The Productivity Costs of Inefficient Hiring Practices: Evidence from Late Teacher Hiring

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Abstract

We use matched employee-employer records from the teacher labor market to explore the trade-offs between the timing of hiring and match quality. Hiring teachers after the school year starts reduces student achievement by 0.042SD in mathematics and 0.026SD in reading. This reflects, in part, a temporary disruption effect in the first year. In mathematics, but not in reading, late-hired teachers remain persistently less effective, evidence of negative selection in the teacher labor market. Late hiring concentrates in schools that disproportionately serve disadvantaged student populations, contributing to challenges in ensuring an equitable distribution of educational resources across students.

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The Productivity Costs of Inefficient Hiring Practices:

Evidence from Late Teacher Hiring

Effective human resource management policies are essential to the success of organizations in all sectors of the economy. Each stage of the human capital pipeline -- attracting, selecting, developing and retaining talent -- is an opportunity for organizations to strengthen the quality of their workforces. Despite this importance, the process by which workers are hired has been relatively understudied, particularly from the demand-side perspective and from the perspective of individual employers (Oyer & Schaefer, 2011). While economists and others have developed and refined theoretical models of hiring, the empirical work on the hiring process is rather limited (e.g., Mortensen & Pissarides, 1999; Oyer & Schaefer, 2011). This limited attention on the hiring process is problematic give that, as Oyer and Schaefer note, "hiring the right employee is potentially as important or more so than motivating the employee to take the right action after the employee has been hired" (2011, p. 1772). The hiring process takes on even greater importance in the public sector, where organizations are typically not at-will employers and employees often enjoy greater job protections (Gregory & Borland, 1999).

In public education, as with organizations in much of the public sector, scholars have devoted relatively little attention to the processes by which teachers are hired (Jacob, 2007; Staiger & Rockoff, 2010), despite mounting evidence of the importance of hiring and match quality in improving productivity (Jackson, 2013; Boyd, Lankford, Loeb, & Wyckoff, 2013; Engel & Jacob, 2011). The enormous size of the education workforce, with almost 3.5 million primary and secondary school teachers, requires that policymakers and school administrators

expend considerable resources trying to staff their schools effectively. And, these are costly decisions, with annual spending on teacher salaries and benefits alone approaching $300 billion nationwide (NCES, 2011). However, many school districts begin the year without a full-time teacher in every classroom (Levin & Quinn, 2003; Engel, 2012). The effects of these search delays on productivity have not been examined.

In this paper, we use matched employee-employer records in the teacher labor market with individual-level data on the timing of teacher hires to examine the effect of late teacher hiring on teachers and students. Importantly, the teaching workforce is one of the few professional sectors of the economy in which researchers can examine arguably direct measures of employee productivity (teachers' contributions to student test scores).[1] This sector provides an interesting example of the effects of hiring practices in an industry with clear seasonality in hiring, employers (schools) that coordinate efforts within a broader school district, and external constraints in making job offers, such as bureaucratic barriers and district policies that limit school hiring processes. As such, lessons concerning teacher hiring have implications for other public sector employers and other industries more broadly.

We present the first empirical evidence concerning the effect of teacher hiring delays on productivity, as measured by student achievement tests. We disentangle two potential mechanisms that influence how delayed hiring affects students. First, we examine how the timing of hiring is related to the effectiveness of the teachers schools are able to hire. We call the net effect of delays on the quality of job candidates (or the quality of the search process itself) the "labor market effect" of late hiring. Second, hiring delays mean that classrooms are not staffed by a permanent teacher by the start of the year. Students in these classrooms may be

[1] Clearly, the ability to raise student test scores is only one goal of schools and thus does not reflect the total productivity of an individual teacher. However, it is useful here as an observable measure of at least part of the teacher's contribution to the school.

taught by temporary or substitute teachers, and when permanent teachers enter the classroom late they may face added challenges in creating a successful instructional environment. These temporary effects of delayed hiring, which we term "disruption effects," may reduce student achievement, but only in that first year when the teacher arrives late. Finally, we examine the effect of hiring delays on teacher retention, where similar considerations exist. Additional search may reduce mobility by producing stronger matches (Jackson, 2013), but hiring delays may also lead schools to select from a more limited labor pool that results in worse match quality and may lead teachers to struggle in their first year, thereby increasing turnover.

We find that late hiring has serious consequences for student achievement. Students in classrooms with teachers hired after the start of the school year do substantially worse than their peers with other newly hired teachers (0.042 SD in mathematics, 0.026 SD in reading). A substantial part of this effect comes from temporary disruptions that affect teachers and students in the year when a teacher is hired late. In mathematics, but not in reading, we also find evidence of a negative labor market effect. These results suggest that schools that hire late lose stronger candidates in mathematics, where the labor supply is more constrained (Jacob, 2007). Finally, we find that teachers who are hired late leave their schools, and the district, at much greater rates than their peers who are hired on-time, which may have negative spillovers on other teachers and students in the school (Ronfeldt, Loeb, & Wyckoff, 2013). Thus, delayed hiring prevents schools from hiring, supporting, and retaining effective teachers.

In the following section, we provide theoretical background and describe past research on hiring, with a focus on the attributes of the teacher labor market. We then describe our data, sample, and empirical approach. Next, we describe the prevalence, characteristics, and distribution of late-hired teachers, and present our findings on achievement effects and retention

patterns. We conclude by discussing the implications of our results for research on hiring practices and for policymakers seeking to raise teacher quality in urban schools.

I. LITERATURE

A. Economic Models of Hiring

Economic models of hiring provide important insight into the trade-offs that schools face when hiring prospective teachers. As in the private sector, public employers and employees – including schools and prospective teachers – face bilateral asymmetric information about job characteristics and employee quality. Additional search, on either the extensive or intensive margin, may improve match quality and enable schools to hire teachers who will be more productive. Evidence suggests that better match quality between schools and teachers can raise student achievement (Jackson, 2013).

Economic models suggest several empirical predictions about the effects of late hiring on student achievement. The large differences in effectiveness across individual teachers (Rockoff, 2004; Chetty, Friedman & Rockoff, 2014) present potentially large payoffs to schools that are able to identify stronger applicants. However, schools and teachers also face important costs in hiring. From the firm's perspective, the cost function is complex for several reasons: (1) conducting a more intensive or extensive search imposes direct costs (Oyer & Schaefer, 2011; Barron, Bishop, & Dunkelberg, 1985); (2) having unfilled vacancies leads to potential lost productivity (e.g., Brencic, 2010), producing non-linearities in the cost function; and (3) delaying hiring may lead firms to lose strong candidates who take positions with other firms (Rogerson, Shimer, & Wright, 2005; Mortensen & Pissarides, 1999).

Delayed hiring timelines can thus contribute both to the extra financial costs of additional search and to the potential negative consequences that hiring delays have for student achievement. For example, competitive search models note that, as firms and employees in the same labor market compete over applicants and vacancies, firms lose potential candidates and employees lose potential jobs over time as offers are made and accepted (Rogerson, Shimer, & Wright, 2005). In other words, schools may lose their preferred candidates to other schools (or professions) if they do not hire on time. This issue may be particularly salient in the teacher labor market, as schools with vacancies in a region are seeking to hire from a (relatively) fixed pool of applicants, while candidates are seeking to be hired into a (relatively) fixed pool of positions. Furthermore, vacancies – which occur when schools are not fully staffed at the start of the year – may lead to lost opportunities to promote student learning. Schools' cost functions are decidedly non-linear over time, as there are substantial jumps in costs from lost productivity for teachers hired after the start of the school year. In this regard, all else equal, hiring a teacher after the start of the school year instead of hiring the same teacher over the summer should reduce student achievement.

Many of these costs accrue even if a school is not actively engaged in search, but simply has delayed the start of its search process for any reason, including bureaucratic barriers. In other words, while the competitive search model tends to imply that firms make intentional choices, weighing the marginal benefits and costs of additional search, similar trade-offs occur even when the delays reflect external constraints.

B. Key Features of the Teacher Labor Market

Much of the scholarly literature on teacher hiring has focused on identifying observable teacher characteristics that are predictive of future performance in the classroom (Wayne &

Youngs, 2003; Ladd, & Vigdor, 2007; Kane, Rockoff, & Staiger, 2008; Rockoff, Jacob, Kane, & Staiger, 2011; Hill, Chen & Staiger, 2015). These studies, on the whole, find few individual characteristics that are strong predictors of teachers' effects on student outcomes or persistence in the profession. However, recent studies point to the potential of intensive candidate screening processes as methods of improving the teacher selection process (Goldhaber, Grout, Huntington-Klein, 2014; Jacob et al. 2015).

There are several key features of the teacher labor market that constrain schools' abilities to control the timing and scope of their search and selection processes. First, there is a distinct seasonality to teacher hiring, as most districts begin their school years at approximately the same time. In many industries, firms face non-linear increases in costs when vacancies arise because of lost productivity. In the teacher labor market, though, the effect of these vacancies begins to bind at approximately the same time across the entire market. Thus, the competition for remaining qualified candidates intensifies near the start of the school year.

Second, competition for teachers is not strictly among firms, per se, because schools are organized into districts. District-level Human Resource staff often coordinate hiring district-wide. Thus, schools in the same district are both in competition for teaching candidates and face important constraints to that competition because the district has interests in how teachers are allocated across schools. In addition, schools in the same district are subject to a formal, internal teacher transfer process, whereby teachers can leave positions in one school to enter another school (Boyd et al., 2011; Grissom, Loeb, & Nakashima, 2014). In other words, the nature of competition across districts is quite different from that of schools in the same district.

Third, unlike firms that can post positions when they know (or foresee) vacancies will arise, the timing of teacher hiring is constrained by several structural barriers. School budgets are

often beholden to potentially slow-moving political processes at the state and local levels. Budget approvals tend to happen later in the year for large, urban districts because they rely on greater levels of state funding and a more complex political process (Levin & Quinn, 2003). These late budget approvals delay the hiring calendar for urban districts compared to neighboring suburban schools that often compete for the same pool of teachers. Furthermore, urban schools are much more likely to have highly mobile populations and to have larger proportions of immigrant students (Ashby, 2010). As a result, these districts have greater difficulties predicting enrollment and staffing needs. Schools cannot hire in the summer for positions that they are unsure will be needed in the fall. These structural barriers produce delays in hiring that are not related to schools' decisions to conduct additional search for candidates.

Fourth, district policies also contribute to hiring delays, as many districts permit teachers to notify their schools late in the spring if they plan to leave or transfer schools and give transferring teachers first priority to choose a position before a search can be opened to the external candidate pool (Levin, Mulhern, & Schunck, 2005). Similarly, teachers are often allowed to announce their retirements after the end of the school year, leaving districts scrambling to find a replacement (Levin & Quinn, 2003). In some districts, schools are required to hire qualified tenured teachers from the "excess pool" before they can post open job positions. Some principals likely have more success navigating the hiring process, and the bureaucratic procedures entailed in it, than others. For example, some administrators may use late hiring strategically in an attempt to subvert district policies and staff their schools with the teachers they want. While collective bargaining is often blamed for some of these challenges, districts in states that prohibit bargaining, such as the one we describe in this study, also struggle to hire teachers on time for similar reasons.

C. The Effects of Late Hiring

In the teacher labor market, late hiring is widespread; estimates suggest that anywhere from 11 to 30 percent of newly hired teachers are hired after the start of the school year (Engel, 2012; Jones, Maier, & Grogan, 2011; Liu & Johnson, 2006). Some schools have particular difficulty attracting qualified applicants for hard-to-staff positions, such as mathematics, science, and special education (Jacob, 2007; Levin, 1985; Podgursky, Monroe, & Watson, 2004), causing positions to remain unfilled as the school year begins. Urban districts and those serving large proportions of low-income students struggle the most to fulfill their staffing needs on time. Nationally, urban and low-income districts hire almost twice as many teachers after the beginning of the school year compared to their wealthier suburban counterparts (Engel, 2012). Challenging working conditions that tend to exist in high-poverty urban schools exacerbate these difficulties. For example, several recent studies have shown that teachers are more likely to plan to leave schools that have poor working conditions, such as unsupportive principals or ineffective colleagues (Ladd, 2011; Boyd et al., 2011; Author, 2012).

Hiring teachers after the start of the school year has potential short-term and long-term implications for student achievement. When teachers are hired late, they have less time over the summer to learn new curricula, develop unit and lesson plans, design activities, and learn school and district operations—all of which may limit their effectiveness in their first year. Late-hired teachers must juggle all of these tasks while they are teaching. Late hiring can also disrupt student learning early in the year. When teachers are hired after the start of the school year, they take over either a class taught by an interim teacher or a newly formed class created because of inaccurate enrollment projections. This instability at the start of the year may limit students' learning during the first few weeks of school before a permanent teacher is hired. Late-hired

teachers then face the additional challenge of establishing or re-establishing classroom norms and procedures and developing relationships with students partway through the year. While we cannot disentangle the relative contributions of these different disruptive factors, all are temporary and affect students only when their permanent teacher arrives after the start of the school year. We characterize the joint effect of these temporary impacts of late hiring as "disruption effects."

In addition, late hiring may have other, more permanent, effects on a schools' workforce. Given the competition across districts and between schools in the same district for a relatively fixed labor supply with seasonal vacancies occurring at roughly the same time across the market, hiring delays can lead districts to face a negatively selected labor market pool as applicants, particularly those with the strongest credentials, have already taken positions elsewhere. The limited literature on this topic is mixed, as Levin and Quinn (2003) find that many highly qualified applicants withdrew from the application process in the urban districts they studied because of hiring delays, while Engel (2012) finds no differences in the certification, college competitiveness, or advanced degree status of teachers hired on-time and those hired late. These observable characteristics, however, are only weakly correlated with effectiveness (Rockoff et al., 2011). Furthermore, late hiring is often "rushed" and "information poor" (Liu & Johnson, 2006), which may lead schools to select less effective candidates. Rutledge et al. (2008) find that when principals hire teachers late, they typically are focused on filling positions rather than undergoing a through process to evaluate a candidate's potential. Unlike past studies, we use direct measures of the effect of hiring on student outcomes to determine whether late hiring causes districts to hire less effective teachers. We call the effect of delays on the underlying effectiveness of teachers hired "labor market effects."

Finally, late hiring can affect student achievement through indirect spillovers on other students and teachers in the school. One primary spillover effect comes through increased teacher turnover, as hiring processes can affect teachers' decisions to stay in their schools and the profession. By forcing districts to hire rapidly, late hiring timelines may produce worse job matches (Liu & Johnson, 2006), thus increasing turnover. Match quality clearly affects teacher productivity, which in turn influences career decisions (Jackson, 2013; Johnson & Birkeland, 2003). Jones, Maier and Grogan (2011) find that, in Michigan, late hires were eight percentage points more likely to leave teaching and nine percentage points more likely to switch schools than on-time hires. Using data from New York City, Ronfeldt, Loeb, and Wyckoff (2013) document that such instability reduces student achievement when teachers leave a school.

We present the first estimates of the direct impact of late hiring on students' academic achievement. Furthermore, we seek to shed light on the trade-off that schools face in searching, exploring two explanations for the productivity effects of late hiring on student achievement – labor market effects and disruption effects. Finally, we examine broader consequences of late hiring on student achievement, including spillover effects that occur from increased teacher turnover.

II. STUDY METHODS

A. Dataset and Sample

We use a comprehensive administrative dataset from a large, urban school district in the southern United States that includes student, teacher, and test records from the 1999-2000 to the 2009-2010 school years. This district has over 130,000 students and nearly 9,000 teachers. Student data include demographic information, teacher identifiers for each subject, and annual state test results in reading and mathematics.

During the period we studied, the district was growing rapidly, hiring hundreds of teachers annually. The district used a hybrid model of teacher hiring, in which potential candidates could apply directly to individual schools or to the central office. Any candidates who applied to the central office were referred to schools that appeared to be good matches. School principals had much say over hiring decisions, but all candidates had to submit an official application to the central office before a formal offer could be extended. Thus, schools were not able to hire independently, the district had a role in the distribution of candidates and offers across schools, and hiring delays could occur at several points during the hiring process. The district also competed for teachers with schools outside of the district, but we only observe within-district hiring.

We use two different samples of teachers, one for our descriptive analyses and one for our analyses of late hiring's effect on student achievement. For our descriptive analyses, including our estimates of the effect of late hiring on teacher retention, we examine all teachers in the district. We define teachers as those who are listed in the human resources data files as being classroom teachers and who are linked to students as the teacher of record in a class. Here, we include more than 10,000 unique teachers over the 10-year panel.

For our central analyses that examine the effects of late hiring on student achievement, we focus on teachers in grades four through eight in mathematics and English language arts (ELA). We use several different specifications for our models, but most require students to have test data in at least two years; as a result, we drop all students with only one year of data. We further exclude from these analyses any students in atypically small classes or in substantially

separate special education classes.[2] Our final dataset for the student achievement analysis includes more than 300,000 student-year records, representing almost 4,000 unique teachers.

We present student and teacher characteristics in these two samples in Table 1. Overall, the students are broadly representative of those in urban school districts across the country: 43% are African-American, 38% are White, and 10% are Hispanic, 10% have limited English proficiency, and 10% enroll in special educational services. Our achievement sample is somewhat higher performing than the overall sample and has somewhat fewer students with limited English proficiency and in special education, but otherwise looks similar in observable characteristics. Teachers are also broadly similar across these two samples, although (as expected) more teachers in the achievement sample are licensed in mathematics or ELA.

B. Measures

Our key predictor measures whether a teacher was hired into the district late, after the school year began. We focus on a teacher's first time hired into the district, not into a specific school, as teachers transfer within the district from school to school. The district administrative data include the date on which each teacher began work, not the date on which they were offered the position.[3] Not surprisingly, more than 70% of all newly hired teachers start work on a single date in mid-to-late August, which is the first day of school for teachers. We categorize all teachers into three mutually exclusive groups: "on-time" hires, "late" hires, and "other" hires.

[2] Specifically, we exclude any teacher-year in which fewer than five students have baseline and outcome test scores. We exclude any class with more than 90% of students in special education. Doing so eliminates 2.3% of the sample in mathematics and 3.3% in reading.

[3] As a result, we cannot distinguish between the effectiveness of teachers hired early in the summer or late in the summer. Furthermore, the data do not include hire dates for teachers in 2002. For teachers hired in 2002, we use their hire date reported in the 2003 data instead. Of course, we cannot examine teachers who entered the district in 2002 and only stayed for one year. We only have data on the date on which a teacher was hired into the district, not on dates of transfers between schools within the district.

We define on-time hires as teachers who have start dates between June 1 and this start-of-school date, while we define late hires as teachers who begin in the fall after school begins.[4] For teachers hired in 1999 or later, 84% fall into one of these two groups. We define all other teachers as "other" hires; we focus our analysis on the comparison between teachers hired late and those hired on-time.[5] We code a time-invariant indicator ($EVER\_LATE_j$) to indicate whether a teacher was initially hired into the district late and a predictor ($NEWHIRE_{jt}$) to indicate whether the teacher was newly hired in the district in a given year.

Our student-level records include student scores on the state tests in mathematics and reading, which serve as the outcomes in most of our analyses. These tests are the main assessments used in the state accountability system, so they carry high stakes for schools but not for students. We standardize these test scores by grade and year to have a mean of zero and a standard deviation of one in the district. Thus, our estimates can be interpreted as standard deviation differences in student performance.

For our analyses of teacher turnover, we focus on two main outcomes, whether the teacher was no longer teaching in the district after a given year and whether the teacher left their

[4] More specifically, we define late-hired teachers as those hired after the first week of the school year in order to avoid any issues of misclassification of teachers who may not complete their paperwork on the first day. Again, teachers whose formal hire date is in August may in fact have been offered the position in the spring, before June 1. We do not include teachers whose formal hire date falls between January 1 and June 1 as late hires because these teachers are more likely mid-semester replacements for teachers who leave (e.g., for maternity leave) rather than true "late hires" who fill positions that were vacant at the start of the school year. We test the sensitivity of our results to these definitions and our findings are quite consistent regardless of the definition used.

[5] The "other" category includes four sets of teachers: those hired in the first week of school, those with hire dates in the spring (from January 1 to June 1), those teachers hired before 1999, and all teachers who have missing hire dates. We include dummy variables for these "other" teachers to include them – and their students – in our analyses that examine student achievement. All of the contrasts that we present in the text are between "late" and "on-time" hires defined above.

school but remained teaching in the district after that year. We focus on the first time a teacher transfers within the district.[6] We censor teachers from the dataset in years after the event occurs.

C. Data-Analytic Approach: Student Achievement

For our student achievement analysis, our primary results derive from a model that exploits variation within-students over time and across teachers within each grade in a given school and year. We include student fixed effects (δ_i) to account for any time-invariant differences across the groups of students who are assigned to teachers hired late or on-time and school-by-grade-by-year fixed effects (θ_{sgt}) to control for the non-random sorting of students or teachers to schools and any cohort effects. Thus, we hope to isolate the effect of the timing of teacher hiring on student achievement. We fit different specifications of the following model:

$$(1) \quad \begin{aligned} Y_{it} &= \beta_1 EVER\_LATE_j + \beta_2 NEWHIRE_{jt} + \beta_3 EVER\_LATExNEWHIRE_{jt} \\ &+ \gamma[f(EXPER_{jt})] + \overline{X_{jt}}'\varsigma + \delta_i + \theta_{sgt} + \varepsilon_{it} \end{aligned}$$

for student *i* with teacher *j* in grade *g*, school *s*, and year *t*.[7] In addition to the predictors described above, we include a vector of teacher-year-level means ($\overline{X}_{jt}$) of students' prior-year test scores and other demographic characteristics to account for classroom composition effects not captured by the student fixed effects.[8] As described below, we fit this model with and without controls for the teacher's experience level, specified as a full set of dummy variables

In this model, we compare students over time as they move across four groups of teachers: late-hired teachers in their first year, late-hired teachers after their first year, on-time-

[6] We do not count a teacher as exiting the district if they subsequently return, although our results are not substantively different if we count any teacher as leaving the district if they do not return the following year.

[7] In all cases we cluster our standard errors at the school-grade-year level to account for the fact that students in the same school and grade are likely to share common unmeasured influences on their achievement.

[8] We also include indicators for "other" hires to ensure that we include all possible students in the district. We omit these coefficients from our tables and discussion for simplicity.

hired teachers in their first year, and on-time-hired teachers after their first year. As such, we can address our research questions by examining parameters β_1, β_2, and β_3, or linear combinations of those parameters. For example, relative to an on-time-hired teacher not in their first year, we can estimate the effect of being in the classroom of a teacher in their first year who was hired on time (β_2) or hired late ($\beta_1+\beta_2+\beta_3$). We are primarily interested in comparisons between late- and on-time-hired teachers in their first year. Thus, we focus on the difference between these two effects: the parameter sum ($\beta_1 + \beta_3$) represents the differential effect on student achievement of being assigned to a late-hired teacher's classroom in her first year relative to an on-time-hired teacher in her first year.

Examining the individual parameters separately enables us to describe the mechanisms underlying any potential impacts and to disentangle the relative contributions of disruption and labor market effects. Parameter β_1 represents the average permanent effect of late hiring across all years a teacher is in the district, including the teacher's first year. Conversely, β_3 represents the effect on student achievement that *only* occurs in the year a teacher was hired late (because late-hired teachers in their first year will be the only teachers for whom this interaction term equals one). This is the temporary disruption effect of late hiring that is unique to the first year.[9]

One important consideration in our analysis is that any effects we find may simply reflect differences in the attractiveness of specific school or job characteristics, rather than the effect of late hiring itself. Clearly, teachers have preferences across schools and evidence shows that the labor market is constrained in some fields more than in others. However, we largely eliminate this potential threat by including school-by-grade-by-year fixed effects in our primary models.

[9]This model assumes that these effects are linear and additively separable. In other words, there are no interactions between the labor market and disruption effects. To the extent that this hypothesis is not true, our results may mask some underlying heterogeneity in these effects.

Because in nearly all cases schools hire for subject area teachers in the same school and grade, restricting our inferences to within school-grade-year cells (in the same subject area) accounts for differences in school or job characteristics. In other words, it is highly unlikely that a school hires specifically for a position more narrowly defined than a particular subject area in a particular grade. The downside of this approach is that our models do not account for spillover effects due to teacher turnover, organizational instability, and peer effects. The existence of any such spillovers, which are more likely among peers in the same school-grade-year cell in a given subject area, would lead our results to be understated.

We vary our preferred specification in several ways to examine other potential threats to validity. One primary potential threat is that our preferred model does not fully capture the sorting of students to teachers. Our model, which controls for student and school-grade-year fixed effects, explicitly accounts for much of this sorting by controlling for any time-invariant characteristics of students and comparing only teachers in the same school, grade, and year. Our central assumption is that, within each grade in a school during a given year, the sorting of students to teachers is based on fixed characteristics of students (e.g., their family income, general behavior, general level of test performance, etc.). However, very specific patterns of student sorting of students to teachers within a given school, grade, and year might introduce bias.

To test this assumption, we fit less restrictive models. First, we replace our school-by-grade-by-year fixed effects with school fixed effects, comparing all teachers in the same school, rather than simply teachers in the same school, grade, and year. Second, we remove school fixed effects entirely and control for the average demographic characteristics of students in the school. If estimates from these less restrictive models are similar to those from our preferred

specification, it suggests that our model has successfully accounted for the sorting of students to different types of teachers based on their fixed characteristics. Finally, to the extent that students are being assigned to teachers (in the same school, grade, and year) based on time-varying characteristics such as their prior-year test scores that are not captured by student fixed effects, our preferred model may be biased. As a result, we remove student fixed effects and replace them with student-level covariates, including a cubic polynomial of students' prior-year achievement test scores in both mathematics and reading.

D. Data-Analytic Approach: Teacher Retention

We use discrete time survival analysis (DTSA) to estimate the risk that a late-hired teacher transfers schools or exits the district compared to an on-time-hired teacher (Singer & Willett, 2003). Given that we only have data through 2009-10, we censor each observation at this point. Furthermore, once a teacher transfers schools for the first time or exits the district, we remove them from the relevant risk set in subsequent time periods.

We model the hazard (i.e. the conditional probability) of exiting the district using logistic regression, as follows:

$$(2) \qquad \text{logit } h(EXIT_{jt}) = \tau_t \sum_{k=1}^{11} I_{t=k} + \phi LATE_j + \pi_t \sum_{k=2}^{11} (I_{t=k} x LATE_j)$$

Here, we examine the probability that teacher *j* exits the district in time *t*, conditional on having not left the district in previous years; we fit analogous models for transfer. We model time as a complexly flexible function of indicator variables, $\sum_{k=1}^{11} I_{t=k}$. The inclusion of the main effect of being a late-hired teacher and its interaction with the full set of time indicators allows us to estimate whether late-hired teachers have a greater probability of leaving the district after each year than their peers hired on time. If our estimate of ϕ is positive and statistically significant, we

can say that late-hired teachers leave the district after their first year at a greater rate than on-time new hires. Similarly, we can compare rates of exit after the second year in the district by examining the linear combination of ϕ and the relevant π_k coefficient.

In each case, our risk set includes only teachers who have not yet left the district. By examining these hazard probabilities over time, we can also recover the probability that a late-hired or on-time-hired teacher remains in the district until year *t*. We also present these survival probabilities in our figures. We extend these analyses by fitting additional models that include controls for teacher experience and school fixed effects. These models explicitly compare late- and on-time-hired teachers with the same levels of experience and who work in the same schools, removing the possibility that any differences in the exit and transfer rates between late- and on-time-hired teachers are due to differences in experience or the schools in which they work.

III. RESULTS

A. The Prevalence, Characteristics, and Distribution of Late Hired Teachers

Across our panel dataset, an average of 18% of new teachers who start in the fall are hired after the school year begins.[10] This pattern matches closely with national evidence (Engel, 2012). In Table 2, we present the number and proportion of late hires over time. The number of late hires has remained relatively steady over the past decade, ranging between 100 and 200 teachers each year. The proportion of late hires has, in contrast, declined somewhat over this period, falling from 23% to 11%, with a spike in 2009-10 up to 36% when the district hired very few new teachers at all. In Figure 1, we display the proportion of these late hires by month of

[10] These figures exclude "Other" hired teachers, defined above. As such, they are conservative estimates of late hiring. Adjusting our definition of "late" and "on-time" hires changes this precise figure somewhat, but in all cases a substantial proportion of teachers are hired in the fall after the school year starts.

hire. Many of these teachers enter schools shortly after the start of the school year, in late August. However, more than half do not begin teaching until October.

Late-hired teachers differ from their peers in the district in several ways. In Columns 1-3 of Table 3, we present the characteristics of on-time and late hires. We find a greater proportion of male and African-American teachers among late hires than among on-time hires. Furthermore, late-hired teachers are both older on average (by 3.6 years) and more likely to have entered the profession by alternative routes (by 11 percentage points) than teachers hired on-time. Similarly, they are less likely to have a subject-area license, a master's degree, or previous teaching experience. Interestingly, more than half of both late-hired and on-time-hired teachers entered the district without prior teaching experience.

In Columns 4-6 of Table 3, we compare late hires who enter their positions very late (in November and December) to other late hired teachers who secure positions earlier in the school year. These differences suggest some evidence of labor market effects. In particular, teachers hired later in the fall are much more likely to be novice teachers (by 10 percentage points) and are less likely to have math licenses (by 3 percentage points). Interestingly, while late hired teachers are more likely to have entered through alternative routes, the pathway of teachers hired very late is more similar to that of teachers hired on time.

Teachers who are hired late also tend to work in different types of schools than their peers who are hired on-time. In Table 4, we present the characteristics of schools in which teachers work, by the timing of their hire. On average, the schools with more late hires are lower-performing, serve greater proportions of African-American students and have higher rates of absenteeism. For example, compared to the average on-time hire, the average late hire enters a school whose students scored 0.05 standard deviations lower in mathematics and 0.04 standard

deviations lower in reading in the previous year. These differences illustrate the importance of including school-by-grade-by-year fixed effects in our models.

Late-hired teachers also tend to cluster in certain schools. In Figure 2, we present the proportion of each school's new hires that were hired late across the ten-year period that we study. We find that nearly 10% of all schools in the district hire all of their teachers before the beginning of the school year. By contrast, 30% of schools hire more than one of every five new hires after the school year starts, and 20% of the district's schools account for 53% of the total number of late hires. Late-hiring is more prevalent in middle and high schools than in elementary schools, where only 13% of teachers are hired late.

Not surprisingly, these schools tend to be those that serve lower-performing students. In Table 5, we present the average student demographic characteristics and achievement results for schools that hire different proportions of teachers. Schools that hire few teachers late (bottom quartile) tend to teach the most advantaged students. By contrast, schools in the top quartile of late teacher hiring (those that hire a large proportion of their teachers late) have substantially lower achieving students (0.25 SD in both mathematics and ELA), are much less likely to make Adequate Yearly Progress, and have students who are absent, on average, 2.5 days more a year. They also serve a greater proportion of African-American students and students living in poverty. These differences suggest that the impact of late hiring is felt disproportionately in low-performing schools, potentially exacerbating existing inequities in these schools.

B. The Direct Effect of Late Hiring on Student Achievement

We find strong evidence that hiring after the school year begins reduces student achievement: for students, being assigned to a classroom with a teacher hired late reduces student achievement. Students in classrooms with late-hired teachers underperform those with

other new teachers hired over the summer by 0.026 standard deviations in reading (p=0.004) and 0.042 standard deviations in mathematics (p<0.001). We present these results in the first row of each panel in Table 6. These effects are quite large, given that a one standard deviation difference in teacher effectiveness is associated with an approximately 0.15 standard deviation difference in student performance (Hanushek and Rivkin, 2010).[11] Put another way, they represent approximately two months of instruction for a typical middle school student (Hill et al., 2008). Thus, students in classrooms whose teachers arrive after the school year started suffer.

In Figure 3, we present the conditional distributions of estimated teacher contributions to student achievement in the first year for late and on-time hires in both math and reading.[12] These figures illustrate two key points. First, in both subjects, the distribution for late-hired teachers falls to the left of that of on-time hires. In fact, the average late-hired teacher falls at the 38th percentile of the on-time hire distribution in mathematics and the 41st percentile in reading. Second, in both subjects, these distributions overlap substantially. Thus, some students of late-hired teachers outperform those of the average on-time hire.

These estimates compare late-hired teachers in their first year to other new hires. If teachers gain district- or school-specific human capital over time, we would expect newly hired teachers to be less effective than other teachers in the district, even conditional on teaching experience. While some new teachers in the district are novices, many are not. By conditioning on experience, we implicitly compare newly hired teachers to other teachers in the district at the same level of experience. In the second row of Panels A and B in Table 6, we confirm that student achievement is 0.036 standard deviations lower in mathematics, and 0.012 SD lower in

[11] This general pattern holds in our dataset.
[12] Note that we are careful not to term these distributions of teacher effectiveness because, particularly for late-hired teachers, they reflect contributions of other adults to their students' test scores.

reading, for students with a newly hired teacher who was hired on-time compared to students whose teachers are not in their first year in the district. Thus, compared to teachers who are not new hires, the total effect of having a late-hired teacher is -0.077 SD in mathematics and -0.039 SD in reading.

In the second column of Table 6, we present results from models that do not condition on experience. We find that our primary result is unchanged, as the effect of having a late-hired teacher in her first year, relative to an on-time new hire, is essentially the same. However, newly hired teachers have less teaching experience than teachers in the district. As expected, we see that not accounting for teacher experience makes the effect of having a new hired teacher more pronounced.

Our results above derive from a model that uses within-student variation across teachers, and compares students who have teachers in the same school, grade, and year. A primary threat to validity of this preferred specification is that very specific patterns of student sorting of students to teachers within a given school, grade, and year might introduce bias. As seen in the remaining columns of Table 6, we fit supplementary models that include school fixed effects and grade-by-year fixed effects instead of school-grade-year effects (column 3), school characteristics instead of school effects (column 4), and student characteristics, including lagged test scores, instead of student fixed effects (column 5). The results in column (5) are particularly instructive because we explicitly account for sorting of students to teachers within a given school, grade, and year on important time-varying characteristics, such as their prior-year test score. Our results are quite consistent across models, suggesting that different patterns of sorting are not driving our results. We see that students of late-hired teachers face a substantial

disadvantage in the first year. In mathematics, these effects range from 0.042 to 0.044 standard deviations. In reading, they range from 0.026 to 0.041 standard deviations.

Finally, in Column 6 of Table 6, we refit our preferred model but include a range of additional teacher characteristics, including teacher race, gender, age, certification pathway, degree, and licensure status. We find that the effects of late hiring are possibly attenuated slightly, although we cannot reject the null hypothesis that they are identical to those in Column 1. This evidence suggests that differences in observable characteristics between late-hired and on-time hired teachers cannot explain the effect of late hiring, hinting at a substantial role for disruption effects. We turn to this question next.

C. Disentangling the Late-Hire Impact: Labor Market and Disruption Effects

The effects shown in Table 6 represent the contribution of both disruption (i.e., productivity losses from not having a teacher hired by the start of the year) and labor market effects (e.g., net effect of negative selection versus any returns to productive match quality from additional search). Our model enables us to disentangle these mechanisms, and we present these results in the second and third rows of Table 7 in both mathematics and reading.

As expected, we find that the mechanism underlying these effects differs by subject. There is a substantial labor market effect in mathematics, but not in reading. In mathematics, teachers who were hired late continue to underperform their peers by 0.020 standard deviations ($p<0.001$) after their first year. This suggests that mathematics teachers who are hired after the beginning of the school year are less effective teachers, on average, than their peers who are able to secure jobs before the start of the school year. By contrast, late-hired English teachers perform no different than on-time-hired teachers after their first year, as evidenced by our near zero and not statistically significant estimate of the labor market effect. These results fit with general

patterns in the teacher labor market, as the supply of mathematics teachers is substantially more constrained than that of reading teachers (Jacob, 2007).

We also find evidence of first-year disruption effects in both subjects. In reading, the disruption effect appears to account for all of the effect of late hiring, reducing student achievement by 0.029 SD. In mathematics, we see a disruption effect of similar magnitude (0.022 SD). Here, the labor market effect of 0.020 SD is approximately the same as the disruption effect, leading to more substantial negative effects of late hiring. As discussed above, this disruption effect can have many causes, including the challenge of establishing a classroom culture or learning a new curriculum in the middle of the year, or the fact that the students may have been taught by a temporary or substitute teacher who was less effective or invested than a permanent teacher would have been. Unfortunately, we do not have data that enable us to identify the teacher in the classroom before the late-hired teacher arrives to examine these possible mechanisms.

In differentiating between disruption and labor market effects, we must consider an additional threat to validity. Our ability to distinguish between these two hypotheses is based on differences in student achievement patterns over the course of a teacher's career. Differential effectiveness in attrition of late-hired teachers could bias our results. In other words, imagine that the late-hired teachers who leave the district after their first year are the very worst performers among all late-hired teachers, while on-time-hired teachers who leave are simply of average effectiveness. In the second year, we would see that late-hired teachers appeared relatively more effective, and we might attribute this trend to a disruption effect in the first year rather than simply a difference in the types of teachers who remained in the district.

In Table 8, we examine whether late-hired teachers who leave are relatively less effective (compared to late-hired teachers who stay) than other on-time-hired teachers who leave (compared to other on-time-hired teachers who stay). First, we predict each teacher's contribution to student achievement, relative to other teachers in their same school, grade, and year, from a version of equation (1) that excludes the predictors related to hiring timing.[13] In the first column of Table 8, we show the relative difference for on-time-hired teachers who leave compared to those who stay. In the second column, we present the same difference for late hires. The third column presents the key result, the difference in these differences. We present two versions of this analysis, one in which we control for teacher experience and one in which we do not. We find no evidence of the type of differential attrition that would bias our results.

Finally, we leverage variation in the start date of teachers hired after the beginning of the school year to conduct exploratory analysis on the nature of labor market effects. Although these exploratory analyses rely on a relatively small sample of late-hired teachers and are limited to variation in hire dates from September to December, they provide further support to our analysis of labor market effects. To the extent that schools face a negatively selected labor market in mathematics (but not reading) when they hire late, we would expect the pool to be even more negatively selected in November than September in math (but not reading).

To examine this variation, we construct a continuous version of hiring timing, representing the number of days after the school start date a teacher was hired. For ease of interpretation, we divide this predictor by 30 so we can interpret the relevant coefficient in terms

[13] We estimate a model similar to equation (1), but we remove the predictors that focus on the timing of hiring. We then predict each student-year residual and average these for each teacher. We fit two versions of this model, one that includes indicators for teacher experience and one that does not.

of months after the start of the school year. We add to the model in Equation (1) the main effect of this new predictor ($MONTHS\_LATE_j$) as well as its interaction with $NEWHIRE_{jt}$.

The results from this extended model support our broad conclusions about the labor market effect. In mathematics, we find that the coefficient on $MONTHS\_LATE_j$ is statistically significant and negative: every additional month a teacher is hired late reduces their persistent effectiveness by 0.011 SD ($p<0.001$) in mathematics. Thus, math teachers hired later in the fall do indeed appear to be of lower overall effectiveness throughout their career than teachers hired earlier in the fall but still after school begins. In reading, though, we find no such effect, as the coefficient is positive (0.006) and not statistically significant. This suggests that the same negative selection dynamics are not in play for English teachers.

D. Spillover Effects: Teacher Retention

Teacher turnover has important consequences for organizational capacity and, ultimately, student achievement. High levels of turnover can produce organizational instability and lead to classrooms staffed by larger proportions of novice teachers, both of which reduce student achievement (Ronfeldt, Loeb, & Wyckoff, 2013). Notably, the district has quite high turnover rates overall. Furthermore, we find that late-hired teachers are much less likely to stay in the district than on-time-hired teachers, and those who remain are more likely to transfer schools. We present our results on teacher retention from our discrete-time survival analysis models in Table 9. We show our results from teacher exits in the top panel and teacher transfers in the bottom panel. Column 1 contains the estimated hazard probability of exiting the district for on-time-hired teachers each year through their 5th year in the classroom. The next three columns illustrate the difference in retention rates for late-hired teachers, overall, controlling for teacher experience, and comparing teachers in the same school using school fixed effects. For example,

the second row (labeled "After 2nd Year") suggests that, among all teachers who stayed in the district for a second year, 19.8% of on-time hires did not return for a third year, compared to 23% of late hires (a 3.2 % point difference). In the bottom panel, we present analogous findings from our analysis of teacher transfers.

We illustrate these differences in Figure 4. In the top panel, we present the estimated hazard probabilities of exiting the district from our baseline model; in the bottom panel we present the implied survival probabilities that teachers in each group have stayed in the district through each year, from 1 to 11. We see much higher rates of exit for late-hired teachers in their first two years. For example, 80% of on-time-hired teachers remain in the district for a second year, compared to just 71% of late hires. As seen in the bottom panel, this retention gap between late-hired and on-time-hired teachers does not narrow appreciably over time. By the fourth year, half of all on-time hires remain in the district, compared to just 39% of late hires. Similarly, we find higher rates of transfer among late-hired teachers, at least in their first year in the district. Five percent of on-time-hired teachers change schools after their first year, compared to 7% of late-hired teachers. As seen in columns 3 and 4 of Table 9, we find quite similar patterns when we compare teachers with the same level of teaching experience or who work in the same schools.[14]

These turnover patterns are further evidence of both the struggles of late-hired teachers in their first year and the relatively poor match quality between late-hired teachers and their positions. Hiring teachers after the beginning of the school years contributes to increased staffing instability in schools.

[14] It is also important to note that our data do not allow us to distinguish between voluntary and involuntary turnover. It could be that some of these differences in exit and transfer rates are due to late hired teachers being more likely to be terminated or counseled out of the district.

IV. CONCLUSION AND IMPLICATIONS

Teacher hiring is a critical, but often overlooked, element of the larger human capital pipeline in education. In many large urban districts, teachers have come to expect the hiring process to be an end-of-summer scramble that continues well past the beginning of the academic year. In the district we study, nearly 20% of teachers are hired in the fall after the school year begins. Ultimately, students pay the price for these delays – for a student, being assigned to a new teacher who is hired late instead of a new teacher hired before school starts reduces achievement by 0.03 to 0.04 standard deviations.

The negative effects can be attributed to two primary mechanisms. First, hiring a teacher after the school year starts results in a meaningful reduction in both reading and mathematics achievement for students specifically in that teacher's first year. These transitory disruption effects impose productivity costs that only occur during a teacher's first year and are not related to negative selection in the labor market. This effect is likely caused by a combination of factors, including lack of planning and preparation time over the summer, insufficient induction to the school and district, the challenges of building a classroom culture after the school year has started, and the fact that students have been in class for weeks or months with an interim teacher or in a very large class. Although we cannot evaluate the relative importance of each of these factors, the key lesson is that not having a permanent teacher in the classroom at the beginning of school produces a disruption that has serious effects on student achievement.

In mathematics, we also find that hiring delays lead schools to hire teachers who continue to be less effective throughout their careers – either because the hiring process during the fall semester is rushed and less thorough or because the most promising candidates have already secured employment earlier in the year. This finding is consistent with evidence of a limited

labor supply of qualified mathematics teachers (Jacob, 2007). While individual schools clearly face different supply-side constraints (Engel, Jacob, & Curran, 2013), our evidence suggests that mathematics teachers hired later in the year tend to be less effective than their colleagues who were hired on time in the same school. In English, on the other hand, we find that teachers hired late are no less effective over the course of their careers than those hired early.

Taken together, these two mechanisms clearly suggest that the total costs of hiring after the beginning the school year on productivity are substantial. When students are assigned to teachers who have been hired after the school year starts, their achievement suffers compared to their peers assigned to other newly hired teachers.

Our estimates focus on the direct effect of late hiring on students in an individual teacher's classroom. As such, they do not account for spillover effects due to teacher turnover, organizational instability, and peer effects. The existence of any such spillovers would lead our results to be understated. We find teachers who are hired late leave their schools and the district at much greater rates than their peers hired on time. These turnover patterns contribute to late-hiring's effects on student achievement. When teachers leave the district, they are replaced by new hires, many of whom are novice teachers. On average, these teachers are less effective at raising student achievement than their more experienced peers who remain in the district. Turnover also causes organizational instability, which disrupts school-wide efforts to coordinate instruction and reduces student achievement (Ronfeldt, Loeb, & Wyckoff, 2013). Late hiring likely also imposes other negative peer effects (e.g., Jackson & Bruegmann, 2009). For example, many teachers who are hired late may miss out on formal pre-service induction programs provided by schools or districts. To the extent that other teachers are called on to provide this

assistance, their own students may suffer. Any such spillover effects would depress the achievement of other students and understate our estimates of late hiring's effect on achievement.

Importantly, the negative consequences of late hiring are often concentrated in low-performing, high-poverty schools, which hire many more teachers after the school year starts than wealthier, suburban schools. These patterns have important consequences for the equitable distribution of educational resources across schools. In the district we study, hiring delays most frequently occur among the worst-performing schools. As a result, the students who most need the support and consistency of effective full-time teachers often begin the year without them. Although we cannot disentangle the many potential causes for these school-level differences in hiring, past research suggests that principals and working conditions each play a key role. Principals have primary responsibility for the hiring process, particularly in districts such as the one we study where hiring takes place, in part, at the school level (Liu & Johnson, 2006). Schools with poor working conditions struggle to attract and retain teachers, producing high rates of turnover that exacerbate the challenges of hiring teachers (Ladd, 2011; Boyd et al., 2011; Author, 2012).

What is clear is that late hiring is an important policy challenge for schools and districts to resolve. Although hiring in districts has slowed in recent years, this trend is not likely to continue. Nationwide, many teachers leave the profession and many more leave their schools and districts, particularly early in the teaching career (Ingersoll & Smith, 2003; Author, 2015; NCES, 2015). Furthermore, the school-aged population is growing and the retirement of a large cohort of baby-boomer teachers has already begun. These trends suggest that, despite budget shortfalls and the recent occurrence of teacher layoffs, schools will soon need to hire large numbers of new

teachers. In fact, some states and districts now report facing teacher shortages as they struggle to identify enough candidates to fill slots (Brenneman, 2015). As others have described in detail, schools and districts need to find ways to move up hiring timelines. Our results should provide policymakers with added urgency to resolve these challenges. In particular, the disruption effects we find in both subjects represents real inefficiency. Simply moving up hiring timelines without changing the personnel ultimately hired would eliminate much of the negative impact of late hiring.

Uprooting the causes of late hiring will take time. Policies will need to be renegotiated and rewritten, central offices will need to invest in organizational capacity, systems will need to be developed to complete budgets and enrollment projects earlier in the year, and principals will need to be supported to navigate human resource systems effectively. These steps are not impossible, and several districts have worked to move up hiring timelines by undertaking budgetary planning earlier in the year and reworking internal teacher transfer processes. This is particularly important for schools and districts that serve low-performing and low-income students.

However, in the near future, many schools will continue to fill open staff positions after the beginning of the school year. Our findings suggest that simply attempting to recruit stronger candidates after the school year has begun will not eliminate the negative consequences of late hiring. Instead, schools and districts must also work to limit the disruption caused by late hiring. Targeting extra support to late-hired teachers cannot solve all of the challenges posed by late hiring, but it can help districts limit the negative effects of this practice, at least in the near term.

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Figure 1. Percent of late-hired teachers by month of hire.

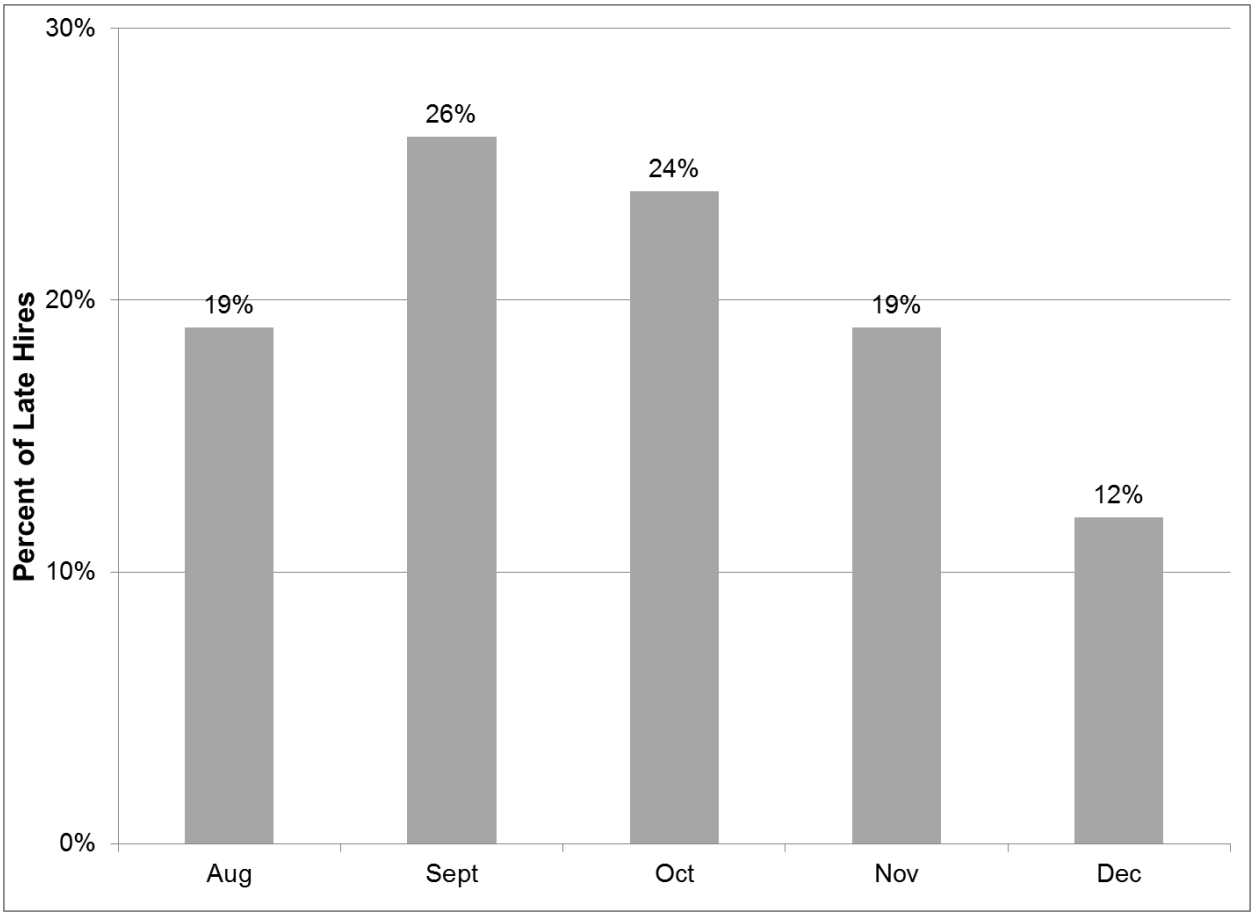


Figure 2. Distribution of the percentage of new hires in a school who were hired late, across schools in the district.

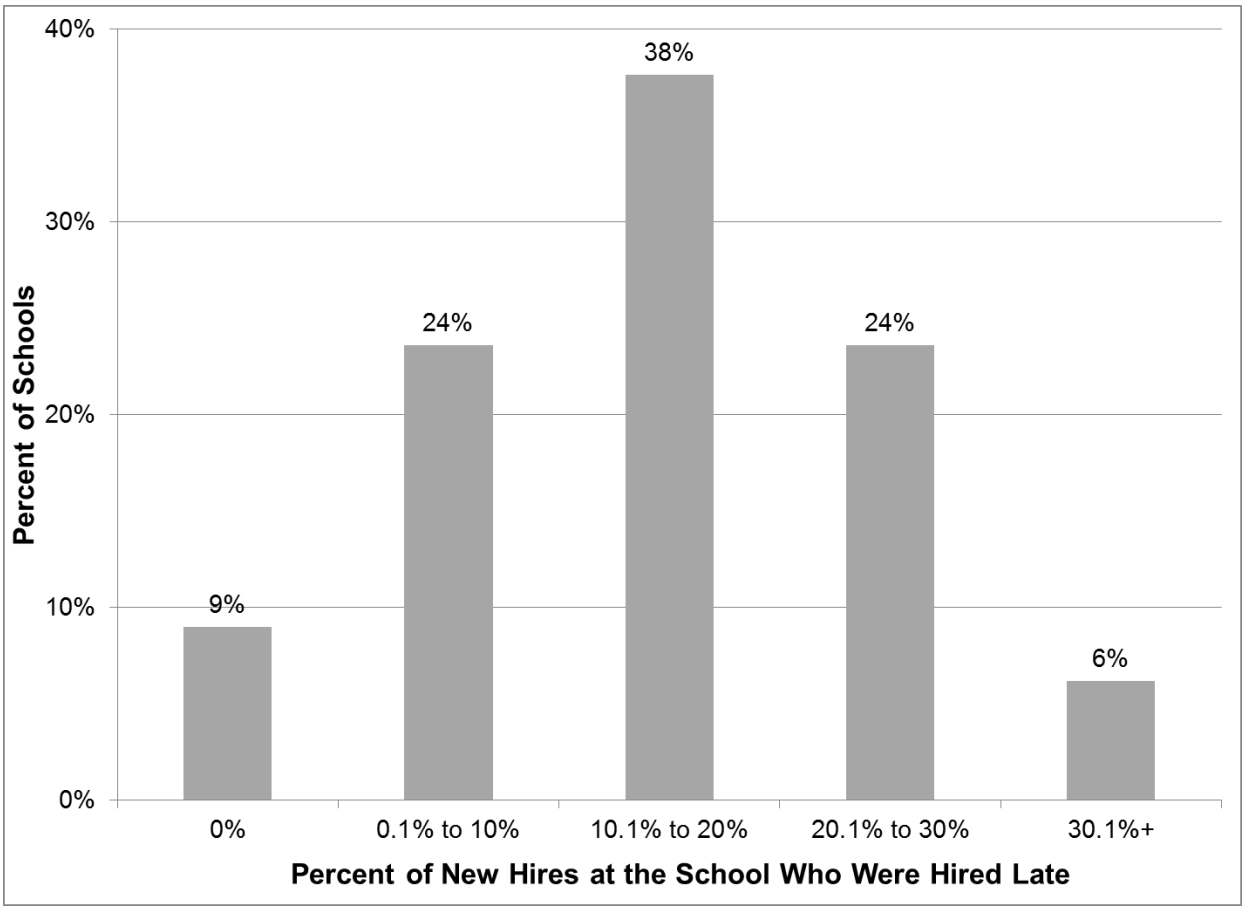
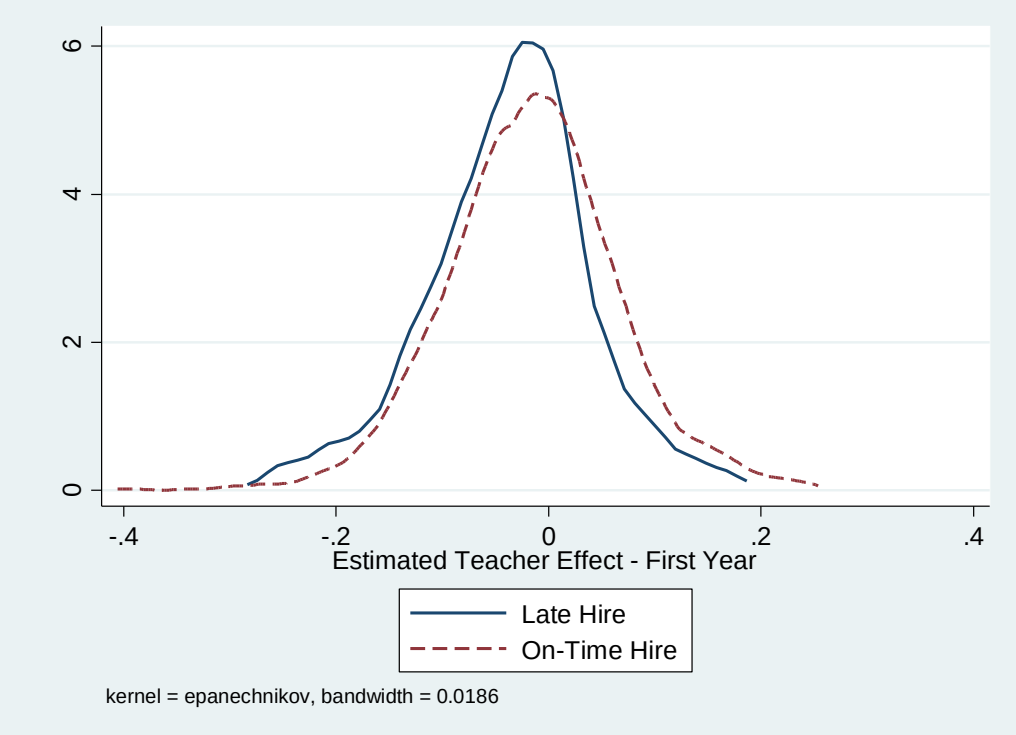


Figure 3. Conditional distribution of teacher contributions to student achievement (value-added) in the first year, for on-time and late-hired teachers in mathematics (top panel) and reading (bottom panel).



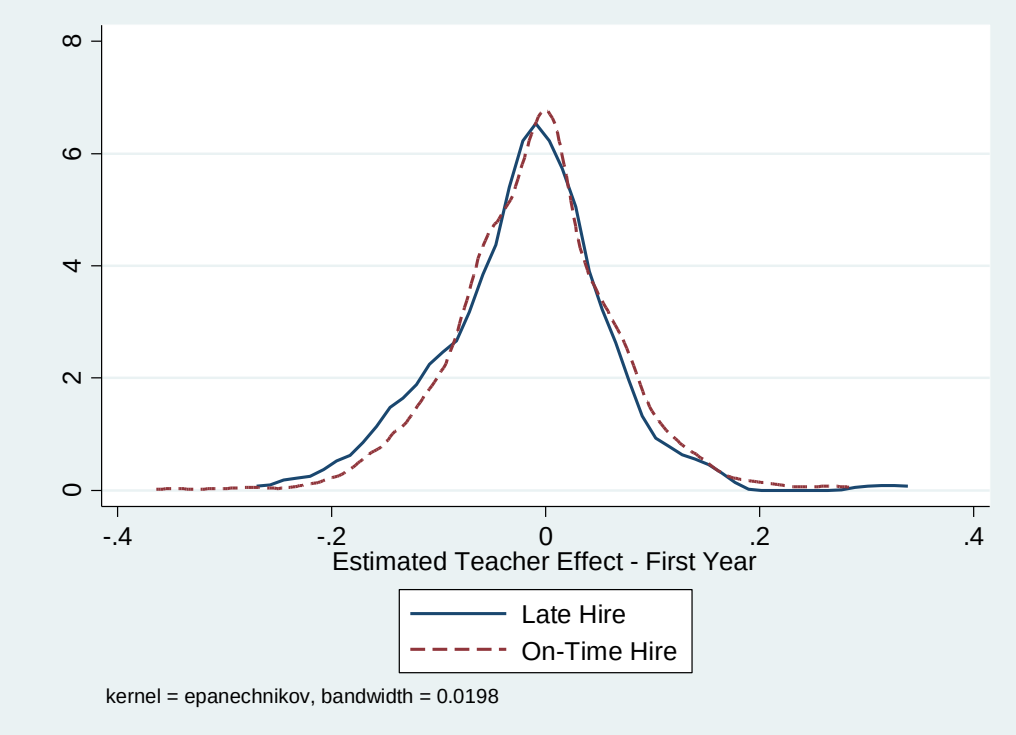
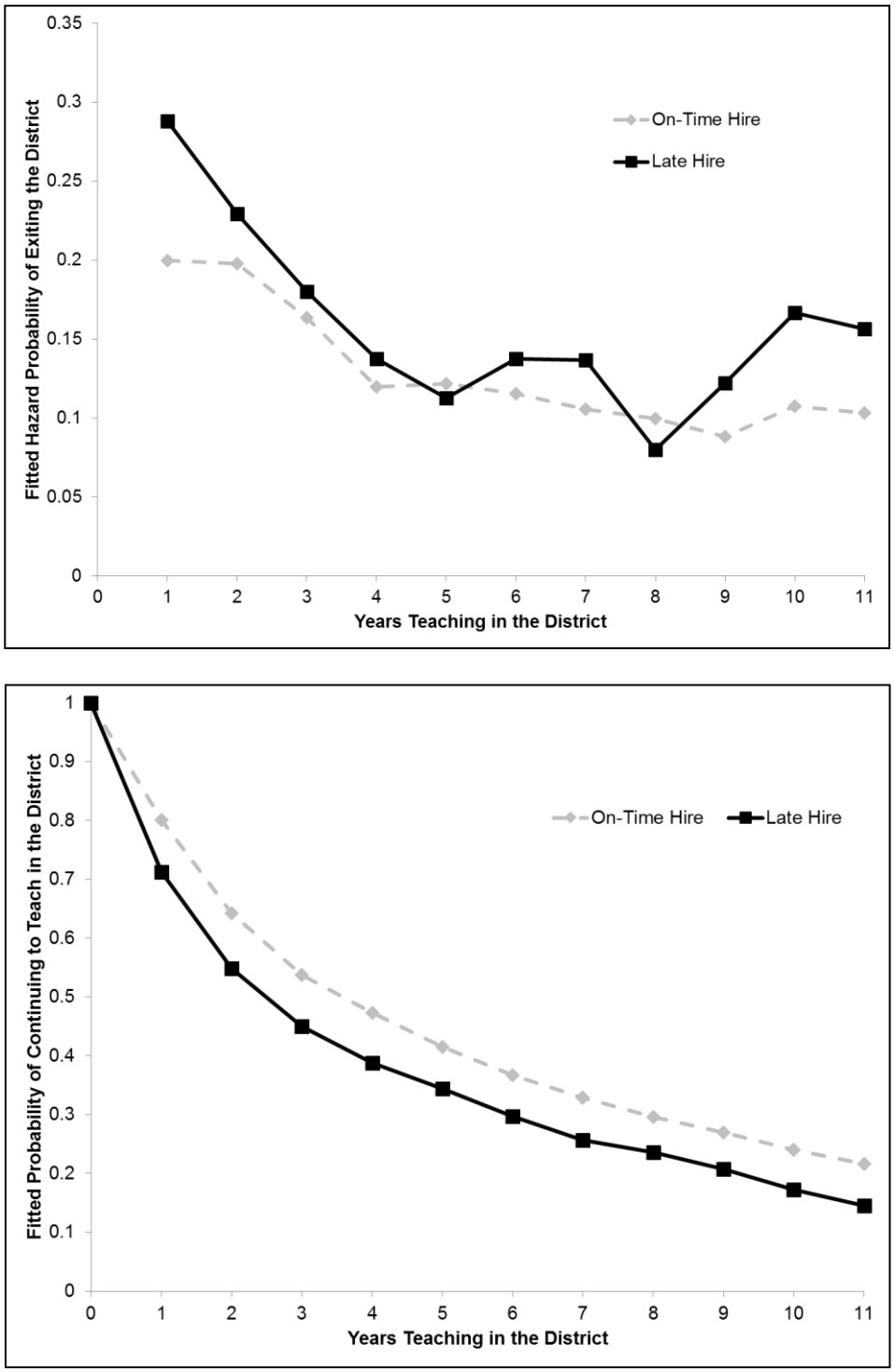


Figure 4. Estimated hazard probability of leaving the district (top panel) and estimated survival probability of remaining in the district (bottom panel), by year for on-time and late-hired teachers.



NOTE: The difference in the fitted hazard of leaving the district between on-time and late-hired teachers is only statistically significant in years 1 and 2.

Table 1. Demographic characteristics of students and teachers in the full sample and the achievement sample.

	Overall (1)	Achievement Sample (2)
Panel A. Student-Year Observations		
African-American	0.425	0.435
Asian-American	0.044	0.043
Hispanic	0.101	0.094
Male	0.508	0.499
Limited English Proficient	0.095	0.076
Special Education	0.099	0.068
Reading score (lagged)	0.010	0.044
Math score (lagged)	0.014	0.053
Days absent (lagged)	8.120	7.430
Number of student-year obs.[a]	1,333,998	342,192
Panel B. Teacher-Year Observations		
New hire	0.154	0.174
Male	0.224	0.167
African-American	0.247	0.283
Asian	0.008	0.006
Hispanic	0.020	0.015
Alternative Pathway	0.264	0.234
Math License	0.100	0.204
English Language Arts License	0.187	0.325
Masters Degree	0.293	0.271
Novice (1st salary step)	0.078	0.085
Number of teacher-year obs.[a]	65,497	12,847

[a] This reflects the total possible sample size. For some variables, the sample size is substantially smaller because of missing data.

Table 2. Number and proportion of teachers hired late and number of newly hired teachers, by year.

Year	Number of Late Hires	Number of New Hires	Proportion Late
1999-00	190	828	0.229
2000-01	176	857	0.205
2001-02	116	683	0.170
2002-03	181	936	0.193
2003-04	158	897	0.176
2004-05	190	1,117	0.170
2005-06	138	987	0.140
2006-07	172	1,077	0.160
2007-08	161	1,172	0.137
2008-09	103	922	0.112
2009-10	110	303	0.363
Total	1,892	10,618	0.178

Table 3. Average characteristics of late-hired and on-time-hired teachers in the district (left panel) and of late hires by time of hiring (right panel) (N=10,616).

Teacher Characteristic	On-Time vs Late Hires			Late Hires in Sept/Oct vs Nov/Dec		
	On-Time	Late	Difference	Sept/Oct	Nov/Dec	Difference
	(1)	(2)	(3)	(4)	(5)	(6)
Male	0.215	0.268	0.053 ***	0.283	0.235	-0.048 **
African-American	0.200	0.283	0.083 ***	0.288	0.272	-0.016
Asian	0.014	0.014	0.000	0.017	0.008	-0.009 *
Hispanic	0.033	0.038	0.005	0.046	0.018	-0.028 ***
Alternative Pathway	0.258	0.365	0.107 ***	0.384	0.319	-0.065 ***
Math License	0.102	0.079	-0.023 ***	0.088	0.060	-0.028 **
English Language Arts License	0.151	0.119	-0.032 ***	0.120	0.116	-0.004
Masters Degree	0.230	0.187	-0.043 ***	0.183	0.196	0.013
Novice (1st salary step)	0.501	0.548	0.047 ***	0.515	0.619	0.104 ***
Age	31.6	35.2	3.6 ***	35.7	34.2	-1.5 ***

Notes:
*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level

Table 4. Average characteristics of the schools in which on-time-hired and late-hired teachers teach.

School Characteristic	On-Time Hires (1)	Late Hires (2)	Difference (3)
Average math score (previous year)	-0.073	-0.121	-0.048 ***
Average reading score (previous year)	-0.101	-0.142	-0.041 ***
School met AYP	0.348	0.288	-0.060 ***
Average days absent	9.08	10.09	1.01 ***
Proportion in Poverty	0.493	0.508	0.015 *
Proportion LEP Students	0.098	0.095	-0.003
Proportion SPED Students	0.101	0.101	0.000
Proportion Asian Students	0.043	0.044	0.001
Proportion Hispanic Students	0.108	0.100	-0.008 ***
Proportion African-American Students	0.460	0.484	0.024 ***

Notes:

*** Significant at the 1 percent level

** Significant at the 5 percent level

* Significant at the 10 percent level

Table 5. Average characteristics of schools by the proportion of teachers hired late (by quartile), with asterisks to denote inference for differences between each quartile and Q1.

School Characteristic	Q1 (Few Late Hires)	Q2	Q3	Q4 (Many Late Hires)
Average math score (previous year)	0.027	-0.075	-0.051	-0.219 ***
Average reading score (previous year)	0.041	-0.091	-0.060	-0.226 ***
School met AYP	0.618	0.574	0.429 ***	0.266 ***
Average days absent	7.668	8.498	8.747	10.212 ***
Proportion in Poverty	0.443	0.508	0.482	0.567 **
Proportion LEP Students	0.106	0.123	0.113	0.113
Proportion SPED Students	0.100	0.109	0.100	0.113
Proportion Asian Students	0.046	0.046	0.044	0.042
Proportion Hispanic Students	0.114	0.135	0.106	0.123
Proportion African-American Students	0.414	0.435	0.438	0.531 ***

Table 6. Effect of late teacher hiring on student achievement, in mathematics and reading.

Comparison	Parameter	School-Grade-Year FE	No Teacher Experience	School FE	School Characteristics	Student covariates
		(1)	(2)	(3)	(4)	(5)
Panel A. Mathematics (n=367,139)						
Late new hire vs. on-time new hire	$\beta_1+\beta_3$	-0.042 ***	-0.044 ***	-0.040 ***	-0.044 ***	-0.044 ***
		(0.007)	(0.007)	(0.012)	(0.012)	(0.012)
On-time new hire vs. non-new hire	β_2	-0.036 ***	-0.044 ***	-0.036 ***	-0.036 ***	-0.044 ***
		(0.003)	(0.003)	(0.006)	(0.006)	(0.007)
Late new hire vs. non-new hire	$\beta_1+\beta_2+\beta_3$	-0.077 ***	-0.088 ***	-0.076 ***	-0.080 ***	-0.088 ***
		(0.007)	(0.006)	(0.012)	(0.012)	(0.012)
Panel B. Reading (n=311,070)						
Late new hire vs. on-time new hire	$\beta_1+\beta_3$	-0.026 ***	-0.029 ***	-0.030 ***	-0.041 ***	-0.030 ***
		(0.009)	(0.009)	(0.010)	(0.012)	(0.011)
On-time new hire vs. non-new hire	β_2	-0.012 ***	-0.022 ***	-0.019 ***	-0.017 ***	-0.016 ***
		(0.004)	(0.004)	(0.005)	(0.005)	(0.005)
Late new hire vs. non-new hire	$\beta_1+\beta_2+\beta_3$	-0.039 ***	-0.051 ***	-0.049 ***	-0.058 ***	-0.046 ***
		(0.009)	(0.009)	(0.010)	(0.012)	(0.011)
Student fixed effects		x	x	x	x	
School-grade-year fixed effects		x	x			x
School fixed effects				x		
School-level averages					x	
Grade-by-year fixed effects				x	x	
Teacher experience controls		x		x	x	x

Notes: All results derive from different specifications of model (1). Standard errors clustered by school-by-grade-by-year reported in parentheses.

*** Significant at the 1 percent level

** Significant at the 5 percent level
* Significant at the 10 percent level

Table 7. Effect of late teacher hiring on student achievement, in mathematics and reading, from model (1).

Comparison	Parameter	Mathematics	Reading
Late new hire vs. on-time new hire (1st year)	$\beta_1+\beta_3$	-0.042 ***	-0.026 ***
		(0.007)	(0.009)
"Labor Market Effect"	β_1	-0.020 ***	0.002
		(0.004)	(0.005)
"Disruption Effect"	β_3	-0.022 ***	-0.029 ***
		(0.008)	(0.010)
N		367,139	311,070

Notes: All models derive from model (1) and include student fixed effects, school-grade-year fixed effects, and controls for teacher experience. Standard errors clustered by school-by-grade-by-year reported in parentheses.

*** Significant at the 1 percent level

** Significant at the 5 percent level

* Significant at the 10 percent level

Table 8. Relative effectiveness of teachers who leave the district compared to teachers who stay, for on-time-hired and late-hired teachers in mathematics (top panel) and reading (bottom panel).

	On-Time Hires	Late Hires	Relative Difference
	(1)	(2)	(3)
Panel A. Mathematics			
Overall	0.000	0.005	0.005
	(0.002)	(0.008)	(0.008)
	[p=0.986]	[p=0.549]	[p=0.569]
Conditional on Experience	0.001	0.007	0.006
	(0.002)	(0.008)	(0.008)
	[p=0.713]	[p=0.369]	[p=0.448]
Panel B. Reading			
Overall	0.001	0.002	0.001
	(0.002)	(0.007)	(0.007)
	[p=0.462]	[p=0.708]	[p=0.885]
Conditional on Experience	0.002	0.004	0.002
	(0.002)	(0.007)	(0.007)
	[p=0.282]	[p=0.542]	[p=0.786]

Notes: Estimates from a difference-in-differences regression model documenting the difference in estimated teacher effectiveness between teachers who stay and leave, for both on-time and late-hired teachers. Column (3) presents this difference-in-differences estimate. Standard errors reported in parentheses. Estimated p-values in brackets.

*** Significant at the 1 percent level

** Significant at the 5 percent level

* Significant at the 10 percent level

Table 9. Fitted hazard probabilities of exiting the district (top panel) or transferring schools within the district (bottom panel) for on-time-hired and late-hired teachers, by year in the district.

Years in District	Average for On-Time Hires	Difference for Late Hired Teachers		
		Overall	Controlling for Experience	Controlling for School Fixed Effects
	(1)	(2)	(3)	(4)
Panel A. Exit the District				
After 1st Year	0.200	0.088 ***	0.087 ***	0.077 ***
After 2nd Year	0.198	0.032 **	0.033 ***	0.027 **
After 3rd Year	0.163	0.017	0.016	0.031
After 4th Year	0.120	0.018	0.017	0.001
Panel B. Transfer Schools within the District				
After 1st Year	0.051	0.019 ***	0.016 ***	0.022 ***
After 2nd Year	0.083	0.002	0.003 **	0.003 **
After 3rd Year	0.075	-0.012	-0.006	-0.010
After 4th Year	0.085	-0.011	-0.006	-0.004

Notes: Standard errors reported in parentheses. Estimated p-values in brackets.
*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level