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RESEARCH ARTICLE

# Local supply, temporal dynamics, and unrealized potential in teacher hiring

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**Abstract**

We explore the dynamics of competitive search in the K–12 public education sector. Using detailed panel data on teacher hiring from Boston Public Schools, we document how teacher labor supply varies substantially across vacancies even within a single district depending on position type, school characteristics, and the timing of job postings. We find that early-posted positions are more likely to be filled and end up securing new hires that are better qualified, more effective, and more likely to remain at a school. In contrast, the number of applicants to a position is largely unassociated with hire quality, suggesting that schools may struggle to identify and select the best candidates even when there is a large pool of qualified applicants. These patterns persist even when we restrict comparisons to only positions within an individual school using school fixed effects. Our findings point to substantial unrealized potential for improving teacher hiring.

## INTRODUCTION

In recent decades, strengthening the quality of the teacher workforce has emerged as a primary focus of efforts to improve the U.S. public education system. This makes sense given the large body of evidence documenting teachers' central role in shaping students' academic achievement and long-term outcomes (e.g., Chetty et al., 2014; Kane & Staiger, 2008; Rockoff, 2004). A broad body of research has examined efforts to improve teachers' performance on the job through professional development, performance evaluation systems, and merit-based pay (e.g., Adnot & Wyckoff, 2015; Donaldson & Papay, 2015; Jackson et al., 2014; James & Wyckoff, 2020), as well as to replace ineffective teachers with more effective teachers (Gordon et al., 2006; Hanushek, 2011; Staiger & Rockoff, 2010). However, we know far less about the potential to strengthen the teacher workforce through a critical step in the human capital pipeline: teacher hiring.

Theoretical models from the personnel economics literature suggest that inefficient hiring in the public education sector may leave considerable potential gains to teacher quality on the table. As Oyer and Schaefer (2011) emphasized, "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" (p. 1772). But hiring remains a relatively understudied part of the process of improving human capital in schools.

In this paper, we provide a rich descriptive exploration of how labor supply and the temporal dynamics of the hiring process are related to the quality of newly hired teachers. The potential to improve teacher quality through the hiring process depends critically on how local teacher labor supply evolves over the course of a hiring period and differs across positions and schools. Job candidates enter and exit the market as schools compete against each other to make offers and attract candidates. Given the distinctly seasonal nature of teacher hiring, applicant quantity and quality decline over time. Public school teachers in large urban districts are frequently hired late in the summer or even after the school year starts, with negative consequences for student achievement (Engel, 2012; Levin & Quinn, 2003; Papay & Kraft, 2016). Competitive search models suggest that schools that advertise positions early will benefit from not only a larger applicant pool, but also the opportunity to move quickly to attract their top candidates (Mortensen & Pissarides, 1999; Oyer & Schaefer, 2011; Rogerson et al., 2005).

We explore these theoretical predictions empirically using 5 years of detailed hiring records across 129 schools in the Boston Public Schools (BPS). BPS provides an advantageous context in which to explore these questions given its early and open hiring process. Unlike most public school systems, BPS gives individual schools substantial autonomy in making staffing decisions and follows an open posting process that allows all schools to start hiring—and all candidates to begin applying—on March 1 (Kraft et al., 2021). In contrast, many larger urban school districts start with an internal transfer process, delaying the open posting process until May or June. BPS effectively operates as an unconstrained open market, allowing us to observe the dynamics of local labor supply as schools compete for teacher candidates within a local market.

We find that there are multiple distinct teacher labor markets at play within a single district, with different implications for hiring effectiveness across positions and schools. On the supply side, the volume of the labor supply varies widely across content areas and over the course of the hiring season. In addition, local labor supply also differs meaningfully across individual schools, even for the same type of positions posted on the same dates, reflecting applicant preferences and differential investments in the hiring process across schools. Thus, the local market for teachers can be very different in the same district depending on the working conditions in the schools where the vacancies are located and the type of position schools are trying to fill.

BPS is located within a metro area with a relatively large potential applicant pool, yet schools that post later in the hiring cycle miss out on much of this pool. We find that teachers enter the market early when given the opportunity; half of all applicants have submitted their first application by April 11 each year—7 weeks into the hiring window. Meanwhile, more than 1 in 6 positions have yet to be posted on July 1, the date by which BPS aims to complete its hiring, and by which point a majority of applicants have already effectively exited the market. More effective candidates enter earlier and, crucially, cease applying to positions earlier, suggesting real benefits from accelerating hiring timelines.

We find that earlier job postings receive more applicants and are more likely to be filled by the start of the school year. Additionally, teachers hired with ample time before the start of the school year are also more likely to remain at their school (an indicator of a positive teacher-school match). These results hold even in models with school fixed effects, suggesting that this pattern is not simply a function of schools that hire early having more favorable work environments. This finding is consistent with prior evidence on the importance of match quality and suggests that earlier hiring is not simply a zero-sum game with a net-zero effect in general equilibrium. Instead, there is potential to improve hiring outcomes for all schools, teachers, and students when the hiring process is less rushed and provides both parties with more information to assess position fit (Liu & Johnson, 2006; Jackson, 2013).

Finally, we find that the size of the applicant pool, conditional on hiring timing and school fixed effects, is largely unassociated with the effectiveness of the hire. Vacancies that attract larger applicant pools are more likely to be filled by candidates who are more attractive based on paper credentials,

such as certification, but no more likely to select candidates who are more effective in the classroom or who are more likely to remain at the school. These patterns suggest that schools struggle to identify and select the best candidates even in the face of a large supply of applicants (e.g., Jacob et al., 2018).

Together, our findings make several contributions to the personnel and education economics literatures as well as to education policy. There is limited evidence examining whether hiring model predictions are consistent with empirical data from the field (Oyer & Schaefer, 2011). We provide new evidence on the nature of competitive search in the teacher labor market, one of the largest occupational sectors in the U.S. Building on a rich prior literature that documents how teacher staffing challenges differ across school characteristics and position types (Bruno, 2022; Cowan et al., 2016; Edwards et al., 2022; Goldhaber et al., 2020, 2021, 2022; Jacob, 2007; Papay & Kraft, 2016), our results affirm the salience of position type and firm characteristics for shaping labor supply. We extend this prior literature by exploring the critical dimension of timing and illustrating its importance for hiring practices.

Our study also extends prior research that leverages data on teacher job applications to examine teachers' preferences and labor supply (Boyd et al., 2011; Engel et al., 2014; Killeen & Loeb, 2022). The ability to include school fixed effects in our models allows us to explore how the temporal dynamics of the hiring process and local supply relate to hiring outcomes, independent of teachers' preferences across schools. This is important because schools that post positions earlier and attract more candidates also differ meaningfully on a whole host of observable (and likely unobservable) characteristics that also influence hiring outcomes.

Here, our findings are inconsistent with model predictions that larger applicant pools produce higher quality or better matched new hires. While posting and hiring earlier does appear to result in more effective and better matched hires, schools do not appear to realize any potential gains when they are successful at attracting larger applicant pools. Even the schools that post early and elicit large volumes of applicants are, on average, staffing their schools with new hires who are not consistently better qualified, more effective, or more likely to remain in their positions than schools hiring from more constrained applicant pools. Ultimately, while timing is important, its advantages may not be fully realized unless schools can screen effectively.

# CONCEPTUAL FRAMEWORK AND RELATED EVIDENCE

## Competitive search

Across labor markets, finding and securing a well-matched employee is a complex endeavor that is essential to a firm's productivity (Oyer & Schaefer, 2011). It requires that both employers and job seekers expend resources (e.g., in time and effort) on the search process and overcome information asymmetries. These search processes operate on both the extensive and intensive margins. Firms need to recruit a sufficiently large number of high-quality applicants for a given position. Larger supply is assumed to improve the probability that a firm will select higher quality applicants (Sedláček, 2014; Villena-Roldán, 2012). Then, firms need to successfully select stronger candidates from among the qualified applicants. Job candidates face similar processes, identifying possible positions to which they might apply and choosing among offers they receive.

The matching of applicants to vacancies is thus a two-sided process that operates in a competitive environment, with firms competing for candidates and candidates competing for positions (Barron et al., 1985; Merkl & van Rens, 2012). In this competitive search framework, three key considerations about supply interact to provide important insights about the hiring process. First, the thickness of labor supply for a given position depends on the requisite skills and training required. Second, labor supply is influenced by the firm itself; firms vary not only in the nature and intensity of search but in their attractiveness to job seekers (Barron et al., 1985). Third, timing is a core element of the process (Mortensen & Pissarides, 1999; Oyer & Schaefer, 2011; Rogerson et al., 2005). Competitive search

models predict that the best applicants will exit the market earlier as employers make them offers, benefiting employers who act early.

These three determinants of supply—position type, firm characteristics, and timing—reflect diverging degrees of malleability. By and large, position types are fixed, determined by needs and features that are likely difficult for a firm to control. Firm characteristics comprise a blend of fixed and variable factors. Some are constant, such as geographic location, while others, such as workplace conditions, are more malleable. Timing depends in large part on the extent to which hiring organizations can feasibly anticipate and act on staffing demands.

How applicant supply affects hiring quality depends on the selectivity of applicants' and firms' searches. A larger supply of applicants to any given vacancy should be associated with better hiring outcomes (Nagler et al., 2020; Sedláček, 2014), but the marginal returns to supply may decline for firms where the cumulative cost of hiring (e.g., interviewing candidates) is high. Firms that need to fill more vacancies may sacrifice the level of attention they provide to filling any individual position as they attempt to fill all open positions (Baydur, 2017; Helpman et al., 2010; Wolthoff, 2018). Indeed, firms often choose to use alternative selection processes, such as informal referrals, to reduce hiring costs and aid in selection (Burks et al., 2015; Schmutte, 2015).

## Hiring in the teacher labor market

We study the hiring process in the context of the teacher labor market, which employs close to 4,000,000 adult workers in the United States, and accounts for approximately 1 in 12 workers with a bachelor's degree or higher.[1] The teacher labor market provides an opportune setting for studying the determinants, dynamics, and implications of supply for hiring effectiveness. First, teacher hiring is distinctly seasonal; nearly all positions open in the spring and summer for start dates in the fall, at the beginning of the school year. Second, within a given district, teachers are typically paid according to a set salary scale based on a combination of years of experience and academic credentials, limiting schools' abilities to use compensation to differentiate their recruitment efforts. In many areas, there is a competitive market for teacher wages when public, private, and charter schools all operate in a local market. Third, state laws regulate the types of candidates that public schools can hire, typically requiring teachers to be licensed in the specific area in which they will teach.

Empirical research on the teacher labor market has established a range of stylized facts about teacher supply (Edwards et al., 2022). Nationally, supply exceeds demand for most types of teaching positions, but some areas experience shortages. There are typically far fewer certified teachers per opening in special education, science, and mathematics than in other content areas (Dee & Goldhaber, 2017; Sutcher et al., 2016). Supply also varies meaningfully across schools based on teachers' preferences and school characteristics (Biasi et al., 2021; Boyd et al., 2011, 2013; Feng et al., 2018; Gross & DeArmond, 2010; Jackson, 2009). Geography is one important determinant. Most teachers end up working close to where they grew up or attended college, and rural districts, for example, have greater difficulty staffing their schools (Boyd et al., 2005; Engel et al., 2014; Goldhaber et al., 2020; Reininger, 2012; Santelli & Grissom, 2022). There is also mounting evidence that teachers prefer schools with more attractive professional environments, anchoring on nonpecuniary benefits in the absence of variation in compensation across schools in the same district (Johnson et al., 2012; Johnston, 2021; Kraft et al., 2016; Lovison & Mo, 2022; Viano et al., 2020). Teacher supply is also responsive to macroeconomic conditions, with the quality of new hires increasing during economic recessions when teaching candidates have fewer outside alternatives (Nagler et al., 2020).

Despite the known seasonality of the market, many teachers are not hired until late in the summer and even after school starts in the fall (Engel, 2012; Levin & Quinn, 2003). In some large districts,

[1] Employment numbers come from the U.S. Census Bureau Educational Attainment in the United States 2019 Detailed Tables (https://www.census.gov/data/tables.html).

upwards of 1 in 5 new teachers are hired after the first day of school; this late hiring has substantial costs for new-hire productivity (Papay & Kraft, 2016).

Several key features of the teacher labor market constrain schools' abilities to control the timing of their search and selection processes. School budgets are often beholden to slow-moving political processes that delay the hiring calendar at the state and local levels. Mobile student populations create challenges for predicting enrollment and staffing needs. Few districts use sophisticated models to predict vacancies that will arise. 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 and require schools to give transferring teachers first priority to choose a position before a search can be opened to the external candidate pool (Levin et al., 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). Some principals also strategically delay job postings to avoid having a transfer teacher or teacher whose position was eliminated placed in their school by the central office.

Efforts to improve teacher hiring with increased school autonomy and more comprehensive screening suggest the potential for substantial benefits. While some reforms, like flexible salary scales, can reinforce disparities in access to highly-effective teachers (Biasi et al., 2021), district hiring reforms that allow for early and open school-based hiring through mutual consent can substantially increase the diversity, retention, and effectiveness of new teacher hires (Keo et al., 2020; Kraft et al., 2021). Research demonstrates that comprehensive screening practices, such as those that include in-person interviews and live or recorded examples of teaching performance, do capture meaningful information about job candidates' future effectiveness in the classroom (Biasi, 2021; Bruno & Strunk, 2019; Chi & Lenard, 2022; Goldhaber et al., 2017; Harris et al., 2010; Jacob et al., 2018; Rockoff et al., 2011; Sajjadiani et al., 2019). However, the degree to which these data are commonly collected and used in effective ways remains an open question.

Evidence suggests that individual schools and districts stand to gain meaningful advantages by conducting early and data-rich hiring processes. While some advantages in the competitive search model are purely partial-equilibrium effects that advantage early movers and disadvantage schools that hire late, there are also reasons to believe that improved hiring is more than a zero-sum game with clear winners and losers. By and large, teacher hiring tends to be "late, rushed, and information poor" (Liu & Johnson, 2006). Hiring reforms that provide teachers with more time and information to consider their options would likely result in better matches where teachers' individual skills are aligned to the specific tasks of their job and the student population they will teach. Ample research has documented the potential to improve student learning through improved student-teacher matching (Aucejo et al., 2019; Bates et al., 2022; Biasi et al., 2021; Graham et al., 2022; Wedenoja et al., 2022). Improved hiring also has the potential to reduce the number of pre-service teachers who exit the profession because of the uncertainty involved with securing a job in the last-minute rush to hire before the school year begins (Goldhaber et al., 2021).

## DATA AND SETTING

We study teacher hiring in Boston Public Schools, which serves approximately 50,000 students with just over 4,000 teachers spread across 129 schools. As shown in Table 1, a plurality of students (42%) are Hispanic, roughly a third (35%) are Black, and close to 1 in 10 (9%) are Asian. The district serves predominantly students with low family income (73%), a third of all students (32%) are English learners, and close to 20% qualify for special educational services. Most of the approximately 6,000 teachers in the district are White (61%), while less than one-third identify as Black (21%) or Hispanic (10%).

BPS operates in a city with a large and well-educated labor force and does not face many of the hiring constraints that hamper other districts. Title II data show that there are 31 teacher preparation programs in the greater Boston area (comprising more than half of the state's providers) that produce

**TABLE 1** Sample summary.

| | All BPS | Classrooms with new hires |
|---|---|---|
| **Panel A. Students** | | |
| *N of student-by-year records* | *185,286* | *47,305* |
| *N unique students* | *71,074* | *34,080* |
| Black | 0.35 | 0.39 |
| White | 0.13 | 0.10 |
| Hispanic | 0.42 | 0.42 |
| Asian | 0.09 | 0.07 |
| Low income (FRPL) | 0.73 | 0.77 |
| Limited English proficiency | 0.32 | 0.30 |
| Special needs | 0.19 | 0.19 |
| Standardized math score | 0.006 | −0.120 |
| | (1.000) | (0.960) |
| Lagged math score | 0.023 | −0.078 |
| | (1.006) | (0.965) |
| Standardized ELA score | 0.004 | −0.089 |
| | (1.002) | (0.980) |
| Lagged ELA score | 0.019 | −0.069 |
| | (1.004) | (0.980) |
| **Panel B. Teachers** | | |
| *Total teacher-by-year records* | *16,566* | *3,241* |
| *N unique teachers* | *5,810* | *2,676* |
| Female | 0.74 | 0.73 |
| Black | 0.21 | 0.24 |
| White | 0.61 | 0.47 |
| Hispanic | 0.10 | 0.12 |
| Asian | 0.06 | 0.06 |
| Experience | 8.58 | 5.22 |

*Notes*: Student-level data only include students in tested grades and subjects. For a summary of applicant characteristics, see Table 2.

more than 2,000 program completers each year. Schools can start the hiring process for the following fall as early as March 1, allowing them to better compete with local charter and suburban schools. The district has one combined process for internal and external hires, rather than giving internal candidates preference to choose positions before posting for external hires. It operates with full mutual consent, meaning that teachers are not forced to take positions they do not choose, and teachers are not placed administratively in schools without agreement from the school principal. During the period we studied, with very rare exception, the district was only able to hire licensed teachers who came through traditional or alternative routes.

To explore the dynamics of teacher hiring, we use rich administrative data spanning the hiring windows for the 2014/2015 through 2018/2019 academic years. We combine administrative datasets from human resources, data on job applications, and demographic and test-score information for students in math and reading classes. Application data include demographic details (e.g., race/ethnicity, gender, and address), application status with dates (e.g., hired/accepted offer), and information about qualifications and experience (e.g., education, certifications, prior experience, prior BPS employment).

Human resources data provide teaching assignments, within-district teaching experience and performance, and teacher demographics. We focus on positions posted in what we might consider the traditional hiring window—March 1 through October 31 of each calendar year. We use these data to construct two primary analytic samples: a sample of 17,986 unique applicant-by-year observations to 3,610 postings and a sample of 3,253 teachers by position and year who were hired to fill job openings.[2]

Hiring data suggest the local teacher labor market in Boston is large and fairly thick. On average, the district posts 900 positions a year with the median position receiving applications from 29 applicants. The first column of Table 2 provides summary statistics about the population of applicants to BPS positions. Applicants span a wide geographic area, although most are relatively local. The large majority (87%) reside within-state, with applicants heavily concentrated in the Boston area. Most enter teaching through traditional certification programs (88%) with Boston Teacher Residency, UMASS – Teach Next Year, and Teach For America constituting the three most common alternative certification programs. Many already work in BPS either as teachers (19%) or in another capacity (11%). The demographic makeup of current BPS teachers and applicants are similar, but much less diverse than the student body. Nearly two-thirds of applicants are White and fewer than a quarter identify as Black or Hispanic.

Two limitations of our data are that we do not observe job offers or hiring data for charter schools and other public school districts in the greater Boston metropolitan area. Hiring is a two-sided market where teachers have preferences across jobs and schools have preferences across candidates. BPS thus competes for teachers with other public charter schools and private schools as well as suburban public schools in the greater Boston metropolitan area. However, there are several reasons to think that BPS schools enjoy meaningful market power to choose among applicants.

First, prior qualitative evidence suggests novice teachers often accept the first job offer they receive given the uncertainty of the hiring timeline and common practice of schools providing limited windows of time for candidates to accept an offer (Liu & Johnson, 2006; National Council on Teacher Quality, 2010). Second, salaries in BPS are generally higher than those in Boston charter or private schools. While BPS starting salaries are comparable to neighboring suburban districts, they increase much more rapidly. Novice BPS teachers who hold a master's degree earned $65,210 in 2018/2019 and teachers in their ninth year earned $106,637. Recent research by Bruhn et al. (2022) also demonstrated that, in part due to higher pay potential and limits on working hours, more teachers move from local charters to BPS than the other way around. Third, interviews with human resources officers in eight districts surrounding BPS suggest that these districts largely operate on a traditional hiring cycle during the summer due to delayed budget approval processes and the common occurrence of teacher resignations occurring late in the summer.[3]

# MEASURES

## Position type

We use detailed job titles to assign positions to one of 16 broad content areas and identify the primary area for each posting.[4]

[2] Thirteen percent of publicly-posted positions are filled by teachers transferring positions within schools. Because these internally-filled positions were open to applicants from the wider market, we include them in our analysis. However, as a robustness check, we replicated our analyses excluding these within-school transfers. This restricted sample yields nearly identical findings to those from the full sample.

[3] These districts include Arlington, Belmont, Chelsea, Framingham, Melrose, Needham, Waltham, and Watertown.

[4] The 16 categories we constructed include, in order of prevalence: special education, elementary general education, science, English as a second language, math, visual or performing arts, English language arts, early childhood education, social studies, physical education, foreign language, vocational, instructional coaching and support, technology, advanced work, and business. The assigned categories align to the core licensure areas

**TABLE 2** Movement of applicants across the search window, by applicant characteristic.

| | *N* | Percent (%) | Median entry by # of days from window opening | Median length of submission period (days) |
|---|---|---|---|---|
| All applicants | 17,986 | 100 | 64 | 8 |
| *Internal applicants* | *5,440* | *30* | *18* | *30* |
| BPS teachers | 3,445 | 19 | 15 | 26 |
| Other BPS employees | 1,995 | 11 | 25 | 37 |
| *External applicants* | *12,546* | *70* | *56* | *2* |
| Boston resident | 3,131 | 17 | 42 | 15 |
| MA resident (excl. Boston) | 7,094 | 39 | 65 | 2 |
| Outside of MA | 2,321 | 13 | 50 | 1 |
| Experience (self-reported) | | | | |
| None | 1,425 | 8 | 45 | 2 |
| 1–2 years | 4,518 | 25 | 42 | 7 |
| 3–4 years | 3,492 | 19 | 41 | 9 |
| 5–9 years | 4,051 | 23 | 41 | 7 |
| 10+ years | 4,447 | 25 | 36 | 13 |
| Not reported | 53 | 0 | 193 | 1 |
| Race/ethnicity | | | | |
| Black | 2,531 | 14 | 36 | 15 |
| Hispanic | 1,348 | 7 | 38 | 7 |
| White | 11,581 | 64 | 43 | 6 |
| Other | 915 | 5 | 38 | 10 |
| Not reported | 1,611 | 9 | 32 | 14 |
| Most recent evaluation score | | | | |
| >1 SD above average | 284 | 2 | 18 | 5 |
| Within 1 SD of average | 2,928 | 16 | 15 | 23 |
| >1 SD below average | 625 | 3 | 21 | 67 |
| Not available | 14,119 | 79 | 52 | 4 |
| Most recent value-added score | | | | |
| > Average (0) | 424 | 2 | 16 | 23 |
| <= Average (0) | 742 | 4 | 16 | 33 |
| Not available | 16,820 | 94 | 42 | 7 |
| Licensure status | | | | |
| Licensed | 11,855 | 66 | 36 | 15 |
| Preliminary | 1,981 | 11 | 46 | 8 |
| Pending | 3,089 | 17 | 41 | 1 |
| Not licensed | 1,061 | 6 | 90 | 1 |
| Certification pathway | | | | |
| Traditional program | 15,816 | 88 | 43 | 5 |
| Alternative route | 2,170 | 12 | 21 | 26 |

*Notes*: To define Median Entry (column 3), we center application dates on the day the hiring window opens such that days from window opening for an application submitted on first day of the hiring window would equal 0, on the following day it would equal 1, and so on; for each applicant we then define their entry date using the centered value for the first application they submit in a given hiring year. Median Length of Submission Period is simply the difference in days between the first and last application submission dates for a given applicant in a given hiring year. SD = standard deviation.

## Market entry and exit

To understand the temporal dynamics of the hiring process, we must first identify when applicants enter and exit the local market for teaching in BPS schools. We functionally define entry (exit) as the date when a candidate first (last) submits an application to a BPS teaching position. For example, when a teacher submits their last application to a BPS position within a given hiring window, we consider them to have exited the market, given that they have ceased to contribute to the supply for any BPS positions past that date. While applicants' final submission date is not strictly synonymous with exit, it appears to be a good proxy in this setting. For the applicants who are hired and for whom there is a recorded hire date, the two dates line up closely, with exit from the submission process preceding hire approval for the median applicant by about 2.5 weeks. It is possible teachers who stop applying to jobs in BPS remain active in the broader Boston-area teacher labor market. However, evidence suggests labor market flows generally move in the direction towards BPS rather than away.

## Applicant and new hire effectiveness

Our first effectiveness measure is an estimate of value-added to student achievement in tested grades and subjects. We estimate applicants' value-added to student achievement by extracting coefficients associated with teacher-by-year fixed effects from a covariate adjusted value-added model.[5] We use current year data for applicants who are hired into tested grades and subjects. For internal applicants for whom current year data are not available, we use data from the most recently available prior year. We then re-standardize these estimates across all applicants within each year to be mean zero with unit variance so the units are on the same scale as the evaluation ratings. We use these estimates to provide descriptive statistics for our application sample.

For our analyses focused on new hires, we model the relationship with teachers' value-added to student achievement directly within an education production function model with student test scores as the outcomes. In this setting, the units are in student test-score standard deviations. These data are available for 9.7% of new hires given that the majority do not teach in tested subjects and grades.

We construct a second measure of teacher effectiveness based on formal teacher evaluation ratings. Principals and other school administrators conduct annual evaluations of BPS teachers using a rubric developed by the state and adapted by the district. Teachers receive ratings on a 4-point scale ranging from *Unsatisfactory* to *Exemplary* across four specific domains: 1) Curriculum, Planning, and Assessment; 2) Teaching All Students; 3) Family and Community Engagement; and 4) Professional Culture. Evaluators consider evidence from classroom observations, instructional artifacts, and progress towards teachers' self-identified professional practice and student learning goals.[6] We construct evaluation scores by assigning integer values of 1 to 4 to the rating categories and averaging across the four evaluation domains. We then standardize these scores across teachers within each year.[7] Evaluation scores are available for 90.7% of new hires.

in Massachusetts. There is some overlap in position types, though most (78%) are limited to a single teaching area. While we see cross-content area postings (3%) such as math and science, most of the remainder of positions are cross-listed as special education (13%), ESL (4%), or both (2%). In cases where positions are listed under multiple content areas, we define that position's content area by the unique combination so that each content category is mutually exclusive.

[5] We estimate teacher value-added scores by regressing standardized achievement scores, separately by content area, on a vector of student demographic characteristics and a cubic polynomial of lagged test scores in both math and ELA, with interactions for the content area and grade of the lagged tests; models are estimated with teacher-by-year and grade-by-year fixed effects. We then standardize value-added scores within year. We have explored a variety of other approaches to estimating teacher value-added (including the use of random instead of fixed effects, adding class-level covariates, etc.); our estimates are robust to value-added model choice.

[6] Measures of teacher effectiveness based on student performance on state standardized tests are not calculated or used by the district.

[7] Given the small share of applicants for whom pre-hire quality measures exist, we explore the robustness of our analyses that rely on these measures to imputed estimates using applicants' self-reported experience to predict unknown or unavailable value-added and evaluation scores.

## New hire outcomes

We explore how hiring timing and supply relate to several different hiring outcomes. A first-order concern is simply whether a position is filled, given that 9.9% of the teaching position postings in our panel did not result in a hire. We also construct two measures of hiring outcomes that are observable teacher characteristics. The first measure captures whether an applicant has a pending or full licensure in the same broad content area as the posting. Just under 90% of new hires hold a license in the content area they are hired to teach. The second is teacher experience, which we dichotomize to reflect whether a teacher has any prior teaching experience. Nearly 80% of new hires have prior teaching experience. While experience is related to teacher effectiveness, some school leaders may proactively choose to hire novice teachers from particular teacher preparation or pipeline programs they view as high quality. Finally, we construct an indicator if a newly hired teacher remains at their school in the following year as a proxy for the quality of the teacher-school match. Seventy percent of new hires remain at their school after the first year in our panel. We have comprehensive data on certification, experience, and retention for all new hires in our analytic sample.

# METHODS

## Determinants of supply

### Position type

We begin our analysis by exploring the extent to which supply varies across types of positions (i.e., by content area). We present descriptive information about variation in demand and supply for the nine highest-demand content areas. These are, by size: special education, elementary general education, science, English as a second language (ESL), math, arts, English language arts (ELA), early childhood education (ECE), and social studies. For each content area, we calculate: 1) the volume of open positions, 2) the ratio of total applications to open positions, and 3) the ratio of unique applicants to open positions. We also explore variation in applicant density across positions within content areas.

### Schools

We examine the degree to which supply differs across schools by decomposing the variance in supply attributable to individual schools within specific position types as follows:

$$N_{jkst}^{Position} = \alpha_k + (\pi_{st} + \varepsilon_{jkst}). \quad (1)$$

We define supply, $N_{jkst}^{Position}$, as the total number of applicants to a given position $j$, in content area $k$, at school $s$, in year $t$. Here we model the error term using random school-by-year effects ($\pi_{st}$) and random error ($"_{jkst}$). We condition these estimates on content-area fixed effects ($\alpha_k$) to account for the large differences in overall supply across content areas.

### Timing

We explore the temporal dynamics of teacher hiring by applicant characteristic, by content area, and by the overall teaching supply. We document trends in the volume of both the supply (the size of the

We also explore adding to our imputation models other quality measures (e.g., using known evaluation scores, along with experience, to impute unknown value-added) when available. We find that our estimates and conclusions are robust to each of these imputed quality measures.

active applicant pool) and demand (number of new job postings) of unique jobs applicants and jobs over the course of the hiring window for each of these content areas, averaged across years. We also estimate the relationship between supply and position posting date as follows:

$$N_{jkst}^{Position} = f\left(W_{jkst}\right) + N_{kt}^{Total} + \tau_t + \delta_k + \varepsilon_{jkst}. \quad (2)$$

Here, we regress the number of applicants ($N_{jkst}^{Position}$) for a given position $j$ within content area $k$, school $s$, and year $t$ on the week in which a position was posted ($W_{jkst}$). In addition to year ($\tau_t$) and content-area ($\delta_k$) fixed effects, we condition on the total volume of applications across the district for a position's primary content area ($N_{kt}^{Total}$) to account for our expectation that different content areas will have varying levels of overall supply over time.[8] We first model $f(W_{jkst})$ graphically using binned scatter plots conditional on the same set of controls in equation (2) and then report results from regression models that use a non-parametric series of indicators for date ranges, as follows: 1) the first week of the window (47% of all postings); 2) the second through eighth week (14%); 3) the ninth through sixteenth week (18%); and 4) more than 16 weeks into the window (21%).

Equation (2) sheds light on the association between position posting dates and teacher supply. However, any relationship we find might be explained by patterns where more (or less) attractive schools are more (or less) likely to post earlier in the hiring cycle. We also present estimates of equation (2) that include school fixed effects to remove fixed differences in the characteristics of schools that might influence the number of applications they receive for open positions. While this does not allow us to identify causal relationships, it does restrict our comparisons to positions within the same school ruling out a large number of potential confounding factors such as neighborhood characteristics, school infrastructure, and stable features of the student population. School fixed effects do not account for features of a school which may vary over time like the principals' leadership style or collegiality of the teaching staff. Such time-varying features might be associated with both the timing of job posting and teacher supply, although we document relative stability in supply and timing within schools over time suggesting unobserved time-varying school features are not likely to drive our results.

## Implications for hire quality

We next examine the relationship between hiring outcomes and both position posting dates and the supply response. We build our models incrementally to demonstrate the separate and conditional associations between timing and supply with hiring outcomes. We first model hiring outcomes as a function of timing, replacing the left-hand variable in equation (2) with the respective hiring outcome variable.

We then estimate, conditional on timing, the association between supply ($N_{jkst}^{Position}$) and our hiring outcomes, $Y$.

$$Y_{jkst} = f\left(W_{jkst}\right) + f\left(N_{jkst}^{Position}\right) + N_{kt}^{Total} + \tau_t + \delta_k + \varepsilon_{jkst}. \quad (3)$$

As above, these additive models control for the size of the total supply within the position's respective content area in a given year, as well as year and content-area fixed effects. We first model $f(N_{jkst}^{Position})$ graphically using conditional binned scatter plots analogous to equation (3) and then report results from regression models that use a non-parametric set of indicators for equally sized quintiles of position supply.[9] Across all our outcomes, we present results from equation (3) without and with school

[8] Results from models that replace fixed effects for content-area and year with content-area-by-year fixed effects yield comparable findings (not shown). In these models, the term $N_{kt}^{Total}$ is dropped because it is collinear with content-area-by-year fixed effects.

[9] We use quintiles rather than the raw number of applications per position given that the total applicant-pool size and distribution of applicants per position varies across teaching content areas. The lowest quintile can (and does) include positions that have netted zero applicants; however, this is a proportionally small set of positions ($n = 16$), which are distributed across content areas.

fixed effects to examine the degree to which the patterns we find hold when restricting estimates to within-school comparisons across positions and over time.

# RESULTS

## Determinants of supply

Consistent with competitive search theory, we find that three key features interact to determine local teacher labor supply in BPS. First, the supply of applicants varies widely across content areas, with substantially fewer applicants for science, math, special education, and English as a second language positions. Second, supply varies across schools within content areas; factors specific to individual schools are important determinants of the number of applicants a position receives and may reflect schools' actions and/or applicants' preferences. Third, timing is a core element of the process, structuring the supply of applicants available within content areas. Applicant activity peaks early in the hiring window, yet many positions are posted well after most applicants have effectively left the BPS labor market, such that late-moving schools will miss out on potential hires. Together, these features work together to structure the supply of applicants to a given position.

### Supply varies substantially across content areas

Echoing past research (e.g., Dee & Goldhaber, 2017; Sutcher et al., 2016), we find substantial variation in both supply and demand across core teaching areas. As seen in Figure 1, positions in traditional shortage areas such as science, math, special education, and English as a second language receive many fewer applications relative to their demand. Demand is highest for special education and elementary education teachers—each of which comprises about 1 in 7 openings (Figure 1a). Despite similarly high demand, however, special education receives many fewer applications per opening than elementary education positions (Figure 1b). Special education and science positions in particular receive roughly one application for every three submitted to elementary school positions. A key metric here is the number of unique applicants per open position (Figure 1c). Special education and science positions have many fewer applicants per position (6) than elementary education (10), early childhood (15), ELA (15), and social studies (16) positions.

However, position type does not fully determine supply. There is also considerable variation in teaching supply across positions within content areas. While the median science position receives 15 applications, some receive more than 50. And, science positions exhibit less variation in supply than other content areas. In Figure 2, we highlight four of the content areas with greatest demand—special education, elementary education, science, and math. Although elementary education positions have high application rates on average, some elementary positions receive 10 to 20 times the number of applicants than others. This variation suggests that, while content area certainly matters for supply, there are important dynamics at play within content areas that structure the supply of applications for a given position.

### Supply varies substantially across schools within content areas

Schools explain a considerable amount of this variation. Within content areas, school-by-year random effects account for 17% of the variation in supply (column 1, Panel A of Table 3). We conduct several tests to better understand the degree to which differences in applicants volume for similar positions across schools is persistent over time. We find quite similar results when we add year fixed effects to the model and change the school-by-year random effects to school random effects (column 3).

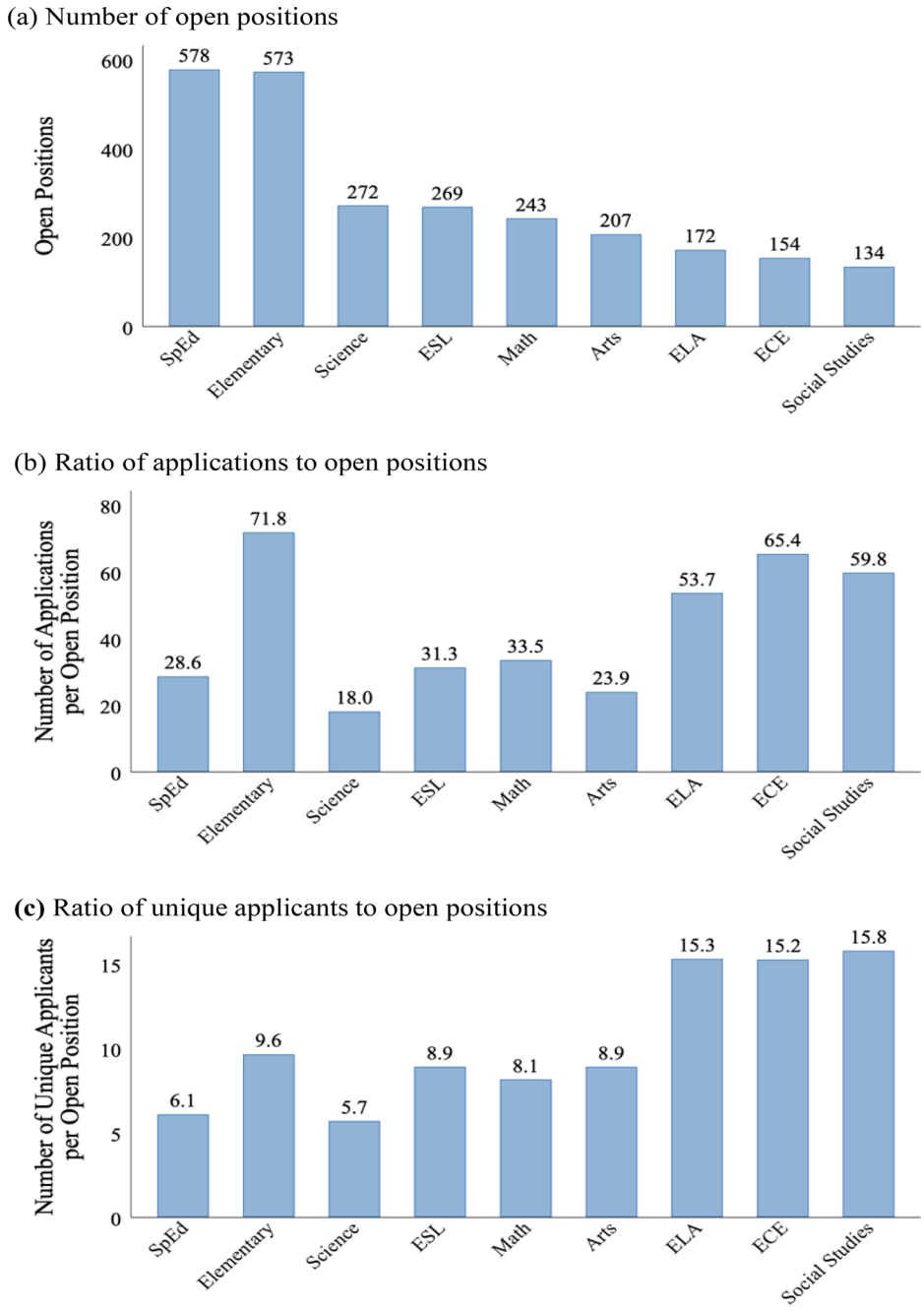



**FIGURE 1** **(a–c)**. Frequency of postings and applications by content area.
[Color figure can be viewed at wileyonlinelibrary.com]
*Notes*: SpEd = special education; ESL = English as a second language; ELA = English language arts; ECE = early childhood education.

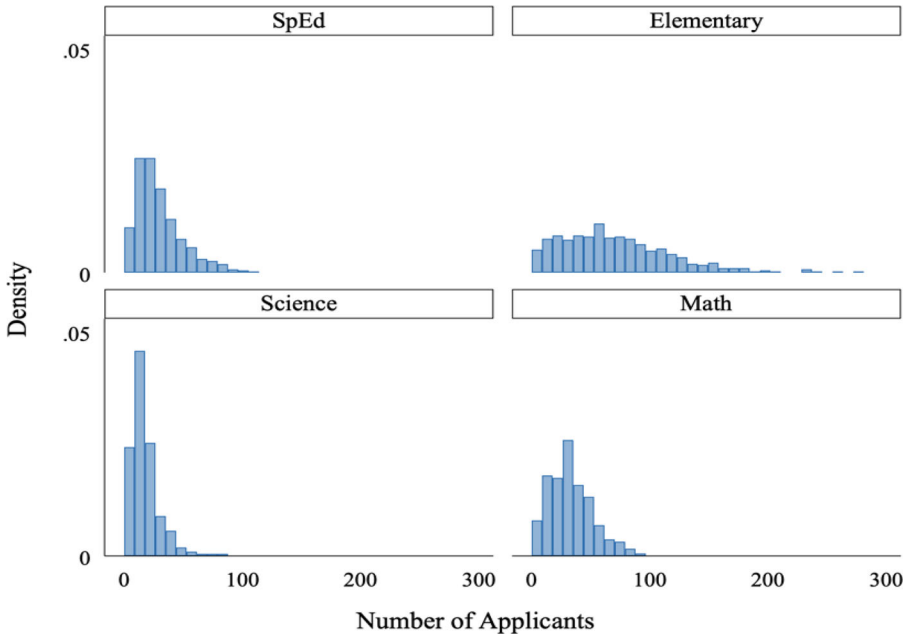



**FIGURE 2** Distribution of the size of the applicant pool applying to a given position in the four largest content areas. [Color figure can be viewed at wileyonlinelibrary.com]

**TABLE 3** Decomposing the variation in the share of applicants applying to bps teaching positions, pooling across content areas.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| **Panel A. Number of applicants** | | | | | | |
| School-by-year | 0.169 | 0.177 | | | | |
| Year | | | | | 0.169 | 0.180 |
| School | | | 0.137 | 0.149 | 0.105 | 0.115 |
| **Panel B. Share of applicant pool** | | | | | | |
| School-by-year | 0.155 | 0.168 | | | | |
| Year | | | | | 0.157 | 0.171 |
| School | | | 0.119 | 0.135 | 0.092 | 0.104 |
| **Panel C. *ln*(number of applicants)** | | | | | | |
| School-by-year | 0.181 | 0.193 | | | | |
| Year | | | | | 0.196 | 0.208 |
| School | | | 0.167 | 0.179 | 0.126 | 0.132 |
| Content area FE | X | X | X | X | X | X |
| Year FE | | | X | X | | |
| Posting-date adjustment | | X | | X | | X |

*Notes*: Models in panel A and panel C also include controls for the size of the overall within-content-area applicant pool. Values are intraclass correlation coefficients. The sample of positions is limited to the nine highest-demand content areas ($n$ = 2,602). In panel C, we impute a value of 0 for *ln*(Number of Applicants) for seven observations where positions received no applications. In columns 2, 4, and 6 we use residualized outcomes conditional on a continuous measure of the date a position was posted during the calendar year. All point estimates are from random effects of school, year, or school-by-year except where fixed effect (FE) variables are noted.

The proportion of variance in position supply explained by school random effects in these models is only marginally smaller than that explained by school-by-year effects. It also remains substantively large when we instead estimate random effects for years nested within schools (columns 5), with school-specific random effects accounting for approximately 10% of the variation in supply.

Results across these three specification remain robust when we adjust the volume of supply for the date a position was posted (columns 2, 4, and 6) we well as when we use alternative measures of supply (Panels B and C).[10] However, these school-by-year effects could be attributable to idiosyncrasies of a given year's labor supply, or due to features specific to a given school. In exploratory analyses not shown, we find that the share of variation explained by schools is larger for high-supply position types (early childhood, elementary, social studies, and English language arts) than for low supply types (special education, science, English as second language, and arts), suggesting that larger labor supply does not benefit all schools equally. These findings support the theory that factors specific to individual schools are important determinants of the number of applicants a position receives. In other words, some schools consistently receive more applications than others.

We illustrate these differences visually in Figure 3(a), estimating the relative average applicant-pool size within a given school, net of year and content area effects. While most schools' applicant pools are statistically indistinguishable from the average, 13% of schools have significantly larger applicant pools (i.e., 95% confidence intervals above the mean) and 16% attract considerably fewer applicants than the district average. This suggest there exists systematic school-specific differences in supply given that we would only expect to find 5% of schools being significantly different from the average by chance using a 95% confidence interval. These school-averaged applicant pools are also distributed similarly across content areas (Figure 3b); schools that elicit below-average supply in one content area also tend to elicit below-average supply in other content areas. School-level rates of applicant supply are also somewhat stable over time. Thirty-six percent of bottom-quintile schools in year $t$ remain in the bottom quintile in year $t+1$ (and 36% remain in the top quintile; see Appendix Table A1[11]). These stable differences across schools may in part be attributable to systematic behaviors on the part of school leaders (e.g., hiring timing, active recruitment), or to features of the schools that make them more or less attractive to applicants (e.g., working conditions, location).

We next examine observable differences in the characteristics of schools that have high (top quintile) and low (bottom quintile) number of applicants (Table 4, columns 1 through 3). Several systematic differences stand out. Schools that benefit from high levels of applicant supply are higher performing; a quarter of the schools with the lowest number of applications have been flagged by the state as persistently underperforming compared to zero schools with typically high numbers of applicants. High-supply schools tend to serve more advantaged student populations than lower-supply schools. They have, on average, fewer students eligible for free or reduced-price lunch, fewer English learners, and their students score about three-tenths of a standard deviation higher in both math and ELA. In addition, high-supply schools are more likely to serve more White students and fewer Hispanic students, although schools on both ends of the supply distributions serve similar proportions of Black students.

[10] We explore several alternative definitions of a school's supply. The first defines supply in terms of the share of the larger applicant pool within a given content area applying to a given position. This approach effectively standardizes the supply within a given content area, but might also attenuate differences across schools depending on the variation in positions' applicant pools. The second converts supply to its logged value, such that changes can be interpreted in percentage units in order to address nonlinearity in the distribution of applicant pools across positions. Each approach produces similar estimates to those from our raw applicant pool definition (see panels B and C of Table 3).

[11] All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at http://onlinelibrary.wiley.com

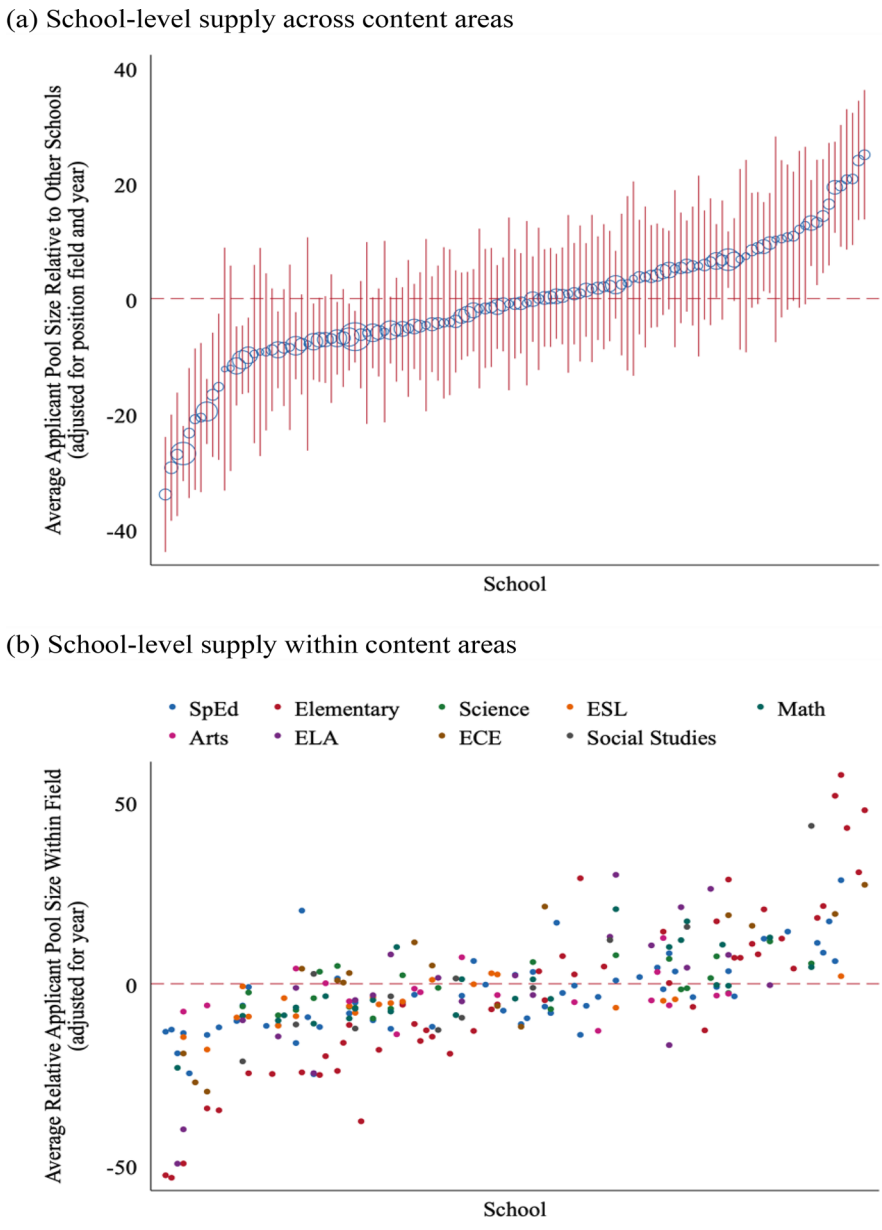



**FIGURE 3** **(a–b)**. Variation in content-area and year-adjusted school-averaged applicant pool sizes. [Color figure can be viewed at wileyonlinelibrary.com]

*Notes*: In panel (a), the figure excludes schools with fewer than five postings across the panel. Red bars represent 95% confidence intervals. Values are centered at the school-level average and weighted in size relative to the total number of positions posted. In panel (b), the figure excludes schools with fewer than five postings across the panel, or schools with positions posted across fewer than three content areas. Values are centered at the school-level average for the content area and sorted according to the schools' across-content-area relative supply (see panel a). Only the nine highest-demand content areas are shown. SpEd = special education; ESL = English as a second language; ELA = English language arts; ECE = early childhood education.

**TABLE 4** Characteristics of high- v. low-supply and early- v. late-posting schools.

| | (1) High-supply schools | (2) Low-supply schools | (3) Difference (high - low) | (4) Early-posting schools | (5) Late-posting schools | (6) Difference (early - late) |
|---|---|---|---|---|---|---|
| *N Schools* | *26* | *25* | | *23* | *26* | |
| Average yearly supply (Applicants) | 304.1 | 265.6 | 38.5 | 273 | 216 | 57 |
| | (39.4) | (40.2) | (56.3) | (38.4) | (36.1) | (52.7) |
| Average yearly demand (Postings) | 5.0 | 10.7 | −5.7*** | 6.6 | 5.2 | 1.4 |
| | (1.2) | (1.3) | (1.8) | (0.8) | (0.7) | (1.1) |
| Applicants per opening | 22.3 | 10.2 | 12.1** | 14.0 | 15.2 | −1.2 |
| | (3.7) | (3.7) | (5.2) | (2.8) | (2.6) | (3.8) |
| Median posting date (in days from window opening) | 39.6 | 22.4 | 17.2* | 0.2 | 90.7 | −90.5*** |
| | (6.2) | (6.3) | (8.8) | (4.9) | (4.6) | (6.7) |
| Average relative supply (net of year and content area effects) | 17.4 | −15.7 | 33.0*** | −4.8 | 3.4 | −8.2*** |
| | (2.3) | (2.4) | (3.3) | (2.4) | (2.2) | (3.3) |
| Student enrollment | 810.9 | 653.3 | 157.6 | 537.4 | 723.3 | −185.9 |
| | (146.9) | (149.8) | (209.8) | (100.1) | (94.1) | (137.4) |
| Serves grades K–5 | 0.88 | 0.68 | 0.20* | 0.78 | 0.65 | 0.13 |
| | (0.08) | (0.08) | (0.11) | (0.10) | (0.09) | (0.13) |
| Serves grades 6–8 | 0.35 | 0.52 | −0.17 | 0.43 | 0.54 | −0.10 |
| | (0.10) | (0.10) | (0.14) | (0.11) | (0.10) | (0.15) |
| Serves grades 9–12 | 0.12 | 0.32 | −0.20* | 0.26 | 0.19 | 0.07 |
| | (0.08) | (0.08) | (0.11) | (0.09) | (0.08) | (0.12) |
| % Black | 0.33 | 0.33 | 0.00 | 0.42 | 0.32 | 0.10** |
| | (0.04) | (0.04) | (0.06) | (0.04) | (0.03) | (0.05) |
| % White | 0.18 | 0.10 | 0.09** | 0.10 | 0.14 | −0.04 |
| | (0.03) | (0.03) | (0.04) | (0.02) | (0.02) | (0.03) |

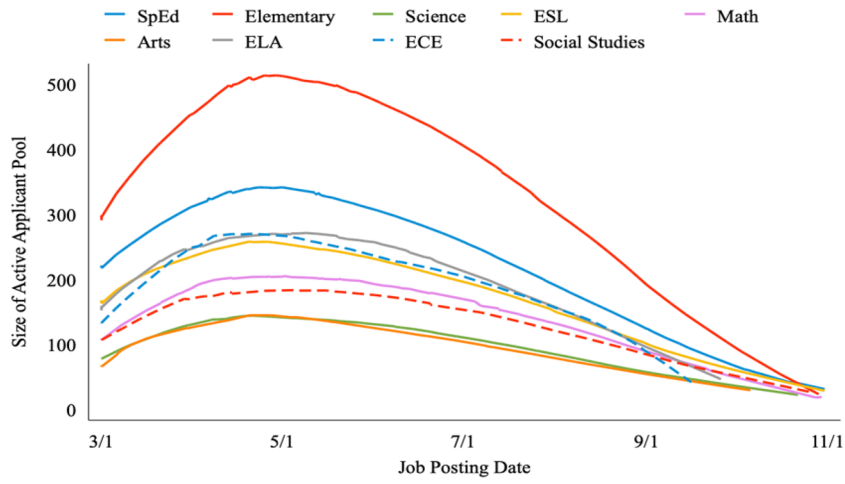
(Continues)

**TABLE 4** (Continued)

| | (1) High-supply schools | (2) Low-supply schools | (3) Difference (high - low) | (4) Early-posting schools | (5) Late-posting schools | (6) Difference (early - late) |
|---|---|---|---|---|---|---|
| % Hispanic | 0.39 | 0.50 | −0.11** | 0.44 | 0.48 | −0.04 |
| | (0.04) | (0.04) | (0.05) | (0.04) | (0.03) | (0.05) |
| % Asian | 0.08 | 0.06 | 0.02 | 0.03 | 0.05 | −0.02 |
| | (0.02) | (0.02) | (0.03) | (0.01) | (0.01) | (0.02) |
| % FRPL | 0.72 | 0.79 | −0.07* | 0.79 | 0.76 | 0.03 |
| | (0.03) | (0.03) | (0.04) | (0.02) | (0.02) | (0.03) |
| % EL | 0.27 | 0.43 | −0.16*** | 0.33 | 0.33 | 0.00 |
| | (0.04) | (0.04) | (0.06) | (0.04) | (0.04) | (0.05) |
| % Special needs | 0.23 | 0.25 | −0.02 | 0.28 | 0.28 | −0.01 |
| | (0.04) | (0.04) | (0.05) | (0.05) | (0.05) | (0.07) |
| Student math achievement | 0.039 | −0.241 | 0.280** | −0.331 | −0.197 | −0.134 |
| | (0.095) | (0.097) | (0.136) | (0.080) | (0.069) | (0.106) |
| Student ELA achievement | 0.043 | −0.279 | 0.322** | −0.386 | −0.194 | −0.193 |
| | (0.103) | (0.105) | (0.147) | (0.101) | (0.088) | (0.134) |
| School flagged by state for underperformance | 0.00 | 0.24 | −0.24*** | 0.17 | 0.04 | 0.14 |
| | (0.06) | (0.06) | (0.09) | (0.06) | (0.06) | (0.09) |

*Notes*: High- and low-supply schools are defined by quintile of school-level supply, where supply estimates represent the relative average applicant-pool size within a given school, net of year and content area effects. Early- and late-posting schools are defined by those in the top (earliest) and bottom (latest) quintile of their median posting date. FRPL = Free or Reduced Price Lunch. EL = English Learner. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

(a) Density of applications by content area




(b) Cumulative distribution of entry into and exit from the BPS teacher labor market


**FIGURE 4** **(a–b)**. The temporal movement of supply across the hiring season.
[Color figure can be viewed at wileyonlinelibrary.com]
*Notes*: Data are pooled across the 2014 through 2017 hiring windows. SpEd = special education; ESL = English as a second language; ELA = English language arts; ECE = early childhood education.

## Timing of hiring structures supply within content area

The volume of applicant supply in BPS evolves substantially over time, with an apex relatively early in the hiring window (around May 1). As seen in Figure 4(a), this pattern is consistent across content areas. In Figure 4(b), we show the cumulative distribution of market entry dates and dates when applicants cease applying. Most positions are posted early; close to half are posted in the first 2 weeks of the hiring window. Teachers in Boston also enter the market early when given the opportunity; half of all applicants have submitted their first application by April 11 each year—7 weeks into the hiring window. However, more than 1 in 6 positions have yet to be posted on July 1, BPS's target for completing hiring. At this point, most applicants (64%) have ceased applying, causing schools that are unable to post positions earlier to miss out on a majority of the potential applicant pool. A range

of structural factors can impede schools' ability to post earlier in the hiring cycle, including delayed budget approvals and teachers who wait to notify their schools that they are leaving until late in the hiring cycle. These supply dynamics also vary across applicant types, with internal candidates applying earlier and more effective candidates leaving the labor pool more quickly. In Table 2, we highlight differences across applicants on two key metrics—the number of days between the opening of the hiring window and when a teacher first applies, and the number of days an applicant remains "active" (i.e., the difference between when they submit their first application and cease applying for new teaching positions in BPS). The most notable differences arise for teachers who are currently employed in BPS and those from outside the district. Internal applicants enter the market significantly earlier and continue actively applying for far longer (see also Appendix Figure A1). External applicants, particularly those from outside of Boston, apply much later and most only apply to positions on 1 to 2 days.

We also see differences in characteristics across schools that post early and late (in Table 4). Schools that post early have a median posting date in the first week of March while schools that post late have a median posting date in the first week of June. Early-posting schools enroll a higher percentage of students who are Black, have students that score roughly a third of standard deviation below the district average on state achievement tests, and are more likely to be flagged for underperformance. The sizes of these differences are meaningful but only statistically significant for Black student enrollment. This highlights the importance of estimating models with school fixed effects that serve to account for persistent differences across schools in these characteristics that are associated with teacher supply and the timing of job postings.

While our application data do not include measures of instructional effectiveness for the entire pool, we can observe measures of internal applicants' past performance. Here, more-effective teachers leave the market much more quickly than their less-effective peers. For the internal applicants for whom we have prior evaluation scores, applicants that score 1 standard deviation above the average left the market after an average of 5 days, compared to 67 days for applicants with scores 1 standard deviation below the average. Similarly, among candidates with prior value-added scores, those who are above average tended to leave the BPS market substantially earlier than those with below-average performance, suggesting that earlier hiring might improve access to these candidates.

## The relationship between timing and supply

The timing of when positions are posted also appears to be systematically related to the total number of applicants who apply. We first provide a non-parametric graphical representation of the relationship between posting date and the quantity of applications in Figure 5 using a binned scatterplot conditional on the full set of controls in equation (2). These plots illustrate a clear negative relationship, with supply decreasing at an accelerating rate as the hiring season progresses into the summer. We estimate this relationship more formally and display the results in Table 5. Positions posted more than 4 months (17 or more weeks) into the hiring window receive seven fewer applications, on average.

In Table 5 column 2 we show that the relationship between when schools post positions and the number of applicants they receive holds even when we restrict comparisons within school by including school fixed effects. We find some evidence of non-linearity, with positions posted shortly after the first week of the hiring window (between weeks 2 and 8) attracting more applicants than those posted in the first week. This may reflect an advantage to posting when most applicants are submitting applications. It may also reflect the benefits of posting after the initial wave of early posts making new postings more visible for candidates when listings are sorted by date on the district job posting website. More broadly, models with school fixed effects confirm that the association between later posting and lower supply is not simply a function of schools that are less attractive to candidates being more likely to post later. In fact, as Table 4 illustrates, it is the schools that typically struggle to attract more applicants that are most likely to post earlier in the hiring season.

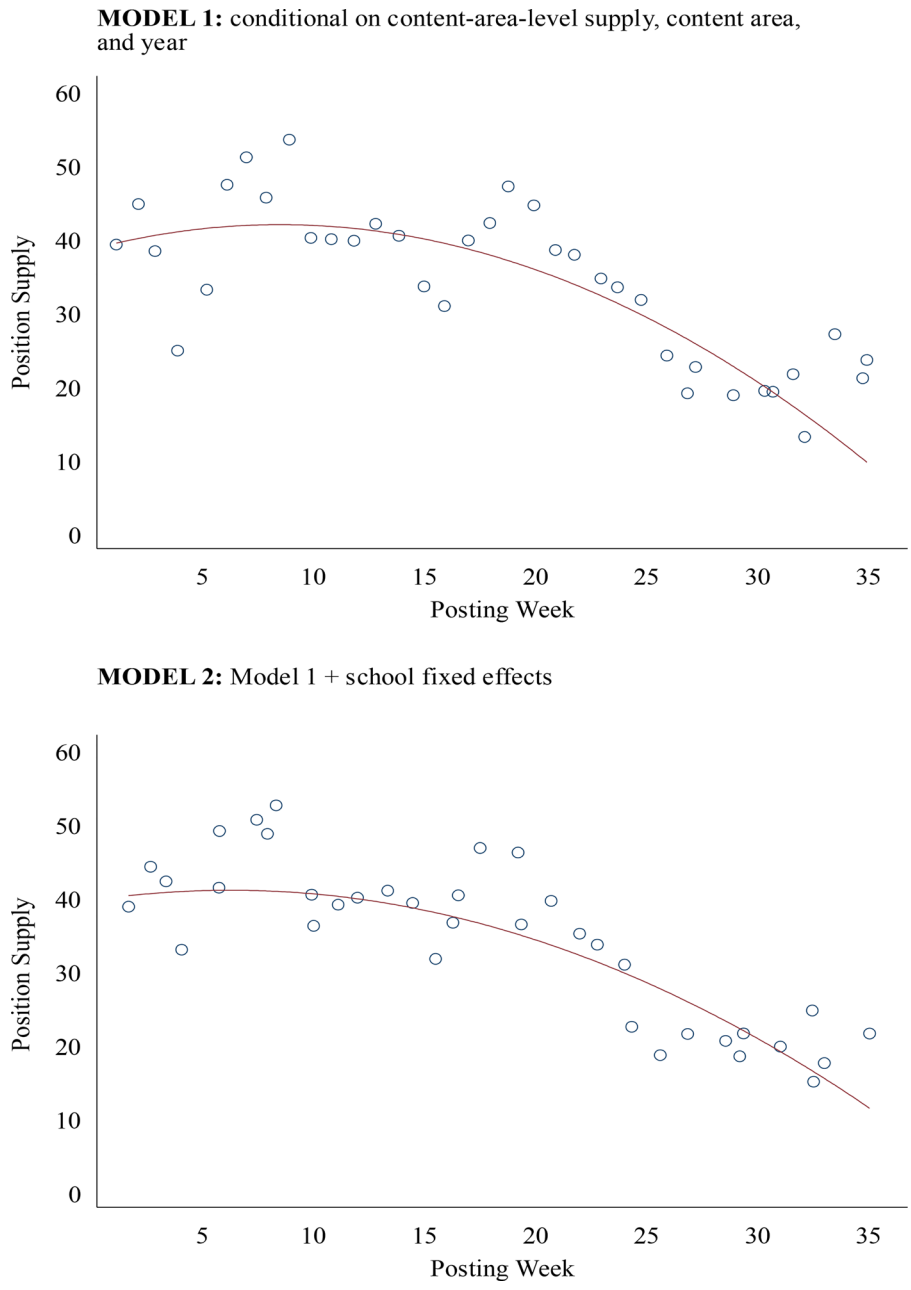



**FIGURE 5** Conditional binned scatterplots of the relationship between hiring timing and position supply. [Color figure can be viewed at wileyonlinelibrary.com]

*Notes*: Figures correspond to equation (2) and the models in Table 5. Each bin represents a given posting week. The red lines are quadratically fitted to the underlying data in the regression models.

## How timing and supply relate to hiring outcomes

Position type, school characteristics, and timing work together to structure the supply of teachers to specific positions in the local labor market. But to what extent do timing and supply predict the success of the hiring process? We explore this question as it relates to both the extensive and intensive

**TABLE 5** The relationship between hiring timing and position supply.

| | (1) | (2) |
|---|---|---|
| Posted weeks 2 to 8 | 2.528 | 7.684*** |
| | (3.861) | (2.455) |
| Posted weeks 9 to 16 | 0.642 | 1.146 |
| | (1.525) | (1.173) |
| Posted week 17 or later | −7.351*** | −8.085*** |
| | (1.316) | (1.226) |
| School fixed effects | | X |
| $R^2$ | 0.38 | 0.37 |
| *N* of positions | 3,611 | 3,611 |

*Notes*: The reference group is positions posted in the first week of the hiring window. Standard errors are clustered within school. All models condition on content-area-level supply and content area and year fixed effects.
***$p < 0.01$, **$p < 0.05$, *$p < 0.10$

margins—that is, how timing and supply are associated with both the probability of filling a position and the quality of the candidate who fills it. We find that timing and supply each predict whether a position is ultimately filled; earlier-posted openings are more likely to be filled as are—conditional on timing—positions with larger applicant pools. We also find that early-posted positions end up with more effective and better qualified new hires than do those that are posted later in the hiring cycle. Conditional on timing, however, applicant supply for a given position is generally unrelated to hire quality, suggesting that schools struggle to identify and select the best candidates from their applicant pools.

## Timing and supply predict whether positions are filled

A first-order concern is whether a candidate actually fills the position. We begin by presenting a non-parametric graphical representation of the relationship between posting date and the probability a position is filled. Figure 6 shows that the timing of posting is negatively related to whether a position is filled, with the likelihood of successfully hiring a candidate declining more rapidly as the hiring season moves into late summer. In Table 6, we model the relationship between the probability of hire and timing in columns 1 (across schools) and 3 (within schools). Because timing matters for supply, we control for it when exploring the relationship between the probability of hire and supply (columns 2 and 4). The results show that both timing and supply matter. Positions posted in July or later are approximately 8 percentage points less likely to be filled than those posted on time. Supply is likewise correlated with the probability a position is filled, with a significantly higher probability (7 percentage points) of a hire being made in the higher quintiles of positions' applicant-pool size than for the lowest quintile of supply. These patterns hold even when we restrict comparisons within schools using school fixed effects.

## Early posting is correlated with more-effective hires

When schools post positions earlier in the hiring cycle, they are more likely to hire more-effective teachers. Graphical illustrations of these relationships in Figure 7 depict clear negative and approximately linear relationships between the timing of position positing and teachers' contributions to student achievement, teacher evaluation scores, teacher experience, and teacher retention. Turning to

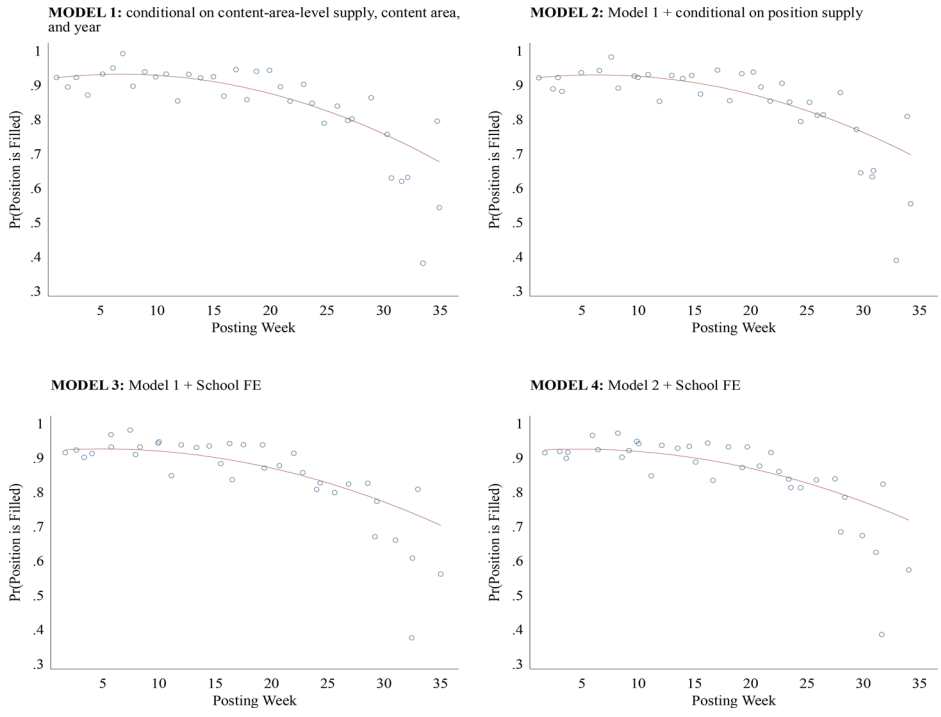



**FIGURE 6** Conditional binned scatterplots of the relationship between hiring timing and the probability a position is filled.

[Color figure can be viewed at wileyonlinelibrary.com]

*Notes*: Figures correspond to equation (3) and the models in Table 6. Each plot bin here represents a given posting week. The red lines are quadratically fitted to the underlying data in the regression models.

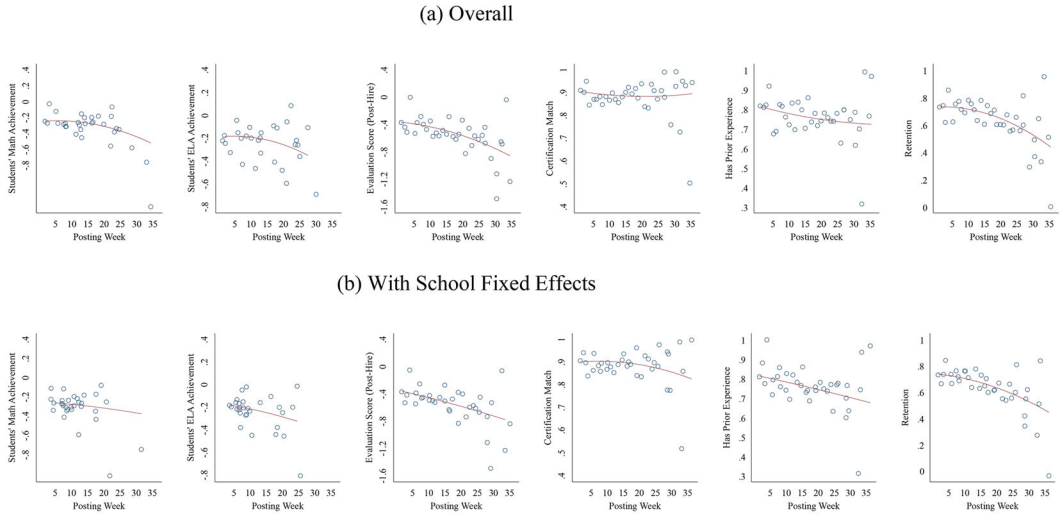



**FIGURE 7** **(a–b)**. Conditional binned scatterplots of the relationship between hiring timing and hire quality.

[Color figure can be viewed at wileyonlinelibrary.com]

*Notes*: Figures correspond to equation (3) and the models in Table 7. Each plot bin here represents a given posting week. The red lines are quadratically fitted to the underlying data in the regression models.

**TABLE 6** The relationship between hiring timing, position supply, and the probability a position is filled.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Posted weeks 2 to 8 | 0.005 | 0.006 | 0.028 | 0.025 |
| | (0.015) | (0.016) | (0.017) | (0.018) |
| Posted weeks 9 to 16 | −0.013 | −0.012 | 0.003 | 0.003 |
| | (0.015) | (0.015) | (0.017) | (0.018) |
| Posted week 17 or later | −0.076*** | −0.068*** | −0.072*** | −0.065*** |
| | (0.016) | (0.016) | (0.017) | (0.017) |
| Number of applicants: Quintile 2 | | 0.042** | | 0.035* |
| | | (0.020) | | (0.020) |
| Number of applicants: Quintile 3 | | 0.067*** | | 0.056*** |
| | | (0.019) | | (0.018) |
| Number of applicants: Quintile 4 | | 0.058*** | | 0.043** |
| | | (0.018) | | (0.020) |
| Number of applicants: Quintile 5 | | 0.073*** | | 0.061*** |
| | | (0.018) | | (0.020) |
| School fixed effects | | | X | X |
| $R^2$ | 0.06 | 0.06 | 0.15 | 0.15 |
| *N* of positions | 3,611 | 3,611 | 3,611 | 3,611 |

*Notes*: The reference group for posting date is positions posted in the first week. The reference group for the number of applicants is the bottom quintile. Quintiles are estimated within content area and year. Standard errors are clustered within school. All models condition on content-area-level supply and content area and year fixed effects. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$

our model-based estimates in Table 7, we find negative associations between later posting and student achievement in the new hires' classrooms at the end of the year. Students whose teachers filled positions that were posted more than 16 weeks into the hiring window make academic achievement gains that are 0.10 standard deviations lower in English language arts than students whose teachers filled positions posted at the start of the window (column 2 Panel B). Estimates for student achievement in math are consistently negative but small and not statistically different from zero.

When schools post earlier, they also end up with teachers who earn higher evaluation scores, both in the position that they were hired into (Table 7 column 3) and, for the subset of teachers with previous experience in BPS, preceding their hire (not shown). We find that posting a position between 9 and 16 weeks into the hiring cycle is associated with new hires that received evaluation scores that are 0.11 standard deviations lower those hired for positions posted in week 1. Teachers hired more than 16 weeks into the hiring window are rated more than 0.30 standard deviations lower, on average. The timing of job postings is associated with other teacher characteristics. Our results also suggest that posting earlier is associated with more new hires who are certified in their content area (column 4) and who have prior teaching experience (column 5). With the exception of certification, all of these relationships between posting timing and hiring outcomes are robust to the inclusion of school fixed effects.

Earlier postings also predict stronger teacher-school matches; teachers who fill positions that are posted earlier are substantially more likely to remain in the school past the year of hire (by nearly 13 percentage points; Panel A of Table 7, column 6). These patterns do not appear to be driven by differences across schools, as results are quite similar in models that include school fixed effects (Panel B). The relationship between late posting and hiring outcomes is consistent with our descriptive evidence on the temporal dynamics of the teacher labor supply; the pool of active—and attractive—applicants dramatically decreases over time. These trends make it more difficult for the latest-posting

**TABLE 7** The relationship between hiring timing and hire quality.

| | (1) Student achievement in math | (2) Student achievement in ELA | (3) Evaluation score (post-hire) | (4) Certification match | (5) Has prior experience | (6) Retention |
|---|---|---|---|---|---|---|
| **Panel A. Overall** | | | | | | |
| Posted weeks 2 to 8 | 0.047 | −0.081 | 0.026 | −0.033** | −0.035 | −0.005 |
| | (0.061) | (0.054) | (0.060) | (0.015) | (0.028) | (0.034) |
| Posted weeks 9 to 16 | −0.090* | −0.028 | −0.114*** | −0.028* | −0.043** | −0.016 |
| | (0.051) | (0.053) | (0.043) | (0.015) | (0.020) | (0.029) |
| Posted week 17 or later | −0.029 | −0.045 | −0.310*** | −0.020 | −0.080*** | −0.126*** |
| | (0.038) | (0.057) | (0.045) | (0.014) | (0.022) | (0.024) |
| $R^2$ | 0.646 | 0.569 | 0.063 | 0.104 | 0.032 | 0.031 |
| **Panel B. With school fixed effects** | | | | | | |
| Posted weeks 2 to 8 | 0.042 | −0.01 | 0.003 | −0.021 | 0.016 | 0.004 |
| | (0.070) | (0.051) | (0.054) | (0.017) | (0.022) | (0.034) |
| Posted weeks 9 to 16 | −0.051 | −0.028 | −0.095*** | −0.020 | −0.033* | −0.021 |
| | (0.052) | (0.057) | (0.038) | (0.016) | (0.018) | (0.028) |
| Posted week 17 or later | −0.018 | −0.104* | −0.309*** | −0.020 | −0.090*** | −0.142*** |
| | (0.057) | (0.053) | (0.043) | (0.015) | (0.022) | (0.024) |
| $R^2$ | 0.674 | 0.600 | 0.166 | 0.150 | 0.114 | 0.125 |
| *N* of students | 7,681 | 7,464 | – | – | – | – |
| *N* of positions | 316 | 315 | 2,949 | 3,253 | 3,253 | 3,253 |

*Notes*: Analysis is limited to positions for which a hire is made. Sample sizes vary across outcomes based on the number of teachers for whom the data are applicable or available. The reference group is positions posted in the first week of the hiring season. In models 1 and 2, student achievement scores are standardized within subject, grade, and year. These models (1 and 2) include controls for lagged student achievement, as well as grade-by-year fixed effects, and standard errors are clustered at the teacher-by-school level. Models 3 though 6 include year fixed effects with standard errors clustered within school. All models condition on content-area-level supply and content area. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$

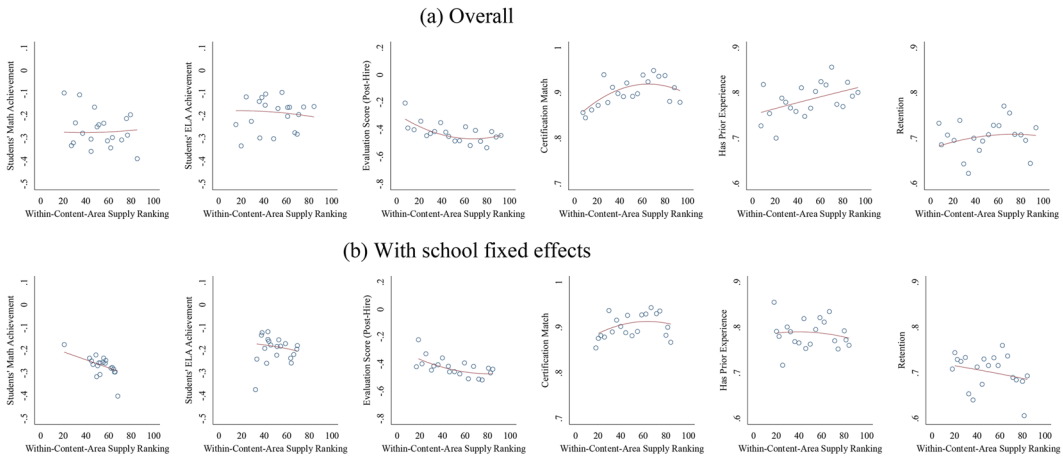



**FIGURE 8** **(a–b)**. Conditional binned scatterplots of the relationship between position supply and hire quality. [Color figure can be viewed at wileyonlinelibrary.com]

*Notes*: Figures correspond to equation (3) and the models in Table 8. Each plot bin here represents a given posting week. The red lines are quadratically fitted to the underlying data in the regression models. The x-axis displays position supply measured as a percentile ranking within content area to provide a common (relative) scale.

schools to attract sufficient candidates with the desired skills, characteristics, and qualifications for their openings.

## Supply is generally unrelated to hire quality

While timing matters for the size of a position's applicant pool and the quality of the teacher who fills the position, position supply is in most cases uncorrelated with the quality of the hire, conditional on timing. The lack of a clear relationship is evident in the conditional binned scatter plots in Figure 8. In Table 8, we find generally nonsignificant associations between applicant volume and student achievement gains in math (column 1) and ELA (column 2), the experience level of the new hire (column 5), and retention (column 6). This is not merely an issue of power; point estimates reveal no clear patterns and are mixed in sign. In some cases, the size of the applicant pool, conditional on timing of posting, is negatively correlated with desired hiring outcomes. Positions with the largest volume of applicants, for example, hire candidates whose evaluation scores are as much as 0.19 standard deviations lower than those with the smallest applicant volume (column 3). The only area for which we see strong and positive associations is for teacher certification; positions that attract the fewest applicants are between 4 and 8 percentage points less likely to end up with an appropriately-certified teacher than those with a larger volume of applicants (column 4).

# Possible explanations for the lack of relationship between supply and hire quality

Larger applicant pools are assumed to be an important indicator of recruitment quality (e.g., Breaugh, 2008), yet our results are not consistent with this expectation. We explore several potential explanations for why supply is not strongly associated with hiring outcomes and why the patterns for some quality outcomes suggest the opposite relationship from what we might expect.

**TABLE 8** The relationship between supply and hire quality, conditional on timing.

| | (1) Student achievement in math | (2) Student achievement in ELA | (3) Evaluation score (post-hire) | (4) Certification match | (5) Has prior experience | (6) Retention |
|---|---|---|---|---|---|---|
| **Panel A. Overall** | | | | | | |
| Number of applicants: Quintile 2 | −0.017 | −0.046 | −0.076 | 0.053*** | 0.020 | −0.033 |
| | (0.057) | (0.064) | (0.065) | (0.018) | (0.026) | (0.026) |
| Number of applicants: Quintile 3 | 0.065 | 0.026 | −0.130** | 0.056*** | 0.028 | 0.002 |
| | (0.064) | (0.062) | (0.059) | (0.020) | (0.030) | (0.027) |
| Number of applicants: Quintile 4 | −0.022 | −0.018 | −0.165*** | 0.079*** | 0.075*** | 0.048 |
| | (0.054) | (0.056) | (0.069) | (0.019) | (0.027) | (0.031) |
| Number of applicants: Quintile 5 | 0.047 | −0.101 | −0.190*** | 0.044*** | 0.049* | −0.008 |
| | (0.061) | (0.065) | (0.060) | (0.019) | (0.030) | (0.027) |
| $R^2$ | 0.648 | 0.571 | 0.069 | 0.111 | 0.036 | 0.034 |
| **Panel B. With school fixed effects** | | | | | | |
| Number of applicants: Quintile 2 | −0.017 | −0.024 | −0.058 | 0.049*** | −0.011 | −0.051* |
| | (0.070) | (0.063) | (0.061) | (0.018) | (0.026) | (0.027) |
| Number of applicants: Quintile 3 | −0.047 | −0.002 | −0.106* | 0.049*** | −0.011 | −0.014 |
| | (0.086) | (0.063) | (0.056) | (0.021) | (0.030) | (0.028) |
| Number of applicants: Quintile 4 | 0.016 | −0.020 | −0.136** | 0.069*** | 0.023 | 0.001 |
| | (0.071) | (0.062) | (0.064) | (0.018) | (0.028) | (0.028) |
| Number of applicants: Quintile 5 | −0.035 | −0.137** | −0.135*** | 0.036* | −0.022 | −0.074*** |
| | (0.081) | (0.060) | (0.052) | (0.020) | (0.029) | (0.025) |
| $R^2$ | 0.675 | 0.601 | 0.169 | 0.154 | 0.115 | 0.129 |
| *N* of students | 7,687 | 7,445 | – | – | – | – |
| *N* of positions | 316 | 315 | 2,949 | 3,253 | 3,253 | 3,253 |

*Notes*: Analysis is limited to positions where a hire is made. Sample sizes vary across outcomes based on the number of teachers for whom data are applicable or available. The reference group for the number of applicants is the bottom quintile of positions. Quintiles are estimated within content area and year. In models 1 and 2, the analysis is conducted at the student level, and student achievement scores are standardized within content area, grade, and year. These models (1 and 2) include controls for lagged student achievement, as well as grade-by-year fixed effects, and standard errors are clustered at the teacher-by-school level. Models 3 though 6 include year fixed effects with standard errors clustered within school. All models condition on content-area-level supply and content area, as well the date the position was posted (i.e., the first week, weeks 2 to 8, weeks 9 to 16, or week 17 or later). ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

## Hypothesis 1: Schools struggle to identify effective teachers given the data available to them

The simplest explanation for the lack of relationship between supply and hire quality is that school leaders may simply be ineffective at screening (e.g., Cannata et al., 2017; Jacob et al., 2018), particularly when it comes to identifying the characteristics of teachers that are most important for success in the classroom. The patterns that emerge are consistent with this hypothesis. For example, while supply is not (or is negatively) associated with measures of teaching effectiveness or instructional quality, it is correlated with the hired teachers' certification status—a teacher trait that is far easier for a school leader to assess at the point of hire than teachers' future effectiveness in the classroom. Schools may be more likely to lean on this easily-observable information when their applicant pools are large and the cost of rigorously screening each applicant is correspondingly higher.

Of course, school leaders can only hire a candidate with high potential for future effectiveness if their pool contains high-potential candidates. To understand if there is a selection mechanism at play here, we examine how the hired candidate compares to her respective applicant pool. For some applicants, we can compare their prior value-added and evaluation scores to other candidates competing for the same positions. If anything, we find that the average hired applicant in high-supply positions falls somewhat lower in the distribution of these pre-hire quality measures than candidates in low-supply positions (Appendix Table A2). We also observe that high-supply positions actually attract candidates, on average, with somewhat better prior evaluation ratings and value-added scores (Appendix Table A3). Thus, principals in high-supply positions appear to have a larger pool of highly effective applicants available, but perform somewhat worse than principals in low-supply positions at identifying these candidates.

## Hypothesis 2: Schools are selecting their hires on other important measures beyond qualifications and effectiveness

Applicant pools for high-supply and low-supply positions differ in other ways, as well. High-supply positions have less-diverse applicant pools, on average, with a higher share of applicants coming from outside of the district. A second possible explanation for the lack of a relationship between supply and hire quality is that the measures we rely on in our analysis may not include the factors that school leaders select on when they make their hiring decisions. The data we have do not support this hypothesis. Schools, for example, might choose to select more-diverse candidates in terms of race and ethnicity in order to build a teaching force that better reflects the demographics of its student body given that a representative teaching force can meaningfully benefit students (Dee, 2004; Gershenson et al., 2022). However, larger supply is not correlated with a greater probability of hiring a teacher of color (Appendix Table A4, Column 1). Given that diversity in the teaching force is inhibited even earlier in the pipeline (i.e., by disparate licensure exam pass rates; Rucinski & Goodman, 2019), we also explore supply as measured by the number of applicants of color. However, even when positions have relatively large shares of applicants of color, these positions are not meaningfully more likely to hire a teacher of color (column 2).

One characteristic not directly observed in our data, but commonly cited by school leaders, is the candidate's potential organizational, job, and group "fit" within the school. For example, principals describe sometimes privileging hiring less experienced teachers who are more committed to working with the student population a school serves rather than more experienced or higher performing teachers (Ingle et al., 2011). Although we cannot measure match quality directly, we can leverage the fact that new hires who are good matches to their schools should have a higher likelihood of retention (Harris et al., 2010; Jackson, 2013; Simon et al., 2019). While late-posted positions end up with hires who are substantially less likely to return to their schools the following year, our results suggest that larger applicant pools do not help schools hire teachers who are better matches. Across schools (column

6, Panel A of Table 8), we find no relationship between position supply and the retention rates of new hires conditional on position content area. Within schools (Panel B), retention rates are even 7 percentage points lower for positions with the highest number of applicants compared to those with the lowest number of applicants, controlling for position content area.

## Hypothesis 3: Large applicant pools are related to hiring delays, which force schools to settle for less desirable candidates

There are a number of paths through which such a phenomenon might occur, several of which relate to the competitive nature of the search process. First, larger applicant pools may take more time to sort through. If a school takes longer to select the strongest candidate when applicant volume is high, that candidate might have already received and accepted other offers before the school is ready to make its own offer. Second, if schools with large applicant pools choose popular candidates who have multiple offers, they may be more likely to fail in recruiting their candidate, delaying hiring. Third, schools may face trade-offs in investing their recruitment resources in building applicant pools versus converting applicants to hires; schools with positions that are more popular in terms of increasing applicant volume may be less successful at recruiting from within their applicant pools. Finally, we may have a spurious association: schools that make offers which are declined, or that are accepted but later reneged upon, might need to repost their openings. By reposting positions, schools would arrive at larger net applicant pools.[12]

We find some evidence that higher supply positions take longer to fill, which would be consistent with this hypothesis. Low-supply positions take about 9 weeks from the posting date for a new hire to be approved, on average, conditional on the school and posting date (Appendix Table A5), while high-supply positions take about 3 weeks longer to fill. This evidence is consistent with the timing patterns we would expect if these high-supply positions had to extend offers to multiple candidates before filling their openings, or were inefficient in the manner in which they extended offers.

## Hypothesis 4: Small applicant pools may result from purposeful, targeted recruitment, in addition to, or instead of, inadequately rigorous recruitment

Our motivating theory of supply assumes that smaller applicant pools will yield fewer quality candidates for a school to select from. However, low supply could also result from purposeful recruitment where a principal targets a high-quality candidate of interest and expedites the process to hire them. In this case, we would expect no relationship (or a negative relationship) between supply and hire quality. We do find some evidence in support of this hypothesis. While we cannot observe the specific recruitment actions schools take, we would expect this process to result in a pattern in which positions with small applicant pools recruit candidates who are in turn more selective in their own search (i.e., applying only for the positions for which they were recruited, versus applicants who cast a wide net). We examine this empirically and find a non-linear relationship between a position's supply and the number of positions for which the average applicant to that position has applied (see Appendix Table A6). Positions with few applicants tend to receive applications from applicants who are either very selective or very undiscriminating. These results indicate that some positions may have small applicant pools because they attract selective or targeted applicants. If we turn instead to the most selective applicants—those applying to only one position—we observe further evidence that higher

[12] Anecdotally, some schools strategically repost positions in order to raise the visibility of older postings (i.e., by bringing them to the top of the queue). We are unable to distinguish in our data the reason a job was reposted.

supply positions elicit somewhat smaller shares of applicants who submit to only one position than do low-supply positions (Appendix Table A7).

### Hypothesis 5: Social and professional networks play a key role in the hiring process, limiting the return from larger applicant pools

Principals and teachers often rely on their social and professional networks to navigate the hiring process. Principals frequently leverage their professional networks and those of their staff to identify and recruit potential new hires (Engel & Finch, 2015). Studies of newly minted graduates from teacher preparation programs find that teacher candidates use their social networks to identify job opportunities, secure interviews, and gather information about the leadership team and working conditions in a school (Cannata, 2010, 2011; Jabbar et al., 2022). Jabbar et al. (2020) found that teachers rely on their personal and professional networks even more in fragmented education markets where greater choice exists. Furthermore, principals may also prefer to hire candidates from specific educator preparation programs that they have had success with in the past.

Although we do not have data to evaluate the potential role of social networks in hiring, they may contribute to these patterns in several ways. First, relying on social networks can lead to the types of purposeful, targeted recruitment that we describe above. Second, and perhaps less productively, it might result in implicit bias in the hiring process, as principals may overlook other markers of effectiveness in exchange for personal/professional network connections. Finally, relying on social networks might reduce the variance in hiring. In other words, when choosing between two candidates with limited predictors of future effectiveness, a principal might choose a candidate from a preparation program they know well or who is part of their broader social network because they perceive the teacher as more likely to be a "sure bet."

Together, our evidence is not consistent with the theory that larger applicant pools on their own enable better hires. While we cannot test all potential hypotheses, results from exploratory analyses are consistent with at least two possible explanations: school are ineffective at selecting high-quality candidates when they have larger pools, perhaps because larger pools limit the time schools can invest in screening each individual candidate (a mechanism we are unable to confirm with our data), and in some cases schools strategically recruit preferred candidates instead of casting a wide net. It is also possible that schools with larger applicant pools increasingly rely on social connections as a sorting mechanism for selecting candidates rather than other qualifications or characteristics. In the absence of better selection, the overall quality of the applicant pool would need to improve for larger pools to yield improved hiring outcomes.

## CONCLUSION

Consistent with prior research, we document considerable asymmetries between the hiring needs of schools and the localized supply of teachers across content areas and schools. Schools seeking to fill vacancies in STEM fields receive roughly half as many applications as those seeking to fill positions in elementary education and the humanities. Some schools consistently receive many fewer applicants than others for positions in the same content areas.

We add to the literature on teacher hiring by documenting how the size and nature of the labor supply evolves over the course of a hiring window. Competitive search models suggest that early hiring should provide schools the benefit of larger applicant pools and more effective hiring. We find that timing is indeed associated with supply and with the quality of candidate a school is able to hire. Positions posted later in the hiring cycle are less likely to be filled, and when they are filled, students in those classrooms have lower academic achievement gains and their teachers exhibit lower instructional quality, are less qualified, and are less likely to remain in the school, indicative of a weaker teacher-

school match. However, the number of individuals applying to a given position is generally unrelated to the quality of the individual hired conditional on posting date. Schools that recruit large applicant pools conditional on timing are more likely to hire candidates who are more attractive based on observable dimensions, such as certification, but no more likely to select candidates who are more effective in the classroom or who remain in their schools—features that may be more difficult for school leaders to identify at the hiring stage.

While our results are largely descriptive, we leverage variation within content areas and schools over time using school fixed effects models. Our findings suggest that efforts to conduct teacher hiring earlier in the hiring cycle and recruit a larger applicant pool have the potential to improve teacher quality, but much of this potential is limited by the challenge of selecting effective teachers during the hiring process. In particular, prior evidence has shown that hiring late—after the school year starts—leads to less effective teachers (Papay & Kraft, 2016). Thus, one clear step all districts can take to increase teacher quality is to reduce the incidence of late teacher hiring. Although districts are unlikely to be able to eliminate instances when teachers notify schools late in the summer they that are not returning or when student enrollment exceeds expectations, they do have some agency over the timing of hiring. BPS was able to reduce the incidence of late hiring by 50% using a collection of hiring reforms which moved the open positing date earlier in the spring and improved the efficiency of the human resources hiring process (Kraft et al., 2021).

Some of the benefits of earlier hiring likely result from partial equilibrium effects as schools compete with one another, and with schools in other districts, for talent. However, our results suggest benefits to early hiring in a general equilibrium framework even if all schools where to move simultaneously towards earlier job posting. Moving the hiring process earlier in the school year could reduce late hiring and create the opportunity to improve teacher-school match quality even if the entire system shifted its timeline earlier. Early job posting expands the search window for both teacher candidates and schools, creating the possibility to conduct more in-depth, information-rich search and hiring processes. This is important because policymakers are concerned with not just the outcomes of individual schools, but with the quality of the public education sector as a whole.

At the same time, simply hiring early in the season or recruiting larger pools of applicants are unlikely in themselves to result in a meaningfully stronger teacher workforce. Consistent with other evidence about the challenges of employee screening (e.g., Goldhaber et al., 2017; Jacob et al., 2018), we find little evidence that schools benefit from larger applicant pools. With weak selection, an expanding labor supply will only increase teacher quality if larger applicant pools also attract higher quality candidates. Districts can take steps to improve teacher quality through the hiring process, but without improved screening and selection these efforts will fail to realize their full potential.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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