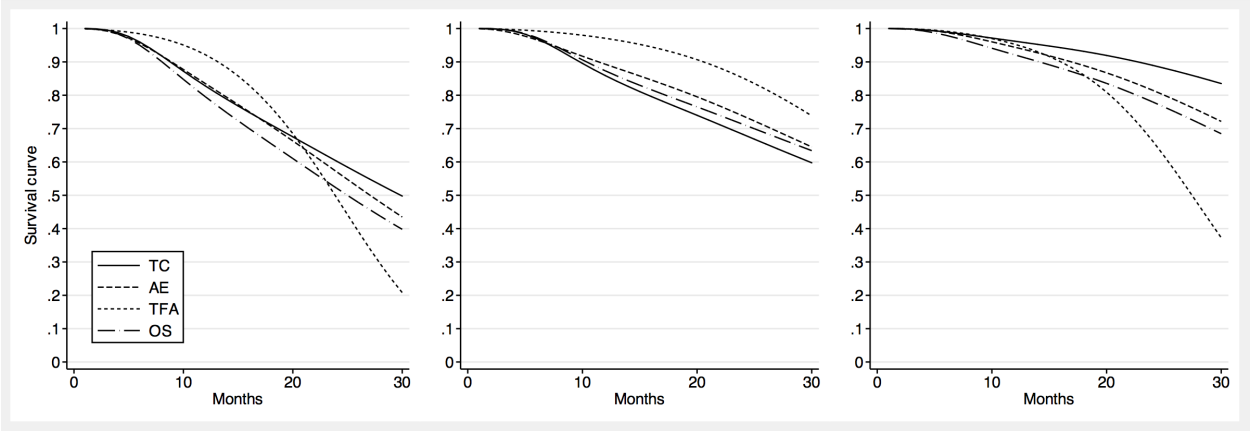
(b) Moving Schools



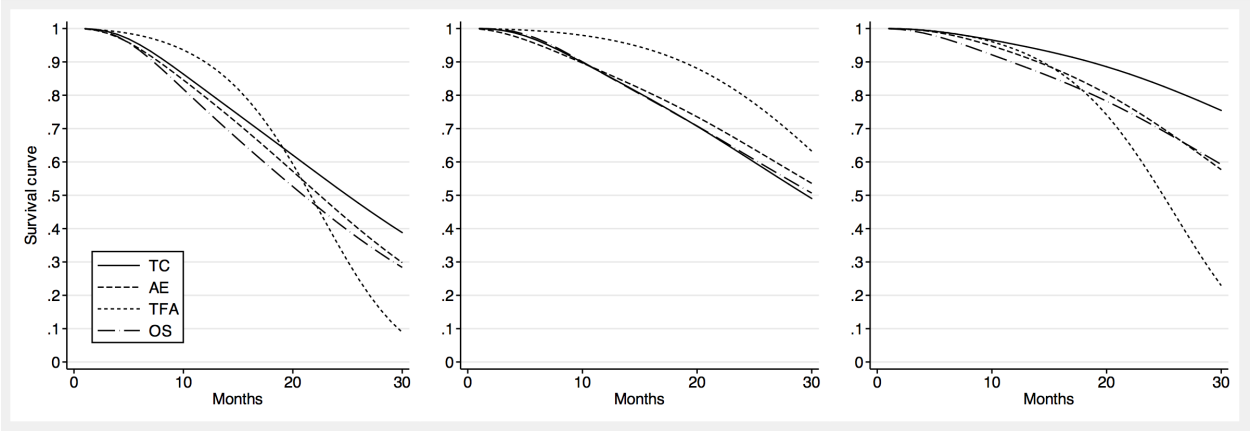
(c) Leaving teaching in North Carolina

Notes. Each school year is coded as having 10 months. Hazard ratios compared to in-state, traditionally prepared teachers. For presentation, graphs limited hazard ratios less than 5.

Figure 3. Predicted Survival Curves from Time Dependent Royston-Parmar model for Turnover (right), Moving Schools (center), and Leaving (right), by Teacher Entry Pathway



(a) Teacher entry pathway



(b) Teacher entry pathway in high minority schools

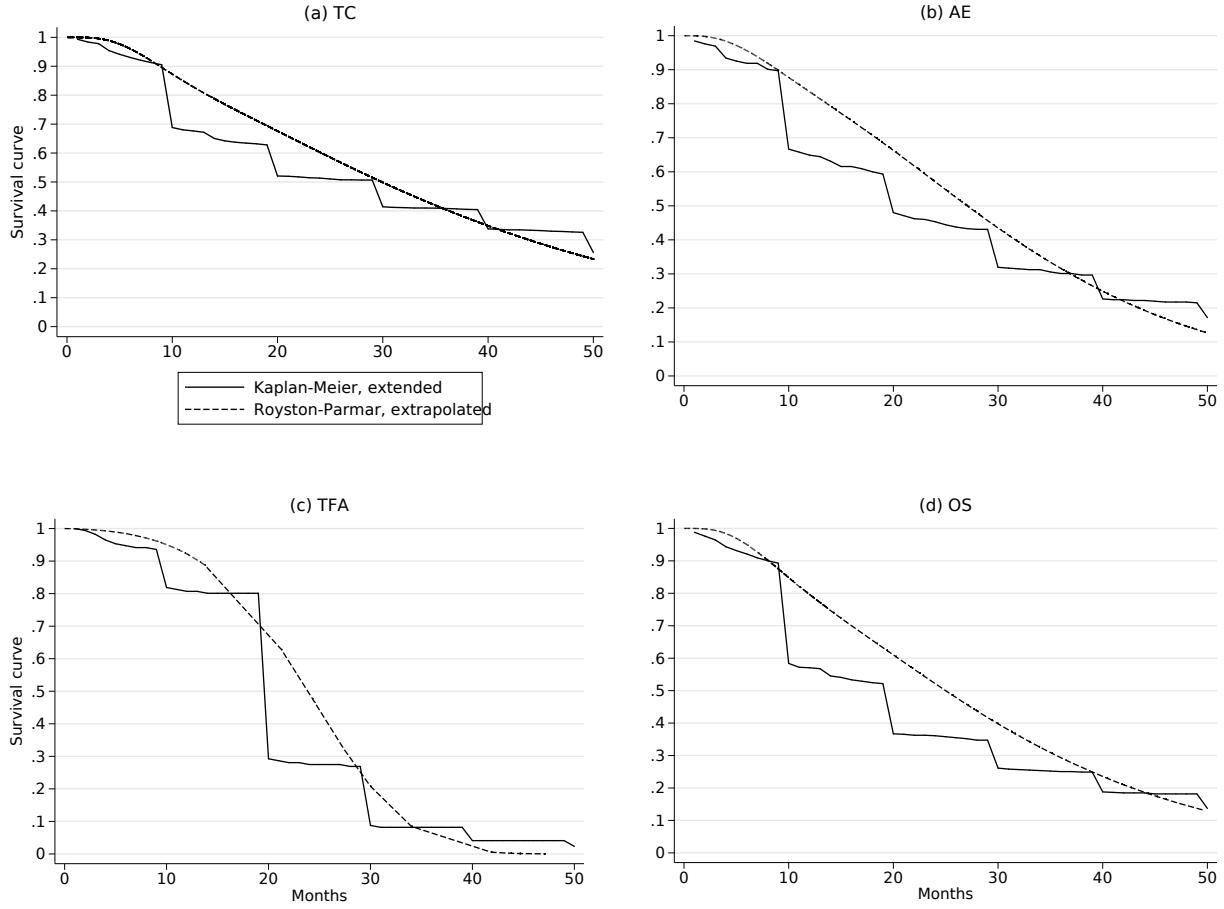
Notes. Each school year is coded as having 10 months. TC = In-state, traditional preparation; AE = Alternate entry; TFA = Teacher For America; OS = Out-of-state prepared. Results from Figure 3b based on a model limited to schools with one more than one standard deviation above minority student enrollment (81% minority enrollment).

two years of their career before dropping steeply around the second year. The only notable difference in the survival curves for moving is the lower rate at which TFA teachers are predicted to move schools compared to all other teachers. Controlling for teacher and school characteristics, in-state traditionally prepared teachers are predicted to remain in teaching at higher rates than teachers from other entry pathways. For instance, at the end of three years of

teaching, the Kaplan-Meier curve for traditionally prepared teachers in Figure 1 showed that 77% of novice teachers remained in teaching. The predicted survival rate, which conditions on the average for each covariate, is 84% at the end of three years. Although the rate at which alternate entry and out-of-state prepared teachers are predicted to leave teaching is reduced when controlling for teacher and school controls, a significant gap persists in regards to the rate at which teachers leave teaching compared to traditionally prepared. Compared to in-state traditionally prepared teachers, the gap is 12% for alternate entry teachers and 16% for out-of-state prepared teachers. TFA teachers are still predicted to leave teaching at the highest rates.

With evidence above of higher turnover rates in schools enrolling more students of color, we re-estimate this Royston-Parmar model for schools a standard deviation above the average minority student enrollment and plot the predicted survival curve across entry pathways in Figure 3b. While the general pattern between entry pathways and teacher turnover persists, all teacher are more likely to turnover in these high minority schools compared to schools with average minority student enrollment, as is depicted in Figure 3a. Of the in-state traditionally prepared teachers to begin their career in high minority schools, only 39% remain in the same school after three years, approximately 30% of alternate entry and out-of-state prepared teachers, and 10% of Teacher For America teachers. Most stark, is that 40% of alternate entry and out-of-state prepared teachers in high minority schools have left teaching by the end of their third year. As schools with a greater share of underserved students are where alternate entry and out-of-state teachers are most likely to find their first teaching job, these high predicted rates of exit from the profession raise concerns that these teachers are not being adequately inducted into the teaching profession in the schools where they begin their careers.

Figure 4. Out-of-sample predictions of teacher turnover, 2009-2010 cohort



Notes. Predictions from Royston-Parmar model based on column 4 of Table 4. Kaplan-Meier survival curve from the 2009-2010 cohort. Each school year is coded as having 10 months. TC = In-state, traditional preparation; AE = Alternate entry; TFA = Teacher For America; OS = Out-of-state prepared.

As a final step, we extend this model by examining how well it predicts teacher turnover outside of the three-year sample used in the analysis up until this point. we use the data on teachers' turnover patterns available from the 2009-2010 cohort to examine the out-of-sample predicted survival rate. Using the same model from above, we predict the survival rate across entry pathways for teachers' fourth and fifth school years. We then contrast the predicted survival curve to this cohort of teachers' observed turnover patterns. In Figure 4, two features stand out.

First, the Kaplan-Meier survival curves indicate that the turnover gap between traditionally prepared teachers is not isolated to their first three years. Among teachers who began teaching during the 2009-2010 cohort, approximately a quarter of traditionally prepared teachers and 15% of alternate entry and out-of-state prepared teachers remain in the same school after five years. With similar levels of moving schools across each entry pathway, the turnover gap continues to be driven by the lower rates at which traditionally prepared teachers leave teaching in North Carolina public schools compared to all other entry pathways. In results presented in the Figures A1 and A2 in the appendix, we find that after five years, 65% of traditionally certified teachers remain in teaching at the end of their fifth year, 45% of alternate entry teachers, 34% of out-of-state prepared teachers, and 10% of TFA teachers.

Second, the predicted survival curves from the Royston-Parmar survival are quite accurate in predicting the cumulative survival rate after five years. The only prediction that is somewhat off is for Teacher For America teachers, all of whom were predicted to have exited teaching. Contrasting the descriptive data and predictions raise the question of how well this model estimates the timing of within-year turnover. The survival curves overestimate the proportion of teachers who remain in the profession during the school year to account for the high level of turnover at the end of the school year.

Conclusion

In this paper, we argue that the convergence of three factors—increased reliance on inexperienced teachers, the diversifications of teacher entry pathways, and the disproportional employment of novice teachers in underserved schools—are fueling a new dynamic in the teacher labor market. Open teaching positions are concentrated in underserved schools with challenging conditions that may lack the supports needed for the induction of new teachers,

particularly for those teachers from out-of-state or alternate entry programs that may require additional supports. Organizational commitment theory suggests that novice teachers bring normative commitments to teaching and face a unique set of perceived costs and affective attachments once they enter the classroom, all of which shape the time they remain in their first school. Difficult social conditions in teachers' first school likely increase demoralization and lack of commitment to remain in their school and the profession, leading to higher levels of turnover, both during and at the end of the school year.

The use of survival analysis to understand the timing of turnover each month gives a nuanced view of the turnover patterns of early career teachers. Consistent with previous research and organizational commitment theory, we find higher turnover rates for early career alternate entry, Teacher For America, and out-of-state prepared teachers compared to in-state traditionally prepared teachers. With teachers trained in traditional university-based programs being more likely to move schools, the turnover gap by entry pathway is driven by much higher rates of leaving teaching among teachers from non-traditional entry pathways. Across the three cohorts in this study, 23% of in-state, traditionally prepared teachers had exited the profession by the end of their third year compared to 45% of alternate entry and out-of-state prepared teachers and 82% of TFA teachers. Controlling for teacher and school characteristics explain a portion of this observed difference in the timing and frequency of turnover across entry pathways. Notably, higher turnover rates are not only driven by end-of-year turnover but within-year turnover as well.

Early career teachers are most likely to turnover from schools with more racial/ethnic minorities, particularly those schools that enroll large numbers of Black students, the schools where alternate entry and out-of-state prepared teachers are most likely to teach. The teacher

turnover from high minority schools is driven by higher rates of leaving teaching, with 42% of teachers in schools with the greatest concentrations of minorities leaving teaching compared to 29% in all other schools. Although we see little evidence that alternate entry or out-of-state prepared teachers are more likely to turnover in under-performing or high minority schools, the higher placement of these underprepared teachers in high needs schools likely aggravates the rate at which they turnover. This finding is particularly concerning as both the within- and end-of-year turnover disrupt the learning environments for students in these underserved schools.

We found evidence that the teachers at greatest risk of leaving are those who received lower evaluation scores from their principal. Although we do find evidence of a relationship between teacher value-added or the average teacher test, our results suggest that previous research on the relationship between teacher quality and turnover may be biased by the extent that it overlooks within-year turnover, particularly in teachers first year. If it is the lowest-performing teachers to turnover midyear, current estimates may significantly underestimate the relationship between teacher quality and turnover, as quality measures would be unobserved for a segment of teachers.

A couple of limitations of the study should be noted. Further, as with most studies of teacher turnover, we are unable to identify whether or not the turnover was voluntary or involuntary. With evidence that early career teachers move within districts during the school year, evidence of whether this assignment was driven by the district would give a more accurate understanding of the factors that shape early career teacher turnover. Second, to address the inherent selection bias in studying differences in teacher entry pathway, this study relies on a rich set of teacher and school characteristics to balance differences across entry pathways and types of schools. That being said, unobserved heterogeneity may bias the relationship between entry

pathway, school type, and teacher turnover. As a result, the results should not be interpreted as the effect of an entry pathway or a teacher working in a school with particular characteristics. Despite these limitations, this study raises several policy implications related to new teacher preparation, hiring, and induction.

In recent decades, states have reduced the barriers into the teaching profession, either establishing procedures for teachers to receive reciprocal licenses in other states or adopting alternative entry pathways into teaching outside traditional, university-based programs (Henry et al., 2014). While such programs have helped states meet staffing shortages in hard-to-staff subjects and schools, questions remain about the extent to which teachers from these new pathways have the same commitment to remain in the profession in-state traditionally prepared teachers. Evidence presented in this paper indicates that alternate entry and out-of-state teachers do fill teaching positions in low-performing schools but also leave teaching at much higher rates than traditionally prepared teachers. This finding suggests that these teachers may benefit from induction supports or financial incentives to improve their overall retention. Evidence of high levels of within-year turnover, particularly in teachers' first year, suggests that such programs could be better targeted to account for this within-year mobility. An alternative approach suggests altering elements of the teacher labor market, by either inducing more experienced and effective teachers to teach in high minority, low-performing schools (Zimmer, Henry, & Kho, forthcoming) or promoting student teaching in underperforming schools (Ronfeldt, 2012).

Findings from this paper also indicate within-year turnover includes sorting to a new school within the same district. Combined with evidence that teachers hired late in the school year have a negative effect on student achievement (Papay & Ronfeldt, 2016), our results suggest that districts would be advised to reassign teachers as early in the year as possible to avoid the

disruption to their students and the school environment when teachers are reassigned once the year has begun.

The evidence of differences in the level and timing of turnover across entry pathways is useful information for administrators faced with hiring inexperienced teachers. Given choice among candidates, principals may be hesitant to hire alternate entry or out-of-state prepared teachers. Further, understanding the timing of turnover also shifts the focus of teacher hiring as a spring and summer activity to one that could occur any point throughout the school year. Recent research on principal time use suggests principals are increasingly pulled out of the classroom and into administrative tasks and organizational management, including hiring (Camburn, et al., 2010; Grissom, Loeb, & Master, 2013; Horng, et al., 2010).

Evidence of within-year turnover suggests that previous studies to focus on annual measures of teacher turnover underestimate the frequency with which turnover occurs and its overall effect on students and their school. Further, within-year turnover is likely more disruptive to the learning opportunities of students, particularly those in underserved schools that face higher annual within-year and end-of-year turnover.

A final contribution of the study relates to its timing. The Great Recession marked a period of flux within the teacher labor market. The supply of new teachers waned and the risk of layoffs for early career teachers peaked in the subsequent years (Goldhaber, Strunk, Brown, & Knight, 2016). This paper highlights how the churn within the teacher labor market during this period did not only occur between school years, but during the year as well, which has ongoing implications for the recruitment and equitable distribution of teachers (Sutcher, Darling-Hammond, & Carver-Thomas, 2016).

References

Allegretto, S. A. & Mishel, L. (2016). The teacher pay gap is wider than ever. Economic Policy Institute. Retrieved from www.epi.org.

Allensworth, E., Ponisciak, S., & Mazzeo, C. (2009). *The schools teachers leave: Teacher mobility in Chicago Public Schools*. Chicago, IL: Consortium on Chicago School Research—University of Chicago.

Allison, P. D. (1982). Discrete-time methods for the analysis of event histories. *Sociological Methodology*, 13, 61-98.

Allison, P. D. (2014) *Event history and survival analysis* (2nd ed). Thousand Oaks, CA: Sage Publications.

Bastian, K. B. & Henry, G. T. (2015) Teachers without borders: Consequences of teacher labor force mobility. *Educational Evaluation and Policy Analysis*, *37*(2), 163-183.

Becker, H. (1960). Notes on the concept of commitment. *Journal of Sociology*, *66*(1), 32-40.

Borman, G. D., & Dowling, N. M. (2008). Teacher Attrition and Retention: A Meta-Analytic and Narrative Review of the Research. *Review of Educational Research*, *78*(3), 367–409.

Boyd, D., Grossman, P. L., Lankford, R. H., Loeb, S., & Wyckoff, J. (2006). How changes in entry requirements alter the teacher workforce and affect student achievement. *Education Finance and Policy*, *1*(2), 176-216.

Boyd, D., Grossman, P. L., Lankford, R. H., Loeb, S., & Wyckoff, J. (2009). Teacher preparation and student achievement. *Educational Evaluation and Policy Analysis*, *31*(4), 416-440.

Boyd, D., Grossman, P. L., Ing, M., Lankford, R. H., Loeb, S., & Wyckoff, J. (2011). The influence of school administrators on teacher retention decisions. *American Educational Research Journal*, *48*(2), 303–333.

Boyd, D., Lankford, R. H., Loeb, S., & Wyckoff, J. (2005). Explaining the short careers of high-achieving teachers in schools with low-performing students. *American Economic Review*, *95*(2), 66–71.

Buckley, J., Schneider, M. & Shang, Y. (2005). Fix it and they might stay: School facility quality and teacher retention in Washington, D.C. *Teachers College Record*, *107*(5), 1107-1123.

Camburn, E.M., Spillane, J.P. & Sebastian, J. (2010). Assessing the utility of a daily log for measuring principal leadership practice, *Educational Administration Quarterly*, *46*(5), 707-737.

Clotfelter, C.T., Ladd, H.F. & Vigdor, J.L. (2007). Teacher credentials and student achievement: Longitudinal analysis with student fixed effects. *Economics of Education*, *26*(6), 673-682.

Cochran-Smith, M. (1999). Learning to teach for social justice. In G. Griffin (Ed.), *The education of teachers: Ninety-eighth yearbook of the national society for the study of education* (pp. 114-144). Chicago, IL: University of Chicago Press.

Costrell, R. M. & Podgursky, M. (2009). Peaks, cliffs, and valleys: The peculiar incentives in teacher retirement systems and their consequences for school staffing. *Education Finance and Policy, 4*(2), 175-211.

Darling-Hammond, L., French, J., & Garcia-Lopez, S. (2002). *Learning to Teach for Social Justice*. New York, NY: Teachers College Press.

Feng, L. (2010). Hire today, gone tomorrow: New teacher classroom assignments and teacher mobility. *Education Finance and Policy*, *5*(3), 278-316.

Firestone, W. A. & Pennell, J. R. (1993). Teacher commitment, working conditions, and differential incentive policies. *Review of Educational Research*, *64*(3), 489-525.

Goldhaber, D. & Cowan, J. (2014). Excavating the teacher pipeline: Teacher preparation programs and teacher attrition. *Journal of Teacher Education, 65*(5), 449-462.

Goldhaber, D. Grout, C., Holden, K. L., Brown, N. (2015). Crossing the border? Exploring the cross-state mobility of the teacher workforce. *Educational Researcher, 44*(8), 421-431.

Goldhaber, D., Gross, B., & Player, D. (2011). Teacher career paths, teacher quality, and persistence in the classroom: Are schools keeping their best? *Journal of Policy Analysis and Management*, *30*(1): 57-87.

Goldhaber, D., Strunk, K. O., Brown, N., & Knight, D. S. (2016). Lessons learned from the reat Recession: Layoffs and the RIF-induced teacher shuffle. *Educational Evaluation and Policy Analysis, 38*(3), 517-548.

Gray, L., and Taie, S. (2015). *Public school teacher attrition and mobility in the first five years: results from the first through fifth waves of the 2007–08 Beginning Teacher Longitudinal Study* (NCES 2015-337). U.S. Department of Education. Washington, DC: National Center for Education Statistics. Retrieved from http://nces.ed.gov/pubsearch.

Grissom, J. A. (2011). Can good principals keep teachers in disadvantaged schools? Linking principal effectiveness to teacher satisfaction and turnover in hard-to-staff environments. *Teachers College Record*, *113*(11), 2552–2585.

Grissom, J. A., Loeb, S. & Master, B. (2013). Effective instructional time use for school leaders: Longitudinal evidence from observations of principals. *Educational Researcher, 42*(8), 433-444.

Grissom, J. A., Loeb, S., Nakashima, N. A. (2013). Strategic involuntary teacher transfers and teacher performance: Examining equity and efficiency. *Journal of Public Policy and Management, 33*(1), 112-140.

Guarino, C. M., Brown, A. B., & Wyse, A. E. (2011). Can districts keep good teachers in schools that need them most? *Economics of Education Review*, *30*(5), 962-979.

Henry, G. T., Bastian, K. C., & Fortner, C. K. (2011). Stayers and leavers: Early-career teacher effectiveness and attrition. *Educational Researcher*, *40*(6), 271–280.

Henry, G. T., Bastian, K. C. & Smith, A. A. (2012). Scholarships to recruit the "Best and Brightest" into teaching: Who is recruited, where do they teach, how effective are they, and how long do they stay?" *Educational Researcher*, *41*(3), 83-92.

Henry, G. T., Fortner, C. K., Bastian, K. C. (2012). The effects of experience and attrition for novice high-school science and mathematics teachers. *Science*, 335, 1118-1121.

Henry, G. T., Purtell, K.M., Bastian, K.C., Fortner, C.K., Thompson, C.L., Campbell, S.L., Patterson, K.M. (2014). The effects of teacher entry portals on student achievement. *Journal of Teacher Education*, *65*(1), 7-23.

Horng, E.L., Klasik, D. & Loeb, S. (2010). Principal's time use and school effectiveness, *American Journal of Education, 116*(4), 491-523.

Ingersoll, R. M. (2001). Teacher turnover and teacher shortages: An organizational analysis. *American Education Research Journal*, *38*(3), 499–534.

Ingersoll, R. M., Merrill, L., & Stuckey, D. (2014). *Seven trends: The transformation of the teaching force.* CPRE Research Report # RR-80. Philadelphia: Consortium for Policy Research in Education.

Johnson, S. M., & Birkeland, S. E. (2003). Pursuing a "sense of success": New teachers explain their career decisions. *American Educational Research Journal*, *40*(3), 581–617.

Johnson, S. M., Kraft, M., & Papay, J. P. (2012). How context matters in high-need schools: The effects of teachers' working conditions on their professional satisfaction and their

students' achievement. *Teachers College Record*, *114*(10), 1–39.

Kalogrides, D., Loeb, S., & Beteille, T. (2013). Systematic sorting: Teacher characteristics and class assignments. *Sociology of Education, 86*(2), 103-123.

Kane, T. J., Rockoff, J. E., & Staiger, D. O. (2008). What does certification tell us about teacher effectiveness? Evidence from New York City. *Economics of Education Review*, *27*(6), 615–631.

Kardos, S. M. & Johnson, S. M. (2007). On their own and presumed expert: New teachers' experience with their colleagues. *Teachers College Record, 109*(9), 2083-2106.

Koski, W. S. & Horng, E. L. (2007). Facilitating the teacher quality gap? Collective bargaining agreements, teacher hiring and transfer rules, and teacher assignment among schools in California. *Education Finance and Policy, 2*(3), 262-300.

Kraft M. A. (2015) Teacher layoffs, teacher quality and student achievement: Evidence from a discretionary layoff policy. *Education Finance and Policy, 11*(4), 1-41.

Ladd, H. F. (2011). Teachers' perceptions of their working conditions: How predictive of planned and actual teacher movement? *Educational Evaluation and Policy Analysis*, *33*(2), 235–261.

Lankford, H., Loeb, S., & Wyckoff, J. (2002). Teacher sorting and the plight of urban schools: A descriptive analysis. *Education Evaluation and Policy Analysis, 24*(1), 37-62.

Lee, K., Carswell, J. J., & Allen, N. J. (2000). A meta-analytic review of occupational commitment: Relations with person and work-related variables. *Journal of Applied Psychology*, 85, 799-811.

Meyer, J. P., Allen, N. J. (1991). A three-component conceptualization of organizational commitment. *Human Resource Management Review*, *1*(1), 61-89.

Meyer, J. P., Allen, N. J., & Smith, C. A. (1993). Commitment to organizations and occupations: Extensions and test of a three-component conceptualization. *Journal of Applied Psychology*, 78(4), 538-551.

National Council on Teacher Quality (2013). NCTQ District Policy. Retrieved from www.nctq.org

Oakes, J., Lipton, M., Anderson, L., & Stillman, J. (2012). *Teaching to change the world* (4th ed.). Boulder, CO: Paradigm Publishers.

Papay, J. P. & Kraft, M. A. (2016). The productivity costs of inefficient hiring practices: Evidence from late teacher hiring. *Journal of Policy Analysis and Management, 35*(4), 791-817.

Redding, C. and Smith, T. M., (2016) Easy in, easy out? Are Alternatively Certified Teachers Turning Over at Increased Rates? *American Educational Research Journal, 53*(4), 1086-1125.

Reininger, M. (2012). Hometown disadvantage? It depends on where you're from teachers' location preferences and the implications for staffing schools. *Educational Evaluation and Policy Analysis, 34*(2), 127-145.

Ronfeldt, M. (2012). Where should student teachers learn to teach? Effects of field placement school characteristics on teacher retention and effectiveness. *Educational Evaluation and Policy Analysis, 34*(1), 3-26.

Ronfeldt, M., Farmer, S. O., McQueen, K., Grissom, J. A. (2015). Teacher collaboration in instructional teams and student achievement. *American Educational Research Journal, 52*(3), 475-514.

Ronfeldt, M., Kwok, A., & Reininger, M. (forthcoming). Teachers' preferences to teacher underserved students. *Urban Education*, 1-36

Ronfeldt, M., Loeb, S., & Wyckoff, J. (2013). How teacher turnover harms student achievement. *American Educational Research Journal*, *50*(1), 4-36.

Royston, P. & Lambert, P. C. (2011). *Flexible parametric survival analysis using Stata: Beyond the Cox Model*. College Station, TX: Stata Press.

Schoenfeld, D. (1982). Partial residuals for the proportional hazards regression model. *Biometrika, 69*, 239-241.

Schweig, J. (2014). Cross-level measurement invariance in school and classroom environment surveys implications for policy and practice. *Educational Evaluation and Policy Analysis, 36*(3), 259-280.

Simon, N. S. & Johnson, S. M. (2015) Teacher turnover in high-poverty schools: What I know and can do. *Teachers College Record*, *117*(3), 1-36.

Smith, T. M., & Ingersoll, R. M. (2004). What are the effects of induction and mentoring on beginning teacher turnover? *American Educational Research Journal*, *41*(3), 681–714.

Sutcher, L., Darling-Hammond, L., & Carver-Thomas, D. (2016). *A coming crisis in teaching? Teacher supply, demand, and shortages in the U.S.* Palo Alto, CA: Learning Policy Institute.

Willett, J. B. & Singer, J. D. (1991). From whether to when: New methods for studying student dropout and teacher attrition. *Review of Educational Research*, *61*(4), 407-450.

Zimmer, R. Hery, G. T., & Kho, A. (forthcoming). The role of governance in school turnaround policies: The case of Tennessee's Achievement School District.

CHAPTER 4

EXPLAINING THE EFFECTS OF TEACHER TURNOVER ON STUDENT ACHIEVEMENT

Introduction

Employee turnover in public sector organizations is consequential both for its relationship with employee productivity and the ways in which it affects the delivery of services to the organization's clients (Grissom, Viano, & Selin, 2015). Research in K-12 public education has examined both issues, although the primary focus has been teacher productivity (e.g. Boyd, Grossman, Lankford, Loeb, & Wyckoff, 2008; Goldhaber, Gross, & Player, 2011). The impact of teacher turnover on students has received considerably less attention in the literature, although recent research in this vein suggests turnover adversely affects student achievement (Hanushek, Rivkin, & Schiman, 2016; Ronfeldt, Loeb, & Wyckoff, 2013). Teacher turnover may harm student achievement through three distinct mechanism: (1) staff instability; (2) classroom disruption; (3) differences in quality of replacement and replaced teacher.

Staff instability impedes the development and maintenance of a cohesive organizational culture and a rigorous instructional program (Bryk et al., 2010; Holme & Rangel, 2012). Teacher turnover, especially when rates are higher, undermines the capacity of schools to maintain a coherent instructional program built around high expectations and teacher leadership. In addition to eliminating lines of professional communication among teachers, students lose connections with adults with whom they have built relationships within their schools. If instructional communication and continuity is most important at the grade level, turnover in a particular grade can affect the instructional program within that grade and communication of teachers about particular students and the objectives for their learning that they have in common. Mid-year

classroom disruptions of the relationships between students and teachers separates the student from a teacher with whom they have built a relationship and who may understand how to tailor instruction to meet the needs of their individual students. It is easy to imagine that the disruption could setback students' performance. Finally, teacher turnover also changes the composition of teachers within a school. Student academic performance will suffer when a less effective teacher replaces the departing teacher. Of course, if the teacher departs due to poor performance and is replaced by a more effective one, the replacement effect could be positive.

Studies from New York City and Texas provide credible estimates of the effect of teacher turnover on student achievement. Ronfeldt and colleagues (2013) find that students in a fourth or fifth grade with fewer teachers returning from the previous year score between 8.2 and 10.2 percent of a standard deviation lower in math and 4.9 to 6.0 percent of a standard deviation lower in English language arts compared to a grade in which all teachers return for the next year. Effects are larger in schools with higher proportions of low-performing and Black students. Hanushek et al. (2016) find similar results, albeit less consistent across model specification, ranging from 4 to 11 percent of a standard deviation in math, with no results reported for English language arts. Even with evidence that turnover effects student achievement to a nontrivial extent, both sets of authors may underestimate the true effect of turnover for two reasons. First, their identification strategy leverages idiosyncratic variation in turnover between grades in the same year and same school and, as an alternative, between years within the same grade and same school. These estimates combine the effects of two between-year mechanisms: staff instability and replacement. Second, they estimate the impact of teacher turnover that occurred the summer prior to when the test scores used for outcomes are measured. With a measure of turnover that is

somewhat distal to the measurement of student performance in the current academic year, their estimates may be further attenuated.

Using unique administrative data that measures individual teacher turnover at the monthly level, we examine effects of the three mechanisms through which teacher turnover harms student achievement. Compared to Ronfeldt et al. (2013) and Hanushek et al. (2016) that measure teacher turnover annually, our monthly turnover measure allows us to distinguish the effect of teacher turnover that occurs before the school year begins, as they both do, as well as turnover during the school year. Moreover, matched student-teacher data allow us to estimate the disruptive effect on the students who lose their teacher during the school year. Using detailed micro-teacher and student administrative data from North Carolina, we estimate a series of models to isolate the effects of each of these mechanisms on student achievement. While most research on teacher turnover has focused on year-to-year turnover, to estimate the disruption effects within a school year, our data support examination of the effects of within-year turnover, which has been shown to constitute a 25 percent increase in year-to-year turnover rates (Redding & Henry, for submission). This data allows us to create three separate measures: classroom-level within-year classroom teacher turnover, grade-level within-year turnover, and grade-level end-of-year turnover. With different measures of the timing and level of turnover, we identify the effects of the three mechanisms that we hypothesize explain the effect of teacher turnover on student performance, including within-year replacement and disruption mechanisms. This study describes how these three mechanisms linked to teacher turnover—staff instability, classroom disruption, and teacher replacement —may affect student achievement.

Teacher Turnover and Student Achievement

Researchers have long identified systematic patterns in the teacher labor market whereby teachers transfer out of under-resourced urban schools with high concentrations of low-income students and traditionally underserved racial/ethnic groups (Hanushek, Kain, & Rivkin, 2004a; Lankford, Loeb, & Wyckoff, 2002). The result of this pattern is that more qualified and effective teachers are less likely to teach the students most in need (Goldhaber, Lavery, & Theobald, 2015; Bastian, Henry & Thompson, 2013). Summarizing the relationship between teacher effectiveness and turnover, Boyd and colleagues (2008) write: "the more effective transfers tend to move to higher achieving schools, while less effective transfers stay in lower-performing schools, likely exacerbating the differences across students in the opportunities they have to learn" (p. 2). In addition to exacerbating the inequitable distribution of teachers across schools, teacher turnover is also assumed to negatively impact student learning.

Ronfeldt, Loeb, & Wyckoff (2013) provide the first plausibly causal estimates of turnover on student achievement by linking turnover in the previous school year and summer to student achievement in the current year. Using school-by-year and school-by-grade fixed effects, the authors leverage differences in grade-level turnover within the same school in the same academic year and in the same grade and school between years to estimate the effect of teacher turnover on student achievement. They attribute the negative effect of teacher turnover to the disruption to teachers and students caused by a teacher leaving a particular grade in a school. This mechanism, what we term staff instability, is distinct from classroom disruption, a separate mechanism that can only be measured by within-year measures of turnover. As the authors estimated the impact of turnover within a grade by comparing with other grades within the same school, their discussion focuses on the consequences of staff instability at this organizational

level while removing school-level confounders. As we measure end-of-year and within-year turnover separately, we describe how the effect of turnover differs depending on its timing and we can investigate the extent to which classroom disruption triggered by teachers leaving during a school year affects student achievement.

As noted above, we hypothesize that there are three mechanisms whereby teacher turnover may impact student achievement: (1) staff instability; (2) classroom disruption; (3) differences in quality of replacement and replaced teacher. While the effect the different mechanisms may be additive, as we describe below, the underlying mechanisms that influence student achievement are distinct. The first mechanism by which teacher turnover may impact student achievement is staff instability. The instability caused by teacher turnover can inhibit the formation of a cohesive organizational culture that is capable of implementing coherent instructional programs. When teachers leave a school, they take with them institutional knowledge about their students, the curriculum, and school programs and policies. Less shared knowledge among the remaining teachers weakens their ability to form a cohesive instructional culture. Further, stability of the teaching staff is vital for the development of staff collegiality and a culture of trust in the school (Bryk & Schneider, 2002; Little, 1982). The social capital that results from the network of inter-relationships forms the basis of professional relationships aimed at improving instruction (Louis & Marks, 1998). Recent research on the school conditions needed for teacher instructional improvement affirm that working in a school with a strong culture of collaboration and high quality peers can affect student achievement (Jackson & Bruegmann, 2009; Kraft & Papay, 2014; Papay, Taylor, Tyler & Laski, 2016; Ronfeldt, Farmer, McQueen, Grissom, 2015). The formation of collaborative relationships that foster instructional improvements would be undermined by both within-year and end-of-year teacher turnover.

The negative effects of staff instability may be particularly detrimental when concentrated in a particular grade. Teachers often meet in grade-level teams to coordinate lesson planning, align their pacing, discuss strategies to engage students, and receive collegial encouragement (Louis, Mark, & Kruse, 1996). Just as schools with high levels of teacher turnover struggle to form a cohesive organizational culture, the challenges of maintaining instructional continuity may be more difficult when turnover occurs at the grade level. The negative effect of grade-level teacher turnover is likely most detrimental when it occurs during the school year. Immediately following a teachers' departure, class sizes may bulge before the teacher is replaced and long- or short-term substitutes may staff the recently vacated classroom (Papay & Kraft, 2016). When a replacement is hired, teachers may be assigned to help orient and mentor the new teacher, reducing the time they can dedicate to their own students (Guin, 2004). In schools where teachers leave midyear, administrators must dedicate time to re-staff classrooms throughout a year that could be used for improving teacher instruction or working conditions (Barnes, Crowe, & Schaefer, 2007).

While the negative impact of teacher instability on student achievement is of overall concern, that turnover occurs at disproportionately high rates in schools with high concentrations of underrepresented minorities and low-income students raises additional equity concerns. The negative effects of turnover on student achievement that Ronfeldt and colleagues (2013) observed are larger in schools with higher proportions of low-performing and Black students. Simon and Johnson (2015) describe several reasons for this phenomenon. Schools with higher turnover rates employ higher concentrations of novice teachers who tend to be less effective (Clotfelter et al., 2007; Henry, Bastian, & Fortner, 2011; Rivkin, Hanushek, & Kain, 2005). Schools with more inexperienced teachers might lack sufficient mentors for new teachers across

different grades and subjects (Loeb, Darling-Hammond, Luczak, 2005). High turnover schools are forced to reallocate teaching assignments each year, which may undermine the accumulation of grade- or subject-specific human capital, further decreasing student achievement (Atteberry, Loeb, & Wyckoff, 2016; Ost, 2014) or inducing additional teacher turnover (Ost & Schiman, 2015). Finally, as we described above, teacher turnover erodes professional norms required to establish trusting relationships and maintain instructional continuity within a school. In high turnover schools faced with a perpetual sense of upheaval, schools may lack amassed social capital with which to ground efforts to improve instruction.

Beyond the ways in which staff instability may impair a school's organizational culture and instruction, teacher turnover may directly harm student achievement through classroom disruptions it causes for individual students. The disruptive effect on student learning is likely to be particularly strong when a teacher leaves during the school year. Losing a teacher midyear can be a destabilizing experience for a child, inflicting psychological and social upheaval. In a review of the literature on the impact of instability on child development, Sandstrom & Huerta (2013) write, "Children thrive in stable and nurturing environments where they have a routine and know what to expect. Although some change in children's lives is normal and anticipated, sudden and dramatic disruptions can be extremely stressful and affect children's feeling of security" (p. 5). The loss of this stability with the departure of a teacher disrupts the continuity of a child's learning experience. When a teacher leaves mid-year, they also sever the social capital they have accumulated between the child and their parents/guardians, weakening the child's academic support system, which may impact students with fewer supports more. The literature on student mobility highlights how the loss of social capital associated with nonstructural mobility results in an adjustment period where students under-perform in school and have a

greater risk of dropping out (Hanushek, Kain, & Rivkin, 2004b; Pribesh & Downey, 1999; Rumberger & Larson 1998; Swanson & Schneider, 1999). On the other hand, it may be that a teacher who leaves midyear is so ineffective that their departure may be beneficial for their students.

This potentially stressful adjustment period for students following a teacher's departure may also result in instructional discontinuities. Instructional routines and procedures must be re-established. The replacement teacher must learn about students' skill level to support their ongoing academic development. The new teacher may also have to negotiate a larger workload if they also have to prepare new lesson plans and teaching materials. Although previous studies have not estimated the direct impact of classroom disruptions due to teacher turnover on student achievement, research on teacher absences suggests that students perform worse in school when assigned to a teacher who is absent more frequently (Clotfelter, Ladd, & Vigdor, 2009; Gerhsenson, 2016; Miller, Murnane, & Willett, 2008). As chronic teacher absenteeism contributes to a similar disruption as within-year turnover, we expect within-year turnover to have similarly negative impacts on student learning.

The final mechanism by which turnover may impact student achievement relates to differences in the quality of the original and replacement teacher. The literature on the relationship between teacher turnover and quality has described how turnover influences the overall composition of the teacher workforce, rather than specific issue of replacement teacher quality. Research from North Carolina, New York City, and Texas has shown an inverse relationship between teacher effectiveness and turnover: less effective teachers are more likely to leave the teaching profession (Boyd et al., 2008; Goldhaber et al., 2011; Hanushek et al., 2004a). In North Carolina, Goldhaber and colleagues (2011) find that the odds of exiting the teaching

professions are 1.72 higher for teachers in the lowest quintile of the effectiveness distribution compared to teachers in the middle quintile. Teachers in the highest quintile are the most likely to remain in teaching. The single exception to this pattern comes from studies in Florida, which find the least *and* most effective teachers exit teaching at the highest rates (Feng & Sass, 2011; West & Chingos, 2009). From a compositional standpoint, teacher exits would only have an adverse influence on student achievement if the teachers who leave were more effective than their replacement. If schools were able to hire a more effective replacement, compositionally, this turnover could benefit students, even though the increased quality might not be sufficient to overcome the effects of the other mechanisms.

In a study of Washington D.C.'s IMPACT teacher evaluation and performance incentive system, Adnot, Dee, Katz, and Wyckoff (2016) report notable gains in teacher performance that result from the district's selective retention policy, which was designed to remove ineffective teachers. They compare the differences in performance between students in a particular grade in a particular school who experienced turnover with those students who did not experience turnover in that grade and school. They find that replacement teachers improved student achievement by an average 8 percent of a standard deviation in math and 5 percent of a standard deviation in reading.

Changes in teacher layoff policies during the Great Recession provide additional evidence of the ways in which policies meant to change the composition of the teacher labor force are linked with student performance gains (Boyd, Lankford, Loeb, & Wyckoff, 2011; Goldhaber & Theobald, 2013; Kraft, 2015). Studying a discretionary layoff policy in Charlotte-Mecklenburg Schools, Kraft (2015) finds no overall relationship between teacher layoffs and

student performance in math or reading. When more effective teachers were those laid off, their students performed worse in the following year.

Compared to these policies that selectively replace the lowest performing teachers, when teacher turnover occurs during the school year, replacement teachers would likely be less effective. Replacement teachers are selected from a diminished applicant pool and likely results in temporary assignment to a less effective teacher. Students may not even be assigned a regular classroom teacher as a replacement. Long-term substitute teachers may fill the vacancy indefinitely. While No Child Left Behind mandated that all classrooms are expected to be staffed by a highly qualified teacher, substitutes were exempt from this legislation, likely resulting in diminished instructional rigor (Miller et al., 2008). That being said, it is possible that some teachers who leave have led chaotic classrooms and the chaos rather than the replacement results in lower achievement. In summary, although evidence suggests benefits from replacing the lowest performing teachers, when turnover occurs during the school year, it is unlikely replacements will be of the same or better quality, which may be detrimental.

Although we have treated each of these mechanisms as conceptually distinct, their effects are likely additive in nature. For instance, while losing a teacher midyear is likely detrimental for a student's academic performance, if they attend a school with high levels of grade-level teacher instability, the negative effect may be even greater if the instability prevents administrators from quickly hiring a replacement. In contrast, if a teacher leaves midyear from a school with low levels of grade-level teacher instability, the staff may be able to better compensate for this loss. Principals could be forced to reallocate trivial amounts of their time to hire replacements and other teachers could help orient the new teacher, integrating them into the school's instructional culture. There is the possibility that the disruptive effect of within-year classroom teacher

turnover would be offset by a higher quality replacement. Even with a diminished labor pool of replacement teachers, the teachers who leave midyear may be so demoralized and perform so poorly with their students that their replacement will be higher quality.

Data and Measures

The goal of this study is to estimate the effect of teacher turnover on student achievement. We address four specific research questions:

(1) What is the average effect of teacher turnover on student achievement?

(2) Does grade-level turnover affect student achievement more of less than when it occurs within versus the end of the school year?

(3) What is the effect of within-year classroom teacher turnover on student achievement?

(4) Do the effects of within-year classroom teacher turnover differ across traditionally underserved student subgroups?

We use administrative data from the state of North Carolina that links students, teachers, and test scores. We draw on a six-year panel of data from the 2008-2009 to 2013-2014 school years. The analytic sample is limited to students in fourth and fifth grade who took End-of-Grade (EOG) tests in English Language Arts (ELA) and mathematics. To these student observations, we link demographic information and school characteristics, which we describe in greater detail below. Our sample includes 2,499,127 student-year observations in ELA and 2,053,975 observations in math.

There are five independent variables in this study that are used to measure the turnover that occurs at different times (i.e. within-year versus end-of-year) and organizational levels (see Table 1). Total grade-level turnover is a fraction of the teachers to turn over from a particular grade between the end of year $t - 1$ and the end of year t over all enrolled teachers in that grade

Table 1. Definition of Independent Variables for Examining the Effect of Turnover

Independent Variable	**Definition**
Total grade-level turnover	A fraction of the teachers to turn over from a particular grade between the end of year $t-1$ and the end of year t over all enrolled teachers in that grade during this period.
Within-year grade-level turnover	The fraction of teachers to turn over from a particular grade during the current school year.
End-of-year grade-level turnover	The fraction of teachers who were employed in a school-by-grade level at the end of the school year $t-1$ and no longer employed at that school at the start of the school year in time t.
October-to-October teacher turnover	The fraction of teachers to turn over from a particular grade from October of year $t-1$ compared to October in year t.
Within-year classroom teacher turnover	An indicator of whether or not a teacher left their school during the school year.

during this period. This measure of total grade-level turnover can be separated as occurring at the end of the previous school year or within the current school year. End-of-year grade-level turnover is the fraction of teachers who were employed at a school at the end of the school year $t-1$ and no longer employed at that school at the start of the school year in time t. Within-year grade-level turnover is measured as the fraction of teachers to turnover from a school during the current school year. Within-year grade-level turnover can be further separated for those students who lost a teacher midyear. We term this final type of turnover within-year classroom teacher turnover, which is measured as an indicator when each specific student's teacher left their school during the school year. Finally, for comparison with Ronfeldt et al. (2013), we create the measure of "lagged attrition", which is measured as the fraction of teachers to turn over from a particular grade in October of year $t-1$ compared to October in year t.

To create these different within-year turnover variables, we draw on monthly teacher pay files, which give detailed information on the school in which a teacher is employed in each month. This data allows us to identify the month when a teacher left their current school. From

this data, we create a binary indicator if the teacher left their school at any point during the school year. As this paper's theory of action assumes that midyear exit for any reason, transferring to other schools, temporarily leaving the school, or leaving the profession, would be similarly disruptive to student learning in the schools the teachers leave.[15] In sensitivity analyses, we separate each type of teacher turnover.

Estimating the effects of these three mechanisms relies on various fixed effect specifications to adjust for unobserved factors correlated with teacher turnover and student performance. To complement the fixed effect estimation, we include a rich set of covariates for school characteristics and school demographic characteristics. These variables are described in Table A1. At the student level, we control for an individual student's prior test scores in reading and mathematics when not employing a student fixed effect specification. Other controls include student gender, race/ethnicity (Black, Hispanic, Asian, American Indian, and multiracial), giftedness, disability status, whether the child is currently or was previously classified as limited English proficient, mobility (structural, within-year, and between-year), and indicators for whether the child was overage or underage for the grade. We also include a continuous variable for the days absent.

To adjust for school-level differences, we include variables for the average student enrollment, total per-pupil expenditures, the district's teacher salary supplement, the percentage of students within a school by race/ethnicity and the percent of students receiving free or reduced lunch. Measures of school climate include the reported violent rates per 1,000 students, the short-

[15] In sensitivity analysis in Table A9 in the appendix we separate the main results for within-year classroom teacher turnover by moving and leaving. In ELA, the estimates are quite consistent for leaving versus moving. In math, we find more consistent evidence of a more negative effect for within-year moving compared to within-year leaving.

term suspension per 100 students, and the percentage of teachers with three years of experience or less.

Methods

As discussed in the previous section, we hypothesize three mechanisms by which teacher turnover may impact student achievement: (1) teacher instability; (2) within-year classroom disruption; (3) replacement quality. We begin with a series of models that estimate the overall impact that total grade-level turnover has on student achievement—the teacher instability mechanism. From there, we describe several estimation strategies to distinguish the extent to which the effect of teacher instability can be explained by differences in the effect of within-year and end-of-year turnover and the disruptive effect to students when a teacher leaves during the year.

To estimate the effect of total grade-level turnover, we estimate models with four fixed effects specifications: school-by-grade, school-by-year, and student-by-school fixed effects. An equation for the first of these models can be written as:

$$Y_{ijgst} = \beta_0 + \beta_1 PCT\ Turnover_{gst} + \beta_2 Y_{it-n} + \beta_3 X_{ijgst} + \beta_4 W_{st} + \phi_{gs} + \gamma_t + u_{ijgst} \quad (1)$$

where Y_{ijgst} is the test score for student *i* in classroom *j* in grade *g* in school *s* at time *t*; $PCT\ Turnover_{gst}$ is the total grade-level turnover measure; Y_{it-n}represents the prior test scores for student *i*; X_{ijgst} represents the set of student covariates; W_{st} represents a set of time-varying school covariates; $\phi_{gs}$is a school-by-grade fixed effect; γ_t is a year fixed effect, and u_{ijgst} is an error term. In this model, standard errors are clustered at the school-by-grade level. This model capitalizes on variation in turnover in the same grade and school over time. This model could be biased by a temporal shock that affects both teacher turnover and student achievement.

To address this concern, we estimate a model with school-by-year fixed effects:

$$Y_{ijgst} = \beta_0 + \beta_1 PCT\ Turnover_{gst} + \beta_2 Y_{it-n} + \beta_3 X_{ijgst} + \beta_4 W_{st} + \lambda_{st} + u_{ijgst} \quad (2)$$

where $\lambda_{st}$is a school-by-year fixed effect. In this model, standard errors are clustered at the school-by-year level. This model leverages variation across grades within the same school in the same year to estimate the effect of turnover. This model controls for any shock that occurs in a year that affects both teacher turnover and student achievement. For instance, a principal's exit from a school could bias OLS or school fixed effects estimates if it influences both teacher turnover and student achievement. Unlike the school fixed effect estimates that may be biased by year-to-year variation at the grade-level, this within-school estimation strategy accounts for any unobserved school shocks. A limitation of both of these models is that they do not account for the bias linked to nonrandom student or teacher sorting. In particular, these models do not account for unobserved, non-time-varying student characteristics, such as innate ability, that may bias the estimated impact of teacher turnover on student achievement. Estimates would be biased if students with lower ability were assigned to teachers more likely to turnover.

To account for these unobserved student characteristics, we specify a model with student-by-school fixed effects:

$$Y_{ijst} = \beta_0 + \beta_1 PCT\ Turnover_{gjst} + \beta_2 X_{ijst} + \beta_3 W_{st} + \delta_{is} + \gamma_t + u_{ijst} \quad (3)$$

where Y_{ijst} is the test score for student *i* in classroom *j* in school *s* at time *t*; β_1 estimates the average difference in test performance in school years when a student is enrolled in a grade in a school with different levels of teacher turnover; X_{ijst} represents the set of time-varying student covariates; W_{st} represents a set of time-varying school covariates; δ_{is} is a student-by-school fixed effect to adjust for time-invariant student and school characteristics; γ_t is a year fixed effect, and u_{ijst} is an error term. In this model, standard errors are clustered at the student-by-school level to account for nonindependence arising from repeated observations of the same

student. These estimates would be biased when time-varying factors caused turnover and students to underperform in the same school year and therefore are used as an additional robustness check.

This first series of models looking at total grade-level turnover assume the effect of turnover is the same when teachers leave over the summer as when they leave during the school year. As the mechanisms that impact student achievement differ depending on the timing of grade-level teacher turnover, we separate the total grade-level turnover measure into end-of-year and within-year grade-level turnover. We then estimate Models 1 through 3, substituting end-of-year and within-year grade-level turnover to examine the extent to which the timing of school turnover may have different effects on student achievement. This set of models allows us to better understand how the timing of grade-level turnover may harm student achievement in different ways. We hypothesize that within-year grade-level turnover has more negative effects than end-of-year grade-level turnover.

Furthermore, for within-year turnover, the negative effects of teacher turnover are likely most detrimental for the students assigned to a teacher who leaves mid-year. Next, we leverage our measure of within-year classroom teacher turnover to estimate the effect turnover has on individual students whose teacher left midyear. Using our measure of within-year classroom teacher turnover, we estimate a series of models to understand the disruptive effect a teacher turning over during the school year has on their students. Within-year classroom teacher turnover is likely correlated with unmeasured determinants of student test performance. To isolate the plausibly exogenous variation in within-year classroom teacher turnover, we adopt two fixed effect modeling strategies. The first model uses student fixed effects to leverage within-student variation over time. This model can be estimated:

$$Y_{ijst} = \beta_0 + \beta_1 Turnover_{ijst} + \beta_2 W_{st} + \tau_i + \gamma_t + u_{ijst} \quad (4)$$

where Y_{ijst} is the test score for student *i* in classroom *j* in school *s* at time *t*; $\text{Turnover}_{\text{ijst}}$ is an indicator of whether or not a student was assigned to a teacher who left during the school year; $\beta_1$estimates the average difference in test performance in school years when a student is assigned to a teacher who turns over compared to years when the student is assigned to teacher who remains in the school for the whole year; W_{st} represents a set of school covariates; τ_i is a student fixed effect to adjust for time-invariant student characteristics; γ_t is a year fixed effect, and u_{ijst} is an error term. Standard errors are clustered at the student level to account for nonindependence arising from repeated observations of the same student.

This model is only identified for students who experience two particular turnover conditions: assignment to a teacher that remains in the school the whole year and a teacher who leaves during the school year. In cases where this model is identified, the student essentially serves as their own comparison group, and their deviations from their average test performance are compared in years with and without a teacher who left midyear. This estimation sample is much smaller than the full sample used in this analysis, as an average of 4 percent of teachers turn over within each school year, or roughly one teacher per school (Paper 1). This model is identified for 72,258 students in ELA and 62,272 students in math. Although this model controls for a rich set of school characteristics, this model would be biased by unobserved school characteristics such as principal turnover that affect mid-year turnover and student achievement. To address this concern, we re-specify this model with a student-by-school fixed effect.

As this student-by-school fixed effects model is biased by uncontrolled for time-varying school factors, any spillover effects from grade-level turnover would bias these estimates. To address this concern, we re-estimate the student and student-by-school fixed effects models with

the measure of end-of-year and within-year grade-level turnover. To avoid double-counting teachers who turn over during the school year, the measure of within-year grade-level turnover includes all teachers in the grade at the school other than the teacher of the students who turned over that year. Appendix Table A6 presents the results using the original, unadjusted measure of within-year grade-level turnover, which are qualitatively similar. This operationalization allows us to understand the extent to which the effect of within-year classroom teacher turnover is independent from the effect of the other turnover that occurs during the school year or over the previous summer. This model can be estimated:

$$Y_{ijst} = \beta_0 + \beta_1 Turnover_{ijst} + \beta_2 PCT\ EOYTurnover_{gst} + \beta_3 PCT\ WY\ Turnover_{gst} + \beta_4 X_{ijst} + \beta_5 W_{st} + \tau_i + \gamma_t + u_{ijst} \quad (5)$$

where β_2 and $\beta_3$are estimated based on variation in the proportion of within-year turnover a student experiences over time. If β_2 and β_3 are significant, it suggests that the effect of turnover is not only linked to the disruption caused by a teacher's departure, but also the staff instability at the grade level. If β_1 remains consistent with the inclusion of the two measures of grade-level turnover, end-of-year ($EOYTurnover_{gst}$) and within-year ($PCT\ WY\ Turnover_{gst}$), in the model, we would have stronger evidence of the direct effect of disruption versus the indirect effect of staff instability. It may also be that there is an additive effect of being in a grade that experiences high turnover and being in a classroom with a teacher who leaves midyear. To test for this hypothesis, we also estimate a model with the interaction between $Turnover_{ijst}$ and $\beta_3 PCT\ WY\ Turnover_{gst}$, the within-year percentage turnover measure.

We then extend these analyses of the effect of within-year classroom teacher turnover in several ways. First, we test the extent to which the effect within-year classroom teacher turnover can be explained by the quality of the departing teacher. To Model 4, we separately add four

measures of teacher quality: teaching experience, average teacher test score, lagged evaluation score, and lagged teacher value-added score. The average teacher test score is a standardized measure of all available tests, including college entrance and PRAXIS exams. The lagged evaluation score takes the teacher's median evaluation score across five domains from the previous school year. The lagged value-added score is obtained from the state's EVAAS score for teachers in tested grades and subjects. In these models, if the effect of within-year classroom teacher turnover is being driven by any of these measures of teacher quality, the estimate would go to zero. If the estimate on within-year classroom teacher turnover remains consistent and statistically significant would provide evidence that the negative effect of losing a teacher during the school year is not driven by the quality of that teacher.

Next, as we observe within-year classroom teacher turnover at the monthly level, we examine the extent to which the effect of turnover differs throughout the course of the school year by replacing the turnover indicator with a series of monthly turnover indicator variables. We also consider differences in the effect of teachers who move versus leave teaching during the school year. We supplement our main analysis with an examination of the heterogeneity of the effects of within-year classroom teacher turnover for underserved student subgroups and students at different performance levels. With the assumption that within-year classroom teacher turnover would be more detrimental for students historically marginalized by the education system, we consider whether the effect of within-year classroom teacher turnover is greater for Black, Hispanic, and economically disadvantaged students. To examine whether within-year classroom teacher turnover is more detrimental for the lowest performing students, we separate students into three groups based on their prior achievement: below the 25th percentile, between the 25th

and 75th percentile, and above the 75th percentile. We then examine the extent to which losing a teacher during the school year is worst for lower, moderately, or higher performing students.

Results

Grade-Level Turnover

In this section, we present the results from a series of models that estimate effects from the underlying mechanisms hypothesized to explain the relationship between teacher turnover and student achievement. Estimates from Table 2 indicate that total grade-level turnover generally has a negative effect on ELA, with no detectable effect in mathematics. In our

Table 2. Estimates of the Effect of Total Grade-Level Turnover on Student Achievement

	ELA			Mathematics		
	(1)	(2)	(3)	(4)	(5)	(6)
Total grade-level turnover	-0.012	-0.040***	-0.022**	-0.009	0.005	0.010
	(0.008)	(0.011)	(0.007)	(0.011)	(0.017)	(0.007)
School-by-Grade FE	x			x		
School-by-Year FE		x			x	
Student-by-School FE			x			x
Observations	2149995	2149995	2149995	1764768	1764768	1764768
R^2	0.65	0.65	0.00	0.68	0.68	0.00

Notes. Models include student controls, school controls, and year fixed effects. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

preferred specifications, the school-by-year and student-by-school fixed effect, we find that losing all teachers predicts either a 0.04 and 0.022 standard deviation decrease in student achievement in ELA. The estimates most comparable to Ronfeldt and colleagues' (2013) results come from columns 1, 2, 4, and 5, the models with school-by-grade and school-by-year fixed effects. Our estimates are slightly smaller and less consistent than the results from New York City.[16]

[16] Tables A2 and A3 reports results directly comparable to Ronfeldt et al. (2013). In administrative data from New York City, teacher turnover is measured by comparing the teachers in a school in October of year *t*-1 compared to October in year *t.* Table A2 and A3 reports the estimates using the various modeling strategies in the current analysis, including Ronfeldt and colleagues' identification strategies, school-by-grade and school-by-year fixed effects (Columns 1 and 3). Even with the October-to-October measure, our estimates are slightly smaller and less consistent than the results from New York City. Depending on the specification, we find an effect that ranges

Table 3. Estimates Comparing the Effect of End-of-Year and Within-Year Grade-Level Turnover

	(1)	(2)	(3)	(4)	(5)	(6)
Within-year grade turnover	-0.052***	-0.073***	-0.082***	-0.119***	-0.089**	-0.074***
	(0.014)	(0.020)	(0.014)	(0.022)	(0.031)	(0.013)
End-of-year grade turnover	-0.006	0.024**	0.010	0.002	0.026*	0.023***
	(0.005)	(0.008)	(0.005)	(0.008)	(0.012)	(0.005)
School-by-Grade FE	x			x		
School-by-Year FE		x			x	
Student-by-School FE			x			x
Observations	2231725	2231725	2231725	1852715	1852715	1852715
R^2	0.65	0.65	0.00	0.68	0.68	0.00

Notes. Models include student controls, school controls, and year fixed effects. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In Table 3, we separate end-of-year and within-year grade turnover and include both in the same model.[17] Across all four specifications, the effects of within-year grade turnover is negative and significant, varying from -0.052 to -0.082 in ELA. The negative effect of within-year grade-level turnover is generally larger in mathematics, ranging from -0.074 to -0.119. However, turnover during the summer is consistently smaller in magnitude and when significant positive, 0.023 to 0.026, further highlighting the importance of separating the timing of turnover, and suggesting that turnover can be beneficial for math achievement. We interpret these positive findings of end-of-year turnover in the context of Grissom, Loeb, & Nakashima's (2013) and Dee and Wyckoff's (2015) recent studies, which find that strategic involuntary turnover or teacher dismissal can result in the recruitment of and replacement by higher performing replacement teachers. Overall, these suggests that grade-level teacher instability operates independently depending on whether the turnover occurred prior to or during the current academic year.

between -0.011 (and not significant) and -0.038 compared to -0.049 and -0.064 in ELA. In mathematics, we find an effect that ranges between -0.021 and -0.053 compared to -0.074 and -0.082.

[17] Tables A4 and A5 run separate models for end-of-year and within-year grade-level turnover. The results are qualitatively similar compared to when both measures are included in the same model.

Classroom Disruption

To this point, we observe consistently negative effects of within-year grade turnover on student achievement in ELA and mathematics but inconsistent estimates of end-of-year grade turnover. These estimates of within-year turnover combine the loss of students' classroom teacher during the school year and teacher instability. In the next series of analysis, we separately identify the extent to which losing a teacher during the school year disrupts the continuity of children's learning experience by directly estimating its effect on student performance from the effects of teacher instability.

In Table 4, we examine the effect of losing a teacher midyear on student achievement for ELA and math, respectively. After estimating a model with an indicator of whether or not students were assigned to teachers who turned over within the school year (columns 1 and 7), we add a control of within-year grade-level turnover that excludes the teacher who turned over (columns 2 and 6). In columns 3 and 7, we then add the end-of-year grade-level measure to the model. The addition of these covariate allows us to test the extent to which the effect of losing a teacher midyear can be explained by the direct effect of classroom disruption compared to other teacher instability. We then estimate a model that tests for an additive effect of losing a teacher within the school year and being in a grade with high within-year teacher instability (columns 4 and 8). We first estimate these models using student fixed effects. These results would be biased if unobserved school characteristics were correlated with within-year classroom teacher turnover and student performance. For instance, a principal's departure may be linked with higher levels of within-year classroom teacher turnover as well as student performance. To address this concern, we then condition on student-by-school fixed effects. Consistency of the estimates

Table 4. Estimates of the Effect of Within-Year Classroom Teacher Turnover

Panel A. Student Achievement in ELA

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Within-year classroom teacher turnover	-0.037***	-0.039***	-0.039***	-0.040***	-0.038***	-0.042***	-0.042***	-0.043***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Within-year grade turnover (adjusted)		-0.053***	-0.053***	-0.054***		-0.049***	-0.049***	-0.049***
		(0.010)	(0.010)	(0.010)		(0.011)	(0.011)	(0.012)
End-of-year grade turnover			0.001				0.005	
			(0.003)				(0.005)	
Within-year teacher classroom turnover * Within-year grade turnover				0.031				0.013
				(0.058)				(0.060)
Student FE	x	x	x	x				
Student-by-School FE					x	x	x	x
Observations	2499127	2499127	2495173	2499127	2499127	2499127	2495173	2499127
R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Panel B. Student Achievement in Mathematics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Within-year classroom teacher turnover	-0.067***	-0.069***	-0.070***	-0.071***	-0.044***	-0.048***	-0.049***	-0.049***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)
Within-year grade turnover (adjusted)		-0.075***	-0.075***	-0.076***		-0.054***	-0.054***	-0.055***
		(0.009)	(0.009)	(0.009)		(0.011)	(0.011)	(0.011)
End-of-year grade turnover			0.015***				0.020***	
			(0.003)				(0.004)	
Within-year classroom teacher turnover * Within-year grade turnover				0.057				0.013
				(0.054)				(0.064)
Student FE	x	x	x	x				
Student-by-School FE					x	x	x	x
Observations	2053975	2053975	2051271	2053975	2053975	2053975	2051271	2053975
R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

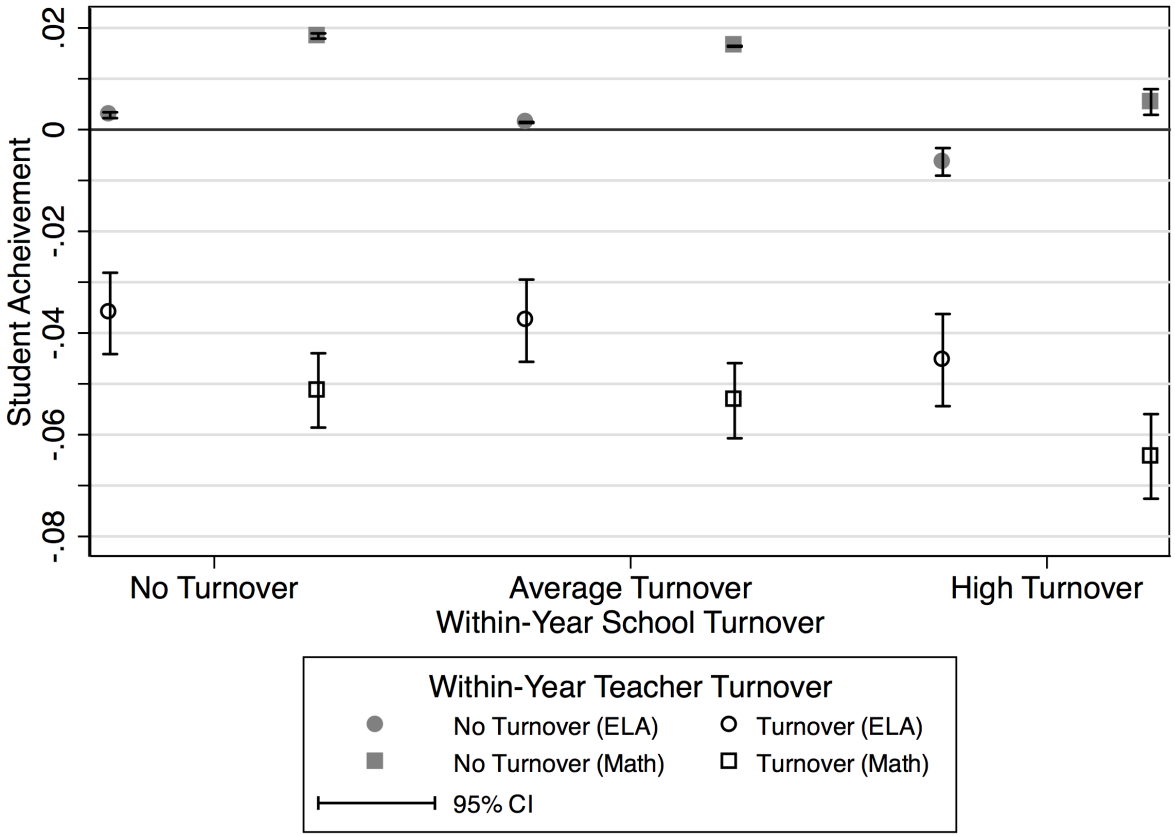
Notes. The adjusted measure of within-year grade turnover is the proportion of teachers to turn over from a grade, not including the current teacher. Models include school controls and year fixed effects. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

across these two specifications would provide strong evidence of the negative effect of within-year classroom teacher turnover.

Across all models in Panel A of Table 4, we find a consistent, negative effect of within-year classroom teacher turnover on ELA test performance. Compared to when a student is not assigned to a teacher who left midyear, they score 0.037 lower in ELA when assigned to a teacher who leaves during the school year. This result translates to the loss of roughly 27 instructional days (CREDO, 2015). This estimate is consistent when we control for within-year and end-of-year grade turnover, suggesting that the disruptive effect of losing a teacher is independent of the effect of teacher instability at both the grade and school levels whether it occurs during the school year or over the prior summer.

When we include an interaction between within-year classroom teacher turnover and within-year grade turnover, we find no evidence of an additive effect of losing one's teacher and experiencing higher levels of within-year teacher instability in other classrooms in the same grade within the school. To better understand these results, Figure 1 plots the predicted probabilities, holding all characteristics in the model at their mean. For a student in a school that has no other within-year school turnover, being assigned to a teacher who leaves during the school year causes a -0.036 standard deviation change in student achievement in ELA. For a student in a grade with average within-year turnover—2.7 percent—losing a teacher within the school year causes a -0.038 standard deviation change. For a student in a grade with high within-year turnover—2 standard deviations above average, or 17.4 percent—losing a teacher within the school year causes a -0.045 standard deviation change in ELA achievement. For students who do not have a teacher who leaves midyear, we only find evidence of a negative effect of within-year school turnover in high turnover schools, where we find a -0.01 effect. This suggests that, except

Figure 1. Predicted Probabilities of the Effect of Within-Year Classroom Teacher and School Turnover



Notes. Predicted probabilities from student fixed effect models (Table 4, column 3 and Table 5, column 3). Average within-year grade-level turnover is 2.7 percent. High within-year grade-level turnover is 17.4 percent, two standard deviations above the mean.

in the case of high turnover schools, the effect of within-year grade-level turnover observed in Tables 2 and 3 is driven by the disruptive effect of losing a teacher midyear as opposed to within-year teacher instability.

Panel B of Table 4 reports the estimates of the effect of within-year classroom teacher turnover on student achievement in math. Compared to when a student is not assigned to a teacher who left midyear, they score 0.067 lower in math when assigned to a teacher who leaves during the school year. This result translates to losing roughly 48 instructional days (CREDO, 2015). Similar to the ELA results, this estimate is consistent when we control for within-year and

end-of-year school turnover, suggesting that the direct effect of classroom disruption is distinct from the indirect effect of school-level teacher instability. Also notable is that the coefficient on end-of-year grade turnover remains positive and statistically significant. In contrast to the ELA findings, when we replace the student fixed effect with a student-by-school fixed effect, the effect of within-year classroom teacher turnover is slightly smaller (-0.067 versus -0.044) than when the student fixed effect is included.[18] Also, like the ELA results, we find no evidence of an additive effect of losing a teacher and being in a grade with high within-year turnover. Figure 1 also depicts these results for math. An "average" student who loses their teacher during the school year but attends a school without any other within-year grade-level turnover is predicted to score 0.051 standard deviations lower in math. For a student in a school with average within-year grade-level turnover, losing a teacher within the school year causes a 0.053 standard deviation decrease. For a student in a school with high within-year turnover, losing a teacher within the school year causes a 0.064 standard deviation decrease in math achievement. Students who attend a school with high within-year turnover but who do not lose their teacher score 0.005 standard deviations better in math.

Within-year classroom teacher turnover and Teacher Quality

To test the extent to which the effect of within-year classroom teacher turnover can be explained by the quality of the exiting teacher, we add to our model four measures of teacher quality: teacher experience, average teacher test score, lagged median evaluation score, and lagged teacher value-added score. If the estimate on within-year classroom teacher turnover goes

[18] In columns 3, 5, and 7 of Tables A2 and A3, to make our estimates of within-year classroom teacher turnover comparable to Ronfeldt and colleagues' estimates we include the indicator of within-year classroom teacher turnover to a model with the October-to-October measure of teacher turnover. In most cases, we find that the estimate on October-to-October turnover is consistent, even when accounting for within-year classroom teacher turnover, suggesting that their results would generally not be biased by not explicitly accounting for within-year classroom teacher turnover. The one exception to this pattern is the estimates from a model with school-by-grade fixed effects that become marginally significant when controlling for within-year classroom teacher turnover.

Table 5. Estimates of the Effect of Within-Year Classroom Teacher Turnover on Student Achievement Controlling for Teacher Quality

Panel A. Student Achievement in ELA

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Within-year classroom teacher turnover	-0.038***	-0.036***	-0.054***	-0.216*	-0.039***	-0.038***	-0.035*	0.001
	(0.004)	(0.005)	(0.016)	(0.089)	(0.004)	(0.005)	(0.015)	(0.001)
Teaching experience	x				x			
Average teacher test		x				x		
Lagged evaluation score			x				x	
Lagged teacher value-added				x				x
Student FE	x	x	x	x				
Student-by-School FE					x	x	x	x
Observations	2498598	2183559	1144153	386713	2498598	2183559	1144153	386713
R^2	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.13

Panel B. Student Achievement in Mathematics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Within-year classroom teacher turnover	-0.069***	-0.070***	-0.074***	-0.118	-0.047***	-0.051***	-0.045**	0.000
	(0.004)	(0.005)	(0.015)	(0.091)	(0.003)	(0.004)	(0.015)	(0.000)
Teaching experience	x				x			
Average teacher test		x				x		
Lagged evaluation score			x				x	
Lagged teacher value-added				x				x
Student FE	x	x	x	x				
Student-by-School FE					x	x	x	x
Observations	2053626	1793809	981132	324927	2053626	1793809	981132	324927
R^2	0.00	0.00	0.01	0.02	0.00	0.00	0.01	0.12

Notes. Models include school controls and year fixed effects. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Lagged evaluation score is the median evaluation score the teacher receives from their principal.

to zero when a measure of teacher quality is introduced, this suggests that the negative effect of losing a teacher during the school year can be explained by the quality of that teacher.

Columns 1 and 5 in Table 5 find no evidence for this hypothesis. Controlling for teacher experience fails to explain the effect of within-year classroom teacher turnover on student achievement in ELA or math. Similarly, when the average teacher test score is added to the model, the estimate on within-year classroom teacher turnover remains consistent. When we control for the lagged median evaluation score, the estimate on within-year classroom teacher turnover is less consistent across models, and in some cases is even larger.[19] The results are the least consistent when lagged teacher value-added score is included. When controlling for lagged teacher-value added in ELA and conditioning on student fixed effects, the negative effect of within-year classroom teacher turnover on ELA achievement is 0.216 standard deviations, with much less precision in the estimate due to the smaller sample size. Yet, when we account for unobserved school characteristics in column 8, the estimate on within-year classroom teacher turnover drops to 0.001 for ELA and is not significant, suggesting that quality of a teacher—as measured by their contribution to student test scores—may explain the negative effect of losing a teacher during the school year. The pattern is similar in math, although the estimate on within-year classroom teacher turnover in column 4 is not significant. To test the extent to which these results are driven by sample differences, we re-estimate our main results from Table 4 limited to this smaller sample. Results in Appendix Table A7 indicate that the changes in coefficients are driven by sample differences rather than the influence of value-added. Balance tests further support this inference. When we test for differences in the sample characteristics in Table A8,

[19] The smaller sample size in this analysis can be explained by the introduction of a statewide evaluation system midway through this study. The North Carolina Department of Public Instruction introduced evaluations for novice teachers in 2010-2011, with all teachers evaluated in subsequent years. We include teacher evaluation scores where present.

we find that students in this subsample score 6 percent of a standard deviation higher in ELA and 7 percent of a standard deviation higher in math, are absent more often, are slightly less likely to receive reduced lunch and be Black. Their schools have a lower suspension rate and fewer Black students. Finally, it is important to note that this analysis only considers the quality of the departing teacher.

Timing of within-year classroom teacher turnover

There are reasons to believe that the effect of within-year turnover may differ depending on the month in which a teacher leaves. The negative effect of within-year classroom teacher turnover may be largest at the start of the year if the replacement teacher is selected from an applicant pool of less effective teachers. On the other hand, if a teacher leaves early in the school year, the replacement teacher may be able to establish instructional continuity and minimize the disruptive effect of losing a teacher early in the school year. A second hypothesis is that within-year classroom teacher turnover may be most detrimental for students when it occurs in the spring. In addition to the issue of replacement teacher quality, losing a teacher later in the year separates the student from a teacher with whom they have built a relationship and who may understand how to tailor instruction to meet the needs of their individual students. This issue is likely particularly salient as students prepare for annual end-of-grade achievement assessments, which generally occurs in May for elementary school students in North Carolina.

When we look at the effect of the month of within-year turnover in Table 6 and Figure A1, we find evidence much more consistent with this second hypothesis, that the negative effect of within-year classroom teacher turnover is driven by losing a teacher in the spring. There is some inconsistent evidence that losing a teacher in the first four months of the school year has a negative effect on student achievement. Yet, when a teacher leaves after December, we find

Table 6. Estimates of the Effect of Within-Year Classroom Teacher Turnover on Student Achievement by Month of Turnover

	ELA		Mathematics	
	(1)	(2)	(3)	(4)
September	-0.107*	-0.070	-0.003	-0.039
	(0.049)	(0.058)	(0.040)	(0.054)
October	-0.028	-0.030	-0.013	-0.007
	(0.026)	(0.027)	(0.029)	(0.031)
November	-0.101***	-0.067*	-0.039	-0.036
	(0.027)	(0.027)	(0.022)	(0.022)
December	-0.021	-0.034	-0.025	0.036*
	(0.019)	(0.020)	(0.016)	(0.016)
January	-0.026**	-0.020*	-0.052***	-0.038***
	(0.009)	(0.008)	(0.008)	(0.007)
February	-0.032***	-0.037***	-0.071***	-0.040***
	(0.008)	(0.007)	(0.009)	(0.006)
March	-0.038***	-0.030***	-0.077***	-0.057***
	(0.009)	(0.008)	(0.007)	(0.007)
April	-0.051***	-0.052***	-0.093***	-0.079***
	(0.010)	(0.010)	(0.009)	(0.010)
May	-0.054***	-0.074***	-0.105***	-0.070***
	(0.011)	(0.012)	(0.011)	(0.012)
End-of-year	-0.015***	-0.013***	-0.023***	-0.017***
	(0.002)	(0.002)	(0.001)	(0.002)
Student FE	x		x	
Student-by-School FE		x		x
Observations	2499127	2499127	2053975	2053975
R^2	0.00	0.00	0.00	0.00

Notes. Models include school controls and year fixed effects. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

evidence that the negative effect of generally increases from January until April or May. In ELA, the negative effect of within-year classroom teacher turnover increases from 0.02 in January to

0.074 in May. In math, the negative effect of within-year classroom teacher turnover increases from 0.039 in January to 0.079 in April.

Finally, it is important to note that the estimates on the month of turnover do not only capture the immediate disruption to their students, but also the effort that teacher has put in to that point in the school year. In other words, the negative effect of losing a teacher in the last months of the school year are not only related to the disruption for students but the quality of instruction that students experienced prior to their teachers' departure. We can imagine a teacher who leaves teaching in the last months of the school year may have been so demoralized that their instruction suffered throughout the school year. The final row of Table 6 provides suggestive evidence that teachers who know they are going to turn over have a negative effect on their students' academic achievement, sometimes referred to as an Ashenfelter dip. Teachers who turn over at the end of the school year also have a small, negative on their students' performance during the prior school year. The effect is 0.013 in ELA and 0.017 in math.

Heterogeneity of the effects of within-year classroom teacher turnover

Elsewhere, we have shown that this pattern also occurs during the school year, with the highest within-year turnover rates in schools serving high concentrations of Black, Hispanic, and economically disadvantaged students (Paper 1). To test the extent to which the effect of within-year turnover differs for Black, Hispanic, or economically disadvantaged students, we present the results using student fixed effects, estimating separate models for each group. For comparison, we also include estimates for White students. We also examine the extent to which lower performing students are more adversely affected by within-year classroom teacher turnover. We separate students into three groups based on their prior achievement: below the 25th

Table 7. Estimates of the Effect of Within-Year Teacher Turnover on Student Achievement by Student Characteristics

Panel A. Student Achievement in ELA

	White	Black	Hispanic	Economically Disadvantaged	Lower Performing	Moderately Performing	Higher Performing
Within-year classroom teacher turnover	-0.046***	-0.028***	-0.049***	-0.032***	-0.018*	-0.041***	0.004
	(0.006)	(0.007)	(0.010)	(0.006)	(0.008)	(0.005)	(0.009)
Student FE	x	x	x	x	x	x	x
Observations	1116927	632844	332180	1428128	611283	1254636	633208
R^2	0.00	0.00	0.00	0.00	0.03	0.00	0.05

Panel B. Student Achievement in Mathematics

Within-year classroom teacher turnover	-0.053***	-0.072***	-0.075***	-0.071***	-0.049***	-0.065***	-0.022**
	(0.005)	(0.006)	(0.009)	(0.005)	(0.007)	(0.005)	(0.007)
Student FE	x	x	x	x	x	x	x
Observations	887432	527995	280945	1152690	503046	1030159	520770
R^2	0.00	0.01	0.01	0.00	0.05	0.01	0.02

Notes. Models include school controls and year fixed effects. Standard errors in parentheses. Lower performing students scored at the bottom quartile on the lagged ELA test; moderately performing include the middle quartiles; higher performing includes students who scored in the top quartile. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

percentile (lower performing), between the 25th and 75th percentile (moderately performing), and above the 75th percentile (higher performing).

Our main results indicate that losing a teacher during the school year causes a 0.037 decrease in ELA achievement when we include all students in the analytic sample. In Panel A of Table 7, counter to the hypothesis that Black and economically disadvantaged students would be more adversely affected by within-year classroom teacher turnover, we find a -0.028 standard deviation effect for Black students and -0.032 effect for economically disadvantaged students. The effect is -0.040 -0.049 for Hispanic students and -0.046 for White students. When the effect of within-year classroom teacher turnover is separated by lagged student performance, we find that the negative effect of within-year classroom teacher turnover is driven by moderately performing students. Compared to when a student does not have a teacher who turns over midyear, being assigned to a teacher who leaves during the school year causes a -0.018 standard deviation change in ELA achievement for lower performing students, a negative -0.041 change for moderately performing students, and no detectable effect for higher performing students.

In math, we find results more consistent with our hypothesis (Panel B of Table 7). Within-year classroom teacher turnover more adversely affects underserved racial/ethnic minorities, economically disadvantaged students, average performing students, and, to a lesser degree, lower performing students. Overall, we found that within-year classroom teacher turnover causes a 0.067 standard deviation decrease in math achievement. The effect is -0.053 for White students compared to 0.072 standard deviations, 0.075 for Hispanic students, and 0.071 for economically disadvantaged students. In terms of prior student performance, the pattern is similar to ELA achievement in that losing a teacher within the year is most detrimental for moderately performing students.

Conclusion

Previous research has identified that teacher turnover harms student achievement, combining the effects of both disruptions to instructional continuity in a school and changes in the composition of new teachers (Hanushek et al., 2016; Ronfeldt et al., 2013). The goal of this paper was to better explain the effect of teacher turnover by distinguishing between two of the three mechanisms that drive this effect: teacher instability and classroom disruption. To identify the effects of these mechanisms, we identified differences in effect of teacher turnover whether it occurred during the prior summer or during the current school year. We found consistent evidence of a negative effect of within-year grade-level turnover. In other words, teacher instability at the grade-level was most detrimental for student achievement when the turnover occurred during the school year. Although less consistent, we found evidence turnover at the end of the school year was linked with student achievement gains in math. This finding aligns with other recent studies that have found that strategic teacher dismissal and transfer can result in assignment of higher performing replacement teachers (Dee & Wyckoff, 2015; Grissom et al., 2013).

We then distinguished the extent to which the detrimental effect of within-year turnover is driven by classroom disruption as compared to grade-level teacher instability. Within-year classroom teacher turnover had a negative effect of 0.037 standard deviations in ELA and between 0.044 and 0.067 standard deviations in math, depending on the specification. These estimates remained consistent when within- and end-of-year grade-level turnover were added to the model, suggesting that the effect of classroom disruption is independent from the effect of within-year classroom teacher turnover. We found no evidence of an additive effect of within-

year teacher and grade-level turnover, likely because within-year turnover is a relatively rare event, with the average school losing only one teacher every year.

With evidence of a consistently negative effect of within-year classroom teacher turnover, we considered how this effect may be explained by teacher quality, differed by the timing of turnover, and differed by whether the teacher moved schools or left teaching. We found that even when controlling for teaching experience, the average teacher test score, or a teacher's lagged evaluation score, the effect of within-year classroom teacher turnover was consistent. The evidence is less consistent when controlling for a teacher's lagged value-added score. In the model with student fixed effects and lagged teacher value-added, we find an even larger negative effect of within-year classroom teacher turnover in ELA and math, although it is only significant in ELA. Yet, in the student-by-school fixed effects, these estimates go to zero and lose significance. We find further evidence that the relationship between within-year classroom teacher turnover and student achievement cannot be explained by teacher quality when we examine subsample differences, finding that these differences are explained by the small sample for which we observe lagged value-added scores for teachers.

In terms of differences in the timing of the effect of within-year turnover, we find strong evidence that losing a teacher later in the school year is more detrimental. In ELA, the negative effect of losing a teacher in May ranged from 0.054 and 0.074 standard deviations. In math, the negative effect of losing a teacher in May ranged from 0.07 and 0.105 standard deviations. There were less notable differences in the effect of a teacher moving schools or leaving school during the school year. In math, we find slight evidence of a more negative effect of within-year moving compared to within-year leaving. Last, we consider heterogeneity in the impact of within-year classroom teacher turnover across student characteristics. We found that losing a teacher during

the school year is less detrimental for Black and economically disadvantaged students in ELA but more detrimental in math. Within-year classroom teacher turnover is consistently more detrimental for Hispanic students than White students. Across ELA and math, losing a teacher is the worst for moderately performing students, and, to a lesser degree, lower performing students.

A couple limitations of this study should be noted. First, this study relies on a series of fixed effect estimation strategies to identify the effect of teacher turnover. The consistency of our estimates across these various specifications, particularly for the estimates of within-year classroom teacher turnover, suggest that we are estimating the unbiased effect of within-year turnover. Still, even with results robust to a student and student-by-school fixed effect, our results do not rule out unobserved factors that occur within a grade that led to a teacher's departure and students in that class to underperform but we believe the consistency of the estimates across identification strategies and the plausibility of this within grade phenomena increase the credibility of our estimates.

Second, given data limitations, we are unable to confidently distinguish the extent to which losing a teacher midyear is driven by the disruption it causes for students versus the change in teacher quality associated with this turnover. We determined that the negative effect of turnover was not driven by the quality of the departing teacher. Yet, by not being able to identify the replacement teacher, we are unable to ascertain their quality, as well as how this compares to the teacher who left midyear. Addressing this issue of replacement teacher quality is an area of future research that will help to better distinguish the mechanisms that drive effect of teacher turnover.

Third, the timing of this study overlaps, in part, with the Great Recession. This timing limits the generalizability of this study, as differences in teacher quality or patterns of mobility

may not compare to periods without the same budgetary shortfall. Although fewer new teachers were hired during the recession, research suggests that teachers who begin their career during recessions are more effective (Nagler, Piopiunik, & West, 2015). In terms of teacher mobility, Goldhaber, Strunk, Brown, & Knight (2016) find that while only a few teachers were laid off in Los Angles and Washington State, the threat of job loss spurred churn in the teacher labor market. A benefit of higher turnover rates during this period is the increased variability with which to estimate the effects of turnover on student achievement.

Better understanding the mechanisms that drive the negative effect of teacher turnover have important policy implications. With stronger evidence of a negative effect of school-level teacher instability than grade-level instability, this suggests that leadership, either at the administrator level or distributed through teacher leaders may be particularly important for creating a positive work environment where teachers are less likely to turnover (Grissom; 2011; Ladd, 2011; Schweig, 2014). Furthermore, with evidence of a larger negative impact from within-year classroom teacher turnover than turnover that occurs over the summer, districts may consider targeting resources—either instructional supports or monetary incentives—teachers most at risk of leaving midyear, particularly if the negative effect is driven by the disruption it has on students or the difficulty in finding a high quality replacement teacher midyear.

With evidence of negative consequences of within-year classroom teacher turnover on student learning, districts and schools could do more to avoid the deleterious effects of within-year turnover. Given our findings that within-year turnover is much more detrimental when it occurs later in the school year, when districts are forced to transfer teachers based on changes in student enrollment, they would be advised to do so as early in the school year as possible. For

schools, in cases of planned health leave of absence, replacement teachers could be hired ahead of time to reduce the disruption of losing a teacher during the school year.

Our previous work has found leaving teaching within the academic year to occur most frequently at the beginning and end of teachers careers. For early career teachers who struggle with the transition into teaching and become demoralized with their efforts to manage their classroom and deliver effective classroom instruction, principals would be advised to identify teachers who are at risk of leaving later in the school year and counsel them out as early in the school year as possible. For teachers eligible for retirement benefits, incentives could be introduced for teachers to stay until the end of the school year rather than retire in the middle of the school year when they become eligible.

More broadly, we hope this analysis brings more breadth to the policy discourse surrounding teacher turnover. As a policy problem, teacher turnover tends to treated as occurring between the end of one school year and the start of the next. Yet, we found a positive effect of end-of-year teacher turnover in math. Instead, the negative effect of teacher turnover is driven by the turnover that occurs during the school year. Furthermore, we also found some evidence that the negative effect of end-of-year teacher turnover is independent from the effect of within-year turnover. As the underlying factors which drive this effect may differ, so too may the policy levers to remedy this problem. For instance, compared to teacher incentive programs that reward teachers in the subsequent school year (e.g. Springer, Swain, & Rodriguez, 2015), incentive programs that exploit loss aversion by asking teachers to give back money if they do not remain in their school may be promote higher retention rates (Fryer, Levitt, List, & Sadoff, 2012).

References

Adnot, M., Dee, T., Katz, V., & Wyckoff, J. (2016). Teacher turnover, teacher quality, and student achievement in DCPS. NBER Working Paper 21922, National Bureau of Economic Research.

Atteberry, A., Loeb, S. & Wyckoff, J. (2016). Teacher churning: Reassignments and the implications for student achievement. *Educational Evaluation and Policy Analysis, 39*(1), 3-30.

Barnes, G., Crowe, E., Schaefer, B. (2007). *The cost of teacher turnover in five school districts: A pilot study.* Washington, DC: National Commission on Teaching and America's Future.

Bastian, K.C., Henry, G. T. & Thompson, C. L. (2013). *I*ncorporating access to more effective teachers into assessments of educational resource equity. *Education Finance and Policy, 8*(4), 560-580.

Boyd, D. Grossman, P., Lankford, H., Loeb, S., & Wyckoff, J. (2008) Who leaves? Teacher attrition and student achievement. NBER Working Paper 14022, National Bureau of Economic Research.

Boyd, D., Lankford, H., Loeb, S., & Wyckoff, J. (2011). Teacher layoffs: An empirical illustration of seniority versus measures of effectiveness. *Education Finance and Policy, 6*(3), 439-454.

Bryk, A., & Schneider, S. (2002). *Trust in schools: A core resource for improvement.* New York: Russell Sage Foundation.

Bryk, A. S., Sebring, P. B., Allensworth, E., Luppescu, S., & Easton, J. Q. (2010). *Organizing schools for improvement: Lessons from Chicago*. Chicago, IL: University of Chicago Press.

Clotfelter, C.T., Ladd, H.F. & Vigdor, J.L. (2007). Teacher credentials and student achievement: Longitudinal analysis with student fixed effects. *Economics of Education*, *26*(6), 673-682.

Clotfelter, C. T., Ladd, H.F., & Vigdor, J.L. (2009). Are teacher absences worth worrying about in the United States? *Education Finance and Policy 4*(2), 115-149.

CREDO (2015). *Urban Charter School Study: Report on 41 Regions*. Center for Research on Education Outcomes. Retreived from http://credo.stanford.edu

Dee, T. S. & Wyckoff, J. (2015). Incentives, selection, and teacher performance: Evidence from IMPACT. *Journal of Policy Analysis and Management*, *34*(2), 267-297.

Feng, L. & Sass, T. (2008). Teacher quality and teacher mobility. CALDER Working Paper 57. Urban Institute.

Fryer, R. G., Levitt, S. D., List, J., Sadoff, S. (2012). Enhancing the efficacy of teacher incentives through loss aversion: A field experiment. NBER Working Paper 18237. National Bureau of Economic Research.

Gershenson, S. (2016). Performance standards and employee: Evidence from teacher absences. *Journal of Public Policy and Management, 35*(3), 615-638.

Goldhaber, D., Gross, B., & Player, D. (2011). Teacher career paths, teacher quality, and persistence in the classroom: Are schools keeping their best? *Journal of Policy Analysis and Management*, *30*(1): 57-87.

Goldhaber, D., Lavery, L., & Theobald, R. (2015). Uneven playing field? Assessing the teacher quality gap between advantaged and disadvantaged students. *Educational Researcher*, *44*(5), 293-307.

Goldhaber, D., Strunk, K. O., Brown, N., & Knight, D. S. (2016). Lessons learned from the Great Recession: Layoffs and the RIF-induced teacher shuffle. *Educational Evaluation and Policy Analysis, 38*(3), 517-548.

Goldhaber, D. and Theobald, R. (2013). Managing the teacher workforce in austere times: The determinants and implications of teacher layoffs. *Education Finance and Policy, 8*(4), 494-527.

Grissom, J. A. (2011). Can good principals keep teachers in disadvantaged schools? Linking principal effectiveness to teacher satisfaction and turnover in hard-to-staff environments. *Teachers College Record*, *113*(11), 2552–2585.

Grissom, J. A., Loeb, S., & Nakashima, N. A. (2013). Strategic involuntary teacher transfers and teacher performance: Examining equity and efficiency. *Journal of Policy Analysis and Management*, *33*(1), 112-140.

Grissom, J. A., Viano, S. L., Selin, J. L. (2015). Understanding employee turnover in the public sector: Insights from research on teacher mobility. *Public Administration Review, 76*(2), 241-251.

Guin, K. (2004). Chronic teacher turnover in urban elementary schools. *Educational Evaluation and Policy Analysis, 12*(42), 1–25.

Hanushek, E. A., Kain, J. F., & Rivkin, S. G. (2004a). Why public schools lose teachers. *Journal of Human Resources*, *39*(2), 326–254.

Hanushek, E. A., Kain, J. F., & Rivkin, S. G. (2004b). Disruption versus Tiebout improvement: The costs and benefits of switching schools. *Journal of Public Economics, 88*(9), 1721-1746.

Hanushek, E. A., Rivkin, S. G., & Schiman, J. C. (2016). Dynamic effects of teacher turnover on the quality of instruction. *Economics of Education Review, 55*, 132-148.

Henry, G. T., Bastian, K. C., & Fortner, C. K. (2011). Stayers and leavers: Early-career teacher effectiveness and attrition. *Educational Researcher*, *40*(6), 271–280.

Holme, J. J. & Rangel, V. S. (2012). Putting school reform in its place social geography, organizational social capital, and school performance. *American Educational Research Journal, 49*((2), 257-283.

Jackson, C. K., & Bruegmann, E. (2009). Teaching Students and Teaching Each Other: The Importance of Peer Learning for Teachers. *American Economic Journal: Applied Economics 1*(4): 85-108.

Kraft, M. (2015). Teacher layoffs, teacher quality, and student achievement. Evidence from a discretionary layoff policy. *Education Finance and Policy*, *11*(4), 1-41.

Kraft, M. & Papay, J. P. (2014). Can professional environments in schools promote teacher development? Explaining heterogeneity in returns to teaching experience. *Educational Evaluation and Policy Analysis, 36*(4), 476-500.

Ladd, H. F. (2011). Teachers' perceptions of their working conditions: How predictive of planned and actual teacher movement? *Educational Evaluation and Policy Analysis*, *33*(2), 235–261.

Lankford, H., Loeb, S., & Wyckoff, J. (2002). Teacher sorting and the plight of urban schools: A descriptive analysis. *Education Evaluation and Policy Analysis, 24*(1), 37-62.

Little, J. W. (1982). Norms of collegiality and experimentation: Workplace conditions ofschool success. *American Educational Research Journal. 19*(3), 325-340.

Loeb, S., Darling-Hammond, L., & Luczak, J. (2005). How teaching conditions predict teacher turnover in California schools. *Peabody Journal of Education*, *80*(3), 44–70.

Louis, K. S., Marks, H. M., & Kruse, S. (1996). Teachers' Professional Community in Restructuring Schools. *American Educational Research Journal, 33*(4), 757-798.

Miller, R. T., Murnane, R. J., & Willett, J. B. (2008). Do teacher absences impact student achievement? Longitudinal evidence from one urban school district. *Educational Evaluation and Policy Analysis*, *30*(2), 181–200.

Nagler, M., Piopiunik, M., & West, M. R. (2015). Weak markets, strong teachers: Recession at career start and teacher effectiveness. NBER Working Paper 21393. National Bureau of Economic Research.

Ost, B. (2014). How do teachers improve? The relative importance of specific and general human capital. *American Economic Journal: Applied Economics, 6*(2): 127-51.

Ost, B. & Schiman, J. C. (2015). Grade-specific experience, grade reassignments, and teacher turnover. *Economics of Education Review, 46*, 112-126.

Papay, J. P., Taylor, E. S., Tyler, J. H., & Laski, M. (2016). Learning job skills from colleagues at work: Evidence from a field experiment using teacher performance data. NBER Working Paper 21986, National Bureau of Economic Research.

Pribesh, S., & Downey, D. B. (1999). Why are residential and school moves associated with poor school performance? *Demography, 36*(4), 521–534.

Rivkin S. G., Hanushek, E. A., Kain, J. F. (2005). Teachers, schools, and academic achievement. *Econometrica*, *73*(2), 417–58

Ronfeldt M., Farmer S., McQueen K., Grissom J. A. (2015). Teacher collaboration in instructional teams and student achievement. *American Educational Research Journal*, *52*(3), 475-514.

Ronfeldt, M., Loeb, S., & Wyckoff, J. (2013). How teacher turnover harms student achievement. *American Educational Research Journal*, *50*(1), 4-36.

Rumberger, R. W., Larson, K.A. (1998). Student mobility and the increased risk of high school dropout. *American Journal of Education*, *107*(1), 1–35

Sandstrom, H., and S. Huerta. 2013. The negative effects of instability on child development: A research synthesis. Low-Income Working Families Discussion Paper 3. Washington, DC: Urban Institute.

Schweig, J. (2014). Cross-level measurement invariance in school and classroom environment surveys implications for policy and practice. *Educational Evaluation and Policy Analysis, 36*(3), 259-280.

Simon, N. S. & Johnson, S. M. (2015) Teacher turnover in high-poverty schools: What we know and can do. *Teachers College Record*, *117*(3), 1-36.

Springer, M. G., Swain, W. A., Rodriguez, L. A. (2016). Effective teacher retention bonuses: Evidence from Tennessee. *Educational Evaluation and Policy Analysis, 38*(2), 199-221.

Swanson, C. B., Schneider, B. (1999) Students on the move: Residential and educational mobility in America's schools. *Sociology of Education*, *72*(1) 54–67

West, M. R. & Chingos, M. M. (2009). Teacher effectiveness, mobility, and attrition in Florida in M. G. Springer (Ed.), *Performance Incentives: Their Growing Impact on American K-12 Education* (251-272). Brookings Institution Press.

APPENDIX A

CHAPTER 2 APPENDIX

Table A1. Covariates used in Regression Analysis

Teacher Characteristics	**School Characteristics**	**School Working Conditions**
Teaching experience	Student enrollment	Distributed leadership ($\alpha = 0.86 - 0.88$)
Female	School level	School leadership ($\alpha = 0.87 - 0.93$)
Race/Ethnicity	Elementary	Facilities and resources ($\alpha = 0.84 - 0.85$)
White	Middle	Professional development ($\alpha = 0.79 - 0.86$)
Black	High	
Hispanic	Urbanicity	
Asian American Indian Multiracial	City	
Age	Suburb	
Entry Portal	Rural	
Traditional	Town	
Alternate entry	% economically disadvantaged	
Teacher For America	% Black students	
Average teacher test	% Hispanic students	
	% Other race/ethnicity	
	Violent acts rate	
	Short-term suspension rate	
	% teachers with 3 years of experience or less	
	Overall performance composite	
	Total per-pupil expenditures ($1000s)	
	Teacher salary supplement ($1000s)	

Table A2. School Working Conditions Measures

Scale	**Survey Items**
Facilities and Resources	Teachers have sufficient access to appropriate instructional materials.
	Teachers have sufficient access to instructional technology, including computers, printers, software and internet access.
	Teachers have access to reliable communication technology, including phones, faxes and email.
	Teachers have sufficient access to office equipment and supplies such as copy machines, paper, pens, etc.
	The reliability and speed of Internet connections in this school are sufficient to support instructional practices.
	Teachers have adequate space to work productively.
	The school environment is clean and well maintained.
Distributed Leadership	Selecting instructional materials and resources
	Devising teaching techniques
	Setting grading and student assessment practices
	Determining the content of in-service professional development programs
	The selection of teachers new to this school
	Establishing student discipline procedures
	Providing input on how the school budget will be spent
	School improvement planning
School Leadership	There is an atmosphere of trust and mutual respect in this school.
	School administrators consistently enforce rules for student conduct.
	School administrators support teachers' efforts to maintain discipline in the classroom.
	The school leadership consistently supports teachers.
	The procedures for teacher evaluation are consistent.
	The faculty and staff have a shared vision.

	Teachers receive feedback that can help them improve teaching.
Professional Development	Sufficient resources are available for professional development in my school.
	An appropriate amount of time is provided for professional development.
	Teachers have sufficient training to fully utilize instructional technology.
	Professional development provides ongoing opportunities for teachers to work with colleagues to refine teaching practices.

Table A3. Percent of Teachers to Turnover by Retirement Eligibility

	Stayer	Within-year mover	Within-year leaver	End-of-year mover	End-of-year leaver
Not eligible for retirement benefits	85.85	1.38	2.41	4.90	5.45
Eligible for full benefits	71.77	2.02	5.11	5.50	15.60
Eligible for reduced benefits	66.02	0.73	8.71	3.58	20.95

Notes. Restricted to teachers over 60 years of age. Observations = 115,629.

Table A4. Percent of Teachers to Turnover by Minority Student Enrollment

	Stayer	Within-year mover	Within-year leaver	End-of-year mover	End-of-year leaver
Bottom decile of minority student enrollment	85.26	1.40	1.85	6.16	5.33
2nd decile	84.38	1.35	2.17	6.13	5.98
3rd decile	83.94	1.44	2.24	6.35	6.03
4th decile	82.99	1.65	2.32	6.68	6.37
5th decile	82.18	1.60	2.55	7.08	6.60
6th decile	80.89	1.80	2.62	7.65	7.03
7th decile	80.60	2.06	2.65	7.92	6.76
8th decile	78.61	2.35	2.85	8.96	7.23
9th decile	76.49	2.43	3.24	9.82	8.02
10th decile	71.44	3.45	3.85	12.08	9.17

Notes. Observations = 559,484

Table A5. Percent of Teachers to Turnover by Economically Disadvantaged Student Enrollment

	Stayer	Within-year mover	Within-year leaver	End-of-year mover	End-of-year leaver
Bottom decile of FRPL	82.67	1.83	2.46	6.59	6.45
2nd decile	83.19	1.56	2.39	6.47	6.39
3rd decile	83.41	1.62	2.26	6.48	6.22
4th decile	82.47	1.61	2.42	7.04	6.46
5th decile	82.39	1.67	2.51	6.85	6.59
6th decile	81.80	1.78	2.52	7.28	6.61
7th decile	80.57	1.94	2.65	8.12	6.71
8th decile	79.40	2.39	2.68	8.54	7.00
9th decile	76.43	2.42	3.23	9.85	8.08
10th decile	74.45	2.72	3.21	11.61	8.01

Notes. Observations = 558, 795

Table A6. Percent of Teachers to Turnover by School Performance

	Stayer	Within-year mover	Within-year leaver	End-of-year mover	End-of-year leaver
Bottom decile of School Performance	73.91	2.45	4.07	10.53	9.05
2nd decile	77.95	2.03	3.26	8.77	8.00
3rd decile	78.86	2.00	2.96	8.59	7.60
4th decile	79.69	1.98	2.82	8.41	7.09
5th decile	80.29	2.14	2.50	8.13	6.95
6th decile	81.59	2.13	2.30	7.64	6.35
7th decile	82.94	1.79	2.30	7.06	5.91
8th decile	83.62	1.67	2.11	6.74	5.85
9th decile	83.87	1.70	1.91	6.69	5.83
10th decile	84.20	1.71	2.14	6.11	5.84

Notes. Observations = 552,805

Table A7. Supplementary Logistic Regression Estimates of Within- and End-of-Year Teacher Turnover

	Within-year turnover			End-of-year turnover		
0-2 years experience	1.79***	1.79***	1.79***	1.62***	1.62***	1.62***
	(19.67)	(19.77)	(19.55)	(27.08)	(27.03)	(27.04)
3-5 years experience	1.34***	1.34***	1.35***	1.30***	1.30***	1.30***
	(10.76)	(10.80)	(10.81)	(16.42)	(16.44)	(16.47)
11-20 years experience	0.64***	0.64***	0.64***	0.72***	0.72***	0.72***
	(-17.98)	(-17.97)	(-17.91)	(-22.16)	(-22.36)	(-22.28)
20+ years experience	0.70***	0.79***	0.79***	0.78***	0.94***	0.94***
	(-11.25)	(-8.03)	(-8.01)	(-12.89)	(-3.44)	(-3.45)
Female	1.11***	1.06	1.11***	1.04***	1.03	1.04**
	(5.36)	(1.31)	(5.12)	(3.47)	(1.06)	(3.23)
Black	0.97	0.97	0.97	0.99	1.00	1.00
	(-1.37)	(-1.09)	(-1.06)	(-0.58)	(0.06)	(0.19)
Hispanic	1.03	1.02	1.02	1.17***	1.17***	1.17***
	(0.45)	(0.40)	(0.38)	(4.66)	(4.57)	(4.60)
Other race	1.00	1.00	1.00	1.02	1.02	1.02
	(-0.09)	(-0.06)	(0.04)	(0.57)	(0.71)	(0.63)
Alternate entry	0.97	0.96	0.96	1.18***	1.17***	1.17***
	(-1.40)	(-1.68)	(-1.68)	(11.80)	(11.02)	(10.82)
Teacher For America	0.85	0.85	0.86	1.95***	1.94***	1.96***
	(-1.54)	(-1.56)	(-1.52)	(16.85)	(16.72)	(16.91)
Out-of-state prepared	1.27***	1.27***	1.27***	1.28***	1.28***	1.28***
	(13.09)	(12.97)	(12.99)	(23.09)	(22.88)	(22.84)
Other	1.05	1.03	1.03	1.19***	1.17***	1.16***
	(1.31)	(0.91)	(0.94)	(7.87)	(7.21)	(7.00)
< 26 years old	0.64***	0.67***	0.66***	1.20***	1.40***	1.25***
	(-10.94)	(-5.26)	(-10.19)	(8.03)	(8.18)	(9.71)
26-30 years old	1.02	0.93	1.06	1.24***	1.28***	1.29***
	(0.73)	(-1.21)	(1.74)	(11.73)	(6.99)	(13.89)
31-40 years old	1.17***	1.12*	1.20***	1.16***	1.26***	1.21***
	(6.14)	(2.18)	(7.34)	(10.15)	(7.40)	(13.06)
51-60 years old	1.56***	1.65***	1.65***	1.24***	1.23***	1.38***
	(16.54)	(9.19)	(19.68)	(12.75)	(5.95)	(20.89)
60+ years of age	2.79***	3.78***	3.71***	1.98***	2.88***	3.32***
	(20.12)	(20.08)	(38.82)	(20.67)	(23.00)	(55.57)
School size (100s)	0.95***	0.95***	0.95***	0.98***	0.98***	0.98***
	(-22.14)	(-22.20)	(-22.00)	(-18.88)	(-19.03)	(-18.79)
City	1.04	1.04	1.04	0.99	0.99	0.99
	(1.23)	(1.20)	(1.15)	(-0.45)	(-0.49)	(-0.47)
Rural	1.04	1.04	1.04	1.01	1.01	1.01

	(1.33)	(1.29)	(1.35)	(0.82)	(0.75)	(0.84)
Town	0.97	0.97	0.97	0.98	0.99	0.99
	(-0.89)	(-0.84)	(-0.81)	(-0.83)	(-0.68)	(-0.70)
Middle school	2.38***	2.39***	2.38***	1.12***	1.12***	1.12***
	(38.55)	(38.63)	(38.46)	(9.16)	(9.21)	(9.17)
High school	5.32***	5.34***	5.33***	1.15***	1.16***	1.16***
	(77.37)	(77.64)	(77.37)	(12.68)	(13.45)	(13.33)
% economically disadvantaged	1.00	1.00	1.00	1.00***	1.00***	1.00***
	(-1.41)	(-1.47)	(-1.75)	(-6.32)	(-6.45)	(-6.85)
% Black students	1.01***	1.01***	1.01***	1.01***	1.01***	1.01***
	(11.44)	(11.50)	(11.51)	(17.52)	(17.62)	(17.69)
% Hispanic students	1.00***	1.00***	1.00***	1.00***	1.00***	1.00***
	(4.57)	(4.65)	(4.74)	(4.72)	(4.84)	(5.04)
% Other race students	1.01***	1.01***	1.01***	1.00	1.00	1.00
	(6.17)	(6.16)	(6.14)	(1.40)	(1.37)	(1.48)
Violent acts rate	1.00***	1.00***	1.00***	1.00	1.00	1.00
	(-3.51)	(-3.52)	(-3.48)	(1.18)	(1.22)	(1.26)
Suspension rate	1.00***	1.00***	1.00***	1.00***	1.00***	1.00***
	(-3.60)	(-3.66)	(-3.76)	(3.60)	(3.62)	(3.44)
Teachers with 3 yrs experience or less	3.84***	3.83***	4.08***	2.22***	2.22***	2.28***
	(16.29)	(16.27)	(16.84)	(16.60)	(16.65)	(17.01)
Overall performance composite	1.00***	1.00***	1.00***	1.00***	1.00***	1.00***
	(-5.05)	(-5.00)	(-5.19)	(-7.01)	(-6.91)	(-6.97)
Per pupil expenditures	1.00***	1.00**	1.00***	1.00**	1.00**	1.00**
	(-3.32)	(-3.27)	(-3.31)	(-3.06)	(-2.94)	(-2.97)
Teacher salary supplement	1.04***	1.04***	1.04***	0.99	0.99	1.00
	(5.58)	(5.61)	(5.85)	(-1.51)	(-1.40)	(-1.23)
Facilities and Resources (std)	0.95***	0.95***	0.95***	1.00	1.00	1.00
	(-4.44)	(-4.44)	(-4.03)	(0.06)	(0.01)	(0.23)
Distributed leadership (std)	0.95***	0.95***	0.95***	0.97***	0.97***	0.97***
	(-3.47)	(-3.50)	(-3.40)	(-4.08)	(-4.20)	(-3.95)
Principal leadership (std)	0.95***	0.95***	0.95***	0.93***	0.93***	0.93***
	(-4.06)	(-4.06)	(-3.94)	(-9.55)	(-9.48)	(-9.42)
Professional development (std)	1.07***	1.07***	1.07***	1.01	1.01	1.01
	(5.02)	(5.09)	(4.95)	(1.13)	(1.31)	(1.38)
Eligible for full retirement benefits	1.55***			2.11***		
	(10.89)			(29.79)		
Eligible for reduced retirement benefits	1.19*			1.43***		
	(2.54)			(8.22)		
Female * < 26 years old		0.98			0.87***	
		(-0.25)			(-3.37)	
Female * 26-30 years old		1.16*			1.01	

		(2.36)			(0.22)	
Female * 31-40 years old		1.09			0.95	
		(1.52)			(-1.40)	
Female * 51-60 years old		1.00			1.15***	
		(0.01)			(3.65)	
Female * 60+ years old		0.97			1.20***	
		(-0.38)			(3.52)	
Change in school size (100s)			0.96***			0.97***
			(-3.53)			(-3.96)
Constant	0.01***	0.01***	0.01***	0.12***	0.12***	0.12***
	(-39.38)	(-37.67)	(-39.40)	(-31.47)	(-30.67)	(-31.94)
Observations	378882	378882	377162	425158	425158	423233
Deviance	144239.93	144369.26	143821.34	353438.77	354396.22	352931.37

Notes. Estimates reported as odds ratios. Estimates include wave fixed effects. *t*-statistics reported in parentheses. * p<0.05; ** p<0.01; *** p<0.001.

Table A8. Supplementary Multinomial Logistic Regression Estimates of Within- and End-of-Year Teacher Moving, Leaving, and Temporary Exit and Return

	Within-year mover	Within-year leaver	End-of-year mover	End-of-year leaver	Temporary Exit and Return
0-2 years experience	1.32***	2.21***	1.40***	1.96***	0.99
	(6.06)	(22.17)	(14.74)	(26.87)	(-0.13)
3-5 years experience	1.10*	1.56***	1.16***	1.51***	1.04
	(2.29)	(12.90)	(7.39)	(17.85)	(0.67)
11-20 years experience	0.75***	0.54***	0.79***	0.60***	0.46***
	(-8.01)	(-18.57)	(-12.97)	(-22.61)	(-12.66)
20+ years experience	0.72***	0.80***	0.68***	1.18***	0.64***
	(-6.76)	(-6.33)	(-14.97)	(6.68)	(-5.67)
Female	1.02	1.09	1.05	0.97	1.38*
	(0.37)	(1.39)	(1.50)	(-0.68)	(2.06)
Black	1.19***	0.83***	1.06**	0.93***	1.01
	(4.95)	(-6.21)	(3.26)	(-3.84)	(0.09)
Hispanic	1.06	1.03	1.13**	1.23***	1.28
	(0.73)	(0.45)	(2.81)	(4.65)	(1.89)
Other race	1.05	0.97	0.95	1.12**	1.15
	(0.72)	(-0.57)	(-1.51)	(3.05)	(1.26)
Alternate entry	1.02	0.90***	1.12***	1.21***	0.96
	(0.64)	(-3.29)	(6.33)	(9.24)	(-0.70)
Teacher For America	0.42***	1.32*	0.65***	4.31***	0.68
	(-4.59)	(2.32)	(-5.83)	(31.40)	(-1.00)
Out-of-state prepared	1.07*	1.44***	1.07***	1.54***	1.16**
	(2.18)	(16.73)	(4.95)	(29.98)	(3.19)
Other	0.84**	1.22***	0.93*	1.49***	0.84
	(-2.90)	(4.44)	(-2.41)	(14.36)	(-1.59)
< 26 years old	0.82	0.61***	1.32***	1.49***	0.61
	(-1.82)	(-4.92)	(5.41)	(6.74)	(-1.54)
26-30 years old	1.08	0.85*	1.11*	1.50***	0.60*
	(0.87)	(-1.99)	(2.46)	(7.85)	(-2.13)
31-40 years old	1.10	1.12	1.17***	1.35***	0.61*
	(1.37)	(1.60)	(4.16)	(6.32)	(-2.31)
51-60 years old	1.04	2.37***	0.98	1.75***	1.77**
	(0.41)	(12.50)	(-0.53)	(11.46)	(2.97)
60+ years of age	1.46**	6.57***	0.95	6.02***	5.42***
	(2.90)	(24.03)	(-0.63)	(32.26)	(7.75)
School size (100s)	0.95***	0.96***	0.96***	0.99***	0.97***
	(-15.05)	(-17.14)	(-19.98)	(-8.08)	(-6.31)
City	1.00	1.06	0.99	1.00	1.02
	(-0.06)	(1.57)	(-0.56)	(-0.09)	(0.21)
Rural	1.10*	0.99	1.05*	0.97	0.93
	(2.29)	(-0.18)	(2.41)	(-1.42)	(-1.12)

Town	1.00	0.94	1.04	0.93*	1.01
	(0.02)	(-1.32)	(1.44)	(-2.53)	(0.08)
Middle school	2.21***	2.54***	1.17***	1.07***	1.21**
	(22.81)	(33.49)	(10.08)	(3.99)	(3.11)
High school	4.53***	6.13***	1.22***	1.13***	2.14***
	(46.58)	(66.18)	(13.47)	(8.14)	(15.46)
% economically disadvantaged	1.00	1.00**	1.00***	1.00***	1.00**
	(0.84)	(-2.69)	(-5.60)	(-4.55)	(-3.08)
% Black students	1.01***	1.01***	1.01***	1.00***	1.00
	(10.08)	(7.22)	(15.90)	(10.55)	(1.21)
% Hispanic students	1.01***	1.00*	1.00***	1.00	1.00*
	(5.23)	(2.05)	(5.82)	(1.80)	(2.18)
% Other race students	1.01**	1.01***	1.00*	1.00	1.00
	(3.28)	(5.53)	(2.48)	(-0.53)	(-1.08)
Violent acts rate	1.00	1.00***	1.00	1.00	1.00
	(-1.54)	(-3.34)	(0.45)	(0.91)	(-1.15)
Suspension rate	1.00**	1.00*	1.00**	1.00	1.00
	(-3.01)	(-2.43)	(2.68)	(1.74)	(-1.47)
Teachers with 3 yrs experience or less	3.87***	4.02***	2.25***	2.25***	1.96**
	(10.71)	(13.59)	(13.23)	(12.13)	(3.18)
Overall performance composite	1.00**	0.99***	0.99***	1.00	1.00
	(-2.62)	(-4.88)	(-10.52)	(0.06)	(-0.53)
Per pupil expenditures	1.00	0.99**	1.00**	1.00	1.00
	(-0.49)	(-3.10)	(-3.28)	(-1.32)	(0.00)
Teacher salary supplement	1.06***	1.02*	1.00	0.99**	1.06***
	(6.46)	(2.05)	(0.48)	(-2.63)	(3.31)
Facilities and Resources (std)	0.93***	0.97*	1.00	1.00	0.93*
	(-4.01)	(-2.22)	(0.20)	(-0.48)	(-2.34)
Distributed leadership (std)	0.93***	0.97	0.96***	0.97**	0.95
	(-3.41)	(-1.76)	(-3.64)	(-2.58)	(-1.64)
Principal leadership (std)	0.97	0.92***	0.90***	0.96***	0.98
	(-1.28)	(-4.66)	(-9.87)	(-3.80)	(-0.68)
Professional development (std)	1.06**	1.07***	1.01	1.01	1.10**
	(3.07)	(4.17)	(1.36)	(0.82)	(2.70)
Female * < 26 years old	1.08	0.89	0.90*	0.86*	1.82
	(0.71)	(-1.08)	(-2.05)	(-2.46)	(1.82)
Female * 26-30 years old	0.92	1.43***	0.97	1.12*	4.55***
	(-0.94)	(4.19)	(-0.56)	(2.09)	(6.08)
Female * 31-40 years old	1.02	1.19*	0.91*	1.08	4.41***
	(0.25)	(2.23)	(-2.35)	(1.38)	(6.65)
Female * 51-60 years old	1.00	1.01	0.95	1.39***	0.90
	(-0.04)	(0.07)	(-0.89)	(6.12)	(-0.49)
Female * 60+ years old	0.82	1.00	1.05	1.32***	0.63
	(-1.27)	(0.04)	(0.52)	(4.44)	(-1.85)
Constant	0.01***	0.01***	0.12***	0.03***	0.00***

	(-28.19)	(-35.58)	(-23.41)	(-37.23)	(-17.69)
Observations	445641	445641	445641	445641	445641

Notes. Estimates reported as relative risk ratios. Estimates include wave fixed effects. *t*-statistics reported in parentheses. * p<0.05; ** p<0.01; *** p<0.001.

Table A9. Logistic Regression Estimates of Within- and End-of-Year Turnover, by School Level

	Within-year turnover			End-of-year turnover		
0-2 years experience	1.77***	1.77***	1.90***	1.50***	1.65***	1.77***
	(13.10)	(8.86)	(17.66)	(16.18)	(13.51)	(21.13)
3-5 years experience	1.42***	1.34***	1.39***	1.25***	1.37***	1.31***
	(8.89)	(4.79)	(9.75)	(10.23)	(9.45)	(10.89)
11-20 years experience	0.65***	0.65***	0.63***	0.72***	0.71***	0.73***
	(-11.65)	(-7.77)	(-15.43)	(-16.01)	(-10.99)	(-14.59)
20+ years experience	0.87***	0.78***	0.76***	1.03	0.89**	0.90***
	(-3.32)	(-3.81)	(-7.63)	(1.38)	(-3.22)	(-3.96)
Female	0.78***	0.93	1.10***	0.90***	1.06**	1.06***
	(-5.96)	(-1.85)	(4.27)	(-4.74)	(2.63)	(3.60)
Black	0.95	0.92	1.01	0.98	0.94*	1.05*
	(-1.34)	(-1.71)	(0.46)	(-0.82)	(-2.35)	(2.55)
Hispanic	1.00	1.16	0.98	1.29***	1.19*	1.12*
	(-0.03)	(1.08)	(-0.37)	(5.61)	(2.24)	(2.36)
Other race	0.94	1.06	1.00	1.00	0.95	1.06
	(-0.91)	(0.58)	(-0.08)	(0.01)	(-0.82)	(1.40)
Alternate entry	1.03	1.08	0.90***	1.20***	1.09**	1.15***
	(0.67)	(1.51)	(-3.85)	(7.42)	(3.04)	(7.26)
Teacher For America	0.94	0.96	0.91	2.14***	1.85***	1.88***
	(-0.32)	(-0.23)	(-0.79)	(11.11)	(8.64)	(10.41)
Out-of-state prepared	1.22***	1.28***	1.23***	1.28***	1.21***	1.24***
	(7.62)	(5.91)	(9.23)	(17.44)	(8.29)	(13.24)
Other	0.98	1.23*	1.02	1.27***	1.25***	1.01
	(-0.35)	(2.22)	(0.38)	(8.02)	(4.34)	(0.26)
< 26 years old	0.73***	0.66***	0.58***	1.35***	1.17***	1.11**
	(-5.21)	(-4.61)	(-10.86)	(9.50)	(3.44)	(2.98)
26-30 years old	1.09	1.04	1.00	1.37***	1.23***	1.14***
	(1.92)	(0.59)	(-0.09)	(12.72)	(5.60)	(4.83)
31-40 years old	1.24***	1.16**	1.21***	1.21***	1.17***	1.19***
	(5.84)	(2.79)	(6.18)	(9.50)	(5.13)	(8.14)
51-60 years old	1.63***	1.61***	1.72***	1.39***	1.33***	1.40***
	(12.67)	(8.53)	(17.83)	(15.34)	(8.71)	(14.98)
60+ years of age	3.51***	3.47***	3.89***	3.51***	2.89***	3.21***
	(23.74)	(15.85)	(33.90)	(41.17)	(22.67)	(38.99)
School size (100s)	1.00	0.99	0.96***	0.96***	0.98**	0.97***
	(-0.51)	(-1.13)	(-18.83)	(-9.60)	(-2.98)	(-16.93)
City	0.95	1.07	1.01	0.96	1.04	0.97
	(-1.25)	(0.99)	(0.31)	(-1.80)	(0.94)	(-1.35)
Rural	1.00	1.13*	0.98	0.98	1.02	1.00
	(0.05)	(1.97)	(-0.50)	(-0.73)	(0.45)	(0.12)
Town	0.98	1.06	0.92	1.00	0.99	0.96
	(-0.38)	(0.72)	(-1.90)	(0.13)	(-0.22)	(-1.19)

% economically disadvantaged	0.99***	0.99***	1.00	1.00***	0.99***	1.00***
	(-5.47)	(-4.69)	(-0.46)	(-7.62)	(-4.55)	(-3.62)
% Black students	1.01***	1.01***	1.00***	1.01***	1.01***	1.00***
	(9.18)	(6.45)	(6.34)	(12.34)	(8.88)	(10.14)
% Hispanic students	1.00	1.01*	1.00*	1.00***	1.00***	1.00**
	(1.63)	(2.37)	(2.21)	(3.98)	(3.44)	(2.66)
% Other race students	1.00**	1.00	1.01***	1.00	1.00	1.00
	(2.95)	(0.59)	(5.56)	(0.48)	(0.52)	(1.63)
Violent acts rate	1.00***	1.00	1.00**	1.00*	1.00	1.00
	(3.36)	(-1.20)	(-2.92)	(2.30)	(0.68)	(0.67)
Suspension rate	1.00**	1.00	1.00**	1.00***	1.00	1.00**
	(3.09)	(0.18)	(-3.26)	(3.64)	(1.93)	(2.63)
Teachers with 3 yrs experience or less	3.86***	3.68***	3.86***	2.41***	1.83***	1.93***
	(11.56)	(6.45)	(13.42)	(13.85)	(5.47)	(8.91)
Overall performance composite	0.99***	0.99***	1.00**	0.99***	0.99***	1.00**
	(-4.53)	(-4.58)	(-3.12)	(-6.89)	(-5.47)	(-3.21)
Per pupil expenditures	1.00	1.03*	1.00**	1.00***	1.00	1.00*
	(-1.54)	(2.30)	(-2.88)	(-3.55)	(0.03)	(-2.51)
Teacher salary supplement	1.01	1.03*	1.04***	0.99*	0.98**	1.02**
	(0.96)	(1.99)	(4.81)	(-2.42)	(-3.01)	(2.69)
Facilities and Resources (std)	0.94***	0.91***	0.97	1.02	1.00	0.99
	(-3.61)	(-3.71)	(-1.82)	(1.59)	(-0.31)	(-1.07)
Distributed leadership (std)	0.99	0.96	0.94***	0.96***	1.01	0.95***
	(-0.66)	(-1.17)	(-3.53)	(-3.47)	(0.71)	(-4.39)
Principal leadership (std)	0.93***	0.94*	0.95**	0.92***	0.91***	0.94***
	(-3.50)	(-2.05)	(-3.15)	(-7.24)	(-5.10)	(-5.17)
Professional development (std)	1.07***	1.06	1.05**	1.01	1.00	1.02
	(3.35)	(1.89)	(3.29)	(1.01)	(-0.00)	(1.55)
Constant	0.02***	0.04***	0.06***	0.18***	0.22***	0.13***
	(-19.69)	(-9.09)	(-21.13)	(-16.46)	(-7.42)	(-22.91)
Elementary school	x			x		
Middle school		x			x	
High school			x			x
Observations	199366	76642	171011	224523	86680	186942
Deviance	66649.18	28150.91	93274.26	183955.86	75325.51	160671.29

Notes. Estimates reported as odds ratios. Estimates include wave fixed effects. *t*-statistics reported in parentheses.
* p<0.05; ** p<0.01; *** p<0.001.

Table A10. Logistic Regression Estimates of Within-Year and End-of-Year Moving within District and State

	Within-year mover		End-of-year mover	
	Within district	Within state	Within district	Within state
0-2 years experience	1.06	1.31***	1.06	1.34***
	(0.94)	(3.91)	(1.24)	(11.56)
3-5 years experience	0.86**	1.35***	1.09*	1.12***
	(-2.87)	(4.77)	(2.25)	(4.91)
11-20 years experience	0.84***	0.76***	0.84***	0.82***
	(-4.03)	(-4.84)	(-5.28)	(-9.56)
20+ years experience	0.82***	0.61***	0.79***	0.64***
	(-3.44)	(-6.39)	(-5.53)	(-15.21)
Female	1.02	0.94	1.05	0.95**
	(0.53)	(-1.46)	(1.75)	(-2.84)
Black	1.33***	0.98	1.11**	1.05*
	(6.81)	(-0.35)	(3.15)	(2.52)
Hispanic	1.04	1.01	1.03	1.13*
	(0.36)	(0.07)	(0.43)	(2.50)
Other race	1.20*	0.84	1.01	0.92*
	(2.14)	(-1.51)	(0.21)	(-2.14)
Alternate entry	1.01	1.00	1.11**	1.10***
	(0.25)	(0.03)	(3.13)	(4.57)
Teacher For America	0.48***	0.15***	0.85	0.38***
	(-3.40)	(-4.64)	(-1.29)	(-10.52)
Out-of-state prepared	1.04	0.95	0.97	1.03
	(1.09)	(-1.18)	(-1.06)	(1.89)
Other	0.85*	0.78**	0.84**	0.92*
	(-2.34)	(-2.62)	(-3.06)	(-2.36)
< 26 years old	0.93	0.83*	0.91	1.35***
	(-0.94)	(-2.04)	(-1.73)	(9.52)
26-30 years old	0.99	0.94	0.92*	1.09***
	(-0.11)	(-0.94)	(-1.99)	(3.37)
31-40 years old	1.07	1.09	1.02	1.06**
	(1.55)	(1.48)	(0.57)	(2.71)
51-60 years old	0.94	1.00	0.83***	0.91***
	(-1.19)	(-0.01)	(-4.86)	(-4.04)
60+ years of age	0.98	0.72**	0.80***	0.69***
	(-0.30)	(-2.66)	(-3.49)	(-7.96)
School size (100s)	0.95***	0.97***	0.95***	0.98***
	(-11.28)	(-6.21)	(-15.04)	(-11.12)
City	1.16**	0.75***	1.13*	0.92***
	(2.66)	(-3.62)	(2.37)	(-3.34)
Rural	1.10	1.10	1.17***	1.04

	(1.69)	(1.36)	(3.37)	(1.49)
Town	0.99	1.02	1.05	1.05
	(-0.11)	(0.28)	(0.81)	(1.68)
Middle school	1.86***	2.43***	1.14***	1.11***
	(14.33)	(16.48)	(4.54)	(5.91)
High school	3.81***	4.49***	1.14***	1.09***
	(34.01)	(28.74)	(4.97)	(5.45)
% economically disadvantaged	1.00	1.00	1.00*	1.00**
	(1.95)	(-0.07)	(-2.54)	(-3.24)
% Black students	1.01***	1.01***	1.00***	1.01***
	(4.88)	(8.12)	(4.80)	(13.57)
% Hispanic students	1.01***	1.01***	1.00	1.00***
	(3.46)	(3.52)	(1.79)	(4.36)
% Other race students	1.00*	1.01*	1.00	1.00
	(2.09)	(2.42)	(1.48)	(1.67)
Violent acts rate	1.00	1.00	1.00**	1.00**
	(-1.47)	(-0.35)	(-2.79)	(3.25)
Suspension rate	1.00**	1.00*	1.00**	1.00
	(-2.59)	(-2.05)	(2.83)	(1.41)
Teachers with 3 yrs experience or less	2.37***	4.63***	1.42**	2.07***
	(5.39)	(7.89)	(2.96)	(10.49)
Overall performance composite	1.00	0.99***	0.99***	0.99***
	(0.56)	(-3.84)	(-4.45)	(-9.28)
Per pupil expenditures	1.00	1.00	1.00	1.00***
	(0.22)	(-0.21)	(-0.61)	(-3.34)
Teacher salary supplement	1.09***	1.01	1.10***	0.98***
	(7.43)	(0.78)	(7.71)	(-4.44)
Facilities and Resources (std)	0.91***	0.98	0.95**	1.04***
	(-4.19)	(-0.81)	(-3.19)	(3.73)
Distributed leadership (std)	0.91***	1.00	0.96*	0.96**
	(-3.75)	(-0.09)	(-2.01)	(-3.07)
Principal leadership (std)	1.01	0.95	0.89***	0.92***
	(0.58)	(-1.60)	(-6.74)	(-6.75)
Professional development (std)	1.10***	0.98	1.10***	0.97*
	(3.78)	(-0.51)	(5.31)	(-2.55)
Constant	0.00***	0.00***	0.01***	0.12***
	(-26.91)	(-21.45)	(-28.49)	(-22.01)
Observations	445641	445641	445641	445641
Deviance	54204.75	33965.56	77641.66	189488.87

Notes. Estimates reported as odds ratios. Estimates include wave fixed effects. *t*-statistics reported in parentheses. * p<0.05; ** p<0.01; *** p<0.001.

Table A11. Linear Probability Model Estimates of Within-year Teacher Turnover

	Within-year turnover		Within-year mover		Within-year leaver	
0-2 years experience	0.038***	0.039***	0.009***	0.009***	0.033***	0.033***
	(10.01)	(10.40)	(4.27)	(4.31)	(12.01)	(12.71)
3-5 years experience	0.017***	0.016***	0.003*	0.003*	0.015***	0.015***
	(13.45)	(12.46)	(2.30)	(2.08)	(12.92)	(11.99)
11-20 years experience	-0.018***	-0.017***	-0.006***	-0.005***	-0.014***	-0.013***
	(-14.01)	(-13.68)	(-7.88)	(-7.08)	(-12.30)	(-12.11)
20+ years experience	-0.010***	-0.005	-0.007***	-0.004**	-0.005*	-0.001
	(-3.69)	(-1.78)	(-4.81)	(-3.23)	(-2.04)	(-0.39)
Female	0.006***	0.003*	0.001	-0.000	0.007***	0.003***
	(5.98)	(2.22)	(1.17)	(-0.47)	(7.37)	(3.62)
Black	-0.002	-0.004*	0.005***	0.004***	-0.007***	-0.008***
	(-0.92)	(-2.34)	(4.74)	(3.90)	(-6.46)	(-8.67)
Hispanic	0.003	0.008*	0.002	0.005*	0.001	0.004
	(0.95)	(2.24)	(1.18)	(2.40)	(0.39)	(1.32)
Other race	-0.000	0.001	0.001	0.001	-0.002	-0.000
	(-0.14)	(0.29)	(0.44)	(0.45)	(-0.66)	(-0.17)
Alternate entry	-0.005***	0.001	0.000	0.003***	-0.006***	-0.001
	(-3.85)	(1.10)	(0.32)	(3.46)	(-5.71)	(-1.13)
Teacher For America	-0.021***	-0.032***	-0.034***	-0.042***	0.009	0.003
	(-3.41)	(-4.28)	(-6.09)	(-5.92)	(1.88)	(0.67)
Out-of-state prepared	0.008***	0.008***	-0.000	-0.001	0.009***	0.009***
	(5.69)	(5.61)	(-0.56)	(-1.18)	(8.26)	(7.92)
Other	-0.001	0.003	-0.004***	-0.003***	0.003**	0.006***
	(-0.31)	(1.62)	(-4.29)	(-3.44)	(2.66)	(4.83)
< 26 years old	-0.034***	-0.033***	-0.007**	-0.006**	-0.031***	-0.030***
	(-9.37)	(-8.66)	(-3.26)	(-2.98)	(-11.22)	(-10.57)
26-30 years old	-0.003	-0.001	-0.002	-0.001	-0.001	-0.000
	(-1.22)	(-0.64)	(-1.92)	(-1.48)	(-0.71)	(-0.12)

31-40 years old	0.006***	0.007***	0.002**	0.002**	0.005***	0.006***
	(5.74)	(6.89)	(2.84)	(3.19)	(5.15)	(5.67)
51-60 years old	0.021***	0.024***	0.000	0.001	0.022***	0.024***
	(11.22)	(13.60)	(0.33)	(1.04)	(13.25)	(15.14)
60+ years of age	0.091***	0.098***	0.005	0.006*	0.093***	0.098***
	(13.36)	(14.13)	(1.80)	(2.61)	(15.10)	(15.73)
School size (100s)	-0.004***		-0.002***		-0.003***	
	(-16.06)		(-8.52)		(-20.30)	
City	-0.003		-0.002		-0.002	
	(-1.41)		(-0.96)		(-1.55)	
Rural	-0.006*		-0.003		-0.004**	
	(-2.02)		(-1.00)		(-2.79)	
Town	-0.008		-0.003		-0.005*	
	(-1.97)		(-0.98)		(-2.49)	
Middle school	0.044***		0.019***		0.030***	
	(15.72)		(11.62)		(14.58)	
High school	0.089***		0.037***		0.061***	
	(19.67)		(13.99)		(16.65)	
% economically disadvantaged	0.000		0.000		0.000*	
	(1.56)		(0.35)		(2.60)	
% Black students	-0.000		0.000		-0.000*	
	(-0.35)		(0.93)		(-2.20)	
% Hispanic students	-0.000		0.000		-0.000	
	(-1.32)		(0.27)		(-1.85)	
% Other race students	0.000		-0.000		0.000	
	(0.55)		(-0.14)		(1.13)	
Violent acts rate	-0.000***		-0.000*		-0.000***	
	(-4.11)		(-2.38)		(-4.26)	
Suspension rate	-0.000***		-0.000*		-0.000**	
	(-3.50)		(-2.21)		(-3.33)	

Teachers with 3 yrs experience or less	0.056***		0.026***		0.036***	
	(8.27)		(6.38)		(6.42)	
Overall performance composite	-0.000***		-0.000*		-0.000***	
	(-4.04)		(-2.37)		(-5.53)	
Per pupil expenditures	-0.000**		-0.000		-0.000**	
	(-3.31)		(-0.49)		(-3.11)	
Teacher salary supplement	0.001**		0.002**		-0.001	
	(2.94)		(2.87)		(-1.44)	
Facilities and Resources (std)	-0.001		-0.001		-0.001	
	(-1.52)		(-1.75)		(-0.97)	
Distributed leadership (std)	-0.001		-0.000		-0.001	
	(-0.89)		(-0.55)		(-0.72)	
Principal leadership (std)	-0.004***		-0.001*		-0.003***	
	(-4.81)		(-2.58)		(-4.75)	
Professional development (std)	0.003**		0.001		0.002**	
	(2.93)		(1.51)		(2.62)	
Constant	0.043**	0.032***	0.028**	0.026***	0.019**	0.007***
	(3.13)	(13.43)	(2.75)	(12.93)	(2.67)	(5.65)
District fixed effect	x		x		x	
School fixed effect		x		x		x
Observations	378882	378882	363814	363814	367819	367819

Notes. Estimates include wave fixed effects. *t*-statistics reported in parentheses. * p<0.05; ** p<0.01; *** p<0.001

Table A12. Linear Probability Model Estimates of End-of-Year Teacher Turnover

	End-of-year turnover		End-of-year mover		End-of-year leaver	
0-2 years experience	0.075***	0.073***	0.037***	0.036***	0.056***	0.055***
	(22.75)	(21.41)	(10.25)	(10.00)	(17.01)	(15.92)
3-5 years experience	0.035***	0.035***	0.014***	0.014***	0.029***	0.028***
	(13.00)	(12.22)	(6.93)	(6.78)	(11.37)	(10.82)
11-20 years experience	-0.033***	-0.033***	-0.017***	-0.016***	-0.022***	-0.022***
	(-19.84)	(-19.19)	(-12.27)	(-11.38)	(-16.46)	(-16.67)
20+ years experience	-0.004	-0.001	-0.024***	-0.022***	0.020***	0.020***
	(-0.83)	(-0.23)	(-11.27)	(-9.32)	(4.84)	(5.03)
Female	0.004*	0.003	-0.001	-0.002	0.007***	0.006***
	(2.23)	(1.33)	(-0.82)	(-1.92)	(4.35)	(3.74)
Black	-0.000	-0.003	0.006**	0.003	-0.007*	-0.008**
	(-0.02)	(-1.05)	(3.09)	(1.41)	(-2.45)	(-2.84)
Hispanic	0.023***	0.024***	0.012*	0.013*	0.016**	0.016**
	(3.92)	(3.93)	(2.32)	(2.59)	(3.19)	(3.33)
Other race	0.004	0.005	-0.003	-0.004	0.009	0.010*
	(0.52)	(0.74)	(-0.72)	(-0.96)	(1.70)	(2.26)
Alternate entry	0.019***	0.021***	0.012***	0.013***	0.010***	0.011***
	(9.78)	(11.13)	(5.62)	(6.65)	(4.69)	(5.30)
Teacher For America	0.157***	0.139***	-0.037***	-0.051***	0.241***	0.226***
	(25.45)	(16.97)	(-5.26)	(-6.16)	(39.47)	(33.19)
Out-of-state prepared	0.029***	0.028***	0.006**	0.006**	0.029***	0.028***
	(9.79)	(9.69)	(3.23)	(3.20)	(7.98)	(7.96)
Other	0.019***	0.019***	-0.004	-0.004	0.026***	0.025***
	(5.96)	(6.35)	(-1.89)	(-1.69)	(8.33)	(8.63)
< 26 years old	0.021**	0.022**	0.017**	0.017**	0.005	0.006
	(3.22)	(3.26)	(3.02)	(3.03)	(1.56)	(1.75)
26-30 years old	0.029***	0.031***	0.006*	0.008**	0.029***	0.030***
	(6.79)	(7.30)	(2.26)	(2.83)	(8.90)	(9.27)
31-40 years old	0.021***	0.021***	0.006***	0.006***	0.019***	0.019***
	(9.01)	(9.65)	(3.85)	(4.11)	(11.29)	(11.66)

51-60 years old	0.034***	0.035***	-0.006***	-0.005**	0.045***	0.046***
	(8.93)	(9.15)	(-3.62)	(-3.26)	(13.61)	(13.57)
60+ years of age	0.179***	0.181***	-0.004	-0.003	0.207***	0.209***
	(30.70)	(30.62)	(-1.45)	(-1.05)	(37.84)	(37.70)
School size (100s)	-0.004***		-0.003***		-0.001***	
	(-8.17)		(-9.35)		(-5.10)	
City	-0.007		-0.006		-0.003	
	(-1.86)		(-1.56)		(-1.23)	
Rural	-0.009*		-0.006		-0.003	
	(-2.40)		(-1.77)		(-1.54)	
Town	-0.014*		-0.009		-0.007*	
	(-2.28)		(-1.71)		(-2.17)	
Middle school	0.014***		0.011***		0.005**	
	(5.19)		(4.49)		(3.19)	
High school	0.020***		0.016***		0.009***	
	(7.30)		(7.42)		(4.63)	
% economically disadvantaged	-0.000		-0.000		-0.000	
	(-0.97)		(-0.99)		(-0.95)	
% Black students	0.001***		0.001***		0.000*	
	(5.23)		(5.95)		(2.49)	
% Hispanic students	0.000		0.000		-0.000	
	(0.31)		(0.49)		(-0.12)	
% Other race students	-0.000		-0.000		-0.000	
	(-0.66)		(-0.45)		(-1.12)	
Violent acts rate	0.000		0.000		0.000	
	(0.39)		(0.14)		(0.61)	
Suspension rate	0.000*		0.000*		0.000	
	(2.19)		(2.04)		(1.86)	
Teachers with 3 yrs experience or less	0.103***		0.081***		0.045***	
	(10.51)		(7.90)		(5.91)	
Overall performance composite	-0.001***		-0.001***		-0.000	
	(-3.69)		(-4.66)		(-1.36)	

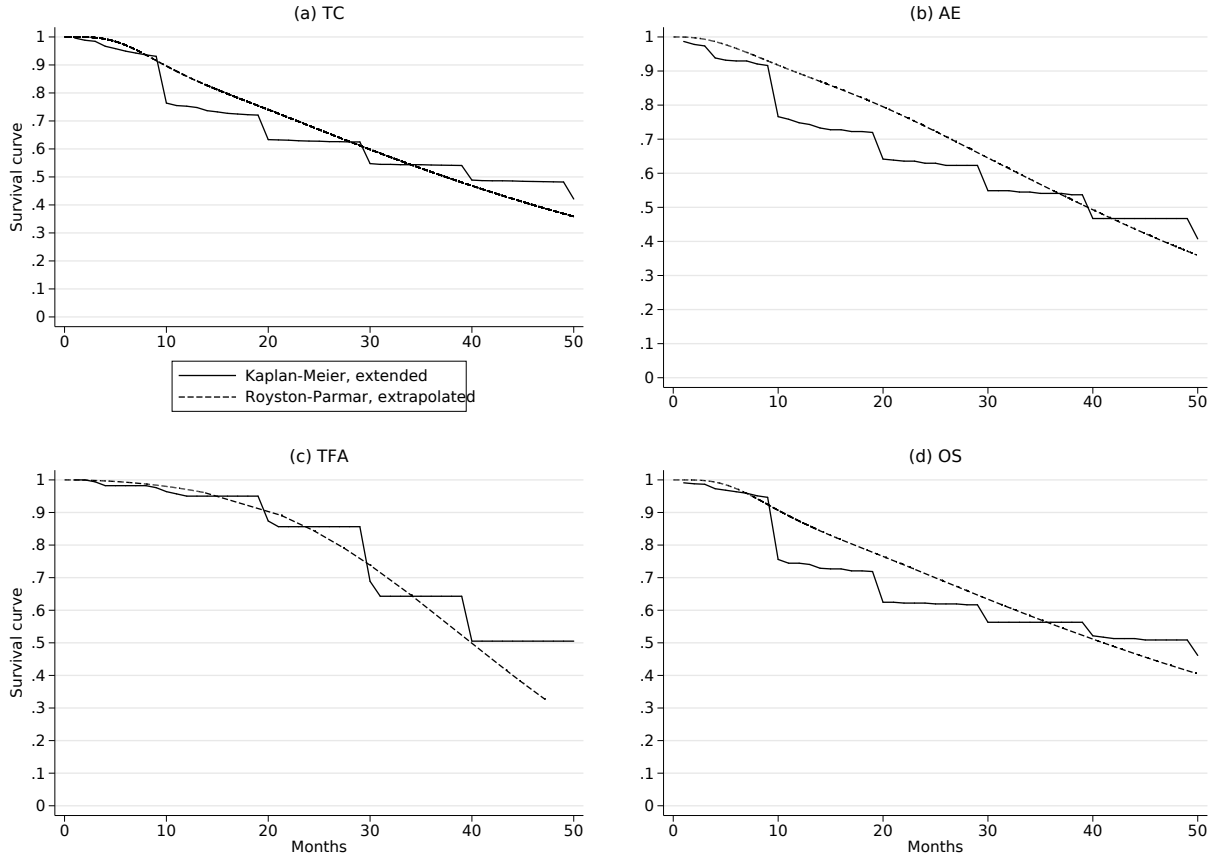
Per pupil expenditures	-0.000**		-0.000		-0.000*	
	(-2.94)		(-1.88)		(-2.17)	
Teacher salary supplement	-0.003		-0.004*		0.000	
	(-1.76)		(-2.13)		(1.12)	
Facilities and Resources (std)	-0.001		-0.001		-0.000	
	(-0.56)		(-0.71)		(-0.06)	
Distributed leadership (std)	-0.003		-0.002		-0.001	
	(-1.92)		(-1.59)		(-1.34)	
Principal leadership (std)	-0.011***		-0.009***		-0.003***	
	(-7.20)		(-6.68)		(-4.19)	
Professional development (std)	0.002		0.002		0.000	
	(1.26)		(1.24)		(0.33)	
Constant	0.141***	0.081***	0.144***	0.075***	0.012	0.007
	(6.11)	(15.86)	(7.03)	(23.93)	(1.15)	(1.76)
District fixed effect	x		x		x	
School fixed effect		x		x		x
Observations	425158	425158	391150	391150	386759	386759

Notes. Estimates include wave fixed effects. *t*-statistics reported in parentheses. * p<0.05; ** p<0.01; *** p<0.001

APPENDIX B

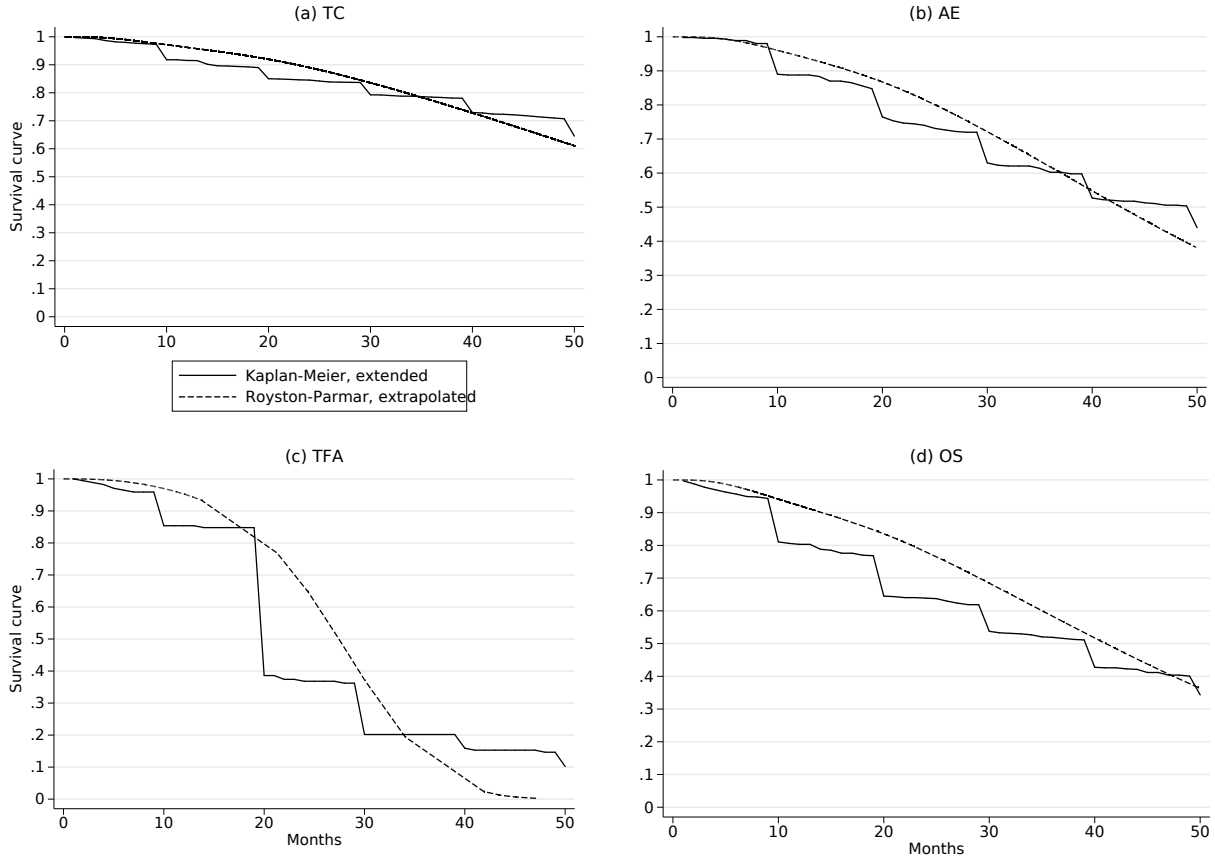
CHAPTER 3 APPENDIX

Figure A1. Out-of-sample predictions of moving schools, 2009-2010 cohort



Notes. Predictions from Royston-Parmar model based on column 4 of Table 4. Kaplan-Meier survival curve from the 2009-2010 cohort. Each school year is coded as having 10 months. TC = In-state, traditional preparation; AE = Alternate entry; TFA = Teacher For America; OS = Out-of-state prepared.

Figure A2. Out-of-sample predictions of leaving teaching in North Carolina, 2009-2010 cohort



Notes. Predictions from Royston-Parmar model based on column 4 of Table 4. Kaplan-Meier survival curve from the 2009-2010 cohort. Each school year is coded as having 10 months. TC = In-state, traditional preparation; AE = Alternate entry; TFA = Teacher For America; OS = Out-of-state prepared.

Table A1. Covariates used in Regression Analysis

Teacher Characteristics	**School Characteristics**	**School Working Conditions**
Entry Portal	School size (100s)	Distributed leadership ($\alpha = 0.86 - 0.88$)
In-state, traditional	School size	School leadership ($\alpha = 0.87 - 0.93$)
Alternate entry	School level	Facilities and resources ($\alpha = 0.84 - 0.85$)
Teacher For America	Middle school	Professional development ($\alpha = 0.79 - 0.86$)
Out-of-state prepared	High school	
Other (Visiting International Faculty; Unclassifiable)	Urbanicity	
Female	Suburb	
Race/Ethnicity	Rural	
White	Town	
Black	% Black students	
Hispanic	% Hispanic students	
Other race (Asian American Indian Multiracial	% Other race/ethnicity	
Age	Violent acts rate	
	Short-term suspension rate	
	% teachers with 3 years of experience or less	
	Overall performance composite	
	Total per-pupil expenditures ($1000s)	
	Teacher salary supplement ($1000s)	

Table A2. School Working Conditions Measures

Scale	**Survey Items**
Facilities and Resources	Teachers have sufficient access to appropriate instructional materials.
	Teachers have sufficient access to instructional technology, including computers, printers, software and internet access.
	Teachers have access to reliable communication technology, including phones, faxes and email.
	Teachers have sufficient access to office equipment and supplies such as copy machines, paper, pens, etc.
	The reliability and speed of Internet connections in this school are sufficient to support instructional practices.
	Teachers have adequate space to work productively.
	The school environment is clean and well maintained.
Distributed Leadership	Selecting instructional materials and resources
	Devising teaching techniques
	Setting grading and student assessment practices
	Determining the content of in-service professional development programs
	The selection of teachers new to this school
	Establishing student discipline procedures
	Providing input on how the school budget will be spent
	School improvement planning
School Leadership	There is an atmosphere of trust and mutual respect in this school.
	School administrators consistently enforce rules for student conduct.
	School administrators support teachers' efforts to maintain discipline in the classroom.
	The school leadership consistently supports teachers.
	The procedures for teacher evaluation are consistent.
	The faculty and staff have a shared vision.

	Teachers receive feedback that can help them improve teaching.
Professional Development	Sufficient resources are available for professional development in my school.
	An appropriate amount of time is provided for professional development.
	Teachers have sufficient training to fully utilize instructional technology.
	Professional development provides ongoing opportunities for teachers to work with colleagues to refine teaching practices.

Table A3. Conditional Means for Teacher Entry Pathways

	In-state, traditional preparation	Alternate entry	Teacher For America	Out-of-state prepared	Other entry pathway
Stayer	0.43	0.32	0.10	0.33	0.34
Within-year mover	0.08	0.08	0.03	0.06	0.09
Within-year leaver	0.05	0.09	0.06	0.10	0.15
End-of-year mover	0.31	0.24	0.16	0.24	0.22
End-of-year leaver	0.13	0.27	0.65	0.27	0.19
Female	0.82	0.64	0.78	0.78	0.74
White teacher	0.85	0.63	0.79	0.87	0.63
Black	0.10	0.28	0.13	0.06	0.16
Hispanic	0.01	0.03	0.02	0.03	0.10
Other race	0.04	0.05	0.06	0.04	0.11
Age	26.18	30.61	23.11	28.69	33.72
Suburb	0.10	0.05	0.01	0.10	0.13
City	0.31	0.33	0.57	0.42	0.39
Rural	0.47	0.47	0.35	0.35	0.40
Town	0.11	0.14	0.06	0.12	0.08
School size (100s)	7.28	8.82	7.32	7.78	7.57
Overall performance composite	74.15	70.63	62.60	73.21	73.66
% economically disadvantaged	60.00	60.95	76.72	58.67	58.75
% Black students	29.59	39.57	68.01	33.32	33.94
% Hispanic students	14.18	12.47	15.62	14.65	14.72
% Other race	7.62	8.27	6.05	8.43	7.57
Teachers with 3 yrs experience or less	0.23	0.25	0.36	0.25	0.24
Suspension rate	19.61	41.33	53.60	22.73	25.54
Violent acts rate	8.53	15.09	15.86	9.52	10.43
Per pupil expenditures	85.98	85.27	89.45	82.88	83.62
Teacher salary supplement	31.07	29.81	28.32	34.91	31.92
Elementary School	0.57	0.16	0.28	0.53	0.48
Middle School	0.18	0.27	0.34	0.25	0.22
High School	0.45	0.67	0.48	0.45	0.56
Facilities and Resources (std)	-0.06	-0.39	-0.93	-0.18	-0.17
Distributed leadership (std)	-0.13	-0.37	-0.85	-0.24	-0.28
Principal leadership (std)	-0.17	-0.47	-0.90	-0.34	-0.32
Professional development (std)	-0.03	-0.22	-0.39	-0.12	-0.10
Observations	8245	1440	502	2986	493

Table A4. Cox Survival Analysis of Turnover, Moving Schools, and Leaving Teaching in North Carolina

	Turnover		Moving		Leaving	
	(1)	(2)	(3)	(4)	(5)	(6)
Alternate entry	1.23***	1.12**	0.85**	0.79***	2.03***	1.78***
Teacher For America	1.89***	1.45***	0.50***	0.40***	5.50***	4.01***
Out-of-state prepared	1.31***	1.28***	0.86***	0.85***	2.18***	2.11***
Other	1.29***	1.24***	0.92	0.90	1.99***	1.91***
Female	0.90***	0.94*	0.98	1.00	0.85***	0.90**
Black	1.00	0.89**	1.06	0.93	0.97	0.88**
Hispanic	0.93	0.89	0.82	0.78*	1.08	1.03
Other race	0.93	0.89*	0.97	0.94	0.91	0.86*
Age	1.01***	1.01***	1.00	1.00	1.02***	1.02***
City		0.94		0.85**		1.09
Rural		0.97		0.92		1.03
Town		0.90*		0.88*		0.99
School size (100s)		0.98***		0.97***		0.98***
Overall performance composite		1.00		1.00		1.00**
% economically disadvantaged		1.00*		1.00		1.00
% Black students		1.00***		1.00***		1.00***
% Hispanic students		1.00		1.00		1.00
% Other race		1.00		1.00		1.00
Teachers with 3 yrs experience or less		0.97		0.75		1.27
Suspension rate		1.00		1.00		1.00
Violent acts rate		1.00		1.00		1.00
Per pupil expenditures		1.00		1.00		1.00
Teacher salary supplement		1.00		1.00		1.00
Middle School		1.28***		1.26***		1.28***
High School		1.59***		1.43***		1.76***
Facilities and Resources (std)		1.01		1.00		1.00
Distributed leadership (std)		0.98		0.97		0.99
Principal leadership (std)		0.94***		0.97		0.91***
Professional development (std)		0.98		0.97		1.00
Observations	253267	253267	253683	253173	306954	305822
Deviance	134281.0	133800.8	77548.8	77163.8	70619.2	69780.4

Notes. Exponentiated coefficients reported. Models stratified by cohort. Robust standard errors (not reported). * p<0.05; ** p <0.01; *** p <.001.

Table A5. Survival Analysis of Moving Schools Within the Same District or Other District

	Move Within Same District				Move to Other District			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Alternate entry	0.92	0.92	0.93	0.93	0.83**	0.74***	0.87*	0.77***
Teacher For America	1.01	0.91	1.17	0.99	0.34***	0.25***	0.37***	0.25***
Out-of-state prepared	0.97	0.94	0.99	0.95	0.82***	0.82***	0.86**	0.86**
Other	0.74	0.73	0.73	0.73	1.07	1.06	1.10	1.06
Female	0.98	0.97	0.97	0.95	0.99	1.03	0.96	1.01
Black	1.20*	1.03	1.18*	1.03	1.04	0.93	1.03	0.93
Hispanic	0.77	0.73	0.81	0.77	0.83	0.80	0.89	0.85
Other race	1.09	1.07	1.14	1.10	0.87	0.85	0.90	0.87
Age	1.02***	1.01***	1.01**	1.01*	1.00	1.00	0.99***	0.99***
City		1.25		1.19		0.70***		0.64***
Rural		1.13		1.10		0.83**		0.80***
Town		0.73*		0.77		0.86		0.87
School size (100s)		0.94***		0.94***		0.98***		0.98***
Overall performance composite		1.00		1.02***		1.00		1.02***
% economically disadvantaged		1.00*		1.01***		1.00**		1.01***
% Black students		1.00		1.00*		1.00***		1.01***
% Hispanic students		1.00		1.00		1.00		1.00*
% Other race		1.00		1.00		1.00		1.00
Teachers with 3 yrs experience or less		0.30***		0.32***		1.09		1.06
Suspension rate		1.00		1.00***		1.00		1.00
Violent acts rate		1.00		1.00		1.00		1.00
Per pupil expenditures		1.00		1.00		1.00		1.00*
Teacher salary supplement		1.01***		1.01***		1.00**		0.99***
Middle School		1.14		1.07		1.37***		1.28***
High School		1.54***		1.34***		1.59***		1.37***
Facilities and Resources (std)		0.97		0.94		1.02		0.99

Distributed leadership (std)		0.97		0.96		0.98		0.98
Principal leadership (std)		0.96		0.94		0.97		0.93*
Professional development (std)		1.02		1.04		0.95		0.97
Observations	246964	246474	290836	290100	257669	257147	268560	267684
Deviance	15533.26	15303.37	11585.1	11295.6	24863.70	24516.65	17588.1	17059.1

Notes. Coefficients from discrete time hazard model reported as odds ratios. Standard errors clustered at the teacher level. * p<0.05; ** p <0.01; *** p <.001. All models include cohort fixed effects.

Table A6. Survival Analysis of Turnover Across School Type

	Elementary School		Middle School		High School	
	(1)	(2)	(3)	(4)	(5)	(6)
Alternate entry	1.26*	1.22	1.32***	1.22*	1.10	1.16**
Teacher For America	1.93***	1.61***	2.11***	1.47***	1.84***	1.76***
Out-of-state prepared	1.39***	1.38***	1.38***	1.34***	1.32***	1.32***
Other	1.43**	1.45***	1.43*	1.36	1.56***	1.54***
Female	0.89*	0.90	0.98	0.99	1.01	0.96
Black	0.98	0.88*	1.06	0.93	0.97	0.92
Hispanic	0.97	0.96	1.22	1.10	0.85	0.84
Other race	0.85	0.84	0.80	0.76	0.84*	0.84
Age	1.02***	1.02***	1.02***	1.02***	1.03***	1.03***
City		0.89		1.01		0.91
Rural		0.92		1.03		0.90
Town		0.88		0.84		0.87
School size (100s)		1.00		0.98		0.97***
Overall performance composite		1.00		1.00		1.00
% economically disadvantaged		1.00		1.00		1.00**
% Black students		1.00*		1.01*		1.00
% Hispanic students		1.00		1.00		1.00
% Other race		1.00		1.00		1.00
Teachers with 3 yrs experience or less		0.86		1.33		0.67*
Suspension rate		1.00		1.00		1.00
Violent acts rate		1.00		1.00		1.00
Per pupil expenditures		1.00		1.00		1.00
Teacher salary supplement		1.00		1.00		1.00**
Facilities and Resources (std)		0.96		0.98		1.07*
Distributed leadership (std)		1.02		0.99		0.98
Principal leadership (std)		0.93*		0.93		0.90***
Professional development (std)		1.02		0.96		0.96
Observations	130242	130242	52718	52718	107400	107400
Deviance	25201.8	25130.1	10723.8	10664.7	27129	26992.3

Notes. Coefficients from discrete time hazard model reported as odds ratios. Standard errors clustered at the teacher level. * p<0.05; ** p <0.01; *** p <.001. All models include cohort fixed effects.

Table A7. Survival Analysis of Moving Schools Across School Type

	Elementary School		Middle School		High School	
	(1)	(2)	(3)	(4)	(5)	(6)
Alternate entry	1.07	1.03	0.85	0.77*	0.79**	0.85*
Teacher For America	0.45***	0.36***	0.39***	0.27***	0.56***	0.56***
Out-of-state prepared	0.87*	0.87*	0.84*	0.83*	0.88*	0.88*
Other	1.04	1.07	1.08	1.03	1.01	1.00
Female	0.95	0.97	0.98	0.98	1.06	0.99
Black	1.12	0.98	1.09	0.94	1.00	0.96
Hispanic	0.89	0.88	1.23	1.10	0.76	0.76
Other race	0.91	0.92	0.85	0.79	0.95	0.98
Age	1.00	1.00	1.02***	1.02***	1.01***	1.01*
City		0.82*		1.06		0.74***
Rural		0.89		1.07		0.77***
Town		0.86		0.94		0.78*
School size (100s)		0.98		1.00		0.96***
Overall performance composite		1.00		1.00		1.00
% economically disadvantaged		1.00		1.00		1.00
% Black students		1.00**		1.01*		1.00
% Hispanic students		1.00		1.00		1.00
% Other race		0.99		1.01*		1.00
Teachers with 3 yrs experience or less		0.68		0.66		0.56*
Suspension rate		1.00		1.00		1.00
Violent acts rate		1.00		1.00		1.00
Per pupil expenditures		1.00		1.00		1.00
Teacher salary supplement		1.00		1.00		1.01**
Facilities and Resources (std)		0.97		0.95		1.06
Distributed leadership (std)		1.02		0.95		0.99
Principal leadership (std)		0.94		1.01		0.93
Professional development (std)		1.01		0.97		0.94
Observations	130450	130242	52758	52718	107684	107400
Deviance	17944.4	17825.8	6942.5	6896.9	17183.8	17033

Notes. Coefficients from discrete time hazard model reported as odds ratios. Standard errors clustered at the teacher level. * p<0.05; ** p <0.01; *** p <.001. All models include cohort fixed effects.

Table A8. Survival Analysis of Leaving Teaching Across School Type

	Elementary School		Middle School		High School	
	(1)	(2)	(3)	(4)	(5)	(6)
Alternate entry	1.72***	1.68***	2.25***	2.17***	1.60***	1.62***
Teacher For America	6.05***	5.37***	6.19***	4.52***	4.25***	3.61***
Out-of-state prepared	2.35***	2.29***	2.42***	2.33***	1.96***	1.94***
Other	2.08***	2.04***	2.09***	1.98***	2.27***	2.25***
Female	0.85*	0.86*	1.02	1.01	0.95	0.92
Black	0.81*	0.76**	1.04	0.94	1.00	0.91
Hispanic	1.10	1.09	1.12	1.03	1.01	0.98
Other race	0.81	0.79	0.85	0.83	0.80*	0.76*
Age	1.03***	1.03***	1.02***	1.02**	1.04***	1.04***
City		1.01		0.99		1.19
Rural		0.91		0.95		1.09
Town		0.94		0.77		1.08
School size (100s)		1.01		0.97		0.98**
Overall performance composite		1.00		1.00		1.00
% economically disadvantaged		1.00		1.00		1.00
% Black students		1.00		1.00		1.00
% Hispanic students		1.00		0.99		1.00
% Other race		1.00		0.99*		1.01
Teachers with 3 yrs experience or less		1.31		1.79		0.96
Suspension rate		1.00		1.00		1.00*
Violent acts rate		1.00		1.00		1.00
Per pupil expenditures		1.00		1.00		1.00
Teacher salary supplement		1.00		1.00		1.00
Facilities and Resources (std)		0.96		1.02		1.06
Distributed leadership (std)		1.01		1.05		0.97
Principal leadership (std)		0.94		0.84**		0.88***
Professional development (std)		1.04		0.98		1.00
Observations	159055	158684	64586	64520	131402	130652
Deviance	15461	15391	7712.1	7660.8	19479.1	19262.1

Notes. Coefficients from discrete time hazard model reported as odds ratios. Standard errors clustered at the teacher level. * p<0.05; ** p <0.01; *** p <.001. All models include cohort fixed effects.

Table A9. Survival Analysis of Temporary Exit and Return

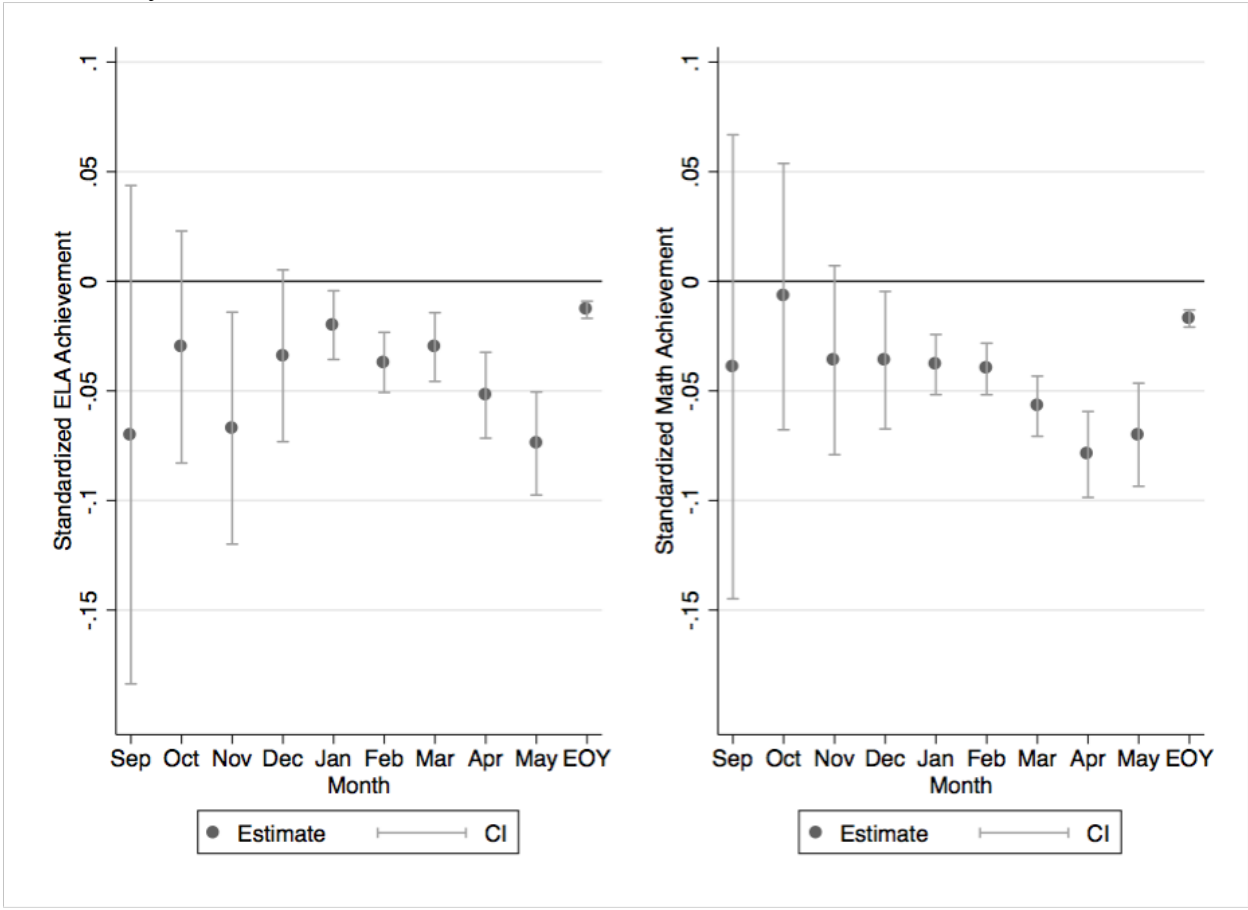
	(1)	(2)	(3)	(4)
Alternate entry	0.88	0.90	0.90	0.92
Teacher For America	0.27**	0.43	0.35*	0.48
Out-of-state prepared	0.94	1.03	0.93	1.00
Other	1.24	1.12	1.20	1.08
Female	1.46**	1.46**	1.51***	1.48**
Black	1.00	1.26	1.05	1.22
Hispanic	0.78	0.80	0.95	0.99
Other race	0.68	0.84	0.76	0.89
Age	1.08***	1.07***	1.06***	1.05***
City		1.09		1.03
Rural		0.85		0.76
Town		0.69		0.77
School size (100s)		0.97*		0.97*
Overall performance composite		0.99		1.00
% economically disadvantaged		1.01**		1.01**
% Black students		0.99**		0.99**
% Hispanic students		1.00		1.00
% Other race		0.99		0.99
Teachers with 3 yrs experience or less		0.21**		0.27**
Suspension rate		1.00		1.00
Violent acts rate		1.00		1.00
Per pupil expenditures		1.00		1.00
Teacher salary supplement		1.00		1.00
Middle School		1.41*		1.31*
High School		4.85***		3.63***
Facilities and Resources (std)		1.13		1.02
Distributed leadership (std)		0.89		0.90
Principal leadership (std)		1.25*		1.22*
Professional development (std)		0.90		0.92
Observations	306954	305822	302505	301385
Deviance	8264.21	7853.52	5294.41	5039.68

Notes. Discrete time models (columns 1-2) estimated using logistic regression. Coefficients reported as odds ratios. Standard errors clustered at the teacher level. Royston-Parmar models (columns 3-4) estimated with 2 knots. * p<0.05; ** p <0.01; *** p <.001. All models include cohort fixed effects.

APPENDIX C

CHAPTER 4 APPENDIX

Figure A1. Effect of Within-Year Classroom Teacher Turnover on Student Achievement in ELA and Math by Month of Turnover



Notes. Estimates from student-by-school fixed effect model (columns 2 and 4 of Table 6). EOY = End of Year.

Table A1. Covariates used in Regression Analysis

Student Characteristics	**School Characteristics**
Prior test scores	Student enrollment
Classmates' prior test scores	Total per-pupil expenditures
Gender	Teacher salary supplement
Race/ethnicity	Racial/ethnic composition
Poverty status	Concentration of poverty
Gifted	Violent acts per 1,000 students
Disability	Short-term suspension rate
Currently limited English proficient	% teachers with 3 years experience or less
Previously limited English proficient	
Structural mobility	
Within year mobility	
Between year mobility	
Days absent	
Overage for grade	
Underage for grade	

Table A2. Estimates of the Effect of October-to-October Grade-Level Turnover on Student Achievement in ELA

	(1)	(2)	(3)	(4)	(5)	(6)
October-to-October grade-level turnover	-0.011	-0.008	-0.038***	-0.036***	-0.024***	-0.022***
	(0.006)	(0.006)	(0.008)	(0.008)	(0.005)	(0.005)
Within-year classroom teacher turnover		-0.054***		-0.051***		-0.034***
		(0.007)		(0.007)		(0.004)
School-by-Grade FE	x	x				
School-by-Year FE			x	x		
School-by-Student FE					x	x
Observations	2275162	2275162	2275162	2275162	2275162	2275162
R^2	0.64	0.64	0.64	0.64	0.00	0.00

Notes. Models include student controls, school controls, and year fixed effects. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A3. Estimates of the Effect of October-to-October Grade-Level Turnover on Student Achievement in Math

	(1)	(2)	(3)	(4)	(5)	(6)
October-to-October grade-level turnover	-0.021*	-0.016	-0.053***	-0.049***	-0.019***	-0.017***
	(0.009)	(0.009)	(0.012)	(0.012)	(0.005)	(0.005)
Within-year classroom teacher turnover		-0.105***		-0.099***		-0.041***
		(0.010)		(0.009)		(0.004)
School-by-Year FE	x	x				
School-by-Grade FE			x	x		
School-by-Student FE					x	x
Observations	1815227	1815227	1815227	1815227	1815227	1815227
R^2	0.67	0.67	0.67	0.67	0.00	0.00

Notes. Models include student controls, school controls, and year fixed effects. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A4. Estimates of the Effect of End-of-Year Grade-Level Turnover on Student Achievement

	ELA		Math	
	(1)	(2)	(3)	(4)
End-of-year grade-level turnover	0.023**	0.010*	0.025*	0.024***
	(0.008)	(0.005)	(0.012)	(0.005)
School-by-Year FE	x		x	
Student-by-School FE		x		x
Observations	2231725	2231725	1852715	1852715
R^2	0.65	0.00	0.68	0.00

Notes. Models include student controls, school controls, and year fixed effects. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A5. Estimates of the Effect of Within-Year Grade-Level Turnover on Student Achievement

	ELA		Math	
	(1)	(2)	(3)	(4)
Within-year grade-level turnover	-0.070***	-0.082***	-0.086**	-0.073***
	(0.020)	(0.014)	(0.031)	(0.013)
School-by-Year FE	x		x	
Student-by-School FE		x		x
Observations	2235679	2235679	1855419	1855419
R^2	0.65	0.00	0.68	0.00

Notes. Models include student controls, school controls, and year fixed effects. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A6. Estimates of the Effect of Within-Year Classroom Teacher Turnover on Student Achievement

Panel A. Student Achievement in ELA

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Within-year classroom teacher turnover	-0.037***	-0.030***	-0.030***	-0.039***	-0.038***	-0.033***	-0.033***	-0.049***
	(0.004)	(0.004)	(0.004)	(0.006)	(0.004)	(0.004)	(0.004)	(0.006)
Within-year grade turnover		-0.050***	-0.050***	-0.054***		-0.041***	-0.041***	-0.049***
		(0.009)	(0.009)	(0.010)		(0.011)	(0.011)	(0.012)
End-of-year grade turnover			0.001				0.005	
			(0.003)				(0.005)	
Within-year classroom teacher turnover * Within-year grade turnover				0.045				0.080**
				(0.028)				(0.028)
Student FE	x	x	x	x				
Student-by-School FE					x	x	x	x
Observations	2499127	2499127	2495173	2499127	2499127	2499127	2495173	2499127
R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Panel B. Student Achievement in Mathematics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Within-year classroom teacher turnover	-0.067***	-0.057***	-0.057***	-0.058***	-0.044***	-0.038***	-0.039***	-0.038***
	(0.004)	(0.004)	(0.004)	(0.006)	(0.003)	(0.003)	(0.003)	(0.005)
Within-year grade turnover		-0.076***	-0.076***	-0.076***		-0.055***	-0.054***	-0.055***
		(0.009)	(0.009)	(0.009)		(0.010)	(0.010)	(0.011)
End-of-year grade turnover			0.015***				0.020***	
			(0.003)				(0.004)	
Within-year classroom teacher turnover * Within-year grade turnover				0.007				-0.000
				(0.025)				(0.025)
Student FE	x	x	x	x				
Student-by-School FE					x	x	x	x
Observations	2053975	2053975	2051271	2053975	2053975	2053975	2051271	2053975
R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes. Models include school controls and year fixed effects. Standard errors in parentheses. Within-year grade turnover is the measure used in Tables 3, not adjusting for the teacher who left midyear. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A7. Sensitivity of within-year teacher turnover estimates to sample size restriction when controlling for teacher value-added

	ELA				Math			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Within-year classroom teacher turnover	-0.216*	-0.218*	0.001	0.000	-0.118	-0.123	0.000	0.000
	(0.089)	(0.088)	(0.001)	(0.000)	(0.091)	(0.092)	(0.000)	(.)
Teacher value-added	x		x		x		x	
Student FE	x	x			x	x		
Student-by-School FE			x	x			x	x
Observations	386713	386713	386713	386713	324927	324927	324927	324927
R^2	0.01	0.01	0.13	0.13	0.02	0.02	0.12	0.12

Table A8. Balance Test for Select Student and School Characteristics Between Full Sample and Value-Added Sample

	Full Sample	VAM Sample
ELA test (std)	0.00	0.06***
Math test (std)	0.02	0.09***
Days absent	5.91	6.24***
Between-year mobility	0.10	0.10
Within-year mobility	0.05	0.04***
Underage for grade	0.01	0.01**
Overage for grade	0.20	0.19***
Gifted status	0.16	0.20***
Disability status	0.13	0.11***
Free lunch	0.46	0.46
Reduced lunch	0.08	0.07***
Black student	0.25	0.24***
Hispanic student	0.13	0.13
Multiracial student	0.04	0.04
American Indian student	0.01	0.01***
Male student	0.50	0.50***
Currently LEP	0.07	0.06***
Formerly LEP	0.05	0.06***
School size (100s)	5.81	5.81
Suspension rate	6.87	6.24***
Violent acts rate	2.43	2.45
% Black students	24.81	23.21***
% Hispanic students	14.36	14.48
% Asian students	2.65	2.73
% multiracial students	4.15	4.19
% American Indian students	1.48	0.97***
Teacher salary supplement	32.64	31.96**
Per pupil expenditures	85.24	86.48***
City	0.30	0.30
Rural	0.46	0.46
Town	0.10	0.10
Observations	2495903	386068

Notes. *t*-test to test for significant differences adjusts for school-level clustering.

Table A9. Estimates of the Effect of Moving Schools and Leaving Teaching Within the School Year

	ELA		Mathematics		ELA		Mathematics	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Within-year moving	-0.036***	-0.032***	-0.074***	-0.050***				
	(0.008)	(0.007)	(0.008)	(0.007)				
Within-year leaving					-0.037***	-0.040***	-0.063***	-0.042***
					(0.005)	(0.004)	(0.004)	(0.004)
Student FE	x		x		x		x	
Student-by-School FE		x		x		x		x
Observations	2499127	2499127	2053975	2053975	2499127	2499127	2053975	2053975
R^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes. Models include school controls and year fixed effects. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$