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Teacher Shortages: A Unifying Framework for Understanding and Predicting Vacancies

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Abstract

We develop a unifying conceptual framework for understanding and predicting teacher shortages at the state, region, district, and school levels. We then generate and test hypotheses about geographic and subject variation in teacher shortages using data on unfilled teaching positions in Tennessee during the fall of 2019. We find that teacher staffing challenges are highly localized, causing shortages and surpluses to coexist. Aggregate descriptions of staffing challenges mask considerable variation between schools and subjects within districts. Schools with fewer local early-career teachers, smaller district salary increases, worse working conditions, and higher historical attrition rates have higher vacancy rates. Our findings illustrate why viewpoints about, and solutions to, shortages depend critically on whether one takes an aggregate or local perspective.

KEYWORDS: teacher shortages; teacher workforce; teacher distribution; geography of education

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Introduction

Current narratives about the existence and severity of teacher shortages paint contrasting pictures. News articles, highlighting examples of schools and districts struggling to recruit and retain teachers, frequently claim that the U.S. is facing a national teacher shortage in the wake of the COVID-19 pandemic (Natanson, 2022; Ward, 2022). Other headlines pronounce that there is no teacher shortage crisis (Thompson, 2022), pointing to many schools reporting to be fully staffed before the beginning of the school year (Fortin & Fawcett, 2022). The absence of a national database containing reliable and detailed data on teacher supply and demand has only further fueled these conflicting perspectives (Bleiberg & Kraft, 2022).

The recent debate over teacher staffing challenges is not new. Many researchers have warned of a massive, widespread teacher shortage for years due to declining enrollments in teacher preparation programs (Berry & Shields, 2017; Sutcher et al., 2019). In contrast, others have suggested that there might be a surplus of teachers, with shortages limited to specific hard-to-staff subject areas and grade levels, because the supply of certified teachers has traditionally exceeded the number of available teaching positions nationally (Cowan et al., 2016; McVey & Trinidad, 2019). These competing narratives have created considerable confusion in the policy arena about the urgency and best approaches to address teacher shortages now and in the future.

In this paper, we demonstrate how views on teacher shortages depend on whether one examines shortages in aggregate or from a more local perspective. Much of the existing literature on teacher shortages either describes national trends in teacher supply and demand or reports the characteristics of individual schools experiencing shortages (e.g., Cowan et al., 2016). However, teacher shortages can vary greatly within states due to local factors that influence the supply of

and demand for teachers. Thus, examining teacher shortages from one point of view may mask substantial heterogeneity in teacher staffing challenges.

We develop a framework that researchers, policymakers, and pundits alike can use to reconcile conflicting perspectives and better understand the nuanced nature of teacher staffing challenges in the U.S. Without a holistic framework to explain these nuances in the teacher labor market, public debates about teacher shortages, which often frame the issue as black and white rather than reflecting its complexities, will likely continue. By synthesizing the extant literature on teacher labor markets, we create a unifying conceptual framework for understanding how each state, region within a state ("region" hereafter), district, and school functions as its own labor market.

Using our framework, we generate a series of testable hypotheses about variation in teacher shortages by region, district, school, and subject and possible predictors of shortages including working conditions, turnover rates, and salary schedules. We test these hypotheses empirically using statewide data from Tennessee on schools' unfilled teaching positions ("vacancies" hereafter) and districts' subject specific staffing challenges at the start of the 2019-2020 school year, before the onset of the COVID-19 pandemic.

We focus our analyses on a measure of unfilled teaching vacancies at the beginning of the school year, an indicator of acute staffing challenges with clear negative consequences for student achievement (Papay & Kraft, 2016). We first conduct a range of descriptive and spatial analyses to determine how the existence and severity of unfilled teacher vacancies vary across schools, districts, and regions within Tennessee. We then examine relationships between regional, district, and school predictors of these unfilled teaching positions in a regression framework. These predictors, informed by our conceptual framework, include the number of

recent graduates from educator preparation programs near the school, the number of early-career teachers who grew up near the school, teacher compensation, the school's historic teacher turnover rate, and a measure of school working conditions. We complement these school-level analyses with district-level survey data concerning subject-specific teacher staffing challenges to document variation in teacher shortages by subject.

Our findings show that teacher staffing challenges are highly localized, with more variation between subjects and schools within districts than between districts or regions. Although less than two percent of Tennessee teaching positions were vacant at the beginning of the 2019-20 school year, we find that these vacancies were concentrated in a quarter of Tennessee schools. Schools with vacancies were located throughout the state with at least 70 percent of the variation in the percent of unfilled teaching positions existing between schools within districts. In accordance with prior research, we also find that district-level teacher staffing challenges vary in aggregate across subjects. However, the severity of subject-specific staffing challenges varies within regions and districts. Districts experiencing difficulties attracting enough applicants in one subject do not necessarily experience staffing challenges in other subjects. Taken together, these findings imply that examining teacher staffing challenges at the state level masks substantial variation across schools and subjects.

Several school and district level factors stand out as strong predictors of teacher vacancies at the start of the school year, our proxy for severe teacher shortages. We provide original empirical evidence that the number of early-career teachers who grew up within 25 miles of the school, school working conditions, and rates of salary increases are predictive of unfilled teaching positions. In particular, historical attrition rates are predictive of having larger vacancy rates at the beginning of the school year. A one standard deviation increase in teacher

turnover is associated with a 67 percent increase in the percent of unfilled teaching positions at a school, a one percentage point increase in vacancy rates. This affirms the hypothesis that schools with "revolving doors" have more acute staffing challenges (Ingersoll, 2001).

Our paper makes several contributions to the literature. Our primary aim is to provide a holistic framework of the nuanced nature of teacher shortages and their predictors. Currently, most research discusses the teacher labor markets as a singular concept and examines a single market. Our conceptual framework sheds new light on why the teacher labor market is best understood as a set of multiple, overlapping labor markets. Our analyses also provide some of the first evidence on variation in teacher shortages between and within multiple labor markets simultaneously. Few studies have been able to examine each of these elements within a single context. We also add to the growing literature that examines predictors of teacher staffing challenges (e.g., Goldhaber et al., 2021). Taken together, the findings from each of our analyses paint a holistic portrait of teacher staffing challenges across a statewide labor market, illustrating how teacher shortages and surpluses can coexist.

Our findings also directly inform policymakers' efforts to address teacher shortages. The heterogeneity in teacher labor markets and staffing challenges that we find underscores the need to understand the specific nature of each school's staffing challenges and prescribe targeted solutions to alleviate them. Further, our results suggest that one possible indicator that education policymakers and school leaders can use to determine which schools to target for recruitment and retention interventions is historical teacher attrition rates due to their strong relationship with teacher staffing challenges.

Conceptual Framework

Market Dynamics for Public School Teachers

Our conceptual framework is informed by a range of theoretical models of supply and demand from the labor and personnel economics literatures (Oyer & Schaefer, 2011; Roy, 1951). Teacher shortages exist when the number of teachers demanded exceeds the number of teachers willing to supply their labor at the current wage. In a competitive market, schools would respond to teacher shortages and surpluses by adjusting wages until labor supply and demand reach an equilibrium. Substantially raising wages would likely alleviate teacher shortages because increasing salaries reduces teacher turnover (Hendricks, 2014, 2015; Sun et al., 2022). However, adjusting wages in the K-12 public teacher labor market is challenging in the short term given the fairly rigid and compressed "step and lane" salary schedules that must be amended through a collective bargaining process in most states (Grissom & Strunk, 2012). In the long run, spending on teacher compensation–a large share of district budgets–is constrained by economic conditions that impact tax revenues at the local and state levels as well as the degree of public support and political will for investing in education (Podgursky & Springer, 2011).

Schools, in theory, can also respond to teacher shortages by decreasing their demand for teachers. However, the number of teachers demanded by schools is also inflexible. The number of teaching positions is largely determined by prescribed student-teacher ratios and district budgets (Loeb & Myung, 2020; Lovenheim & Turner, 2017; Wood et al., 2019). Compulsory schooling laws, high barriers to closing schools, and maximum class size requirements substantially constrain flexibility around the number of teachers demanded, leaving schools to compete for teachers when supply is limited (Harris, 2017).

Supply of Teachers

Because of the inflexibility of teacher wages and demand for teachers, most policy solutions aimed at alleviating teacher shortages focus on increasing teacher supply. The number of individuals willing and able to teach depends on a wide range of factors, including the status of the teaching profession, barriers to entry into the profession, wage expectations, retention rates, and preferences for working conditions (Croft et al., 2018; Loeb & Myung, 2020; Lovenheim & Turner, 2017). Although many discussions of teacher supply treat all teachers in a state or country as one labor market, the supply of teachers in a given region within a state or at a particular school likely varies because factors influencing teacher supply often vary across regions, districts, and schools within the same state. We illustrate this idea graphically in Figure 1 which depicts how teacher labor supply is influenced by market factors that operate at different market levels. We describe these key factors below.

National Level

Prestige of the Teaching Profession. When teaching is seen as a less prestigious profession, fewer individuals are willing to become teachers. Declines in public perceptions of teaching correlate with decreases in interest in teaching as a profession and enrollment in educator preparation programs (EPPs) (Kraft & Lyon, 2022). Although the prestige of teaching likely varies across locales, there are no geographic barriers to its influence. Rather, it is likely affected by national changes in perceptions of teachers' social standing and role in American society over time.

State Level

Barriers to Entry. Each state sets its own teacher certification requirements, limiting the supply of individuals who are eligible to work as teachers in public schools. As of 2020, only

eight states offer full licensure reciprocity, meaning that in the vast majority of states, teachers certified in one state cannot teach in another without taking additional tests or courses (Evans et al., 2020). This inability to transfer teaching credentials between states creates 50 distinct statewide teacher labor markets rather than one national teacher labor market, likely creating variation in the teacher supply by state.

Regional Level

Geographic Preferences. A growing body of literature demonstrates that teachers' strong preferences for where they live and work create geographic variation in the teacher supply (Engel & Cannata, 2015). First, teachers have strong preferences to teach close to their hometown. Compared to other professions, teachers are more likely to work within 20 miles of their high school, with 85 percent of teachers teaching less than 40 miles from where they attended high school (Boyd et al., 2005; Reininger, 2012). Second, teachers favor jobs closer to their EPP (Fowles et al., 2014). Student teaching placements, which tend to be near EPPs, are highly predictive of teachers' first job placements as well. Two out of five student teachers go on to work in the district where they completed their student teaching after graduation (Krieg et al., 2016). Finally, teachers have strong geographic preferences for where they teach within regions. Teachers prefer to teach in communities closer to amenities such as transportation and shopping venues as well as in higher income neighborhoods with lower crime rates (Boyd et al., 2011a; Miller, 2012).

District Level

Teacher Compensation. Teacher compensation affects not only interest in joining the profession, but also where teachers choose to work. Both salary levels and rates of increase over time can shape teachers' preferences (Lovenheim & Turner, 2017; Roy, 1951). Teachers'

salaries typically vary at the district level because they are usually set by districtwide salary schedules. District salary increases attract more experienced and higher quality teachers and increase teacher retention (Biasi, 2021; Hendricks, 2014, 2015; Lankford & Wyckoff, 1997; Sun et al., 2022). Large districts and districts with strong unions tend to have higher salaries, especially for more experienced teachers (Cowen, 2009; Rose & Sonstelie, 2010). Prior research shows that salaries vary meaningfully between regions within a state as well (Lankford et al., 2002).

School Level

Working Conditions. More teachers are willing and able to work at schools with supportive working conditions. Studies of teacher job applications show that schools that serve higher achieving and more economically advantaged students and have earlier teacher hiring timelines benefit from more applicants than other schools in the same district (Engel et al., 2014; Jackson, 2009; Papay & Kraft, 2016). However, much of these differences in perceived teacher preferences for student characteristics are likely explained by differences in working conditions between schools serving more and less advantaged students. Teachers prefer schools with more administrative support, better school culture, and stronger relationships among faculty, which are more likely to be found at schools serving historically advantaged students and vary between schools within the same district (Johnson et al., 2012; Ladd, 2011; Lovison & Mo, 2022; Viano et al., 2020).

Teacher Attrition. High levels of teacher attrition indicate that many individuals are no longer willing or able to participate in a labor market. Prior research has shown that retention rates are higher in suburban schools than urban and rural ones (Cowen et al., 2012; Hanushek et al., 2004; Jacob, 2007; Lankford et al., 2002; Miller, 2012). However, much of the variation in

attrition rates exists between schools within districts. Schools within the same district serving larger populations of economically disadvantaged and low-achieving students have higher attrition rates (Hanushek et al., 2004; Lankford et al., 2002).

Subject Level

Within geographic labor markets, the supply of teachers likely varies by subject because certification requirements and the availability and attractiveness of teachers' outside professional options differ by subject area. Many special education certificates require teachers to take extra courses and pass additional tests, creating an additional barrier to entry to special education teaching positions (Special Education Resource Project, 2019). Individuals with the ability to earn science, technology, engineering, and math (STEM) certifications likely have higher earning potential outside of the education profession than, for example, elementary education teachers (Hansen et al., 2019; West, 2013). This likely creates a lower supply of STEM teachers when teachers' salaries are lower than other STEM careers.

The Intersection of Teacher Supply and Demand: Teacher Shortages and Surpluses

Taken together, the evidence concerning the localness of the teacher supply and the variation in factors that influence it implies that each region, district, and school within a state acts as its own labor market. This motivates three hypotheses concerning variation in teacher shortages and surpluses, the intersection of teacher supply and demand. We discuss each of these hypotheses below along with the relevant research concerning teacher shortages.

Hypothesis 1: Shortages vary by school, district, and region

Because states, intra-state regions, districts, and schools function as distinct labor markets, teacher shortages likely vary geographically. However, much of the existing research examines teacher shortages in aggregate by determining whether the number of teachers supplied

is less than the number of teachers demanded for all schools in the United States or all schools in one district. With the exception of one study (Sutcher et al., 2019), these studies show that there are more newly certified teachers and total applicants to teaching positions (measures of teacher supply) than teachers hired or the number of available teaching positions (measures of teacher demand) suggesting an overall surplus of teachers (Bruno & Strunk, 2019; Cowan et al., 2016; Engel et al., 2014; Goldhaber et al., 2017; James et al., 2022). At the same time, a recent study estimates aggregated teacher shortages by reporting the number of vacant teaching positions by state. They find that 1.67 percent of teaching positions are vacant with substantial variation by state (Nguyen et al., 2022).

A handful of studies explore variation in teacher shortages between schools by examining characteristics of schools experiencing staffing challenges (Cowan et al., 2016; Jacob, 2007; McVey & Trinidad, 2019). Taken together, they find that schools in urban and rural districts, schools serving higher proportions of students of color and low-income students, and middle and high schools face more difficulties filling teaching positions (Cowan et al., 2016; Goldhaber et al., 2020; Jacob, 2007; McVey & Trinidad, 2019). Further, data from the 2017-18 Civil Rights Data Collection show that schools in the top quartile of enrollment of students of color have over four times as many uncertified teachers than schools in the bottom quartile of students of color (National Center for Education Statistics, 2021). Three studies examine variation in applications for teaching positions by school. They find that higher-performing schools, schools serving more historically advantaged students, schools that post positions earlier in the hiring cycle, and schools located in desirable neighborhoods are more likely to have a surplus of applicants (Boyd et al., 2011b; Engel et al., 2014; James et al., 2022). However, these studies provide little

evidence concerning geographic variation in teacher shortages because each examines a single large urban district.

Hypothesis 2: Shortages are associated with geographic preferences, compensation, working conditions, and teacher attrition

Teacher shortages may vary geographically because the factors that influence teacher supply differ by geographic labor market. These factors that determine teacher supply likely influence teacher shortages as well. We note that we do not examine the role of barriers to entry, such as certification requirements, and the prestige of the profession because we cannot measure state or national variation in teacher shortages, the levels we hypothesize that these factors vary, using our single state dataset.

Prior research has shown that teacher turnover is closely associated with teacher staffing challenges. Sutcher et al. (2019) show that the majority of the demand for teachers is a result of pre-retirement attrition. Further, schools with above average attrition rates are twice as likely to report difficulty filling vacant positions (Ingersoll, 2001). A recent study also shows that schools that host student teachers and schools that are closer to EPPs are less likely to have staffing challenges (Goldhaber et al., 2021).

Hypothesis 3: Statewide, regional, and district teacher staffing challenges may vary by subject.

Even within localized labor markets, teacher shortages can also differ by subject because teacher supply varies by subject due to differences in certification requirements and the availability and attractiveness of outside professions. The number of STEM teachers who exit the profession has outpaced the number of newly certified STEM teachers for two decades (Goldhaber et al., 2015). The majority of states consistently report science, math, special education, and foreign language as critical shortage areas (McVey & Trinidad, 2019). In Boston Public Schools, English, early childhood education, and social studies have more than twice as

many qualified job candidates per open position, on average, as special education and science (James et al., 2022). Subject-specific staffing challenges exist at the school level as well. Less than five percent of schools nationally report having challenges finding elementary education teachers while one in five have difficulty filling STEM teaching positions (Cowan et al., 2016).

Our conceptual framework illustrates why teacher shortages may differ between regions, districts, schools, and subjects within the same state due to variation in factors that influence teacher supply at each market level. We test the hypotheses generated from the conceptual framework using statewide school-level survey data documenting the number of unfilled teaching positions and district-level survey data concerning subject-specific staffing challenges to illustrate variation in teacher shortages and surpluses. Taken together, the findings from our analyses paint a holistic portrait of teacher staffing challenges across a statewide labor market.

Data

We test our hypotheses by analyzing state-wide data on teacher shortages during the fall of 2019 in Tennessee, a large labor market of over 60,000 public school teachers. Focusing on variation in teacher shortages at the state level reflects the state-specific nature of teacher licensures while also providing a wide range of variation across regions, districts, and schools. Tennessee provides policy-relevant context because it serves a large and diverse population of students in urban, suburban, and rural schools. Tennessee educates nearly one million public school students, one third of which are economically disadvantaged.[1] Forty percent of Tennessee students identify as students of color. Tennessee is also home to the 14th largest rural student population in the United States as well as two major cities, Nashville and Memphis. Thirty percent of Tennessee students attend rural schools while 20 percent attend schools in large cities.

Our analyses draw on survey items from the 2018-19, 2019-20, 2020-21, and 2021-22 Tennessee Educator Surveys and administrative records for all Tennessee students and teachers from the 2010-11 to 2019-20 school years. Our administrative data include records of teacher certification and employment, educator preparation program graduation, and student enrollment and demographics, and achievement as well as school directory information. We supplement these data with geographic information including school coordinates and district boundary files from the National Center for Education Statistics and commuting zone data maintained by the Penn State Commuting Zones/Labor Markets Data Repository. We also use data collected from the 2019-20 survey of Tennessee school districts to describe subject-specific teacher staffing challenges.

Teacher Vacancies at the Start of the School Year

We use unfilled teacher vacancies at the start of the school year as our outcome of interest because it is a direct measure of acute teacher shortage. Fall vacancies occur when there are not enough teachers supplied to meet demand. Unfilled teaching positions after the start of the school year represent some of the most severe staffing challenges and are not representative of vacant positions that occur before the school year begins (Papay & Kraft, 2016). For this reason, we emphasize that our findings do not describe variation in all types of open teaching positions but rather some of the most severe staffing challenges.

Our measure of teacher vacancies at the start of the school year comes from the 2019-20 Tennessee Educator Survey. The Tennessee Education Research Alliance and the Tennessee Department of Education have administered this survey to all Tennessee educators annually since the 2011-12 school year. To quantify school-level teacher shortages, we worked with the Tennessee Education Research Alliance to add a survey item to the 2019-20 Tennessee Educator

Survey that asked administrators to state how many unfilled teaching positions their school had at the start of the 2019-20 school year.[2] Two-thirds of Tennessee traditional public schools operating during the 2019-2020 school year had at least one administrator answer this survey question. Our analytic sample includes 1,085 of Tennessee's 1,650 traditional public schools.[3]

To evaluate how well our analytic sample represents the population of schools in Tennessee, we compare it to the full population of Tennessee schools operating during the 2019-20 school year and non-respondent schools in Table 1. On average, schools in our analytic sample have a lower percentage of economically disadvantaged (35 percent vs. 39 percent) and Black students (17 percent vs. 31 percent), lower teacher attrition rates (13 percent vs 17 percent) and higher average test scores (0.12 std. dev. vs. 0.02 std. dev for math achievement) than schools for which we do not have survey data on teacher vacancies. A lower percentage of schools in our sample are located in cities (23 percent vs. 40 percent) compared to non-respondents. These differences are due to low administrator response rates on the Tennessee Educator Survey for schools in Nashville and Memphis compared to the rest of the state (36 percent vs. 72 percent) which serve a high percentage of economically disadvantaged students and students of color. These differences imply, if anything, that our statewide calculations may be understating the degree of vacancies in the state. Outside of Memphis and Nashville, our respondents reflect the population of Tennessee schools.[4]

We use the number of unfilled teaching positions reported at each school to create our two measures of teacher shortage – an indicator for having any vacant positions at the beginning of the school year and the percent of vacant teaching positions.[5] A limitation of this measure is that it is self-reported several months after the vacancies occurred. Therefore, it might not be accurate if administrators choose to provide a socially desirable answer or cannot remember the

number of vacancies at the start of the school year. However, there is a dearth of data concerning teacher shortages or unfilled teaching positions at the state-level or disaggregated at a smaller geographic level (Bleiberg & Kraft, 2022; Nguyen et al., 2022; Saez-Armstrong, 2021), making these school-level reports of vacancies one of the best measures of severe teacher shortages currently available.

Regional Supply of Early-Career Teachers

To test our second hypothesis, we examine the relationships between a school's vacant teaching positions at the start of the school year and labor market characteristics that may vary geographically and affect teacher shortages. We use two measures to quantify the number of available early-career teachers within a region: the number of graduates from EPPs within 25 miles of the school in the last three years and the number of first year teachers in the last three years who went to high school within 25 miles of the school.[6] We define regions as a set of geographic circles with individual schools at their centroid to create school-specific measures of local early-career teacher supply. We set the radius of these geographic circles as 25 miles given that 75 percent of first-year teachers who went to high school in Tennessee and 50 percent of EPP grads work within 25 miles of their EPP, as displayed in Figure 2.[7]

We use an item from the Tennessee Educator Survey that asks teachers to list the zip code of their residence in the year they graduated from high school to determine teachers' hometowns.[8] We include EPP graduates and first-year teachers from the last three years because recent research finds that a significant portion of certified individuals enter the profession more than a year after receiving their teaching degree (Goldhaber et al., 2022; Goldhaber et al., 2014). We scale the first two measures of teacher supply per 1,000 public K-12 students attending schools within the 25-mile radius to account for variation in population density across the state.

District Salary Measures

We also examine the relationship between school-level teacher vacancies at the beginning of the school year and district-level teacher compensation because districts can, to some degree, increase wages to attract and retain teachers (Hendricks, 2014, 2015; Sun et al., 2022). We use two measures of pecuniary compensation: base salary and a measure of how much salaries increase over the first ten years of a teacher's career. Not only do workers favor jobs with higher wages, but they may also be more likely to stay when they are rewarded for their experience, performance, or both (Lovenheim & Turner, 2017; Roy, 1951). We use the salary in the lowest step and lane (usually the pay for a teacher with zero years of experience and a B.A. only) of each traditional public school district's 2019-20 salary schedule as our measure of base compensation.[9] We adjust base salaries to account for differences in cost of living using the 2019 Comparable Wage Index for Teachers created by the National Center for Education Statistics (Cornman et al., 2019).[10]

To determine salary returns to experience, we calculate the annualized rate of change in salaries between the base salary and the salary on the tenth step in the lowest lane of the salary schedule. For districts with a traditional salary schedule, this is the difference in salaries between having zero and ten years of experience for a teacher with a B.A. only. We focus on salary returns to experience in the first ten years because nearly 80 percent of teachers who transferred districts between the 2018-19 and 2019-20 school years had ten years of experience or less. We calculate annualized salary growth using the following formula where $Salary_{10}$ is the salary at the tenth step in the lowest lane of the district's salary schedule and $Salary_{base}$ is the district's base salary:

$$SalaryIncreases_{0,10} = \left(\frac{Salary_{10}}{Salary_{base}}\right)^{\frac{1}{10}} - 1 \quad (1)$$

School Working Conditions

We construct an aggregate measure of school working conditions from 43 survey items on 2018-19 Tennessee Educator Survey. We use teachers' ratings of working conditions from the prior school year because they would reflect teachers' perceptions of a school prior to the beginning of the school year when staffing decisions are made. To determine which survey items described school working conditions, we use Merrill's (2021) comprehensive taxonomy of teacher working conditions. We then aggregate teacher survey responses for each item to the school level and perform a principal component analysis to reduce the 43 items into one measure of school working conditions.[11] We only include schools where there were at least five respondents for all items and at least 30 percent of a school's teachers responded to all items in the principal component analysis to ensure that responses are representative of the school's teachers.[12] Our primary measure is the first principal component from the principal component analysis. This component accounts for 48 percent of the variation across our 43 items. We standardize this measure at the school level and list the survey items included in our working conditions measure with their coefficients and loadings in Appendix B.

School Attrition Rate

Prior research has linked teacher turnover with teacher staffing challenges (Ingersoll, 2001; Sutcher et al., 2019). Turnover is also likely related to unobservable school characteristics that shape its desirability as a workplace. Thus, we include schools' three-year teacher attrition rate to proxy for both observed and unobserved elements of a school that shape its desirability as a workplace.[13] We use a lagged three-year attrition rate between the 2015-16 and 2017-18 school years to ensure that the relationship between attrition rates and 2019-20 vacancies is not driven by an unusually large amount of teacher exiting the school in the prior year (2018-19), creating

an extraordinary high number of unfilled teaching positions. Turnover may mediate the relationship between our vacancy measures and other predictors like working conditions and salary that are related to teacher retention. However, teacher retention rates are an easily measurable indicator of staffing challenges and can explain unobserved elements of the desirability of a workplace. Therefore, we estimate our models with and without turnover to examine how much of the relationships between other factors and unfilled teaching positions turnover explains.

We describe variation in our six hypothesized predictors of vacancies by plotting their kernel density functions in Figure 3. Three-quarters of schools have access to less than 11 EPP graduates within 25 miles per 1,000 students as seen in Figure 3 Panel A. There is less variation in the number of early-career teachers who went to high school within 25 miles of the school. We show that ninety percent of schools in our sample have between 2 and 5 early-career teachers who went to high school within 25 miles of the school per 1,000 students in Figure 3 Panel B.

Figure 3 Panels C and D show variation in base salaries and annualized salary growth between base salary and the 10th step of the salary schedule respectively. After adjusting for cost of living, the majority of base salaries range from $43,000 to $53,000 with a standard deviation of $3,879. Nearly three-quarters of our sample has salary increases between one and two percentage points for each additional year of experience—corresponding to an additional step—on the salary schedule. Even these small differences are meaningful. For example, the difference in salaries on the 10th step of the salary schedule for two districts with base salaries of $50,000 but an annualized rate of change in salary of one percent compared to two percent is over $5,700 ($55,231 vs. $60,949).

Our measure of school working conditions, plotted in Figure 3 Panel E. Our standardized measure, derived from our principal component analysis, has a relatively symmetric distribution. Attrition rates vary widely across schools with a standard deviation of eight percentage points and a long right tail. We show that over half of schools in our sample have historical attrition rates less than 15 percent in Figure 3 Panel F. However, one in five schools have historical attrition rates over 20 percent.

Subject-Specific Staffing Challenges

The 2019-20 Tennessee Educator Survey did not ask administrators to disaggregate their school's vacancies at the beginning of the school year by subject area. Thus, we are unable to examine differences in teacher vacancies by subject area at the school level. Instead, we analyze reported subject level teacher staffing challenges from a 2019-20 survey of Tennessee school districts to determine variation in staffing difficulties by subject and geography. Over 95 percent of Tennessee school districts responded to this survey. Districts reported whether they did 1) not have enough applications, 2) not have enough high-quality applications, 3) have enough high-quality applications, or 4) not need any teachers for each subject area.[14] In addition to supplying information concerning subject area staffing challenges, these data also provide more nuance in hiring difficulties than the reported number of vacancies by describing the quantity and quality of applications received as well as whether or not there was demand for teachers in that subject.

Methods

Hypothesis 1: Shortages vary by school, district, and region.

To examine the extent to which teacher shortages vary by school, district, and region, we first describe patterns in the percent of vacant teaching positions at the beginning of the 2019-20 school year at the state, region, district, and school levels. Here, we define our measure of a

region as a mutually exclusive set of commuting zones to facilitate an analyses using a fully nested set of geographic units. Commuting zones are aggregations of counties that contain where most people live and work determined based on commuting flows from home to work reported in the 2010 American Community Survey (Fowler et al., 2016). These measures have been used in prior research to describe geographic patterns of employment, economic opportunity, and intergenerational mobility (e.g., Chetty et al., 2014; Chetty & Hendren, 2018; Autor & Dorn, 2009).[15] Tennessee has 24 commuting zones and 141 school districts. All Tennessee traditional public school districts are fully embedded within one commuting zone.[16]

Then, we formally measure the variation in the severity and existence of school-level teacher shortages associated with the region, district, and school (the residual variance) using a variance decomposition analysis (Chingos et al., 2015). We use a binary indicator for having at least one unfilled teaching position to examine the variation in the existence of school-level teacher shortages. To measure the severity of teacher shortages, we use the percent of unfilled teaching positions at the beginning of the school year as the outcome. Specifically, we estimate a multilevel model of each of our outcomes with no predictors other than the constant for each level where schools are nested within districts, nested within commuting zones. We calculate the variance for each level and divide it by the total variance to find the amount of variation explained at each level. We estimate these models separately for elementary and secondary schools to ensure that variation described by each geographic level is not a result of the different labor pools that exist for elementary and secondary schools due to certification requirements.

Hypothesis 2: Shortages are associated with geographic preferences, compensation, working conditions, and teacher attrition.

Next, we describe the associations between regional, district, and school characteristics and teacher vacancies using a set of descriptive regressions. Our fully specified regression model, estimated by OLS, is represented by the following equation:

$$Y_{sd} = \beta_0 + \beta_1 EPPGrads_{sd} + \beta_2 NewTeachers_{sd} + \beta_3 BaseSalary_d + \beta_4 SalaryIncreases_d + \beta_5 WorkingConditions_{sd} + \beta_6 AttritionRate_{sd} + \boldsymbol{X_s\gamma} + \varepsilon_{sd} \quad (2)$$

Here, Y_{sd} is either or a variable that equals one when school *s* in district *d* has any vacant teaching positions or the percent of unfilled teaching positions for school *s*.

Our variables of interest correspond to the hypothesized predictors of teacher shortages in Hypothesis 2. Regional variables of interest, $EPPGrads_{sd}$ and $NewTeachers_{sd}$ are the number of graduates from EPPs within 25 miles of the school in the last three years per 1,000 students and the number of first year teachers in the last three years who have a hometown within 25 miles of the school per 1,000 students, respectively. To examine the relationship between pecuniary compensation and vacancies, we include $BaseSalary_d$, the salary for the lowest step and lane of the salary schedule adjusted for differences in cost of living across Tennessee as well as $SalaryIncreases_d$, the annualized rate of change between base salary and the tenth step of the lowest lane of district *d's* salary schedule. $WorkingConditions_{sd}$ is the measure of the school's working conditions created from survey items from the 2018-19 Tennessee Educator Survey using principal component analysis.[17] $AttritionRate_{sd}$ is the percent of the school's teachers who left the school each year across the three years prior to most recent year.

To account for school characteristics that might be associated with vacant positions other than our hypothesized predictors of shortage, we include $\boldsymbol{X_{sd}}$, a vector of school-level characteristics in our model. $\boldsymbol{X_{sd}}$ includes indicators for a school's urbanicity and grade level as

well as 2018-19 school-level student characteristics: the number of students, average math achievement on state tests[18], the percent of female, economically disadvantaged, English learner, Black, Hispanic, Asian, American Indian, and Pacific Islander students, and the percent of students with disabilities. For school-level characteristics, we use data from the prior school year (2018-19) because it reflects the information teachers would have had when they were making their career decisions. We cluster our standard errors at the district level.[19]

Hypothesis 3: Statewide, regional, and district teacher staffing challenges may vary by subject.

Finally, we explore variation in teacher shortages by subject during the 2019-20 school year using district level survey data on teacher staffing challenges. We first provide the survey results aggregated to the state level for each subject to determine the extent to which teacher staffing challenges vary by subject statewide. Then, we examine variation in subject-specific shortages between and within regions (commuting zones) and districts by mapping district staffing challenges for three subjects: secondary math, secondary social studies, and elementary education. We choose one hard-to-staff subject, secondary math, and two other subjects considered easier to find qualified applicants for, secondary social studies and elementary education, to explore how staffing challenges vary within the same district by subject.

Findings

Hypothesis 1: Shortages vary by school, district, and region.

Table 2 presents the number of unfilled teaching positions statewide as well as the percent of schools with vacant positions. We examine vacancies at the start of the school year for elementary schools (schools that do not offer any grades above 6th grade) and secondary schools (all other schools) separately because they have separate labor markets due to certification requirements. Most Tennessee teaching licenses allow teachers to either teach in grades K-5 or a

specific subject in grades 6-12. Statewide, less than 2 percent of teaching positions were vacant at the beginning of the year. Only 591 of the over 40,000 teaching positions in our sample were reported as vacant. While this number might suggest Tennessee public schools face very limited shortages, unfilled vacancies at the start of the school year is an extreme measure: it does not capture the broader staffing challenges of ensuring every student is taught by an effective teacher who is certified in their subject area. This number also masks important differences across grade levels. The percent of unfilled positions in secondary schools is twice as large as in elementary schools with secondary schools accounting for 73 percent of vacancies.

We also show that vacancies are not equally distributed across schools in Table 2. Three out of four Tennessee schools did not report any unfilled positions. Of the schools that have vacancies, over half have only one unfilled teaching position. Only five percent of schools in our sample have more than two vacancies. Additionally, a higher percentage of secondary schools have unfilled teaching positions. Eighteen percent of elementary schools have a vacancy while almost a third of secondary schools have at least one vacant teaching position at the start of the school year. Taken together, the statistics in Table 2 provide evidence that examining staffing challenges statewide masks substantial variation across grade levels and between schools.

To examine the extent to which vacant positions vary between regions, districts, and schools, we depict geographic variation in vacancy rates for secondary teaching positions in Figure 4. We display the percent of unfilled teaching positions in each commuting zone, our measure of region in these analyses, in Figure 4 Panel A. There is little variation in vacancy rates between commuting zones. With the exception of one commuting zone, the percent of vacant positions in a commuting zone ranges from zero to three percent. Figure 4 Panel B provides evidence that there is some variation in vacancy rates between districts within commuting zones.

In half of the commuting zones, at least one district has a vacancy rate over two percent and one district has a vacancy rate less than or equal to one percent.

Most of the variation in the percent of unfilled teaching positions exists at the school level. We present the percent of vacant teaching positions at each school in our sample in Figure 4 Panel C. Schools with unfilled positions can be found throughout Tennessee. Ninety-two percent of Tennessee commuting zones have at least one school with a vacancy. Further, there is little visual evidence of commuting zones or districts with high concentrations of schools with unfilled teaching positions. Of the 119 districts with more than one school in our sample, only one district has vacant positions in all of their schools. Metro Nashville Public Schools and Memphis-Shelby County Schools stand out as concentrated areas of shortages with six out of ten Nashville and Memphis schools in our sample having a least one unfilled teaching position.

The results of our variance decomposition analysis across commuting zones, districts, and schools confirm that most of the variation in vacant teaching positions is unexplained by commuting zones or districts. As shown in Table 3, commuting zones and districts only account for up to 7 percent of the variation in either of our school-level vacancy measures in elementary schools and up to 30 percent for secondary schools. Less than two percent of the variation in our vacancy measures is explained by the commuting zone at either level.

Hypothesis 2: Shortages are associated with geographic preferences, compensation, working conditions, and teacher attrition.

The results of our previous analyses show that most of the variation in unfilled teaching positions is between schools within districts. To determine what regional, district, and school-level factors may predict teacher shortages, we examine differences in teacher labor market characteristics between schools with and without vacancies at the beginning of the school year in Table 4.[20] Consistent with evidence on the localized nature of teacher labor markets, schools

with vacancies have fewer EPP grads and early-career teachers who went to high school within 25 miles per 1,000 students. In terms of compensation, there is little difference in the cost of living adjusted base salary or our salary returns to experience measure between schools with and without teacher shortages. Schools with vacancies have substantially higher turnover rates and worse reported working conditions than schools without vacancies. Turnover rates are 38 percent higher, on average, in schools with vacancies (19 vs. 14 percent). Teachers also rate working conditions 0.53 standard deviations lower, on average, in schools with vacancies.

Results from a regression model where each of these predictors is included simultaneously further illustrate that more localized factors are associated with unfilled teaching positions. In Table 5, we show the results from a taxonomy of models where we add predictors of vacancies at smaller geographic units in each subsequent column. Columns 1 though 4 display results from the models where an indicator for having at least one vacancy at the start of the school year, a measure of the existence of a teacher shortage in a particular school, is the outcome. Our teacher supply measures, the number of EPP graduates and the number of early-career teachers who went to high school within 25 miles of the school, are negatively associated with the existence of vacant teaching positions at the start of the school year as predicted by our conceptual framework. These relationships are not statistically significant.

When district compensation measures are added to the model, we find that a half a percentage point increase, an approximately one standard deviation increase, in the annualized rate of change in teacher salaries between base salary and salary on the tenth step of the district's salary schedule is associated with a 4.5 percentage point decrease (an 18 percent decrease) in the probability that a school has any unfilled teaching positions. Our results provide little evidence that base salary is associated with vacancies, which may not be surprising given the limited

variability in starting wages across districts. Favorable school working conditions are also negatively associated with our vacancy measures as we hypothesized. A one standard deviation increase in working conditions is associated with a 4 percentage point decrease (a 16 percent decrease) in the probability of having any vacant teaching positions.

When school-level attrition rates are added to the model, we find a positive and statistically significant relationship between attrition rates and our vacancy measures. A one percentage point increase in attrition rates is associated with a 0.8 percentage point increase in the probability of having any vacant teaching positions. This implies that an eight percentage point increase, a one standard deviation increase, in a school's turnover rate is associated with a 26 percent increase in the probability of having at least one unfilled teaching position.

We present results from models using the percent of vacant teaching positions, a measure severity of teacher shortages, as the outcome in Columns 5-8 of Table 5. We find that there is a negative and statistically significant relationship between the number of early-career teachers went to high school within 25 miles from the school and vacancy rates. An additional early-career teacher who went to high school within 25 miles of the school per 1,000 students is associated with a 0.49 percentage point decrease in the percent of unfilled teaching positions, a 33 percent decrease. We do not detect any significant relationships between the number of EPP grads within 25 miles and vacancy rates.

Similar to the models where the existence of any unfilled teaching positions is the outcome, salary growth and school working conditions are negatively associated with the severity of teacher shortages and attrition rates are positively associated with the severity of teacher shortages. In particular, the positive relationship between attrition rates and vacancy rates is quite large. An eight percentage point increase (a one standard deviation increase) in attrition

rates is associated with a nearly one percentage point increase in vacancy rates, a 67 percent increase. Interestingly, the relationship between the percent of unfilled teaching positions and school working conditions is no longer statistically significant when attrition rate is added to the model. This suggests that teacher turnover may mediate the relationships between the severity of teacher shortages and school working conditions, a predictor of teacher retention (Johnson et al., 2012; Ladd, 2011; Lovison & Mo, 2022; Viano et al., 2020).

Among the 13 school characteristics we include as covariates in our models, school level, school size, the percent of students who are Black, and average math achievement are statistically significant predictors of vacancies across most specifications. We show the relationships between our covariates and both of our vacancy measures in Appendix Tables A2 & A3. Elementary schools have a lower probability of having any unfilled positions and have lower vacancy rates, consistent with prior research that finds that the vast majority of schools do not report difficulty filling elementary teaching positions (Cowan et al., 2016). Large schools with 1,200 or greater students have a probability of having any vacancies that is 20 percentage points higher than schools with less than 300 students, but the relationship between school size and vacancy rates is negative. This result is likely mechanical because one vacancy in a small school results in a larger increase in vacancy rates than a large school.

Schools at the 90th percentile in Black student population (45% Black students) in the sample have a probability of having any vacant teaching positions that is over 15 percentage points higher than schools at the 10th percentile of Black students (1% Black students). This is consistent with prior work showing that schools serving higher concentrations of Black students face more acute staffing challenges (Dee & Goldhaber, 2017). However, this relationship is attenuated and becomes statistically insignificant when historical school attrition rates are added

to the model. Average math achievement also is negatively associated with both of our vacancy measures, but it is only statistically significant when the outcome is the indicator for having any unfilled teaching positions at the beginning of the school year.

Hypothesis 3: Statewide, regional, and district teacher staffing challenges may vary by subject.

We display the percent of districts reporting teacher staffing challenges by subject in Figure 5. The percent of districts without enough applications for teaching positions varies substantially by subject. For example, only one in five districts report not having enough applications for elementary teacher and secondary social studies positions. However, nearly two-thirds of districts report not having enough applications for math, science, foreign language, and special education positions.

Similar to our vacancies analysis, examining subject-specific teacher staffing challenges at the state level may mask heterogeneity by region and district. To understand the geographic variation in perceived subject-specific teacher staffing challenges, we map reports on staffing challenges by district for secondary math, secondary social studies, and elementary education teachers in Figure 6 Panels A, B, and C, respectively. Taken together, these maps provide evidence that subject-specific shortages vary more so within commuting zones, our measure of region, than across commuting zones. Perceived staffing challenges for secondary math teachers exist in all but one commuting zone with the handful of districts with enough high-quality applicants spread throughout Tennessee. Eighty-six percent of commuting zones with multiple districts have at least one district that has enough high quality applications for secondary social studies positions and one district that does not. This pattern is similar for elementary education.

Figure 6 also shows that district staffing challenges vary within district by subject. Although a similar percentage of districts report having too few applicants for secondary social

studies and elementary education teaching positions, districts experiencing staffing challenges in social studies are not necessarily the same districts reporting issues finding elementary teachers. Thirty percent of districts that report not having enough high quality applications for either social studies or elementary education do have enough high quality applications for the other subject. For example, Metro Nashville Public Schools and Hamilton County Schools (Chattanooga) report that they do not enough high quality applications (or too few applicants) for elementary education teachers but enough high quality applicants for social studies teachers. Analogously, Knox County Schools (Knoxville) does not have enough high quality applications for social studies teachers but does not lack elementary education teachers.

Discussion and Conclusion

Our conceptual framework provides a unifying lens for reconciling the competing narratives about the existence and severity of teacher shortages. We illustrate that there is truth in both narratives because of differences in aggregate and local perspectives. Shortages can occur for individual schools even when there is a statewide surplus, and schools can enjoy a surplus of labor even when there is a statewide shortage. In particular, aggregating measures of teacher shortages, such as vacant teaching positions at the beginning of the school year, can mask substantial heterogeneity by school and subject. The results from our analyses show that when the majority of schools do not have any vacant teaching positions at the beginning of the school year, many schools can experience severe shortages. Further, we find that much of the variation in teacher staffing challenges occurs between schools within districts, similar to findings concerning the variation in qualified teachers (Lankford et al., 2002). We find little evidence that schools with shortages are concentrated in any particular area of Tennessee. The local supply of early-career teachers, school working conditions, salary increases for additional experience, and,

in particular, historical attrition rates, have strong relationships with vacant teaching positions. Additionally, teacher staffing challenges can vary by subject within and between districts.

Although we use pre-pandemic data to demonstrate substantial variation in the existence and severity of teacher shortages, the patterns we find and the factors that generate staffing challenges are likely similar to those affecting the current teacher labor market in the wake of the COVID-19 pandemic. Preliminary results from the 2020-21 and 2021-22 Tennessee Educator Surveys show that the percent of schools reporting any vacancies increased by approximately one-third between fall of 2019 and fall of 2021. However, the larger patterns of grade-level and geographic variation in schools with vacancies appears just as relevant for the 2021-22 academic year. These patterns suggest wide variation in the severity of teacher shortages across schools exists in a labor market experiencing increased teacher vacancies, further illustrating that teacher shortages and surpluses likely coexist.

Given the varied nature of teacher shortages, policy solutions aimed at alleviating teacher shortages will have to go beyond increasing the overall size of teacher workforce to be effective. Policies will need to target efforts to address market failures and ameliorate shortages at specific schools and in specific subjects. Addressing shortages is as much about widening the teacher pipeline as it is shaping what subjects teachers choose to teach and where they are willing to supply their labor. For example, macro changes like universal loan forgiveness programs and the loosening of certification requirements, two common policy solutions to alleviate teacher shortages, may not reduce local shortages for STEM teachers in rural schools. In a school where shortages are driven by high turnover, increasing the number of teachers recruited through student teaching and Grow Your Own programs may not be as effective as reducing vacancies by improving working conditions and providing financial incentives to retain teachers.

We show that one indicator policymakers and school leaders can use to identify schools likely to be experiencing severe teacher shortages are historical teacher attrition rates. By using historical data, states and districts can target schools with persistently large amounts of turnover for intervention before staffing needs for the upcoming school year are known. However, high turnover rates may be a symptom rather than a cause of staffing challenges. To improve teacher turnover and alleviate shortages, our results, combined with prior research, indicate that schools can improve working conditions and districts may need to increase compensation (Hendricks, 2014; Johnson et al., 2012; Ladd, 2011; Lovison & Mo, 2022; Viano et al., 2020).

Decision makers need detailed data on teacher labor markets such as annual teacher attrition rates and the number of filled and unfilled teacher vacancies by specific licensure areas to determine which schools are experiencing staffing challenges, the nature of a specific school's teacher shortage, and the appropriate policy solution. Currently, less than 20 states publish teacher demand data such as vacancy rates and number of new hires. Only four states report state-level teacher shortage information publicly with two states disaggregating their shortage data at the district level (Saez-Armstrong, 2021). Because most states likely do not have the impetus or capacity to collect teacher market data, we believe that the federal government will need to play a strong role in encouraging and supporting states to collect these data.

One possible solution for the federal government to induce states to collect and report teacher shortage data would be increase reporting requirements for teacher shortage areas, which are needed to administer federal loan forgiveness and grant programs such as the Teacher Education Assistance for College and Higher Education (TEACH) Grant Program. States could report them by school for each subject and determine them using data such as attrition rates or vacancies. Although most states register statewide subject area shortages, only eight states

currently report specific counties, districts, or geographic areas with shortages. Additionally, the federal government could incentivize states to collect teacher labor market data by expanding its Statewide Longitudinal Data Systems Grant Programs to explicitly support SEAs in collecting these data in a timely fashion (Bleiberg & Kraft, 2022).

Our findings have implications for research as well as policy. We show that there are likely differences in teacher supply, demand, and shortages between statewide labor markets and more local ones. Thus, researchers should be careful to only draw conclusions about the level of the labor market(s) studied whether that be a state, district, or school and use caution when making policy recommendations for other levels. Further, future research should strive to examine teacher labor markets and evaluate policies aimed at alleviating teacher shortages from both statewide and more local perspectives.

Endnotes

1. Tennessee considers students eligible for free or reduced-price lunch by direct certification and homeless, foster, runaway, and migrant students economically disadvantaged.
2. The 2019-20 Educator Survey was administered between February 24, 2020 and April 10, 2020. During the survey window, schools started to close due to the COVID-19 pandemic (Pepper, 2020). Although some teachers and administrators may have answered the survey during the pandemic, the survey items we use ask about unfilled teaching positions at the start of the school year, prior to the pandemic. We view our results as describing teacher shortage in the most recent pre-pandemic year.
3. Our sample includes all Tennessee traditional public schools (except state special schools such as schools for the deaf, blind, and correctional facilities) that offered one grade between grades one and 12 and had at least one administrator report school's unfilled teaching

positions on the Educator Survey. We exclude charter schools from our analysis because only 14 of the 90 (16%) charter schools in Tennessee reported unfilled teaching positions. We also exclude three schools that answered the survey but did not report their grade level (K-5, K-8, 9-12, etc.) from our analysis. If more than one administrator answered the survey, we first use the principal's response and then an assistant principal's response. If multiple responses still remain, we first use responses without any missing vacancy data. If more than two administrators answered the survey, we then use the vacancy report that matches the majority of the responses. Finally, we drop any remaining duplicate responses at random.

4. We also estimate a version of our main models weighted by the inverse of the propensity to respond to the survey to account for possible non-response bias. We use the predicted value from a logistic regression that predicts the likelihood of responding to the unfilled teaching position question as a function of the school-level characteristics included as covariates in our main model as the propensity to respond. Results are similar and are displayed in Online Appendix Tables A4 and A5.
5. We create the percent of vacant teaching positions by dividing the number of unfilled teaching positions at the start of the school year by the total number of teaching positions, the sum of the number of teachers (filled teaching positions) and the number of vacancies.
6. Due to differences in certification requirements, we only include individuals who graduated from elementary or early childhood education program in our measures of EPP graduates for elementary schools. Analogously, we exclude individuals who are graduates from elementary or early childhood education program in our EPP graduate measures for secondary schools. For our measures of early career teachers who went to high school locally, we only include early-career teachers who teach in that grade level.

7. To ensure that our estimates of the relationship between early career teacher supply and our vacancy measures are not sensitive to our choice of region used to construct the teacher supply measure, we estimate a version of our main models where we use alternate measures of early career teacher supply: the number of EPP graduates in the last three years in the commuting zone per 1,000 students and the number of new teachers in the least three years that went to high school in the commuting zone per 1,000 students. Results are similar and are displayed in Appendix Tables A2 and A3.
8. Because a teacher's high school residence is time-invariant, we use responses concerning high school zip code from the 2018-19, 2019-20, 2020-21, 2021-22 surveys to construct teachers' hometowns. We were able to determine hometowns for 45 percent of first year teachers in the 2017-18, 2018-19, and 2019-20 school years. We calculate "as the crow flies" distance from the population weighted centroid of the teacher's high school zip code to each school's address to determine the number of teachers who attended high school within 25 miles of the school. We calculate the distance from the address of a graduate's EPP to each school's address to determine the number of EPP grads with 25 miles. The number of students is determined by the number of students attending schools within 25 miles.
9. We use the lowest lane of the salary schedule for the following reasons: some Tennessee districts do not have a different salary schedule for teachers with higher degrees; half of Tennessee teachers hold a Bachelor's degree as their highest degree.
10. We also estimate our models with unadjusted salaries. Results are similar and can be found in Appendix Tables A6 and A7.
11. We use principal component analysis rather than factor analysis to reduce the survey items because we seek to create one measure that best describes most of the variance in the

working condition items instead of creating multiple variables that describe different dimensions of working conditions. We also note that most of our items loaded on the first component providing little evidence that various dimensions of working conditions exist in our measure. We list the loadings in Online Appendix B.

12. In our regression models, our school working conditions measure equals zero for schools that we were unable to calculate working conditions due to the low response rates on the Tennessee Educator Survey. We include an indicator in our models that equals one for schools with missing working conditions data. To ensure that our results are robust to our decisions around the creation of and the modeling approach for the working conditions measure, we estimated a version of our main models where we interacted the missingness measure with all explanatory variables to examine whether or not the relationships between each explanatory variable and our vacancy measures are differential for observations where the working conditions measure is missing. We also estimated a version of our main model where the working conditions measure is created for all schools regardless of the percent of teachers who responded. Results are similar and are available by request.
13. We construct this as the sum of the number of teachers who left a school in the prior three school years, including teachers who transferred to another school, divided by the sum of the number of teachers working at the school for each of the three school years prior to 2018-19. Attrition rates across school years are moderately to highly correlated.
14. The subject areas on the survey included: early childhood, elementary education, secondary English, secondary math, secondary science, secondary social studies, technology, foreign language, fine arts, health/physical education, special education, English as a second language, and career and technical education.

15. We prefer the use of commuting zones to other measures of region (e.g., metropolitan statistical areas) because they include rural areas and provide substantial variation in small geographic areas (Fowler & Jensen, 2020).
16. The Achievement School District (ASD), Tennessee's statewide turnaround school district, serves schools in Nashville and Memphis. For our analyses, we assign ASD schools to the school district where the school is located.
17. For schools that we were unable to calculate working conditions for due to the low response rates on the 2018-19 Tennessee Educator Survey, $WorkingConditions_s$ equals zero and we include an indicator in our models that equals one for schools with missing working conditions data. We also include the percent of teachers who responded to the survey as a covariate in our regressions to ensure response rates do not bias the relationship between school working conditions and vacancy rates. The percent of teachers who responded to the survey is positively correlated with school working conditions (Pearson coefficient: 0.29).
18. In our analyses, we use the school's average math test score on the 2018-19 state standardized test as our measure of achievement.
19. We exclude 35 schools in our analytic sample from our regression models: 31 schools do not have achievement scores in the prior year; one school does not have student demographics in 2018-19 and three schools do not have attrition rates prior to 2018-19.
20. We present differences in all 2018-19 student characteristics between schools with and without vacancies in Appendix Table A1.

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Figures

Figure 1. How Factors Affect Teacher Labor Supply at Different Market Levels

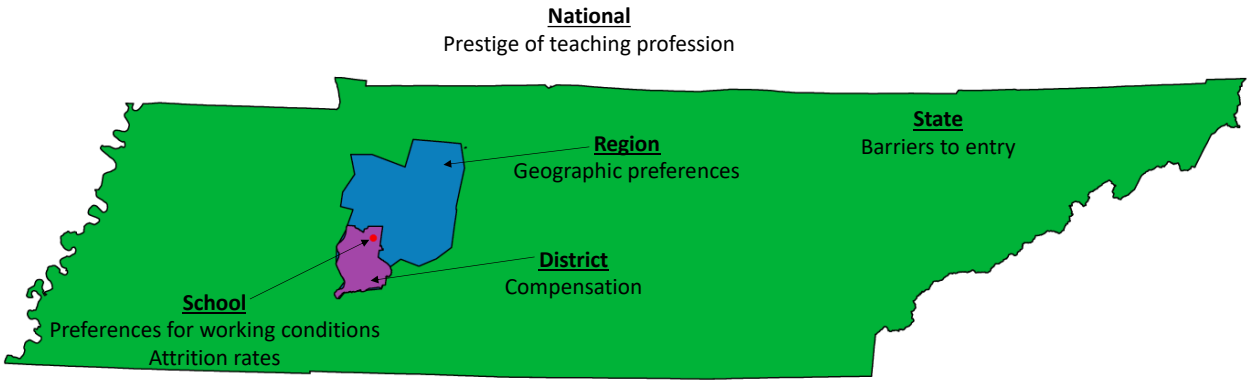
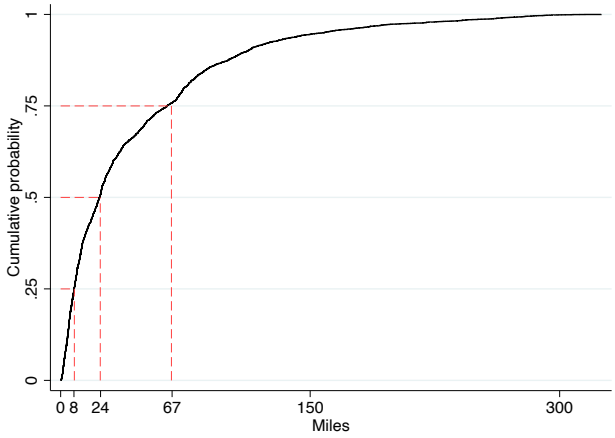


Figure 2. Cumulative Density Function of Distance to Teaching Placements

Panel A: Distance from Educator Preparation Program (EPP) to Teaching Placement for Tennessee EPP Graduates



Panel B: Distance from High School Zip Code to Teaching Placement for Tennessee High School Graduates

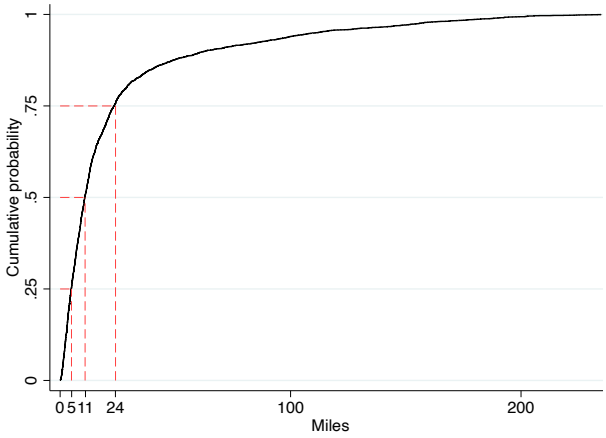
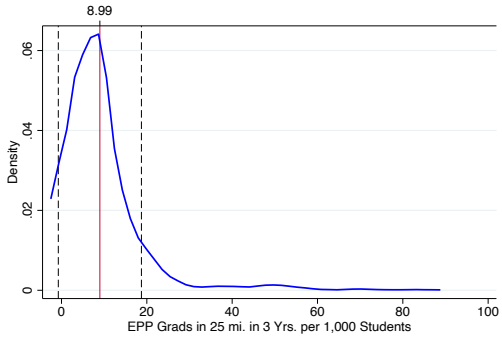
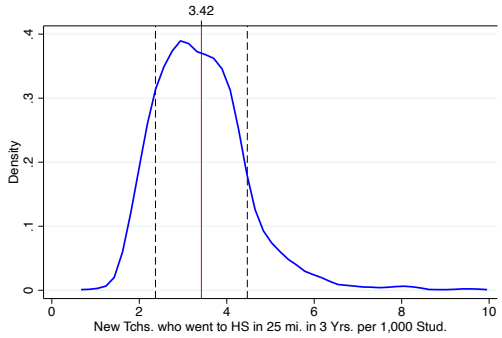


Figure 3. Kernel Density Functions of Geographic Predictors of Vacancies in Public Schools

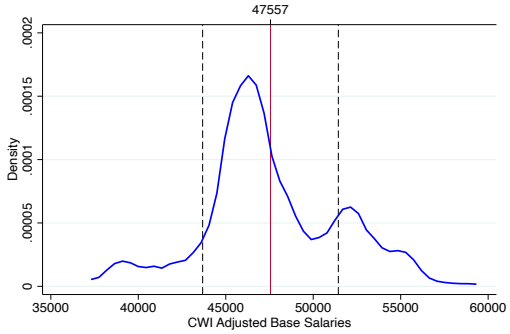
Panel A: EPP Grads in 25 Mi. in Last 3 Years per 1,000 Stud



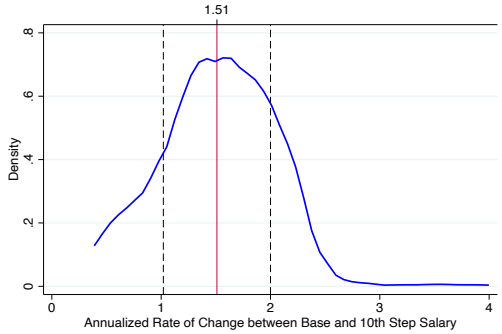
Panel B:1st Year Teachers in Last 3 Years who Went to HS. in 25 Mi. per 1,000 Stud.



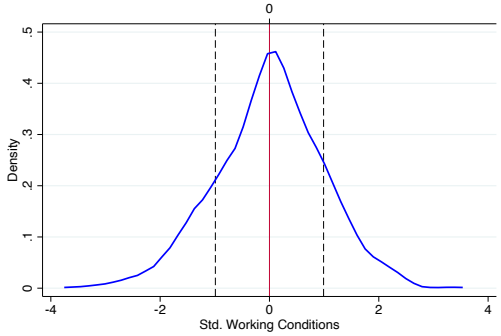
Panel C: Comparable Wage Index Adjusted Base Salaries



Panel D: Annualized Rate of Change between Base and 10th Step Salary



Panel E: Standardized Sch. Working Conditions



Panel F: Three Year Teacher Attrition Rate

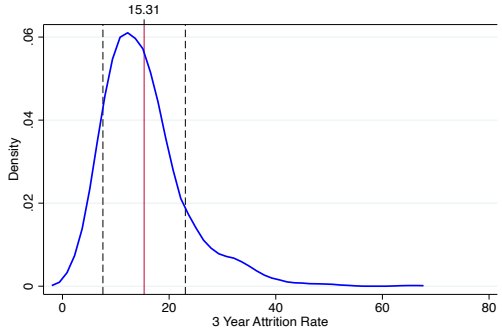
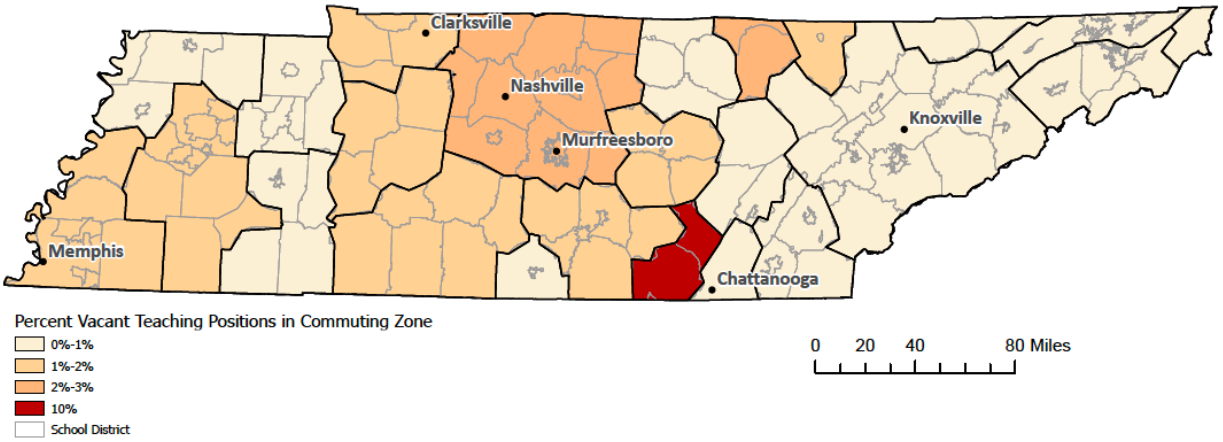
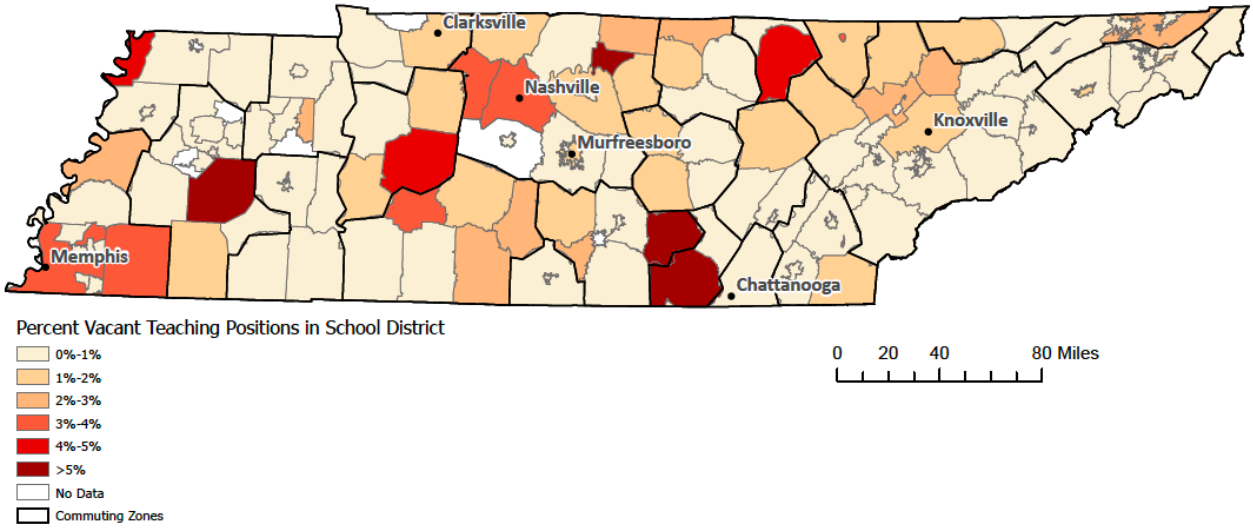


Figure 4. Percent Vacant Teaching Positions in Secondary Schools by Region, District, and School

Panel A: Commuting Zone



Panel B: School District



Panel C: School

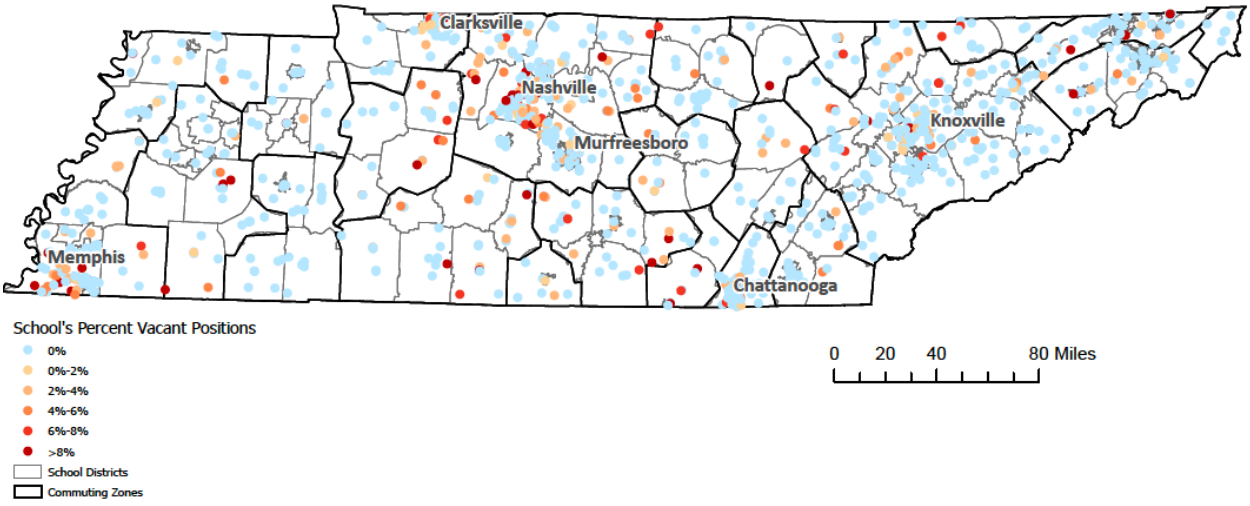


Figure 5. School District Perceived Staffing Challenges by Subject

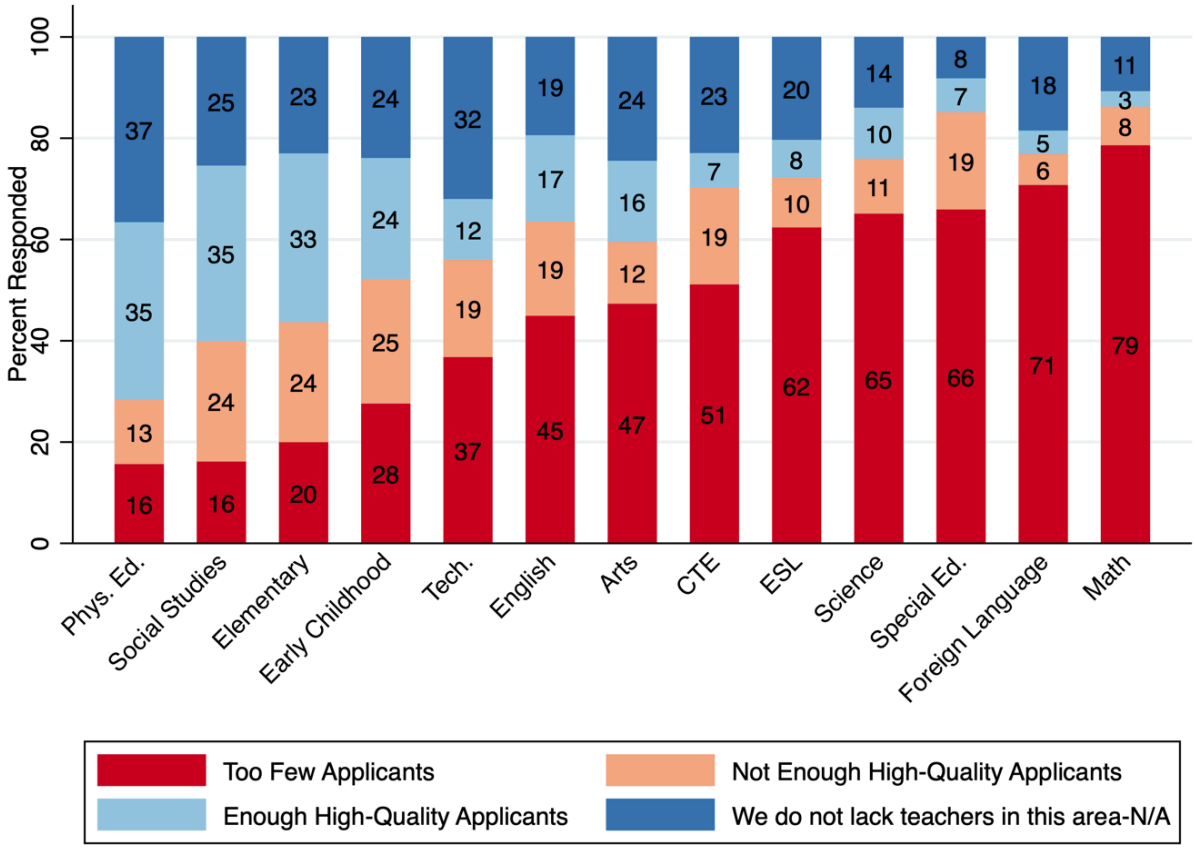
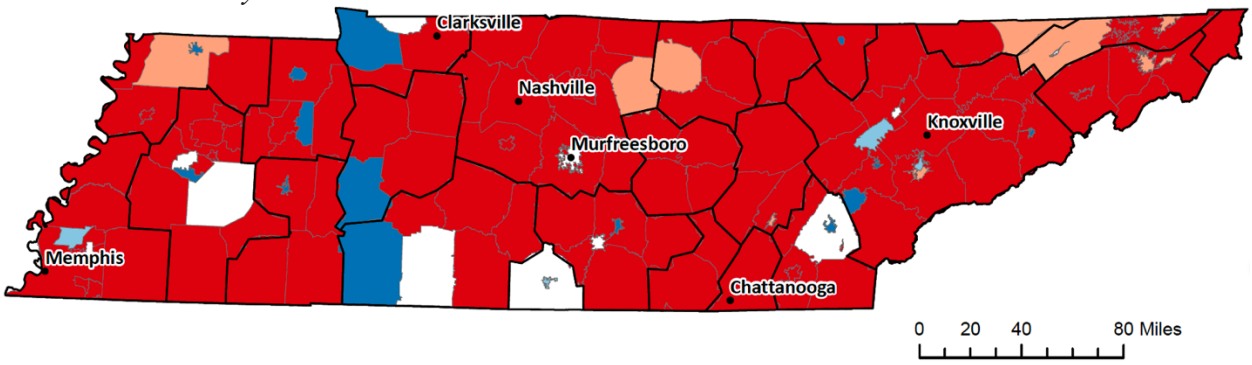
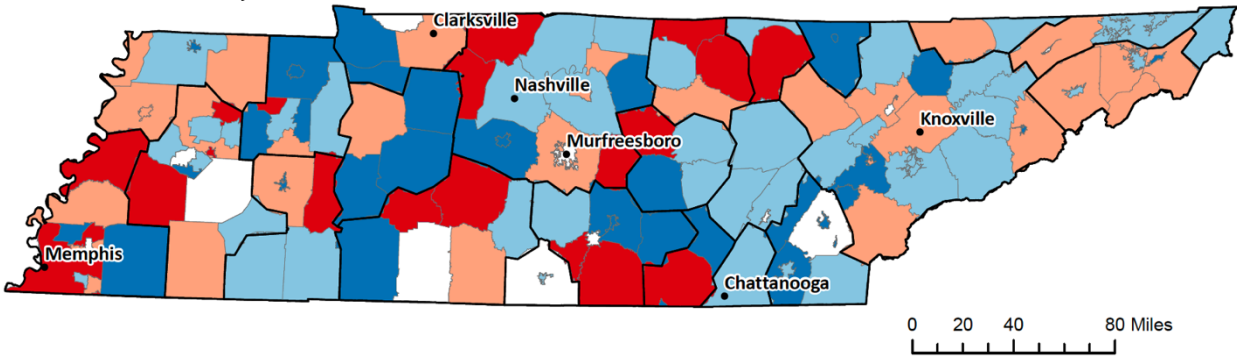


Figure 6. Perceived Staffing Challenges by District

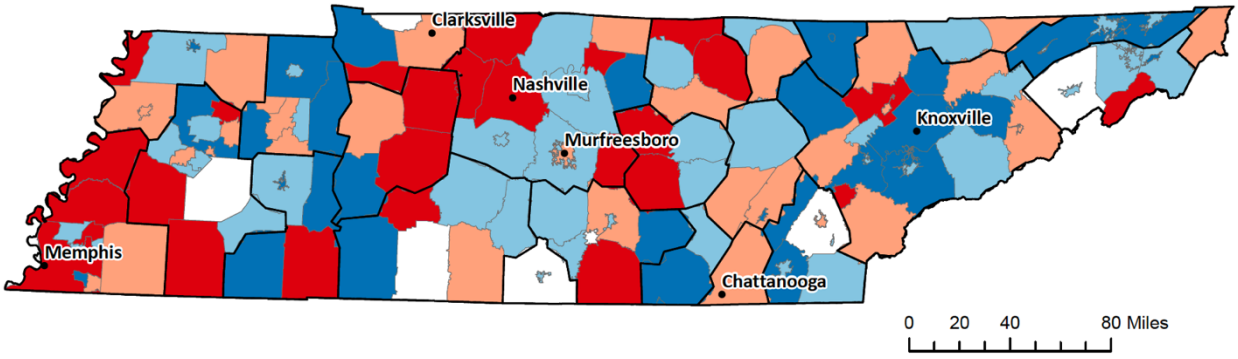
Panel A: Secondary Mathematics



Panel B: Secondary Social Studies



Panel C: Elementary Education



Legend

- Not enough applications
- Not enough high quality applications
- Enough high quality applications
- We do not lack teachers in this area-N/A
- Unsure/No data
- Commuting Zones

Tables

Table 1. Analytic Sample Characteristics

	All TN Schools	Analytic Sample	Non-Respondents
Pct. of Schools	100%	66%	34%
Avg. N. Students	601.7	630	547.3
Avg. Pct. Economically Disadvantaged	37%	35%	39%
Avg. Pct. Students with Disabilities	16%	16%	15%
Avg. Pct. English Learner	48%	48%	48%
Avg. Pct. Female	4%	4%	5%
Avg. Pct. Asian	2%	2%	2%
Avg. Pct. Black	22%	17%	31%
Avg. Pct. Hispanic	11%	10%	11%
Avg. Pct. Native American	0%	0%	0%
Avg. Pct. Pacific Islander	0%	0%	0%
Avg. Pct. White	65%	70%	56%
Avg. Std. Math Achievement	0.09	0.12	0.02
Avg. Std. Reading Achievement	-0.04	-0.02	-0.08
Avg. Pct. Teachers with Masters	50%	53%	44%
Avg. Teacher Yrs. Experience	11.78	11.83	11.7
Avg. CWIFT Adjusted Base Salary	$46,976	$47,571	$45,833
Avg. 2019 Attrition Rate	14%	13%	17%
Pct. City	28%	23%	40%
Pct. Suburban	17%	18%	14%
Pct. Town	17%	18%	15%
Pct. Rural	38%	41%	32%
Pct. Elementary School	48%	46%	52%
N Schools	1,650	1,085	565

Note. Our state sample includes all Tennessee traditional public schools (except state special schools including schools for the deaf, blind, and correctional facilities) that offered one grade between grades one and 12. Our analytic sample includes all Tennessee traditional public schools that had at least one administrator report school's unfilled teaching positions on the administrator version of the Tennessee Educator Survey. We also exclude four schools that answered the survey but did not report their grade level (K-5, K-8, 9-12, etc.) from our analysis. We use the school's 2018-19 average math test score on state standardized tests as our measure of achievement. 52 and 57 schools did not have math and reading achievement scores during 2018-19. Base salary is the salary in the lowest step and lane of each traditional public school district's 2019-20 salary schedule adjusted for cost of living using the 2019 Comparable Wage Index for Teachers (CWIFT) (Cornman et al., 2019). Attrition rates are calculated using percent of the schools' teachers in 2018-19 that did not return to that school in 2019-20. Elementary schools are schools that only offer grades between kindergarten and 5th grade.

Table 2. State and School Level Teacher Vacancies

	Full Sample	Elementary Schools	Secondary Schools
Statewide			
Total Vacancies	591	160	431
Pct. of Vacancies	100%	27.07%	72.93%
Total Teaching Positions	42,608	17,272	25,336
Pct. Vacant Teaching Positions	1.39%	0.93%	1.70%
Schools			
Avg. Number of Vacancies	0.55	0.32	0.74
Avg. Pct. Vacant Positions	1.48%	0.98%	1.91%
Pct. With 0 Vacancies	75%	82%	69%
Pct. With 1 Vacancy	14%	11%	16%
Pct. With 2 Vacancies	6%	4%	8%
Pct. With 3+ Vacancies	5%	3%	7%
N. Schools	1,085	503	582

Note. Elementary schools are schools that only offer grades between kindergarten and 5th grade. All other schools are considered secondary schools. The number of teaching positions is the sum of the total number of teachers at the school and vacant teaching positions.

Table 3. Variance Decomposition of School-level Teacher Vacancy Measures

	Elementary Schools		Secondary Schools	
	Has Vacant Position Indicator	Pct. Vacant Positions	Has Vacant Position Indicator	Pct. Vacant Positions
Commuting Zone	0.61%	0.00%	1.38%	0.15%
District	6.07%	5.14%	16.10%	29.95%
School (residual variance)	93.32%	94.86%	82.52%	69.90%

Note. To determine the proportion of the variance explained by each geographic level, we divide the variance explained by the level, determined using a hierarchical linear model, by the total variance. We use commuting zones as our measure of region in these analyses.

Table 4. Traditional Public School Vacancy Predictor Characteristics

	Has Vacancies	No Vacancies	Difference
EPP Grads in 25 Mi. in Last 3 Yrs.	7.914	9.35	-1.437**
	(8.094)	(10.22)	
Early Car. Tchs. who Went to HS in 25 Mi. Last 3 Yrs.	3.149	3.507	-0.358***
	(0.958)	(1.066)	
CWIFT Adjusted District Base Salary	$47,151	$47,693	-$542**
	(3,435)	(4,010)	
District Salary Annualized Rate of Change	1.467	1.528	-0.061
	(0.562)	(0.468)	
Std. School Working Conditions	-0.41	0.116	-0.526***
	(1.046)	(0.942)	
School Attrition Rate (Last 3 Yrs.)	0.1929	0.1397	5.320***
	(0.095)	(0.065)	
N Schools	265	785	1,050

Note. *** p<0.01, ** p<0.05, * p<0.1. EPP and HS, and are abbreviations for educator preparation program and high school, respectively. We only include EPP graduates with secondary education certifications and 1st year teachers in secondary schools respectively in our local teacher supply measures. Base salary is the salary in the lowest step and lane of each traditional public school district's 2019-20 salary schedule adjusted for cost of living using the 2019 Comparable Wage Index for Teachers (CWIFT) (Cornman et al., 2019). We calculate the annualized rate of change in salaries between the base salary and the salary of the tenth step in the lowest lane of the salary schedule. We construct the measure of school working conditions from survey items on 2018-19 Tennessee Educator Survey (TES) using principal component analysis. The sample for school working conditions includes the 932 schools that had more than 5 teachers and 30 percent of teachers respond to the TES. The attrition rate is the sum of the number of teachers who left a school in the prior three school years divided by sum of the number of teachers working at the school for each of the three school years prior to 2018-19.

Table 5. Estimated Relationships between Vacant Teaching Positions and Geographic Predictors of Vacancies in Traditional Public Schools

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Outcome: Has Vacant Position Indicator				Outcome: Percent Vacant Positions			
EPP Grads in 25 Mi. in Last 3 Yrs.	-0.001	-0.001	-0.001	-0.001	-0.004	-0.007	-0.006	-0.009
	(0.001)	(0.001)	(0.001)	(0.001)	(0.010)	(0.011)	(0.011)	(0.011)
Early Car. Tchs. who Went to HS in 25 Mi. Last 3 Yrs.	-0.021	-0.021	-0.014	-0.001	-0.485***	-0.487***	-0.448***	-0.364**
	(0.015)	(0.015)	(0.015)	(0.015)	(0.181)	(0.179)	(0.164)	(0.156)
Log. of CWIFT Adjusted District Base Salary		-0.113	-0.052	-0.036		2.088	2.502	2.726*
		(0.199)	(0.192)	(0.176)		(1.685)	(1.647)	(1.593)
District Salary Annualized Rate of Change		-0.092**	-0.088***	-0.070**		-0.912***	-0.867***	-0.606*
		(0.036)	(0.031)	(0.031)		(0.341)	(0.313)	(0.365)
Std. School Working Conditions			-0.040**	-0.034*			-0.375*	-0.290
			(0.019)	(0.019)			(0.215)	(0.201)
School Attrition Rate (Last 3 Yrs.)				0.009***				0.124**
				(0.003)				(0.055)
Observations	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050
Adj R Squared	0.108	0.115	0.147	0.159	0.101	0.110	0.124	0.150

Note. Standard errors clustered at the district-level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Covariates include indicators for missing school working conditions, percent of teachers who responded to the 2018-19 Tennessee Educator Survey, a school's urbanicity, and grade level as well as 2018-19 school-level student characteristics: the number of students, average math achievement on state tests, the percent of female, economically disadvantaged, English learner, Black, Hispanic, Asian, American Indian, and Pacific Islander students, and the percent of students with disabilities. EPP and HS are abbreviations for educator preparation program and high school respectively. Base salary is the salary in the lowest step and lane of each traditional public school district's 2019-20 salary schedule adjusted for cost of living using the 2019 Comparable Wage Index for Teachers (CWIFT) (Cornman et al., 2019). We calculate the annualized rate of change in salaries between the base salary and the salary of the tenth step in the lowest lane of the salary schedule. We construct the measure of school working conditions from survey items on 2018-19 Tennessee Educator Survey (TES) using principal component analysis. The attrition rate is the sum of the number of teachers who left a school in the prior three school years divided by sum of the number of teachers working at the school for each of the three school years prior to 2018-19.

Figure Notes

Figure 2 Note. Sample includes 12,688 first year teachers from the 2017-18, 2018-19, and 2019-20 school years. We calculate the geodetic distance from the address of their EPP to their teaching placement for these teachers in Panel A. 6,619 first year teachers (52%) attended a Tennessee Educator Preparation Program (EPP). We calculate geodetic ("as the crow flies") distance from the population weighted centroid of the teacher's high school zip code to their address of their teaching placement for 3,720 teachers who reported their high school zip code (45% of the sample) and went to high school in Tennessee (66% of teachers with reported zip codes) in Panel B.

Figure 3 Note. Sample includes 1,050 (64%) traditional public schools. Red line represents mean value and dotted lines represent values one standard deviation from the mean. EPP and HS are abbreviations for educator preparation program and high school respectively. Base salary is the salary in the lowest step and lane of each traditional public school district's 2019-20 salary schedule adjusted for cost of living using the 2019 Comparable Wage Index for Teachers (Cornman et al., 2019). We calculate the annualized rate of change in salaries between the base salary and the salary of the tenth step in the lowest lane of the salary schedule. We construct the measure of school working conditions from survey items on 2018-19 Tennessee Educator Survey (TES) using principal component analysis. The sample for Panel E includes 932 schools that had more than 5 teachers and 30 percent of teachers respond to the TES. The attrition rate is the sum of the number of teachers who left a school in the prior three school years divided by sum of the number of teachers working at the school for each of the three school years prior to 2018-19.

Figure 4 Note. Sample includes the 1,085 (66%) traditional public schools that had at least one administrator report the number of vacant teaching positions on the Tennessee Educator Survey. We use commuting zones as our measure of region in these analyses.

Figure 5 Note. Total respondents: 137 (97%) districts. Samples for each subject vary from 125 to 135 districts because not all districts responded or were unsure of staffing challenges for each subject. Tech., CTE, and ESL are abbreviations for technology, career and technical education, and English as a second language respectively.

Figure 6 Note. Total respondents for secondary mathematics: 130 (92%) districts. Total respondents for secondary social studies: 129 (91%). Total respondents for elementary education: 135 (96%). We exclude the Achievement School District, a statewide turnaround school district, from our maps because it does not have geographic boundaries.

Online Appendix A

Table A1. Public Secondary School Characteristics by 2019-20 Vacancy Status

	Has Vacancies	No Vacancies	Difference
EPP Grads in 25 Mi. in Last 3 Yrs.	7.914	9.350	-1.437**
	(8.094)	(10.22)	
Early Car. Tchs. who Went to HS in 25 Mi. Last 3 Yrs.	3.149	3.507	-0.358***
	(0.958)	(1.066)	
CWIFT Adjusted District Base Salary	$47,151	$47,693	-$542**
	($3,435)	($4,010)	
District Salary Annualized Rate of Change	1.467	1.528	-0.061
	(0.562)	(0.468)	
Std. School Working Conditions	-0.410	0.116	-0.526***
	(1.046)	(0.942)	
School Attrition Rate (Last 3 Yrs.)	19.29%	13.97%	5.320***
	(9.50%)	(6.51%)	
EPP Grads in CZ in Last 3 Yrs.	8.038	9.632	-1.594*
	(8.752)	(12.50)	
Early Car. Tchs. who Went to HS in CZ Last 3 Yrs.	3.565	4.023	-0.458***
	(0.899)	(1.227)	
Total Students	741.4	607.8	133.7***
	(475.6)	(377.3)	
Avg. Std Math Achievement	-0.021	0.168	-0.189***
	(0.649)	(0.562)	
Pct. Economically Disadvantaged	40.45%	36.15%	4.30%***
	(17.24%)	(16.09%)	
Pct. Students with Disabilities	16.31%	15.99%	0.32%
	(9.73%)	(6.00%)	
Pct. Female	47.85%	48.32%	-0.47%*
	(4.67%)	(3.69%)	
Pct. English Learners	5.30%	3.41%	1.89%***
	(9.39%)	(6.985)	
Pct. Asian	1.78%	1.78%	0%
	(2.41%)	(2.66%)	
Pct. Black	25.68%	14.21%	11.47%***
	(27.49%)	(18.64%)	
Pct. Hispanic	11.74%	8.84%	2.90%***
	(13.22%)	(10.63%)	
Pct. Indigenous Persons	0.40%	0.44%	-0.04%
	(0.47%)	(0.49%)	
Pct. Pacific Islander	0.23%	0.20%	0.03%
	(0.37%)	(0.33%)	
Pct. White	60.16%	74.53%	-14.37%***
	(32.30%)	(23.39%)	
N Schools	265	785	1,050

Note. *** p<0.01, ** p<0.05, * p<0.1. EPP, HS, and CZ are abbreviations for educator preparation program, high school, and commuting zone. Base salary is the salary in the lowest step and lane of district's 2019-20 salary schedule adjusted for cost of living. We calculate the annualized rate of change in salaries between the base salary and the salary of the tenth step in the lowest lane of the salary schedule. We construct the measure of school working conditions from survey items on 2018-19 Tennessee Educator Survey (TES) using principal component analysis. The sample for school working conditions includes the 932 schools that had more than 5 teachers and 30 percent of teachers respond to the TES. Schools' student characteristics are from the 2018-19 school year. We use the school's 2018-19 average math test score on state standardized tests as our measure of achievement.

Table A2. Estimated Relationships between Indicator for Vacant Teaching Positions and Geographic Predictors of Vacancies in Public Secondary Schools (Full Covariates).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPP Grads in 25 Mi. in Last 3 Yrs.	-0.001	-0.001	-0.001	-0.001				
	(0.001)	(0.001)	(0.001)	(0.001)				
New Tchs. who Went to HS in 25 Mi. Last 3 Yrs.	-0.021	-0.021	-0.014	-0.001				
	(0.015)	(0.015)	(0.015)	(0.015)				
EPP Grads in CZ in Last 3 Yrs.					-0.001	-0.001	-0.000	-0.000
					(0.001)	(0.001)	(0.001)	(0.001)
New Tchs. who Went to HS in CZ Last 3 Yrs.					-0.023*	-0.021	-0.022*	-0.018
					(0.013)	(0.013)	(0.013)	(0.014)
Log. of CWIFT Adjusted District Base Salary		-0.113	-0.052	-0.036		-0.105	-0.043	-0.030
		(0.199)	(0.192)	(0.176)		(0.200)	(0.193)	(0.176)
District Salary Annualized Rate of Change		-0.092**	-0.088***	-0.070**		-0.090**	-0.085***	-0.068**
		(0.036)	(0.031)	(0.031)		(0.036)	(0.031)	(0.032)
Std. School Working Conditions			-0.040**	-0.034*			-0.040**	-0.035*
			(0.019)	(0.019)			(0.019)	(0.019)
School Attrition Rate (Last 3 Yrs.)				0.009***				0.008**
				(0.003)				(0.003)
City	0.015	0.017	-0.009	-0.009	0.018	0.018	-0.006	-0.007
	(0.038)	(0.039)	(0.036)	(0.035)	(0.038)	(0.038)	(0.035)	(0.035)
Town	-0.005	-0.023	0.004	0.020	-0.002	-0.020	0.010	0.026
	(0.050)	(0.052)	(0.049)	(0.049)	(0.051)	(0.052)	(0.050)	(0.050)
Rural	0.036	0.023	0.037	0.052	0.035	0.021	0.039	0.055
	(0.052)	(0.052)	(0.049)	(0.049)	(0.052)	(0.051)	(0.050)	(0.050)
Elementary School	-0.119***	-0.105***	-0.084**	-0.064*	-0.117***	-0.106***	-0.079**	-0.059
	(0.037)	(0.037)	(0.037)	(0.037)	(0.039)	(0.039)	(0.040)	(0.039)
Middle School	0.072	0.069	0.053	0.053	0.068	0.066	0.050	0.050
	(0.052)	(0.052)	(0.048)	(0.048)	(0.052)	(0.052)	(0.048)	(0.048)
300-600 Total Students	0.031	0.033	0.025	0.042	0.029	0.031	0.022	0.038
	(0.041)	(0.040)	(0.040)	(0.041)	(0.042)	(0.041)	(0.040)	(0.041)
600-900 Total Students	0.069	0.072	0.049	0.072	0.067	0.070	0.046	0.069
	(0.047)	(0.045)	(0.045)	(0.046)	(0.046)	(0.045)	(0.044)	(0.045)
900-1200 Total Students	0.112	0.129*	0.079	0.102	0.108	0.124*	0.074	0.098
	(0.071)	(0.069)	(0.065)	(0.066)	(0.072)	(0.070)	(0.065)	(0.067)
Greater than 1200 Total Students	0.226***	0.233***	0.172**	0.201**	0.224***	0.231***	0.169**	0.197**
	(0.085)	(0.083)	(0.078)	(0.079)	(0.085)	(0.083)	(0.078)	(0.079)
Avg. Std Math Achievement	-0.115***	-0.114***	-0.087***	-0.080**	-0.114***	-0.112***	-0.086***	-0.080**
	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
Pct. Economically Disadvantaged	-0.001	-0.001	-0.002	-0.002	-0.001	-0.001	-0.002	-0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Pct. Students with Disabilities	0.004	0.003	0.004	0.004*	0.004	0.003	0.004	0.004
	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)
Pct. Female	0.000	-0.000	-0.001	0.000	-0.000	-0.001	-0.001	0.000
	(0.005)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)	(0.004)
Pct. English Learners	0.007*	0.003	0.002	0.001	0.007*	0.003	0.003	0.001
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Pct. Asian	-0.006	-0.006	-0.005	-0.004	-0.006	-0.006	-0.004	-0.004
	(0.008)	(0.007)	(0.006)	(0.006)	(0.008)	(0.007)	(0.006)	(0.006)
Pct. Black	0.004***	0.004***	0.004***	0.002	0.003***	0.004***	0.003***	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Pct. Hispanic	-0.001	0.001	0.002	0.001	-0.001	0.001	0.002	0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Pct. Indigenous Persons	0.007	0.015	0.006	0.002	0.003	0.011	0.002	-0.001
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.025)	(0.025)	(0.025)
Pct. Pacific Islander	0.042	0.052	0.035	0.045	0.046	0.055	0.038	0.048
	(0.047)	(0.047)	(0.041)	(0.040)	(0.046)	(0.046)	(0.040)	(0.040)
Observations	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050
Adj R Squared	0.108	0.115	0.147	0.159	0.109	0.115	0.149	0.160

Note. Standard errors clustered at the district-level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. 2018-19 school-level student characteristics. The model also includes an indicator for missing working conditions and the percent of teachers who responded to the Tennessee Educator Survey.

Table A3. Estimated Relationships between Percent Vacant Teaching Positions and Geographic Predictors of Vacancies in Public Secondary Schools (Full Covariates).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPP Grads in 25 Mi. in Last 3 Yrs.	-0.004	-0.007	-0.006	-0.009				
	(0.010)	(0.011)	(0.011)	(0.011)				
New Tchs. who Went to HS in 25 Mi. Last 3 Yrs.	-0.485***	-0.487***	-0.448***	-0.364**				
	(0.181)	(0.179)	(0.164)	(0.156)				
EPP Grads in CZ in Last 3 Yrs.					-0.010	-0.013*	-0.010	-0.011
					(0.008)	(0.008)	(0.007)	(0.007)
New Tchs. who Went to HS in CZ Last 3 Yrs.					-0.267**	-0.255*	-0.268**	-0.208*
					(0.130)	(0.129)	(0.131)	(0.124)
Log. of CWIFT Adjusted District Base Salary		2.088	2.502	2.726*		2.180	2.619	2.807*
		(1.685)	(1.647)	(1.593)		(1.766)	(1.714)	(1.661)
District Salary Annualized Rate of Change		-0.912***	-0.867***	-0.606*		-0.902**	-0.852***	-0.590
		(0.341)	(0.313)	(0.365)		(0.353)	(0.317)	(0.369)
Std. School Working Conditions			-0.375*	-0.290			-0.380*	-0.293
			(0.215)	(0.201)			(0.220)	(0.206)
School Attrition Rate (Last 3 Yrs.)				0.124**				0.127**
				(0.055)				(0.055)
City	0.414	0.272	0.098	0.089	0.414	0.263	0.091	0.080
	(0.456)	(0.442)	(0.429)	(0.401)	(0.438)	(0.426)	(0.414)	(0.386)
Town	0.088	-0.235	-0.047	0.184	0.022	-0.300	-0.089	0.162
	(0.412)	(0.440)	(0.423)	(0.437)	(0.397)	(0.420)	(0.403)	(0.413)
Rural	0.092	-0.138	-0.049	0.169	-0.022	-0.256	-0.141	0.100
	(0.340)	(0.351)	(0.328)	(0.326)	(0.353)	(0.364)	(0.340)	(0.336)
Elementary School	-1.150**	-1.058**	-0.905**	-0.620	-1.292**	-1.215**	-1.020**	-0.715
	(0.481)	(0.462)	(0.456)	(0.524)	(0.511)	(0.494)	(0.485)	(0.549)
Middle School	0.191	0.230	0.083	0.077	0.133	0.173	0.027	0.029
	(0.395)	(0.384)	(0.405)	(0.404)	(0.402)	(0.392)	(0.413)	(0.412)
300-600 Total Students	-1.035	-1.024*	-1.114*	-0.872	-1.034	-1.020	-1.118*	-0.867
	(0.626)	(0.615)	(0.666)	(0.592)	(0.630)	(0.619)	(0.669)	(0.592)
600-900 Total Students	-1.571**	-1.556**	-1.763**	-1.420**	-1.546**	-1.530**	-1.748**	-1.399**
	(0.670)	(0.651)	(0.736)	(0.628)	(0.671)	(0.653)	(0.736)	(0.627)
900-1200 Total Students	-1.544**	-1.417*	-1.830**	-1.498*	-1.602**	-1.480*	-1.898**	-1.546**
	(0.767)	(0.760)	(0.849)	(0.765)	(0.785)	(0.780)	(0.865)	(0.775)
Greater than 1200 Total Students	-2.197**	-2.183**	-2.648***	-2.238**	-2.179**	-2.165**	-2.652***	-2.230**
	(0.933)	(0.915)	(0.960)	(0.905)	(0.934)	(0.915)	(0.959)	(0.900)
Avg. Std Math Achievement	-0.654*	-0.701*	-0.494	-0.391	-0.598*	-0.644*	-0.438	-0.343
	(0.354)	(0.359)	(0.369)	(0.362)	(0.340)	(0.345)	(0.357)	(0.350)
Pct. Economically Disadvantaged	-0.007	-0.011	-0.015	-0.014	-0.004	-0.008	-0.012	-0.012
	(0.016)	(0.016)	(0.016)	(0.015)	(0.017)	(0.018)	(0.017)	(0.016)
Pct. Students with Disabilities	0.043	0.040	0.042	0.051	0.041	0.038	0.040	0.049
	(0.055)	(0.051)	(0.054)	(0.055)	(0.056)	(0.052)	(0.055)	(0.056)
Pct. Female	-0.035	-0.037	-0.039	-0.027	-0.041	-0.043	-0.044	-0.031
	(0.066)	(0.065)	(0.064)	(0.056)	(0.067)	(0.066)	(0.064)	(0.056)
Pct. English Learners	0.035	0.009	-0.002	-0.009	0.036	0.011	-0.002	-0.009
	(0.029)	(0.032)	(0.032)	(0.031)	(0.029)	(0.034)	(0.034)	(0.033)
Pct. Asian	-0.014	-0.007	0.006	0.011	0.007	0.015	0.025	0.028
	(0.059)	(0.048)	(0.046)	(0.042)	(0.059)	(0.047)	(0.046)	(0.041)
Pct. Black	0.039***	0.044***	0.042***	0.021	0.038***	0.044***	0.041***	0.019
	(0.012)	(0.012)	(0.012)	(0.016)	(0.011)	(0.012)	(0.012)	(0.016)
Pct. Hispanic	-0.021	-0.009	-0.002	-0.009	-0.020	-0.009	-0.002	-0.009
	(0.019)	(0.022)	(0.022)	(0.022)	(0.019)	(0.023)	(0.022)	(0.022)
Pct. Indigenous Persons	-0.215	-0.173	-0.242	-0.293	-0.245	-0.202	-0.278	-0.322
	(0.266)	(0.264)	(0.256)	(0.260)	(0.275)	(0.275)	(0.263)	(0.266)
Pct. Pacific Islander	0.154	0.202	0.080	0.220	0.155	0.199	0.079	0.224
	(0.358)	(0.322)	(0.317)	(0.331)	(0.333)	(0.299)	(0.298)	(0.316)
Observations	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050
Adj R Squared	0.101	0.110	0.124	0.150	0.095	0.104	0.120	0.147

Note. Standard errors clustered at the district-level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. 2018-19 school-level student characteristics. The model also includes an indicator for missing working conditions and the percent of teachers who responded to the Tennessee Educator Survey.

Table A4. Estimated Relationships between Indicator for Vacant Teaching Positions and Geographic Predictors of Vacancies in Public Secondary Schools Weighted by Inverse of the Propensity to Report Vacancies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPP Grads in 25 Mi. in Last 3 Yrs.	-0.001	-0.001	-0.001	-0.002				
	(0.001)	(0.001)	(0.001)	(0.001)				
Early Car. Tchs. who Went to HS in 25 Mi. Last 3 Yrs.	-0.021	-0.021	-0.012	-0.004				
	(0.016)	(0.015)	(0.015)	(0.016)				
EPP Grads in CZ in Last 3 Yrs.					-0.001	-0.001	-0.000	-0.001
					(0.001)	(0.001)	(0.001)	(0.001)
Early Car. Tchs. who Went to HS in CZ Last 3 Yrs.					-0.024*	-0.021	-0.022	-0.015
					(0.014)	(0.014)	(0.014)	(0.015)
Log. of District Base Salary		-0.080	-0.021	-0.012		-0.074	-0.014	-0.010
		(0.199)	(0.190)	(0.173)		(0.200)	(0.192)	(0.175)
District Salary Annualized Rate of Change		-0.085**	-0.079***	-0.059*		-0.083**	-0.076**	-0.057*
		(0.035)	(0.029)	(0.031)		(0.036)	(0.030)	(0.031)
Std. School Working Conditions			-0.045**	-0.039**			-0.046**	-0.040**
			(0.019)	(0.020)			(0.019)	(0.020)
School Attrition Rate (Last 3 Yrs.)				0.010**				0.009**
				(0.004)				(0.004)
Observations	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050
Adj R Squared	0.115	0.122	0.160	0.177	0.116	0.122	0.161	0.177

Note. Standard errors clustered at the district-level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Covariates include indicators for missing school working conditions, percent of teachers who responded to the 2018-19 Tennessee Educator Survey, a school's urbanicity, and grade level as well as 2018-19 school-level student characteristics: the number of students, average math achievement on state tests, the percent of female, economically disadvantaged, English learner, Black, Hispanic, Asian, American Indian, and Pacific Islander students, and the percent of students with disabilities. EPP, HS, and CZ are abbreviations for educator preparation program, high school, and commuting zone respectively. Base salary is the salary in the lowest step and lane of each traditional public school district's 2019-20 salary schedule adjusted for cost of living using the 2019 Comparable Wage Index for Teachers (CWIFT) (Cornman et al., 2019). We calculate the annualized rate of change in salaries between the base salary and the salary of the tenth step in the lowest lane of the salary schedule. We construct the measure of school working conditions from survey items on 2018-19 Tennessee Educator Survey (TES) using principal component analysis. The attrition rate is the sum of the number of teachers who left a school in the prior three school years divided by sum of the number of teachers working at the school for each of the three school years prior to 2018-19. Observations are weighted by the inverse of the propensity to have a response for the vacancy question on the TES. We use the predicted value from the logistic regression that predicting the likelihood of responding to the unfilled teaching position question as a function of the school-level characteristics included as covariates in our main model.

Table A5. Estimated Relationships between Percent Vacant Teaching Positions and Geographic Predictors of Vacancies in Public Secondary Schools Weighted by Inverse of the Propensity to Report Vacancies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPP Grads in 25 Mi. in Last 3 Yrs.	-0.001	-0.001	-0.001	-0.002				
	(0.001)	(0.001)	(0.001)	(0.001)				
Early Car. Tchs. who Went to HS in 25 Mi. Last 3 Yrs.	-0.021	-0.021	-0.012	-0.004				
	(0.016)	(0.015)	(0.015)	(0.016)				
EPP Grads in CZ in Last 3 Yrs.					-0.001	-0.001	-0.000	-0.001
					(0.001)	(0.001)	(0.001)	(0.001)
Early Car. Tchs. who Went to HS in CZ Last 3 Yrs.					-0.024*	-0.021	-0.022	-0.015
					(0.014)	(0.014)	(0.014)	(0.015)
Log. of District Base Salary		-0.080	-0.021	-0.012		-0.074	-0.014	-0.010
		(0.199)	(0.190)	(0.173)		(0.200)	(0.192)	(0.175)
District Salary Annualized Rate of Change		-0.085**	-0.079***	-0.059*		-0.083**	-0.076**	-0.057*
		(0.035)	(0.029)	(0.031)		(0.036)	(0.030)	(0.031)
Std. School Working Conditions			-0.045**	-0.039**			-0.046**	-0.040**
			(0.019)	(0.020)			(0.019)	(0.020)
School Attrition Rate (Last 3 Yrs.)				0.010**				0.009**
				(0.004)				(0.004)
Observations	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050
Adj R Squared	0.115	0.122	0.160	0.177	0.116	0.122	0.161	0.177

Note. Standard errors clustered at the district-level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Covariates include indicators for missing school working conditions, percent of teachers who responded to the 2018-19 Tennessee Educator Survey, a school's urbanicity, and grade level as well as 2018-19 school-level student characteristics: the number of students, average math achievement on state tests, the percent of female, economically disadvantaged, English learner, Black, Hispanic, Asian, American Indian, and Pacific Islander students, and the percent of students with disabilities. EPP, HS, and CZ are abbreviations for educator preparation program, high school, and commuting zone respectively. Base salary is the salary in the lowest step and lane of each traditional public school district's 2019-20 salary schedule adjusted for cost of living using the 2019 Comparable Wage Index for Teachers (CWIFT) (Cornman et al., 2019). We calculate the annualized rate of change in salaries between the base salary and the salary of the tenth step in the lowest lane of the salary schedule. We construct the measure of school working conditions from survey items on 2018-19 Tennessee Educator Survey (TES) using principal component analysis. The attrition rate is the sum of the number of teachers who left a school in the prior three school years divided by sum of the number of teachers working at the school for each of the three school years prior to 2018-19. Observations are weighted by the inverse of the propensity to have a response for the vacancy question on the TES. We use the predicted value from the logistic regression that predicting the likelihood of responding to the unfilled teaching position question as a function of the school-level characteristics included as covariates in our main model.

Table A6. Estimated Relationships between Indicator for Vacant Teaching Positions and Geographic Predictors of Vacancies in Public Secondary Schools (Unadjusted Salaries)

	(1)	(2)	(3)	(4)	(5)	(6)
EPP Grads in 25 Mi. in Last 3 Yrs.	-0.001	-0.001	-0.001			
	(0.001)	(0.001)	(0.001)			
Early Car. Tchs. who Went to HS in 25 Mi. Last 3 Yrs.	-0.022	-0.017	-0.011			
	(0.016)	(0.015)	(0.015)			
EPP Grads in CZ in Last 3 Yrs.				-0.001	-0.000	-0.000
				(0.001)	(0.001)	(0.001)
Early Car. Tchs. who Went to HS in CZ Last 3 Yrs.				-0.024*	-0.026*	-0.022
				(0.014)	(0.014)	(0.014)
Log. of District Base Salary	-0.203	-0.294	-0.369	-0.231	-0.349	-0.424
	(0.325)	(0.313)	(0.288)	(0.331)	(0.324)	(0.297)
District Salary Annualized Rate of Change	-0.095***	-0.094***	-0.078**	-0.094**	-0.093***	-0.077**
	(0.036)	(0.032)	(0.032)	(0.037)	(0.032)	(0.032)
Std. School Working Conditions		-0.039**	-0.033*		-0.040**	-0.034*
		(0.019)	(0.019)		(0.019)	(0.019)
School Attrition Rate (Last 3 Yrs.)			0.09***			0.009***
			(0.003)			(0.003)
Observations	1,050	1,050	1,050	1,050	1,050	1,050
Adj R Squared	0.115	0.148	0.160	0.116	0.150	0.162

Note. Standard errors clustered at the district-level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Covariates include indicators for missing school working conditions, percent of teachers who responded to the 2018-19 Tennessee Educator Survey, a school's urbanicity, and grade level as well as 2018-19 school-level student characteristics: the number of students, average math achievement on state tests, the percent of female, economically disadvantaged, English learner, Black, Hispanic, Asian, American Indian, and Pacific Islander students, and the percent of students with disabilities. EPP, HS, and CZ are abbreviations for educator preparation program, high school, and commuting zone respectively. Base salary is the salary in the lowest step and lane of each traditional public school district's 2019-20 salary schedule. We calculate the annualized rate of change in salaries between the base salary and the salary of the tenth step in the lowest lane of the salary schedule. We construct the measure of school working conditions from survey items on 2018-19 Tennessee Educator Survey (TES) using principal component analysis. The attrition rate is the sum of the number of teachers who left a school in the prior three school years divided by sum of the number of teachers working at the school for each of the three school years prior to 2018-19.

Table A7. Estimated Relationships between Percent Vacant Teaching Positions and Geographic Predictors of Vacancies in Public Secondary Schools (Unadjusted Salaries)

	(1)	(2)	(3)	(4)	(5)	(6)
EPP Grads in 25 Mi. in Last 3 Yrs.	-0.006	-0.005	-0.008			
	(0.011)	(0.011)	(0.011)			
Early Car. Tchs. who Went to HS in 25 Mi. Last 3 Yrs.	-0.463**	-0.429**	-0.354**			
	(0.184)	(0.167)	(0.161)			
EPP Grads in CZ in Last 3 Yrs.				-0.013*	-0.010	-0.011
				(0.008)	(0.007)	(0.007)
Early Car. Tchs. who Went to HS in CZ Last 3 Yrs.				-0.218*	-0.235*	-0.185
				(0.126)	(0.126)	(0.119)
Log. of District Base Salary	2.502	2.066	1.015	3.012	2.368	1.274
	(2.697)	(2.780)	(2.377)	(2.599)	(2.685)	(2.239)
District Salary Annualized Rate of Change	-0.883***	-0.854***	-0.626*	-0.867***	-0.838***	-0.607*
	(0.305)	(0.292)	(0.343)	(0.314)	(0.296)	(0.348)
Std. School Working Conditions		-0.377*	-0.290		-0.381*	-0.292
		(0.219)	(0.204)		(0.222)	(0.208)
School Attrition Rate (Last 3 Yrs.)			0.123**			0.126**
			(0.054)			(0.055)
Observations	1,050	1,050	1,050	1,050	1,050	1,050
Adj R Squared	0.109	0.123	0.148	0.104	0.118	0.145

Note. Standard errors clustered at the district-level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Covariates include indicators for missing school working conditions, percent of teachers who responded to the 2018-19 Tennessee Educator Survey, a school's urbanicity, and grade level as well as 2018-19 school-level student characteristics: the number of students, average math achievement on state tests, the percent of female, economically disadvantaged, English learner, Black, Hispanic, Asian, American Indian, and Pacific Islander students, and the percent of students with disabilities. EPP, HS, and CZ are abbreviations for educator preparation program, high school, and commuting zone respectively. Base salary is the salary in the lowest step and lane of each traditional public school district's 2019-20 salary schedule. We calculate the annualized rate of change in salaries between the base salary and the salary of the tenth step in the lowest lane of the salary schedule. We construct the measure of school working conditions from survey items on 2018-19 Tennessee Educator Survey (TES) using principal component analysis. The attrition rate is the sum of the number of teachers who left a school in the prior three school years divided by sum of the number of teachers working at the school for each of the three school years prior to 2018-19.

Online Appendix B: Teacher Working Conditions Survey Items and Factor Loadings

We use 43 survey items on 2018-19 Tennessee Educator Survey to construct our measure of school working conditions. To determine which survey items to include in our principal component analysis, we use Merrill's (2021) classifications of dimensions of teacher working conditions. These categories include: leadership and teacher empowerment, faculty, parents and community, school features and climate, professional development, instructional materials and support, time use, and perceptions of safety. We determined that the survey items listed below describe dimensions of the above categories. Then, we aggregate teacher survey responses for these items to the school level and perform principal component analysis. We use the principal component that accounts for the largest amount of the variance as our measure of teacher working conditions. We include the eigenvectors that represent the coefficients for each variable in the construction of the first component and loadings, the amount of variation in each variable described by the first component, of each item in the table below.

Survey Item	Eigenvector (Coefficient)	Loading (Prop. Variance Explained)
Please indicate the extent to which you agree or disagree with the following statements regarding your school. (strongly disagree, disagree, agree, strongly agree)		
There is an atmosphere of trust and mutual respect within this school.	0.191	0.873
Staff at this school have an effective process for solving problems.	0.199	0.906
Teachers are encouraged to participate in school leadership roles.	0.181	0.827
I feel supported by other teachers at this school.	0.167	0.762
Our school staff is a learning community in which ideas and suggestions for improvement are encouraged.	0.198	0.902
The principal at my school communicates a clear vision for this school.	0.181	0.825
The staff feels comfortable raising issues and concerns that are important to them with school leaders.	0.179	0.818
I like the way things are run at this school.	0.195	0.890
School leadership effectively handles student discipline and behavioral problems.	0.182	0.829
Students treat adults with respect at this school.	0.168	0.767
Students in my school are often threatened and bullied.	-0.116	0.529
I feel safe at my school.	0.175	0.798
I feel prepared to respond to any type of emergency situation that may occur at my school.	0.164	0.750
Teachers in my school are allowed to focus on teaching students with minimal interruptions.	0.172	0.787
My individual planning time is sufficient.	0.097	0.442
My collaborative planning time is sufficient.	0.118	0.538

Teachers with demonstrated effectiveness in teaching have opportunities to lead instructional improvement efforts in my school.	0.174	0.793
This school provides meaningful opportunities for parents to partner with staff in the school to support student learning.	0.172	0.785
Parents respond to my suggestions for helping their child.	0.132	0.600
My curriculum/instructional materials are easy to use.	0.105	0.478
I am able to deliver high quality lessons by using the curriculum/instructional materials as designed.	0.108	0.494
I am able to use assessments and tasks provided by curriculum/instructional materials without having to modify or develop my own.	0.099	0.452
My curriculum/instructional materials are engaging to my students	0.122	0.558
Teachers at my school have high expectations for all students.	0.164	0.748
The processes used to conduct my teacher evaluation are fair to me.	0.150	0.684
In general, the teacher evaluation process used in my school has led to improvements in my teaching.	0.157	0.715
In general, the teacher evaluation process used in my school has led to improvements in student learning.	0.160	0.731
How often do each of the following take place within your school? (Never, rarely, sometimes, almost always)		
School leadership is adequately visible and available to address staff/student needs.	0.176	0.803
School leadership proactively seeks to understand the needs of teachers and staff.	0.187	0.853
Think about all of the teachers in your school. About how many teachers in this school (None, some about half, most, nearly all)		
Feel responsible when students in this school fail.	0.143	0.650
Feel responsible to help each other do their best.	0.166	0.756
Help maintain discipline in the entire school, not just their classroom.	0.175	0.799
Take responsibility for improving their school.	0.182	0.832
Implement effective instructional strategies.	0.163	0.743
Please indicate the frequency with which the following instructional improvement statements have applied to you during this school year. (never, rarely, sometimes, frequently)		
I have received specific professional learning suggestions that are tailored to my needs.	0.156	0.711
My professional learning experiences this year have been closely aligned to the feedback I received on my evaluation.	0.162	0.737
My professional learning has been closely aligned to the instructional materials I use in class.	0.142	0.648
In general, the professional learning I have received this year has led to improvements in my teaching.	0.155	0.706

In a typical week, what percentage of instructional time do you spend dealing with student behavioral and disciplinary issues? (5 percent or less; 6 percent to 10 percent; 11 percent to 15 percent; 16 percent to 25 percent; more than 25 percent)	-0.102	0.500
On average, how many hours per week do you spend creating or sourcing materials to use for classroom instruction including planning time during and outside of school hours? (Less than 2 hours; 2 to 4 hours; 4 to 6 hours; 6 to 10 hours; More than 10 hours)	-0.042	0.190
Numeric Open Response		
About how many minutes per week during school hours do you have for individual planning/prep time?	0.015	0.070
About how many minutes per week during school hours do you spend meeting with other teachers to discuss instruction?	0.006	0.025
About how many minutes per week during school hours do you spend on other school business (school improvement planning, administrative duties)?	-0.023	0.106