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Jessalynn James
Brown University

Matthew A. Kraft
Brown University

John Papay
Brown University

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Local Supply, Temporal Dynamics, and Unrealized Potential in Teacher Hiring

Jessalynn K. James, Matthew A. Kraft, and John P. Papay[†]

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We explore the dynamics of competitive search in the K-12 public education sector. Using data from Boston Public Schools, we document how teacher labor supply varies substantially by position types, schools, 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. Our findings point to substantial unrealized potential for improving teacher hiring.

JEL: I2, J2, J45, J65

[†] James: Brown University, P.O. Box 1985, Providence, RI 02912 (email: jessalynn_james@brown.edu). Kraft: Brown University, P.O. Box 1938, Providence, RI 02912 (email: mkraft@brown.edu). Papay: Brown University, P.O. Box 1938, Providence, RI 02912 (e-mail: john_papay@brown.edu). We are grateful to Boston Public Schools for sharing the necessary data, to Emily Qazilbash for insight into the BPS hiring process, Coral Flanagan and Emily Skahill for helping identify positions' content areas, and to seminar participants at AEFP and the Annenberg Institute for feedback on earlier drafts of this research.

I. 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, Friedman, and Rockoff 2014; Kane and 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 and Wyckoff 2015; Donaldson and Papay 2015; Jackson, Rockoff, and Staiger 2014; James and Wyckoff 2020), as well as to replace ineffective teachers with more effective teachers (Gordon, Kane, and Staiger 2006; Hanushek 2011; Staiger and 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 emphasize, "hiring the right employee is potentially as important or more so than motivating the employee to take the right action after the employee has been hired" (2011, p. 1772). 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 and Quinn 2003, Liu and Johnson 2006, Papay and Kraft 2016). Competitive search models suggest that early hiring should provide schools that act early with the advantage not only of a larger applicant pool, but also with the opportunity to move quickly to attract their top candidates (Mortensen and Pissarides 1999; Oyer and Schaefer 2011; Rogerson, Shimer, and Wright 2005).

We test these theoretical predictions empirically using 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, the typical public school district begins 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.

BPS schools are 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. Teachers enter the market early when given the opportunity; half of all applicants have submitted their first application by April 11 each year—seven weeks into the hiring window. Meanwhile, more than one in six 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.

Finally, we find that while earlier postings receive more applicants and are more likely to be filled by the start of the school year, the size of the applicant pool conditional on hiring timing is largely unassociated with the effectiveness of the hire. Schools that recruit large applicant pools are more likely to hire 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 (an indicator of a positive teacher-school match). 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 and Schaefer 2011). We provide new evidence on the nature of competitive search in one of the largest occupational sectors in the U.S, and one with structural similarities to other public sector labor markets, unionized industries, and professions requiring certified credentials. Our results affirm the salience of position type, firm characteristics, and search timing for shaping labor supply.

However, our findings are inconsistent with model predictions that larger applicant pools produce higher-quality or better matched new hires. Schools do not appear to be realizing the potential gains from expanding their applicant pools through early hiring, nor do we find evidence consistent with schools leveraging larger pools to select more qualified candidates. 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.

II. Conceptual Framework and Related Evidence

A. 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, Bishop, and Dunkelberg 1985; Merkl and 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. 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, Bishop, and Dunkelberg 1985). Third, timing is a core element of the process (Mortensen and Pissarides 1999; Oyer and Schaefer 2011; Rogerson, Shimer, and Wright 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 their 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, Popiunik, and West 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, Itskhoki, and Redding 2010; Wolthoff 2018). Indeed, firms often choose to use alternative selection processes, such as informal referral processes, to reduce hiring costs and aid in selection (Burks et al. 2015, Schmutte 2015).

B. Hiring in The Teacher Labor Market

We study the hiring process in the context of the teacher labor market, which employs close to 4 million adult workers in the United States, and accounts for approximately one 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. Third, state laws regulate the types of candidates whom 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. Nationally, supply far 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 and Goldhaber 2017; Sutcher, Darling-Hammond, and Carver-Thomas 2016). Supply also varies meaningfully across schools based on teachers' preferences and school characteristics (Biasi, Fu, and Strom 2021; Boyd et al. 2013; Feng, Figlio, and Sass, 2018; Jackson 2009; Gross and DeArmond 2010; Boyd et al. 2010; Johnston 2020; Viano et al. 2020). 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, Jacob, and Curran 2014; Goldhaber et al. 2020; Reininger 2012). There is also mounting evidence that

[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).

teachers prefer schools with more attractive professional environments, anchoring on non-pecuniary benefits in the absence of variation in compensation across schools in the same district (Johnson, Kraft, and Papay 2012; Johnston 2021; 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). Finally, hiring in many districts occurs in highly structured ways that place constraints on timing, typically by requiring districts to post positions for internal candidates before opening them to the external labor market.

Empirical research on the teacher hiring process itself is much more limited. By and large, teacher hiring tends to be "late, rushed, and information poor" (Liu and Johnson 2006). While 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 forthcoming; Goldhaber, Grout, and Huntington-Klein 2017; Jacob et al. 2018; Rockoff et al. 2011; Sajjadiani et al. 2019), few schools use such measures and those that do tend not to select applicants based on the information with the most predictive power for teachers' future effectiveness (Harris et al. 2010). Despite the known seasonality of the market, teacher hiring also tends to happen quite late, with many teachers hired over the summer and after school starts in the fall (Engel 2012; Levin and Quinn 2003; Rutledge et al. 2008). In some large districts, 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 and Kraft 2016). While some reforms, like flexible salary scales, can reinforce disparities in access to highly-effective teachers (Biasi, Fu, and Strom 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 (Kraft et al. 2021; Keo et al. 2020).

III. 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 one in ten (9%) are Asian. The district is predominantly low 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 only thirty percent 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. 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 preferences to choose positions before posting for external hires. It operates with full mutual consent, meaning that teachers are not forced to take positions that they do not choose, and teachers are not placed administratively in schools without agreement from the school principal.

To explore the dynamics of teacher hiring, we use rich administrative data spanning the hiring windows for the 2014-15 through 2018-19 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. The final analytic sample includes 3,610 postings and 17,986 unique applicant-by-year observations.[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 and receives 38 applications for each position. 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. Nearly all (87%) reside within-state, with applicants heavily concentrated in the Boston area. Many already work in BPS either as teachers (19%) or in another capacity (11%). The demographic make-up 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.

IV. Measures

Position type. We use detailed job titles to assign positions to one of 16 broad content areas and identify the primary content area for each posting.[3]

[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] The sixteen 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

Market entry and exit. To understand the temporal dynamics of the hiring process, we must first identify when applicants enter and exit the market. 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 her last application to a BPS position within a given hiring window, we consider her to have exited the market, given that she has 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 two and a half weeks.

Hire quality. We explore the quality of a hiring outcome in several ways. A first-order concern is simply whether a position is filled. In addition, we evaluate the new hire's teaching quality in their new position using both principals' ratings of classroom teaching practice (i.e., observation scores) and estimates of teachers' contributions to student achievement (i.e., value-added), for positions that can be linked to students in tested grades and subjects. We additionally test the robustness of these post-hire measures of quality using pre-hire measures of quality among a subsample of applicants incumbent to BPS, for whom these data are available. We standardize both quality measures by school and year. We also explore measures of teacher credentials, such as prior teaching experience and whether the teacher has pending or full licensure in the same broad content area as the posting. Finally, we estimate the probability of the teacher remaining in the school in the following year as a proxy for the quality of the teacher-school match.

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support, technology, advanced work, and business. The assigned categories align to the core licensure areas in the state of Massachusetts.

V. Methods

A. 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 per position. 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:

$$(1) \qquad \mathrm{N}_{jkst}^{Position} = \alpha_k + \pi_{st} + \varepsilon_{jkst}$$

We define supply, $\mathrm{N}_{jkst}^{Position}$, as the total number of applicants to a given position j, in field k, at school s, in year t. We estimate the school-level average of supply using random school-by-year effects (π_{st}) conditional on position-type fixed effects (α_k). The error term ($\varepsilon_{\mathrm{jkst}}$) represents random error. We additionally test for robustness to other specifications, including adding year fixed effects to the model and changing the school-by-year effect to a school random effect.

Timing. We explore the temporal dynamics of teacher hiring by applicant characteristic, by content area, and for the overall teaching supply. We document trends in the volume of both supply (the size of the active applicant pool) and demand (number of new job postings) over the course

of the hiring window for each of these teaching fields, averaged across years. We also estimate the relationship between supply and timing as follows:

$$(2) \qquad \mathrm{N}_{jkst}^{Position} = f\left(W_{jkst}\right) + \mathrm{N}_{kt}^{Total} + \tau_t + \delta_k + \varepsilon_{jkst}$$

Here, we regress the supply of applicants ($\mathrm{N}_{jkst}^{Position}$) for a given position j within position type k, school s, and year t on the week in which a position was posted (W_{jkst}). In addition to year (τ_t) and position-type (δ_k) fixed effects, we condition on the total volume of supply within a position's primary content area (N_{kt}^{Total}) to account for our expectation that different teaching fields will have varying levels of overall supply over time. We specify the date on which a position was posted ($PostingDate_{jkst}$) as a 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 16th week (18%); and 4) more than 16 weeks into the window (21%). We also fit supplementary models with school fixed effects to account for factors outside of the schools' hiring actions that might influence supply (e.g., teachers' preferences for working in lower-poverty, higher-achieving schools).[4]

B. Implications for Hire Quality

We examine the relationship between these factors and the quality of a school's new hire across the range of hiring outcomes described in the preceding section. We build our models incrementally to demonstrate the separate and conditional associations between timing and supply on hiring quality. We first model hire quality as a function of timing, replacing the left-hand variable in (2) with the respective hiring outcome variable.

[4] In models 2 and 3, we additionally include random school effects, as well as for position-type-by-year fixed effects in lieu of separate fixed effects for position type and year; the latter set of models exclude the term N_{kt}^{Total} as it is collinear with position-by-year fixed effects. Both approaches yield comparable findings (not shown).

We then estimate, conditional on timing, the association between supply ($N_{jkst}^{Position}$) and measures of hiring quality, Y. Here, we specify supply using quintiles of the position-level applicant counts within content area and year[5]:

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

As above, these additive models include a control for the size of the total supply within the position's respective content area in a given year, as well as year and subject fixed effects. We likewise test for robustness to school fixed effects.

VI. Results

A. 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 across content areas, with substantially fewer applicants availing themselves to positions in science, math, special education, and English as a second language. 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 teaching fields. 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

[5] We use quintiles rather than raw number of applications per position given the non-normal distribution of applicant-pool sizes within and across teaching fields. 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.

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, 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 one in seven openings (Panel A). In spite of similarly high demand, however, special education receives many fewer applications per opening than elementary education positions (Panel B). 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 (Panel C). 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 teaching fields. While the median science position receives 15 applications, some receive more than 50. And, science positions exhibit less variation in supply than other fields. In Figure 2, we highlight four of the fields 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.

Supply varies substantially across schools within content areas. This variation suggests that, while field certainly matters for supply, there are important dynamics at play within teaching

fields that structure the supply of applications for a given position. Schools explain a considerable amount of this variation. Within content areas, school-by-year effects account for 17 percent of the variation in supply (column 1, Panel A of Table 3). We find quite similar results when we adjust the volume of supply for the date a position was posted (column 2) and apply an alternative definition of supply (Panels B and C).[6] 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.

We conduct several tests to better understand the degree to which differences in application volume for similar positions across schools is persistent over time. First, we estimate models that combine school random effects with year fixed effects (columns 3 and 4). The proportions of variance in position supply explained by school random effects in these models are only marginally smaller than those explained by school-by-year effects. They remain substantively large when we nest years within schools (columns 5 and 6), with school-specific random effects accounting for approximately ten percent of the variation in supply. These results 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 Panel A of Figure 3, estimating the relative average applicant-pool size within a given school, net of year and teaching field 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%

[6] 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 teaching field applying to a given position. This approach effectively standardizes the supply within a given field, 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).

attract considerably fewer applicants than the district average. There are more high- and low-supply schools than would be expected by chance, implying systematic school-specific differences in supply. These school-averaged applicant pools are also distributed similarly across content areas (Figure 3, Panel B); schools that elicit below-average supply in one subject area also tend to elicit below-average supply in other subject areas. School-level rates of applicant supply are also somewhat stable over time. 36% of bottom-quintile schools in year t remain in the bottom quintile in year $t+1$ (and 36% remain in the top quintile; Appendix Table 1). 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 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 0 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 language 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 include elementary-aged students and tend to serve more white students, and fewer Hispanic students, although schools on both ends of the supply distributions serve similar proportions of Black students.

Timing of hiring structures supply within field. Across fields, 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 panel A of Figure 4, this pattern is consistent across content areas. In panel 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 two 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—seven weeks into the hiring window. However, more than one in six positions have yet to be posted on July 1, BPS's target for completing hiring. At this point, most applicants (64%) have ceased applying, meaning that late-moving schools are missing out on a majority of the potential applicant pool. We see similar patterns across subject areas.

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 1). External applicants, particularly those from outside of Boston, apply much later and most only apply to positions on one to two days.

We see generally similar patterns across other teacher characteristics, like teacher experience and race. Like many districts, BPS has specifically aimed to diversify its teaching

workforce. Patterns of market entry and exit suggest, however, that schools in the district might not be successfully leveraging early hiring in this regard. The median Black candidate, for example, enters the market somewhat earlier and remains in the applicant pool somewhat longer than white and Hispanic applicants, although these differences disappear when taking into account other applicant characteristics (e.g., experience, licensure, and where the applicant is coming from).

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 scores 1 SD above the average left the market after an average of five days compared to 67 days for applicants with scores 1 SD below the average. Similarly, among candidates with prior value-added scores, those who 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 timing of when positions are posted also appears to be systematically related to the total number of applicants who apply. In Table 5, we show that positions posted earlier receive more applications. For example, positions posted more than four months (seventeen or more weeks) into the hiring window receive seven fewer applications, on average. 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 at the beginning of the window. This may reflect an advantage to posting when most applicants are submitting applications. It may also reflect the benefits of posting when relatively few other schools are actively hiring, making new postings more visible for candidates.

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. Thus, 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, Table 4 illustrates that it is school that typically struggle to attract more applicants that are most likely top post earlier in the hiring seasons. The earliest-posting schools are, on average, more likely to be labeled as Underperforming, serve lower-achieving students and larger populations of Black students suggesting these schools are actively working to attract more candidates by listing job opening early.

B. Timing, Supply and 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 margins—that is, how timing and supply are associated with both the probability of filling a position and the quality of candidate who fills it. We find that timing and supply are each predictive of whether a position is ultimately filled; earlier-posted openings are more likely to be filled with a candidate the following year, 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. In Table 6, we show that both timing and supply matter. We

document 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). Timing strongly predicts the probability of a position being filled when the position is posted very late. 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.

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 (Table 7). While estimates are imprecise, 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 on average between 5 and ten percent of a standard deviation lower than students whose teachers filled positions posted at the start of the window (columns 1 and 2).

The timing of job postings is associated with other teacher characteristics as well. Schools that post earlier end up with teachers who earn higher scores on their classroom observations, both in the position that they were hired into (column 3) and, for the subset of teachers with previous experience in BPS, preceding their hire (not shown). Our results also suggest that posting earlier is likewise associated with more new hires who are appropriately certified in their field (column 4) and who have prior teaching experience (column 5).

Earlier postings are also predictive of 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, 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 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 (Table 8). We observe 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 observation scores are as much as 19 percent of a standard deviation 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 least number of applicants are between four and eight percentage points less likely to end up with an appropriately-certified teacher than those with a larger volume of applicants (column 4).

C. Possible Explanations for the Lack of Relationship Between Supply and Hire Quality

In addition to variation in supply across content areas and schools, there are clearly important temporal dynamics in the teacher labor market. While schools that hire late have fewer

applicants and worse hiring outcomes, we find no systematic relationship between supply itself and hire quality. It is not readily apparent, however, 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. 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.

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 classroom observation 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 quality

measures than candidates in low-supply positions (Appendix Table 2). We also observe that high-supply positions actually attract candidates, on average, with somewhat better prior evaluation ratings and value-added scores (Appendix Table 3). 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. 2018). However, larger supply is not correlated with a greater probability of hiring a teacher of color (Appendix Table 4, 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 and Goodman 2019), we also explore supply as measured by the number of applicants of color. However, even when positions have relatively large shares of non-white applicants, 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 "fit" within the school. 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, Johnson, and Reinhorn 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), positions with the highest supply have retention rates that are no different than positions with the lowest level of supply. Within schools (Panel B), retention rates for the highest-supply positions are 7 percentage points lower than retention rates for the lowest-supply positions.

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.[7]

We find some evidence that higher-supply positions take longer to fill, which would be consistent with this hypothesis. Low-supply positions take about nine weeks from the posting date for a new hire to be approved, on average conditional on the school and posting date (Appendix Table 5), while high-supply positions take about three 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 her. 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

[7] 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.

Appendix Table 6). 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-supply positions elicit somewhat smaller shares of applicants who submit to only one position than do low-supply positions (Appendix Table 7).

Together, this information is not consistent with the theory that larger applicant pools on their own enable better hires. Results from exploratory analyses are consistent with 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. 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.

VII. Conclusion

Competitive search models suggest that early hiring should provide schools the benefit of larger applicant pools and more effective hiring. This analysis demonstrates the size and nature of the labor supply evolves over the course of a hiring window and that timing is indeed associated 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. At the same time, however, conditional on posting date, the

number of individuals applying to a given position is generally unrelated to the quality of the individual hired. 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.

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. However, even in the presence of a large applicant pool, timing alone may not be sufficient if all schools where to move simultaneously towards earlier job posting. Consistent with other evidence about the challenges of employee screening (e.g., Jacob et al. 2018, Goldhaber et al. 2017), even in a context where schools routinely receive large numbers of applicant per position, simply hiring early in the season or recruiting larger pools of applicants are unlikely in themselves to result in a meaningfully stronger teacher workforce. 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.

Understanding the nature of competitive search within the K-12 public education sector is important in its own right given its scale and important role that teachers play in promoting human capital development. While teacher labor markets are distinct in many ways, our analyses also

shed light on the search dynamics of other credentialed professions, public employees, and unionized industries. Consistent with model predictions, our results suggest that position type, firm characteristics, and timing are all important factors that shape labor supply. However, our results point to the challenges of capitalizing on the benefits of attracting more job candidates when observable characteristics and screening processes are not strong predictors of future performance on the job.

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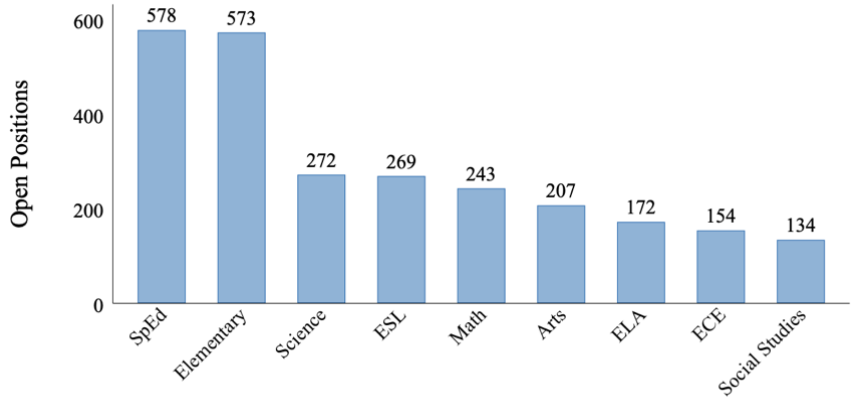
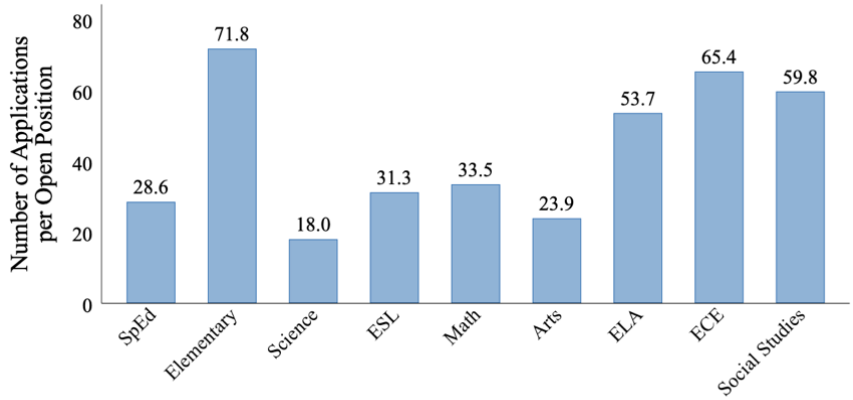
Panel A. Number of Open Positions



Panel B. Ratio of Applications to Open Positions



Panel C. Ratio of Unique Applicants to Open Positions

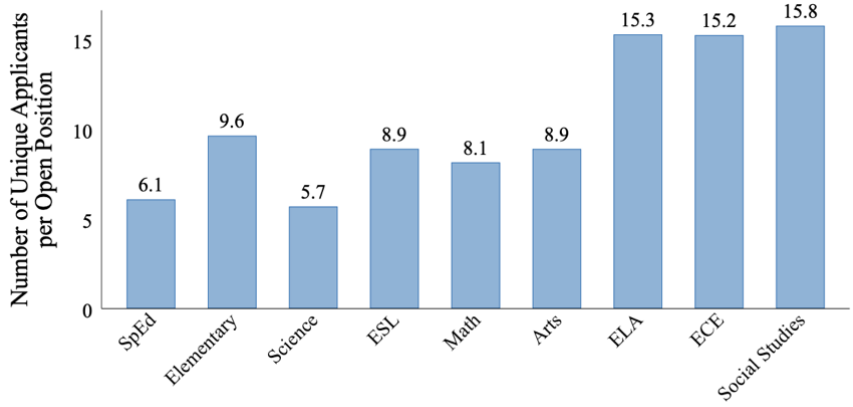


Figure 1

Frequency of Postings and Applications by Teaching Field

Notes: SpEd = special education; ESL = English as a second language; ELA = English language arts; ECE = early childhood education.

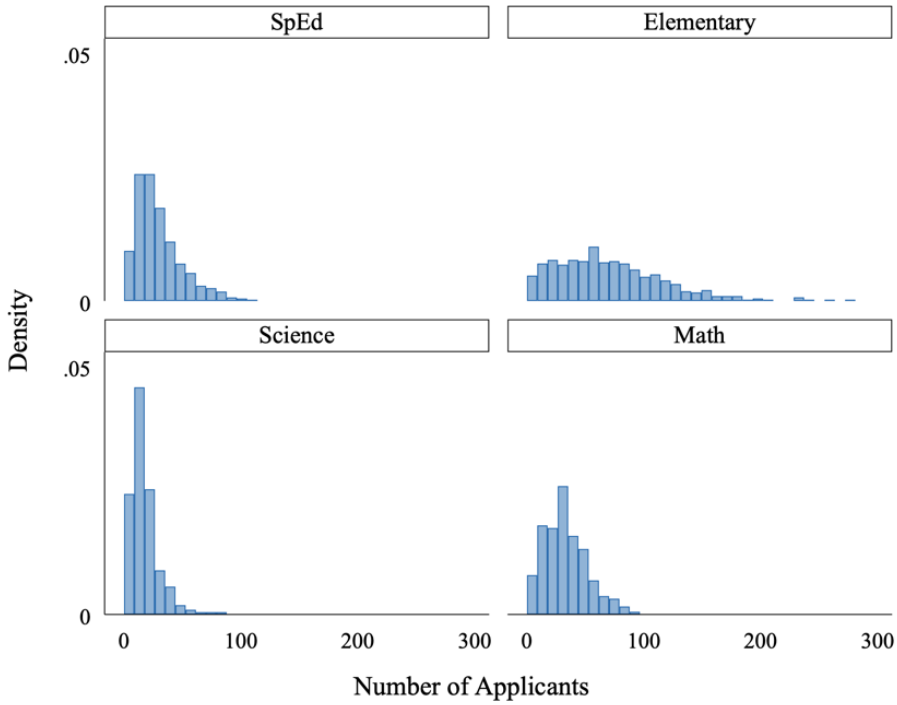
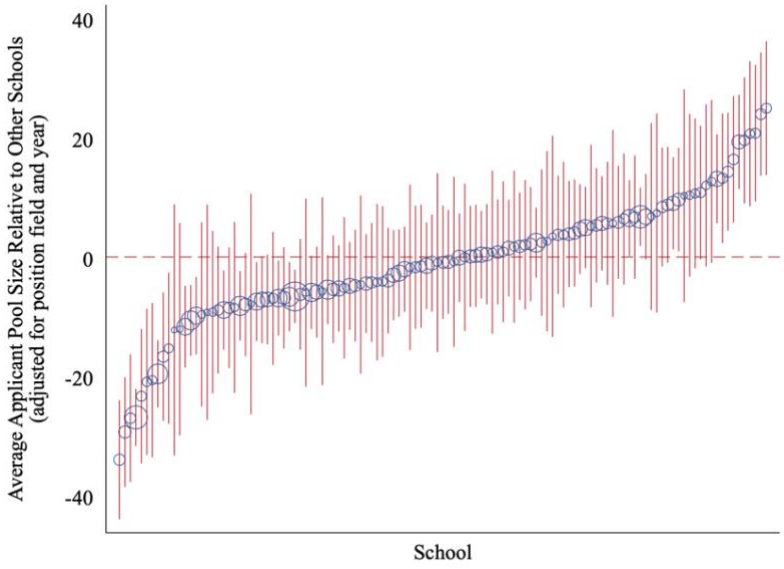


Figure 2

Distribution of the Size of the Applicant Pool Applying to a Given Position in the Four Largest Teaching Fields

Panel A. School-Level Supply Across Content Areas



Panel B. School-Level Supply Within Content Areas

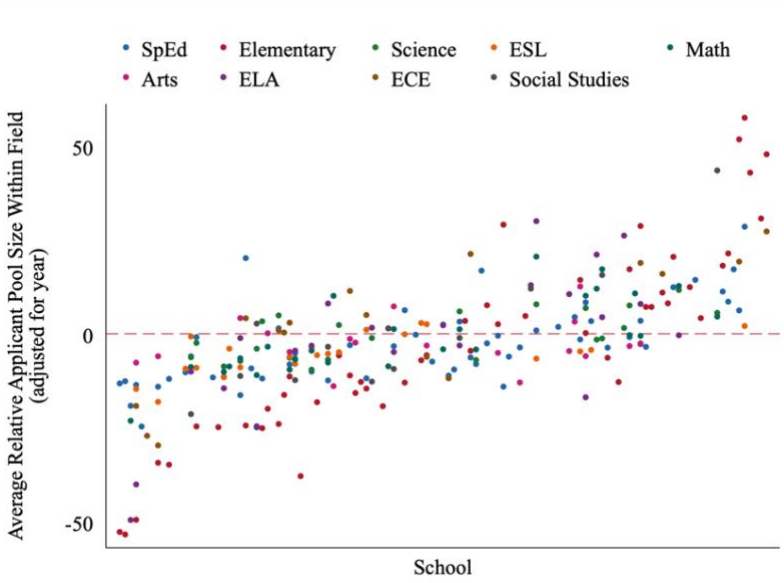
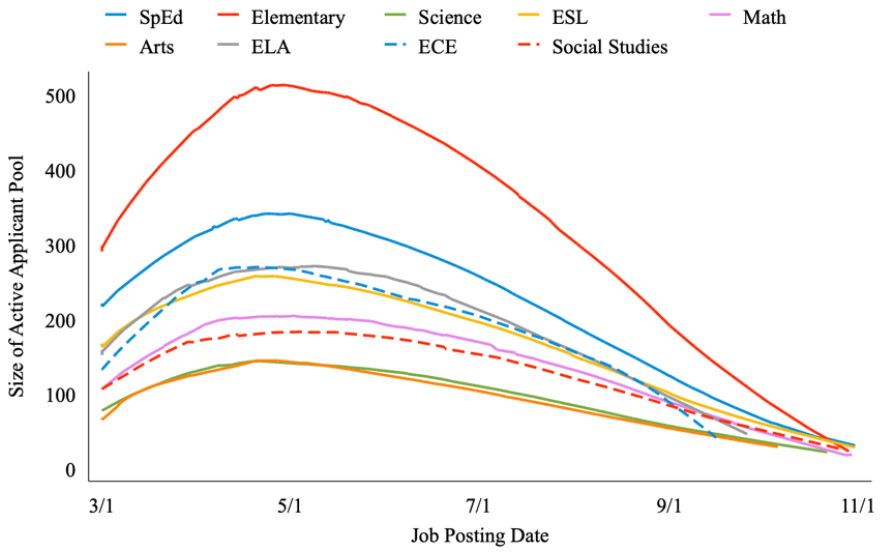


Figure 3

Variation in Field- and Year-Adjusted School-Averaged Applicant Pool Sizes

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-subjects 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.

Panel A. Density of Applications by Content Area



Panel B. Cumulative Distribution of Entry into and Exit from the BPS Teacher Labor Market

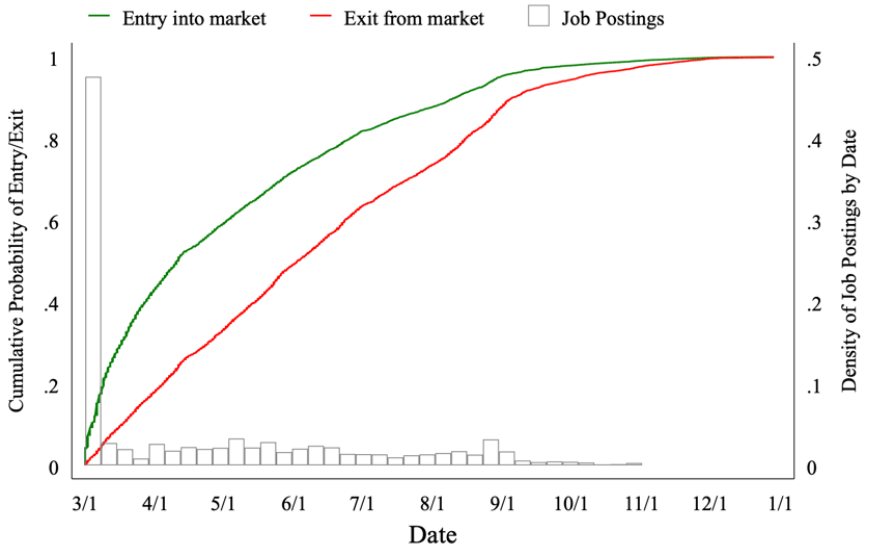


Figure 4

The Temporal Movement of Supply Across the Hiring Season

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.

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.

Table 2

Movement of Applicants Across the Search Window, by Teacher Characteristic

	N	%	Median Entry by # of Days from Window Opening	Median Length of Submission Period (in 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 Observation 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
Certification 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

Table 3

Decomposing the Variation in the Share of Applicants Applying to BPS Teaching Positions, Pooling Across Teaching Fields

	(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
Subject 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-field applicant pool. Values are intraclass correlation coefficients. The sample of positions is limited to the nine highest-demand content areas ($n = 2{,}602$).

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)	39.63	22.40	17.23*	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)
% 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)
% LEP	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 teaching field effects. Early- and late-posting schools are defined by those in the top (earliest) and bottom (latest) quintile of their median posting date. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

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 subject-level supply and subject and year fixed effects. $***\ p < 0.01$.

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 subject and year. Standard errors are clustered within school. All models condition on subject-level supply and subject and year fixed effects. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 7
The Relationship Between Hiring Timing and Hire Quality

	(1) Student Achievement in Math	(2) Student Achievement in ELA	(3) Observation 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 subject-level supply and subject area. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

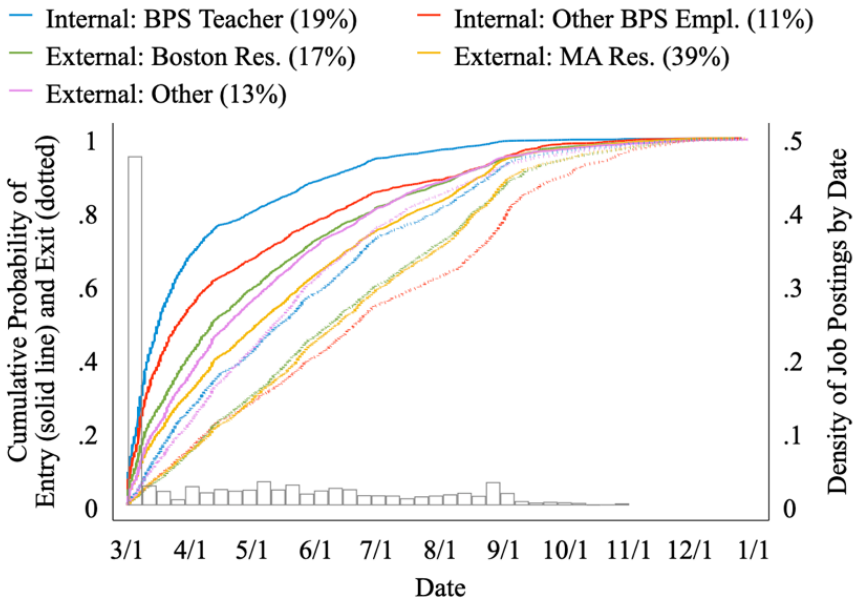
Table 8

The Relationship Between Supply and Hire Quality, Conditional on Timing

	(1) Student Achievement in Math	(2) Student Achievement in ELA	(3) Observation 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 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 for the number of applicants is the bottom quintile of positions. Quintiles are estimated within subject and year. In models 1 and 2, the analysis is conducted at the student level, and 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 subject-level supply and subject 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). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

APPENDIX



Appendix Figure 1
Cumulative Distribution of Entry into and Exit from the BPS Teacher Labor Market, Internal Versus External Applicants

Notes: Entry into the market is represented by solid lines, while exit is indicated by the dotted lines.

Appendix Table 1
Quintile Matrix of School Supply from Year t to t + 1

			Year *t* + 1				
			Q1 (smallest)	Q2	Q3	Q4	Q5 (largest)
Year *t*	Q1 (smallest)	N	22	8	9	14	8
		Row %	36%	13%	15%	23%	13%
	Q2	N	13	24	14	13	7
		Row %	18%	34%	20%	18%	10%
	Q3	N	12	11	14	13	10
		Row %	20%	18%	23%	22%	17%
	Q4	N	10	12	17	10	17
		Row %	15%	18%	26%	15%	26%
	Q5 (largest)	N	7	9	11	14	23
		Row %	11%	14%	17%	22%	36%

Note: School supply is adjusted for the teaching area.

Appendix Table 2
The Relationship Between Position Supply and Selection Quality

	Pre-Hire Value-Added Score		Pre-Hire Observation Score	
	(1)	(2)	(1)	(2)
Number of Applicants: Quintile 2	0.151	0.316	0.036	0.036
	(0.362)	(0.454)	(0.135)	(0.138)
Number of Applicants: Quintile 3	0.047	0.087	-0.022	-0.018
	(0.355)	(0.458)	(0.130)	(0.135)
Number of Applicants: Quintile 4	-0.340	-0.385	-0.223*	-0.233*
	(0.347)	(0.451)	(0.127)	(0.133)
Number of Applicants: Quintile 5	-0.331	-0.346	-0.136	-0.121
	(0.350)	(0.450)	(0.127)	(0.133)
School Fixed Effects		X		X
R^2	0.12	0.31	0.03	0.13
N of Positions	323	323	1,394	1,394

Notes: The outcome value is the teacher's quintile in the within-position applicant performance distribution in terms of pre-hire value-added scores (columns 1 and 2) or pre-hire classroom observation scores (columns 3 and 4). Analysis is limited to positions for which a hire is made and where at least five applicants have a known score on the respective performance measure. The reference group is the bottom quintile of positions. Quintiles of supply are estimated within subject and year. All models condition on the posting year, subject-level supply, and subject 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). * $p <$ 0.10.

Appendix Table 3

Distribution of Position-Average Applicant Characteristics Across Quintiles of Supply

	Quintile of Applicant Supply			
Position Average:	2	3	4	5
Gender				
Female	0.009	0.009	0.022***	0.039***
	(0.009)	(0.008)	(0.008)	(0.009)
Male	-0.008	-0.007	-0.018**	-0.035***
	(0.008)	(0.008)	(0.008)	(0.008)
Not specified	-0.002	-0.002	-0.004	-0.004*
	(0.002)	(0.002)	(0.003)	(0.002)
Race/Ethnicity				
Black	-0.013*	-0.017**	-0.014*	-0.019***
	(0.007)	(0.008)	(0.008)	(0.008)
Hispanic	-0.008	-0.015**	-0.015**	-0.014*
	(0.006)	(0.007)	(0.007)	(0.008)
Asian	-0.014*	-0.011	-0.014*	-0.016**
	(0.008)	(0.008)	(0.008)	(0.007)
White	0.042***	0.052***	0.053***	0.061***
	(0.010)	(0.011)	(0.010)	(0.010)
Not specified	-0.016*	-0.012	-0.016*	-0.017***
	(0.008)	(0.008)	(0.008)	(0.007)
Internal v. External Applicants				
Internal: current BPS teacher	-0.049***	-0.069***	-0.066***	-0.084***
	(0.009)	(0.010)	(0.010)	(0.010)
Internal: other BPS employee	-0.009	-0.025***	-0.036***	-0.041***
	(0.006)	(0.007)	(0.006)	(0.007)
External: Boston resident	0.018***	0.020***	0.024***	0.026***
	(0.008)	(0.007)	(0.006)	(0.006)
External: MA resident	0.035***	0.058***	0.059***	0.077***
	(0.008)	(0.007)	(0.007)	(0.007)
External: Not from MA	0.005	0.017***	0.019***	0.023***
	(0.005)	(0.005)	(0.005)	(0.005)
Experience (self-reported)	-1.188***	-1.516***	-1.552***	-1.940***
	(0.203)	(0.185)	(0.199)	(0.186)
Evidence of Prior Teaching Quality				
Has prior observation score in BPS	-0.058***	-0.086***	-0.090***	-0.113***
	(0.009)	(0.010)	(0.010)	(0.010)
Pre-hire observation score	0.091***	0.085***	0.124***	0.139***
	(0.028)	(0.028)	(0.027)	(0.027)
Has prior value-added score in BPS	-0.021***	-0.029***	-0.024***	-0.035***
	(0.007)	(0.006)	(0.006)	(0.006)
Pre-hire value-added score	-0.022	0.024	0.040	0.033
	(0.054)	(0.057)	(0.056)	(0.054)
Certification match	0.022***	0.034***	0.037***	0.020**
	(0.009)	(0.008)	(0.008)	(0.009)

Notes: Each row presents estimates from regressions of the position-level average for each teacher characteristic on quintiles of supply relative to the bottom quintile. Regressions include controls for school, year, content area, and posting week fixed effects (grouped by first week, weeks two to eight, nine to sixteen, and seventeen or more weeks into the hiring window). Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Appendix Table 4
The Relationship Between Supply and Diverse Hiring, Conditional on Timing

	(1) Quintiles defined by N of all candidates	(2) Quintiles defined by N of racial/ethnic minority candidates
Panel A. Overall		
Number of Applicants: Quintile 2	-0.030	-0.029
	(0.027)	(0.027)
Number of Applicants: Quintile 3	-0.048*	-0.038
	(0.026)	(0.026)
Number of Applicants: Quintile 4	-0.003	0.005
	(0.027)	(0.026)
Number of Applicants: Quintile 5	-0.016	-0.009
	(0.026)	(0.026)
R^2	0.035	0.036
Panel B. With School Fixed Effects		
Number of Applicants: Quintile 2	-0.028	-0.025
	(0.026)	(0.027)
Number of Applicants: Quintile 3	-0.049*	-0.038
	(0.025)	(0.025)
Number of Applicants: Quintile 4	-0.002	0.006
	(0.027)	(0.027)
Number of Applicants: Quintile 5	-0.013	-0.006
	(0.027)	(0.026)
R^2	0.090	0.090
N of Positions	3,226	3,226

Notes: Analysis limited to positions for which a hire is made. The outcome variable is the probability that the applicant identifies as Black, Hispanic, or a race or ethnicity other than white/Caucasian. The reference group is the bottom quintile of applicant pool size. Quintiles are estimated within subject and year. Models include year fixed effects with standard errors clustered within school. In column 1, supply is determined in terms of all applicants (as in Table 7); in column 2, supply is defined in terms of all applicants who identify as a racial or ethnic minority. All models condition on subject-level supply and subject 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). * $p < 0.10$.

Appendix Table 5
The Relationship Between Position Supply and the Length of Time Taken to Fill the Position

	(1)	(2)	(3)
Number of Applicants: Quintile 2	0.366	0.864***	0.836***
	(0.359)	(0.347)	(0.279)
Number of Applicants: Quintile 3	1.638***	2.258***	1.650***
	(0.370)	(0.361)	(0.293)
Number of Applicants: Quintile 4	1.510***	2.501***	1.683***
	(0.349)	(0.345)	(0.285)
Number of Applicants: Quintile 5	2.782***	3.804***	2.898***
	(0.353)	(0.348)	(0.295)
Conditional on Subject-Level Supply	X	X	X
Subject & Year Fixed Effects	X	X	X
School Fixed Effects		X	X
Conditional on Posting Week			X
R^2	0.07	0.24	0.45
N of Positions	3,219	3,219	3,219

Notes: The reference group is positions with applicants applying to the fewest number of positions. Standard errors are in parentheses. Approximately 1 percent of filled positions (n=34) does not have a recorded hire approval date. *** $p < 0.01$.

Appendix Table 6

The Relationship Between Position Supply and the Number of Applications Submitted by the Average Applicant

	(1)	(2)	(3)
Number of positions applied to by average applicant: quintile 2	6.906***	4.695***	4.476***
	(1.727)	(1.700)	(1.641)
Number of positions applied to by average applicant: quintile 3	9.311***	6.053***	5.236***
	(1.891)	(1.889)	(1.832)
Number of positions applied to by average applicant: quintile 4	4.873***	2.463	1.575
	(1.954)	(1.976)	(1.925)
Number of positions applied to by average applicant: quintile 5	-8.127***	-7.954***	-8.475***
	(2.065)	(2.106)	(2.058)
Conditional on Subject-Level Supply	X	X	X
Subject & Year Fixed Effects	X	X	X
School Fixed Effects		X	X
Conditional on Posting Week			X
R^2	0.40	0.49	0.53
N of Positions	3,583	3,583	3,583

Notes: The reference group is positions with applicants applying to the fewest number of positions. Standard errors are in parentheses. *** $p < 0.01$.

Appendix Table 7

The Relationship Between Position Supply and the Share of Applicants Applying to Only One Position

	(1)	(2)	(3)
Number of Applicants: Quintile 2	-0.028***	-0.015***	-0.014***
	(0.006)	(0.005)	(0.005)
Number of Applicants: Quintile 3	-0.041***	-0.025***	-0.021***
	(0.006)	(0.006)	(0.005)
Number of Applicants: Quintile 4	-0.048***	-0.032***	-0.026***
	(0.006)	(0.006)	(0.006)
Number of Applicants: Quintile 5	-0.049***	-0.034***	-0.026***
	(0.005)	(0.006)	(0.006)
Conditional on Subject-Level Supply	X	X	X
Subject & Year Fixed Effects	X	X	X
School Fixed Effects		X	X
Conditional on Posting Week			X
R^2	0.41	0.49	0.50
N of Positions	3,595	3,595	3,595

Notes: The reference group is positions with the fewest number of applicants. Standard errors are in parentheses. *** $p < 0.01$.