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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, grade level, and subject variation in teacher shortages using data on teaching vacancies 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 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 the longstanding debate surrounding 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; McVey & Trinidad, 2019). However, teacher shortages can vary greatly within states due to local factors that influence the supply of and demand for

teachers—e.g., compensation, school working conditions, and teachers' geographic preferences. Thus, examining teacher shortages from one point of view may mask substantial heterogeneity in teacher staffing challenges.

Our aim is to develop a framework that researchers, policymakers, and pundits alike can use to reconcile conflicting perspectives and better understand the nature of teacher staffing challenges in the U.S. We accomplish this by synthesizing the extant literature on teacher labor markets and developing 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 this framework, we generate a series of testable hypotheses about variation in teacher shortages by region, district, school, grade level, 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 unfilled teaching positions ("vacancies" hereafter) at the start of the 2019-2020 school year, before the onset of the COVID-19 pandemic.

We conduct a range of descriptive and spatial analyses to determine how the existence and severity of teacher vacancies, an extreme measure of staffing challenges that has negative consequences for student achievement (Papay & Kraft, 2016), vary across schools, districts, and regions within Tennessee. We then examine relationships between regional, district, and school predictors of 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 also document variation in teacher shortages by subject using district-level survey data concerning subject-specific teacher staffing challenges.

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 only 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 80 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 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 vacancies at the state level masks substantial variation across schools.

Given the localized nature of teacher staffing challenges, several school and district level factors stand out as strong predictors of teacher vacancies. 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 the percent of unfilled teaching positions. In particular, historical attrition rates are predictive of having vacancies. A one standard deviation increase in teacher turnover is associated with a 48 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. By describing unfilled teaching positions across a variety of labor markets simultaneously, these analyses provide some of the

first evidence concerning the extent to which teacher shortages are widespread, concentrated in certain regions within a state, or vary widely by school. We also add to the growing literature concerning possible predictors of teacher staffing challenges (e.g., Goldhaber et al., 2020; Goldhaber et al., 2021). Our work also complements recent efforts to quantify the scale of teacher shortages in the wake of the COVID-19 pandemic (Nguyen et al., 2022) by providing a framework to better understand the nature of these shortages and predicting where they are likely to arise. 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

Demand for 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 and attracts more experienced teachers (Hendricks, 2014, 2015; Sun et al., 2022). However, wages in the K-12 public teacher labor market are fairly rigid and compressed due to collectively bargained salary schedules and budget constraints determined through local, state, and federal funding formulas.

Schools, in theory, can 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 fixed budget constraints (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 in the demand for teachers and teacher wages, most policy solutions aimed at alleviating teacher shortages focus on increasing the supply of teachers. 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 shortages 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 for two reasons. First, factors influencing teacher supply often vary across regions, districts, and schools within the same state. While some factors affecting teacher supply

including state certification requirements impact all schools, other factors such as wages, retention rates, and working conditions can vary considerably across local geographies. Prior research shows that most of the salary variation is between intra-state regions rather than between districts within the same region (Lankford et al., 2002). Not only do retention rates vary across locales, schools within the same district serving larger populations of low-income and low-achieving students have higher attrition rates (Cowen et al., 2012; Hanushek et al., 2004; Jacob, 2007; Lankford et al., 2002; Miller, 2012).

Studies of teacher job applications show that schools in high-income neighborhoods that serve higher achieving and more economically advantaged students and have earlier teacher hiring timelines benefit from more applicants (Boyd et al., 2011a; 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 higher levels of administrative support, better school culture, and stronger relationships among faculty, which are more likely to be found at schools serving historically advantaged students (Johnson et al., 2012; Ladd, 2011; Lovison & Mo, 2022; Viano et al., 2020).

Second, a growing body of literature demonstrates that teacher labor markets are highly localized (Engel & Cannata, 2015). Compared to other professions, teachers are more likely to work within 20 miles of their hometown, with 85 percent of teachers teaching less than 40 miles from where they attended high school (Boyd et al., 2005; Reininger, 2012). In addition to their hometown, the location of teachers' education preparation programs (EPP) is predictive of teachers' job placements. Teachers are more likely to teach in the same locale where they received their college degree and favor jobs closer to their EPP (Fowles et al., 2014). Student

teaching placements, which tend to be near EPPs, are also highly predictive of teachers' first job placements. Two out of five student teachers work in the district where they completed their student teaching after graduation (Krieg et al., 2016). Thus, teacher supply in a given area likely varies depending on the number of teachers who grew up there and EPP programs located nearby.

Taken together, the evidence concerning the localness of the teacher supply and the geographic variation in factors that influence the supply of available teachers implies that each region, district, and school within a state acts as its own labor market.

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

Because states, intra-state regions, districts, and schools function as distinct labor markets, teacher shortages likely vary geographically. We depict examples of factors that may influence teacher shortages in different geographic labor markets in Figure 1. High barriers to entry, including certification requirements and licensure tests, likely influence statewide teacher shortages, while the local availability of teacher candidates may affect teacher shortages and surpluses in some regions, and school working conditions may influence teacher supply across individual schools. Because of this variation, there could exist a surplus of teachers in the labor market as a whole but a shortage in an area with few college graduates and EPPs. A school with desirable working conditions experiencing a surplus of applicants may exist in the same district as schools with high attrition rates and poor working conditions. Thus, teacher shortages and surpluses can coexist.

Within geographic labor markets, the supply of teachers likely varies by subject and grade level. Certification requirements and the availability and attractiveness of other professions outside of education differ by subject area. Special education certificates may require teachers to

take extra courses and pass additional tests (Special Education Resource Project, 2019). Science, technology, engineering, and math (STEM) teachers may have higher earning potential outside of the education profession than, for example, elementary education teachers (Hansen et al., 2019; West, 2013). Thus, geographic variation in teacher shortages can also differ for each subject and grade level. This can contribute to subject-specific shortage being concentrated in one region of the state. Schools may also experience a shortage in one subject and a surplus of applicants for another.

Prior Research on Teacher Shortages and Surpluses

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. Measures of teacher supply include the number of newly certified teachers, the number of individuals who recently graduated from EPPs, and the number of applicants to teaching positions. Researchers often capture demand using measures such as the number of teachers hired, the number of teachers who exited the profession, and teacher workforce projections (Bruno & Strunk, 2019; Cowan et al., 2016; Engel et al., 2014; Goldhaber et al., 2017; James et al., 2022; Sutcher et al., 2019). With the exception of one study that projects future teacher supply and demand (Sutcher et al., 2019), these studies show that there are more newly certified teachers and total applicants to teaching positions than teachers hired or the number of available teaching positions, indicating an overall surplus of teachers (Bruno & Strunk, 2019; Cowan et al., 2016; Engel et al., 2014; Goldhaber et al., 2017; James et al., 2022). One recent study directly examines 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).

Aggregating teacher staffing challenges to the national, state, or district level may mask heterogeneity in teacher shortages and surpluses because of the localized nature of teachers' labor supply preferences and the wide variation in factors that influence supply at each of these levels. A handful of studies explore variation in teacher shortages at the school level by examining characteristics of schools experiencing difficulty filling vacant positions using national school survey data (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; 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.

Prior research has also established that teacher shortages vary by subject. 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).

Research concerning school-level factors related to teacher shortages shows 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). Taken together, this body of work implies that the ability to retain teachers is imperative to alleviating teacher shortages.

Our paper is most closely related to two recent studies that describe characteristics of individual schools experiencing shortages across an entire state. Goldhaber et al. (2020) examine how shortages, as measured by the number of job openings and teachers holding emergency credentials, vary across districts. They find that shortages are particularly concentrated in rural districts across California. In a second paper, Goldhaber et al. (2021) explore how shortages, measured by the proportion of new teacher hires with emergency certifications, vary at the school level. They find that schools that host no or few student teachers, and schools farther away from EPPs are more likely to have staffing challenges. We build on these studies by analyzing teacher shortages across a range of position dimensions and levels of aggregation.

Hypotheses

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 level. Drawing on this framework and existing evidence, we propose three empirical hypotheses about the nature of teacher shortages:

> ***Hypothesis 1:*** Teacher shortages within states vary by grade level, school, district, and region.
>
> ***Hypothesis 2:*** Variation in teacher shortages is associated with geographic preferences, compensation, working conditions, and teacher attrition.
>
> ***Hypothesis 3****:* Statewide, regional, and district teacher staffing challenges vary by subject.

We test these hypotheses using statewide school-level survey data documenting the number of unfilled teaching positions and district-level survey data concerning staffing challenges. Our statewide data allow us to describe how variation in teacher staffing challenges across multiple dimensions intersect, illustrating how teacher shortages and surpluses can coexist. We also provide original empirical evidence concerning teacher labor market conditions associated with having unfilled teaching positions. Taken together, the findings from each of 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. The state of Tennessee provides an advantageous 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 as well as 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, 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

Our outcome of interest, 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] Unfilled teaching positions provide a direct measure of teacher shortages because they occur when there are not enough teachers to meet demand. Sixty-three percent of Tennessee schools operating during the 2019-2020 school year

had at least one administrator answer this survey question. Our analytic sample includes 1,098 of Tennessee's 1,740 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 (36 percent vs. 41 percent) and Black students (18 percent vs. 36 percent), lower teacher attrition rates (13 percent vs 19 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 charter schools (1 percent vs. 12 percent) and are located in cities (24 percent vs. 46 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 (30 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.

We use the number of unfilled teaching positions reported at each school to create our primary measure of teacher shortage – the percent of vacant teaching positions at the beginning of the school year.[4] We calculate these percentages for the state overall as well as for commuting zones, districts, and individual schools. Commuting zones, aggregations of counties that contain where most people live and work, serve as our regional labor market unit. Commuting zones are determined based on commuting flows from home to work reported in the 2010 American Community Survey (Fowler et al., 2016) and 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). We prefer the use of commuting zones to other regional labor market units (e.g., metropolitan statistical areas and Bureau of Economic Analysis's economic areas) because they include rural areas and provide substantial variation in small geographic areas (Fowler & Jensen, 2020). Tennessee has 24 commuting zones and 141 school districts. Because Tennessee has countywide school districts, school district and commuting zone boundaries are coterminous; each Tennessee school district is fully embedded within one commuting zone.[5]

Early-Career Teacher Supply

To test our second hypothesis, we examine the relationships between a school's vacant teaching positions and labor market characteristics that may vary across geographies and affect teacher supply. First, we hypothesize that teacher shortages may vary due to the inequitable geographic distribution of available teachers. In Tennessee, three quarters of first year teachers who grew up in the state teach within 24 miles of where they went to high school as seen in Figure 2 Panel A. Similarly, in Figure 2 Panel B we show that half of early-career teachers who attend a Tennessee EPP teach within 24 miles of their EPP. Thus, we use two measures to quantify the number of available early-career teachers within a commuting zone: the number of graduates from EPPs within the school's commuting zone in the last three years and the number of first year teachers in the last three years who have a hometown within the commuting zone.[6] 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.[7] We include graduates and first-year teachers from the last three years because recent research finds that a significant portion of certified individuals enter the teaching 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 students attending schools within the commuting zone to account for variation in population density across the state.

Although commuting zones were created using home to work commuting flows, teachers might not commute as far as other workers (Reininger, 2012). Additionally, commuting zones vary in size due to variation in the number and size of counties included in each commuting zone. To capture the number of available early-career teachers in a more localized labor market area, we use 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 as alternative measures of local teacher supply. We choose 25 miles as the radius for our labor market because 75 percent of first-year teachers who grew up in Tennessee and 50 percent of EPP grads work within 25 miles of their high school or EPP, as displayed in Figure 2.[8]

District Salary Measures

We also examine the relationship between school-level teacher vacancies 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, they may be more likely to stay when they are rewarded for their experience and/or performance (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 more than 78 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 using principal component analysis. We use 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 to include in our principal component analysis, we use Merrill's (2021) comprehensive taxonomy of teacher working conditions. We then aggregate teacher survey responses for these items to the school level. We only include schools where there were at least five respondents for all items included in the principal component analysis and at least 30 percent of a school's teachers responded to all items to ensure that responses are representative of the school's teachers. Our primary measure is the first principal component from a principal component analysis that accounts for 49 percent of the variation across our 43 items, which we

standardize at the school level. We list the survey items included in our working conditions measure with their factor 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.[11] 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) directly causing vacancies. 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 eight hypothesized predictors of vacancies by plotting their kernel density functions in Figure 3. The number of EPP grads in a school's commuting zone per 1,000 students ranges from 0 to 43 with a standard deviation of nine EPP grads per 1,000 students as seen in Figure 3 Panel A. Three-quarters of schools have access to less than ten EPP grads per 1,000 students. There is less variation in the number of early-career teachers who went to high school within the commuting zone. We show that ninety percent of schools in our sample have between 2.6 and 5 early-career teachers who went to high school in their commuting zone

per 1,000 students in Figure 3 Panel B. Patterns are similar for our alternative measures of local teacher supply, the number graduates who attended EPPs and the number of early-careers who went to high school within 25 miles of the school, as seen in Figure 3 Panels C and D.

Figure 3 Panels E and F 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 $50,000 with a standard deviation of $3,845. Three-quarters of our sample has salary increases between one and two percentage points for each additional year of experience/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 G, closely resembles a standard normal 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 H. 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 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 within secondary schools. 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.[12] 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

To examine the extent to which teacher shortages vary by school, district, and commuting zone, we first describe patterns in the percent of vacant teaching positions at the beginning of the 2019-20 school year at the state, commuting zone, district, and school levels. Then, we formally measure the variation in the severity and existence of school-level teacher shortages associated with the commuting zone, district, and school using a variance decomposition analysis (Chingos et al., 2015). To measure the severity of teacher shortages, we use the percent of unfilled teaching positions as the outcome. As a secondary outcome, we also use a binary indicator for having at least one unfilled teaching position to examine the variation in the existence of school-level teacher shortages. 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. From this model, we calculate the variance for each level and divide it by the total variance to find the amount of variation explained at each level.

Next, we describe the associations between commuting zone, district, and school characteristics and teacher vacancies to test our second set of hypotheses using a set of descriptive regressions. Our fully specified Ordinary Least Squares model is represented by the following equation:

$$Y_{sdc} = \beta_0 + \beta_1 EPPGrads_c + \beta_2 NewTeachers_c + \beta_3 BaseSalary_d + \beta_4 SalaryIncreases_d + \beta_5 WorkingConditions_s + \beta_6 AttritionRate_s + \boldsymbol{X_s\gamma} + \varepsilon_{sdc} \quad (2)$$

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

Our variables of interest correspond to the hypothesized predictors of teacher shortages in Hypothesis 2. Commuting zone variables of interest, $EPPGrads_c$ and $NewTeachers_c$, are the number of graduates from EPPs in the school's commuting zone in the last three years and the number of first-year teachers in Tennessee in the last three years who had a hometown in the commuting zone, respectively. Both are scaled per 1,000 students living in the commuting zone to account for population density. We also estimate a version of equation 2 where we replace $EPPGrads_c$ and $NewTeachers_c$ with 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 as alternative measures of local teacher supply. To examine the relationship between pecuniary compensation and vacancies, we include $BaseSalary_d$ in our models, 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. $WorkingConditions_s$ measures of the school's working conditions created from survey items from the 2018-19 Tennessee Educator Survey using principal component analysis.[13] $AttritionRate_s$ is the percent of the school's teaching faculty 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 vacancies other than our hypothesized predictors of shortage, we include $\boldsymbol{X_s}$, a vector of school-level characteristics in

our model. $\boldsymbol{X_s}$ 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[14], 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.[15]

Finally, we explore variation in teacher shortages by subject during the 2019-20 school year using district level survey data concerning 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 within commuting zones and districts by mapping individual district staffing challenges for three subjects: secondary math, secondary social studies, and elementary education. We choose one traditionally hard-to-staff subject, secondary math, and two other subjects usually considered easier to find qualified applicants for, secondary social studies and elementary education, to explore how staffing challenges vary within the same district or school by subject.

Findings

Hypothesis 1: Shortages vary by grade level, 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 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 609 of the over 40,000 teaching positions in our sample were reported as vacant. While this number might seem to suggest Tennessee public schools face very limited shortages, unfilled vacancies at the start of the school year are an extreme measure that does not capture 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 vacant teaching positions.

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, about half have only one unfilled teaching position. Only six percent of schools in our sample have more than two vacancies. Additionally, a higher percentage of secondary schools have unfilled teaching positions. One out of five elementary schools experience a vacancy while one 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 vacancies statewide masks substantial variation that exists across grade levels and between schools.

To examine the extent to which vacant positions vary between commuting zones, districts, and schools, we depict geographic variation in vacancy rates for secondary teaching positions in Figure 4. We focus on secondary schools in our following analyses because they experience more acute staffing challenges and compete for teachers who have a common set of licensures. We display the percent of unfilled teaching positions in each commuting zone 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 three 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 101 districts with more than one school in our sample, only four districts have vacant positions in all of their secondary schools. Metro Nashville Public Schools and Memphis-Shelby County Schools stand out as concentrated areas of shortages with three quarters of Nashville and Memphis secondary 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 between schools within districts. As shown in Table 3, commuting zones and districts only account for up to 20 percent of the variation in either of our school-level vacancy measures. Less than two percent of the variation in our vacancy measures is explained by the commuting zone.

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 commuting zone, district, and

school-level factors may predict teacher shortages, we examine differences in teacher labor market characteristics between secondary schools with and without vacancies in Table 4.[16] Consistent with evidence on the localized nature of teacher labor markets, schools with vacancies are located in commuting zones that produce fewer EPP grads and early-career teachers per 1,000 students. However, only the difference in the number of early-career teachers with a hometown in the commuting zone is statistically significant. Differences are similar for our alternative measures of local teacher supply that use a 25 mile radius around the school to determine labor market size. 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 39 percent higher, on average, in schools with vacancies (20 vs. 14 percent). Teachers also rate working conditions 0.42 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 district and school-level factors are associated with unfilled teaching positions, illustrating the highly localized nature of teacher staffing challenges. 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 and the percent of unfilled teaching positions is the outcome. Columns 1 though 4 display results from the models where we use our commuting zone teacher supply measures, the number of EPP graduates and the number of early-career teachers who went to high school in the commuting zone. These measures are negatively associated with the percent of vacant teaching positions as predicted by our conceptual framework. These relationships are not statistically significant. When we replace our

commuting zone supply measures with our alternative, school-centric measures of local teacher supply, as seen in Columns 5 through 8, we find that there is a negative and statistically significant relationship between the number of early-career teachers that grew up 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, approximately a one standard deviation increase, is associated with a 0.61 percentage point decrease in the percent of unfilled teaching positions, a 32 percent decrease. We do not detect any significant relationships between the number of EPP grads within 25 miles and vacancy rates.

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 0.66 percentage point decrease (a 36 percent decrease) in a school's vacancy rate. 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 0.38 percentage point decrease (a 20 percent decrease) in vacancy rates.

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 0.12 percentage point increase in the school's percent of vacant teaching positions. This implies that an eight percentage point increase, an approximately one standard deviation increase, in a school's turnover rate is associated with a 49 percent increase in its vacancy rate. However, the relationship between the

percent of unfilled teaching positions, the number of local early-career teachers who grew up within 25 miles of the school, and school working conditions are no longer statistically significant when attrition rate is added to the model. This suggests that teacher turnover may mediate the relationships between vacant positions, the local teacher supply and school working conditions, predictors of teacher retention (Hendricks, 2014; Johnson et al., 2012; Ladd, 2011; Lovison & Mo, 2022; Redding, in press; Viano et al., 2020).

We present results from models using a binary indicator for having any unfilled teaching positions as the outcome in Table 6. With the exception of school attrition rates, none of the other predictors are statistically significant across all specifications. This provides further evidence of the strong relationship between historical attrition rates and teacher staffing challenges.

Among the 13 school characteristics we include as covariates in our models, only the percent of students who are Black and school size are significant predictors of vacancies across specifications. As shown in Appendix Tables A4 & A5, a one standard deviation increase in the percentage of Black students in a school is associated with a 0.9 percentage point increase (a 47 percent increase) in vacancy rates. 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. Large schools with 1200 or greater students have vacancy rates that are 3 to 4 percentage points lower than schools with less than 300 students, but the relationship between school size and having any vacant positions is positive and statistically insignificant. This result is likely mechanical because one vacancy in a small school results in a larger increase in vacancy rates than a large school.

Hypothesis 3: Statewide, commuting zone, 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 commuting zone 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 to understand the geographic variation in teacher staffing challenges. Taken together, the maps displayed in Figure 6 provide descriptive evidence that subject-specific shortages vary more so within commuting zones 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 teacher staffing challenges.

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 can mask substantial heterogeneity by school and subject. The results from our analyses show that when most schools do not have any vacant teaching positions, many schools can experience severe shortages. Further, we find that teacher staffing challenges are localized at the school level. We find little evidence that schools with shortages are concentrated in any particular area of Tennessee. School and district-level factors, including 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 and schools.

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. In order to fully eliminate shortages, 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 provide pecuniary retention incentives.

Our results show that one possible indicator that education policymakers and school leaders can use to determine which schools are likely experiencing severe teacher shortages are historical teacher attrition rates. By using historical data, states and districts may be able to 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 may need to improve working conditions and districts may need to increase pecuniary returns to experience for early-career teachers and/or frontload salary schedules (Hendricks, 2014; Johnson et al., 2012; Ladd, 2011; Lovison & Mo, 2022; Viano et al., 2020).

Timely and detailed data concerning teacher turnover, available teaching positions, and vacancies are needed to determine which schools are experiencing staffing challenges, the nature of a specific school's teacher shortage, and the appropriate policy solution. Less than 40 percent of states publish teacher demand data including vacancy rates and number of new hires and only four states report state-level teacher shortage information publicly with two states, Colorado and Illinois, disaggregating their shortage data at the district level (Saez-Armstrong, 2021). One possible solution to increase the available data on teacher shortage would be to expand federal reporting requirements concerning teacher labor markets and teacher shortages. Currently, states are required to report subject and geographic teacher shortage areas to the U.S. Department of Education for federal loan forgiveness and grant programs. Although most states register statewide subject area shortages, only eight states report specific counties, districts, or geographic areas with shortages.

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. Students who are considered economically disadvantaged in Tennessee include students eligible for free and reduced-price lunch through direct certification as well as homeless, foster, runaway, and migrant students.
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 in August of 2019, prior to the pandemic. Thus, we view our results as describing teacher supply, demand, and shortage in the most recent pre-pandemic year.
3. Our sample includes all Tennessee schools (except state special schools including 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 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. 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 three 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. The total number of teaching positions is the sum of the number of teachers (filled teaching positions) and the number of vacancies.
5. 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.
6. Our regression analyses focus on secondary schools. We only include EPP grads that graduated from a program other than elementary education and early-career teachers at secondary schools in our local teacher supply measures because the elementary and secondary school labor markets are likely separate due to differences in certification requirements.
7. 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.
8. We calculate geodetic ("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. Similarly, we calculate the geodetic distance from the address of a graduate's EPP to each school's address to determine

the number of EPP grads with 25 miles of the school. 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; a handful of districts use evaluation scores and other measures to determine lanes and steps on the salary schedule rather than degree and experience; 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 A2 and A3.
11. 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.
12. 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.
13. 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.
14. We standardize student test scores on TNReady (Grades 3-8) and end of course assessments (EOCs) (Grades 9-12) within grade, subject, and year and use them to create a subject by

school by year average test score for the TNReady and EOCs separately. In our analyses, we use the school's 2018-19 average TNReady math test score as our measure of mathematics achievement. If a school does not offer TNReady, we use the average math EOC score.

15. We exclude schools in our analytic sample from our regression models for the following reasons: six schools do not have achievement scores in prior years; one school does not have student demographics in 2018-19 and one school does not have attrition rates prior to 2018-19. We also exclude all six charter schools from our multivariate analysis because two of the six charter schools do not report any salary information for teachers with ten years of experience.

16. We present the differences in all 2018-19 student characteristics between secondary schools with and without vacancies during the 2019-20 school year in Appendix Table A1.

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Figures

Figure 1. Concept Map

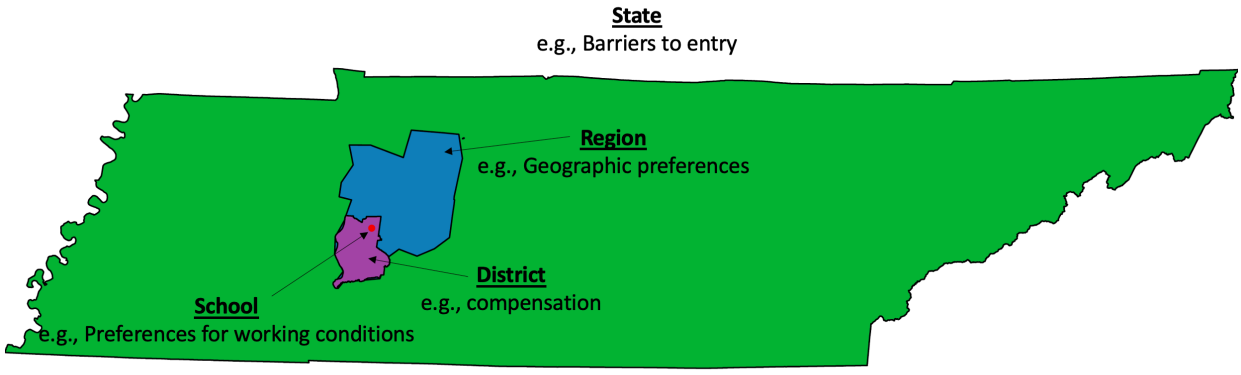
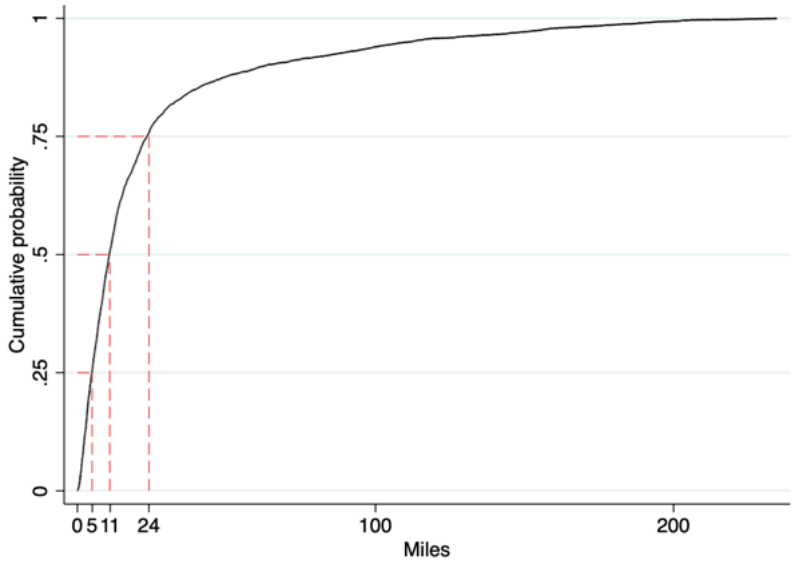


Figure 2. Cumulative Density Function of Distance to Teaching Placements

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



Panel B: Distance from Educator Preparation Program to Teaching Placement for Tennessee EPP Graduates

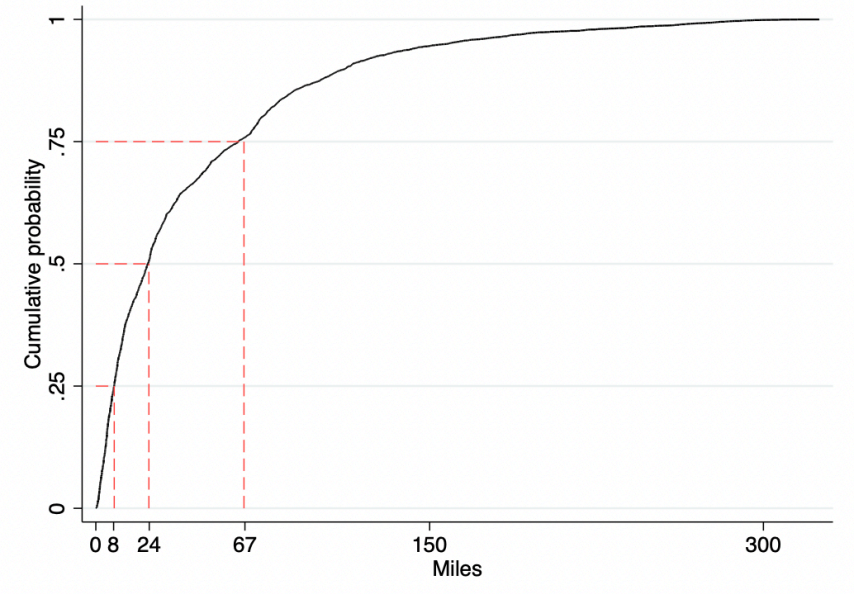
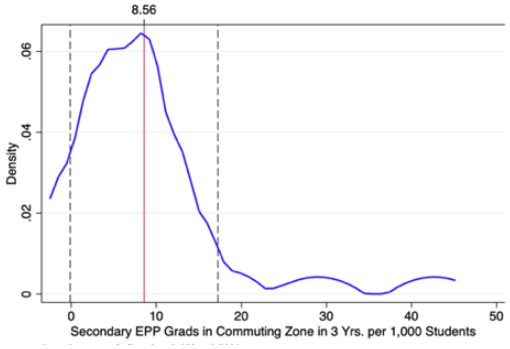
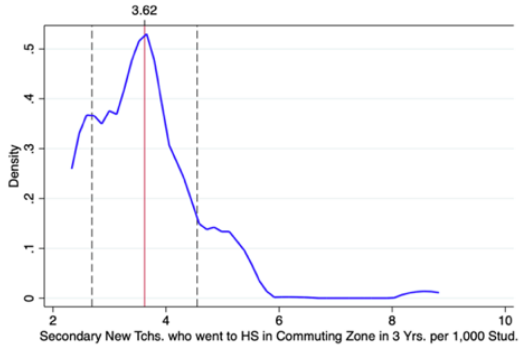


Figure 3. Kernel Density Functions of Geographic Predictors of Vacancies in Public Schools

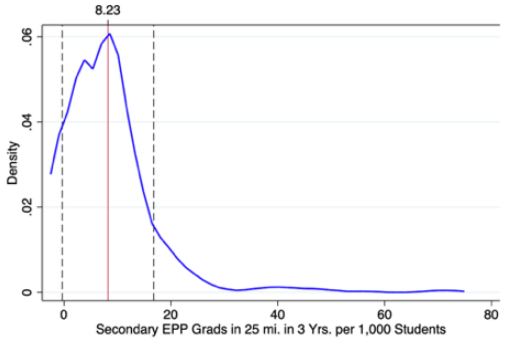
Panel A: EPP Grads in CZ in Last 3 Years per 1,000 Stud.



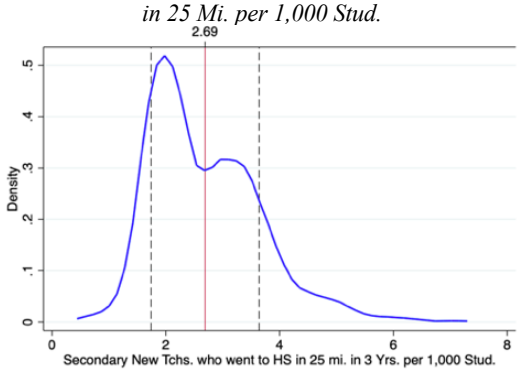
Panel B:1st Year Teachers in Last 3 Years who Went to HS. in CZ per 1,000 Stud.



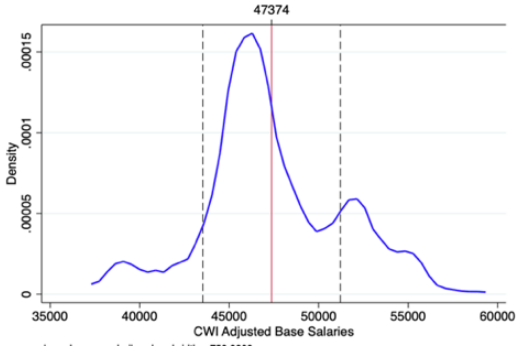
Panel C: EPP Grads in 25 Mi. in Last 3 Years per 1,000 Stud



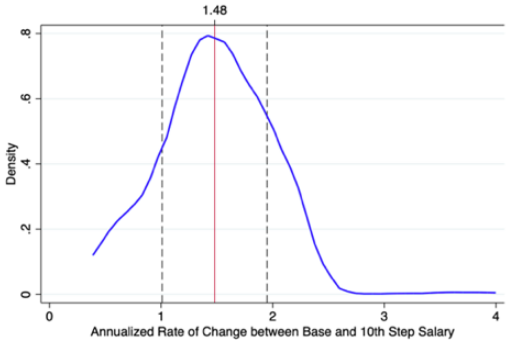
Panel D:1st Year Teachers in Last 3 Years who Went to HS. in 25 Mi. per 1,000 Stud.



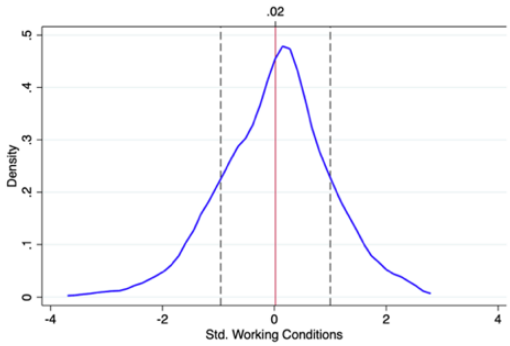
Panel E: Comparable Wage Index Adjusted Base Salaries



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



Panel G: Standardized Sch. Working Conditions



Panel H: Three Year Teacher Attrition Rate

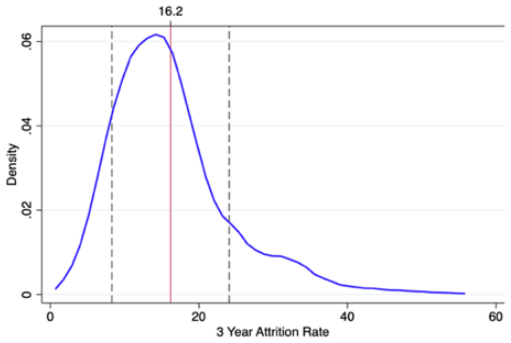
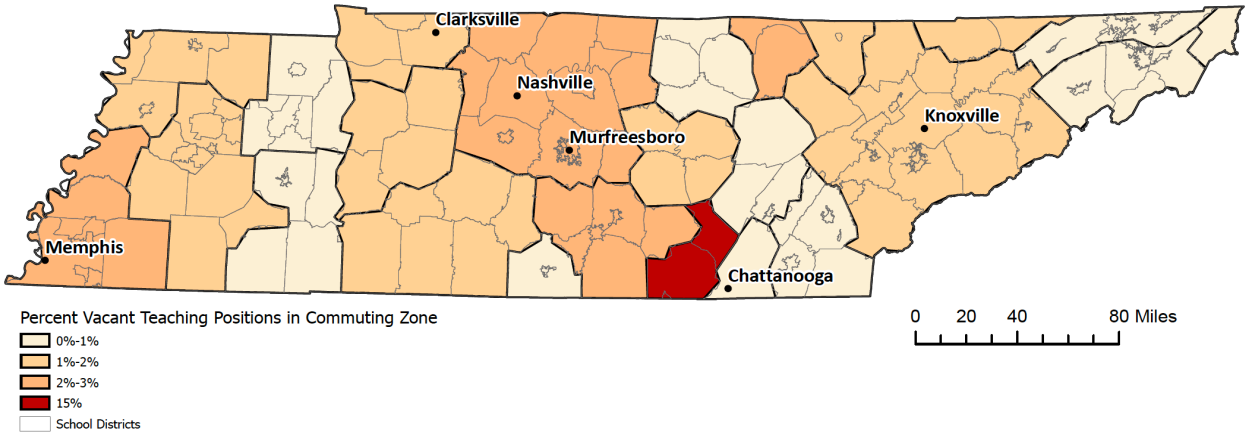
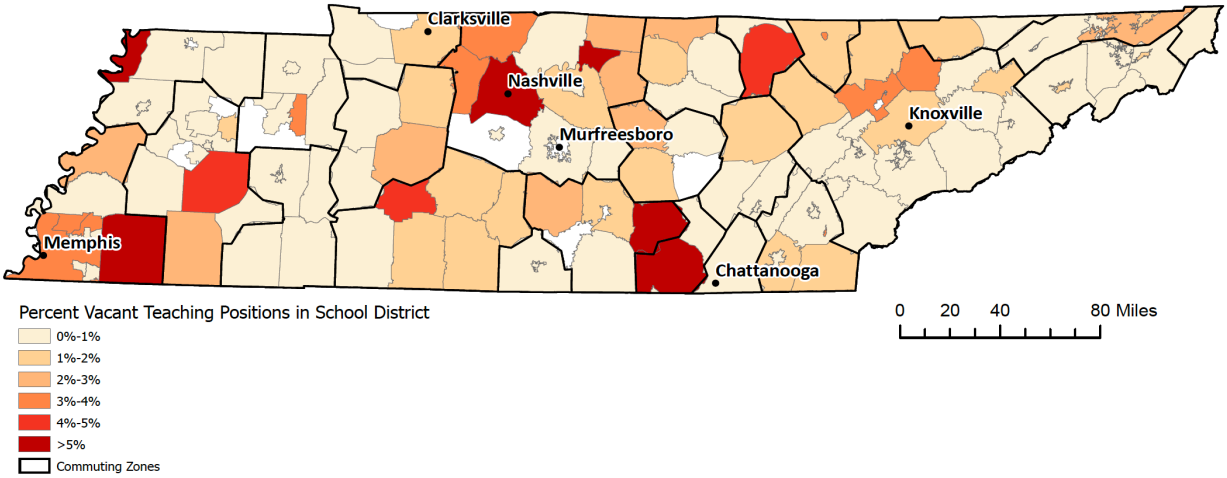


Figure 4. Percent Vacant Teaching Positions in Secondary Schools by Commuting Zone, District, and School

Panel A: Commuting Zone.



Panel B: School District



Panel C: School

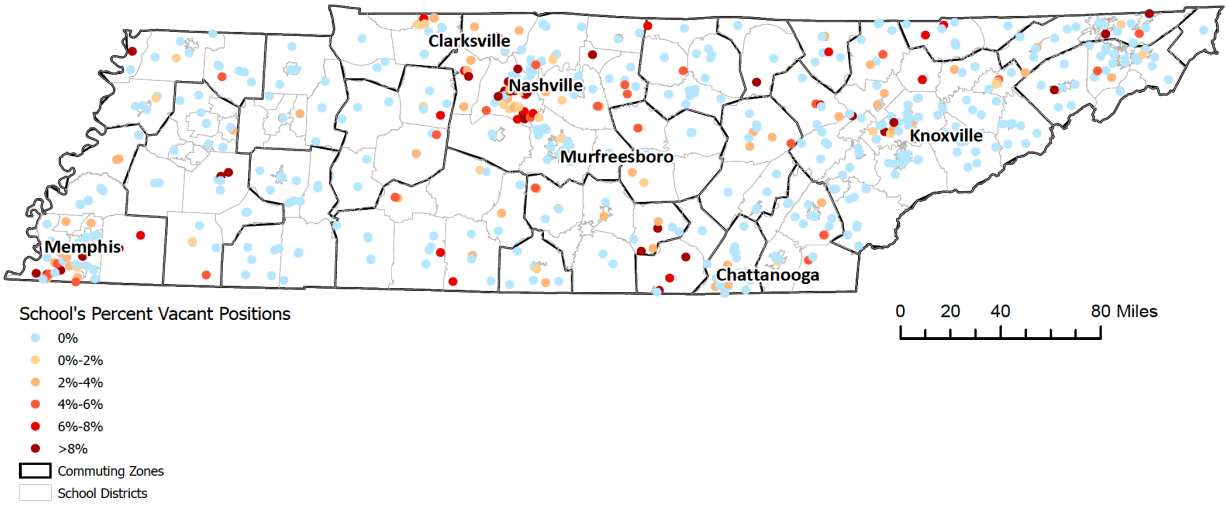


Figure 5. School District Perceived Staffing Challenges by Subject

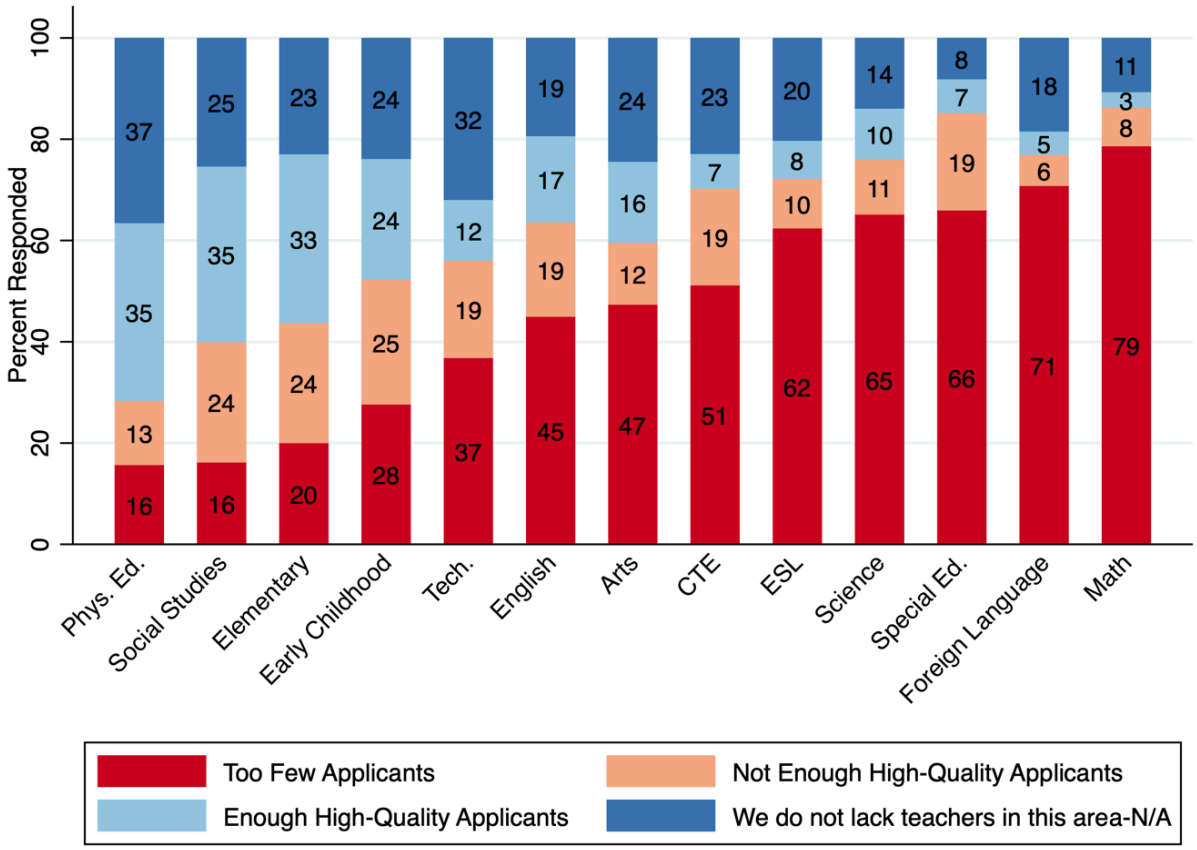
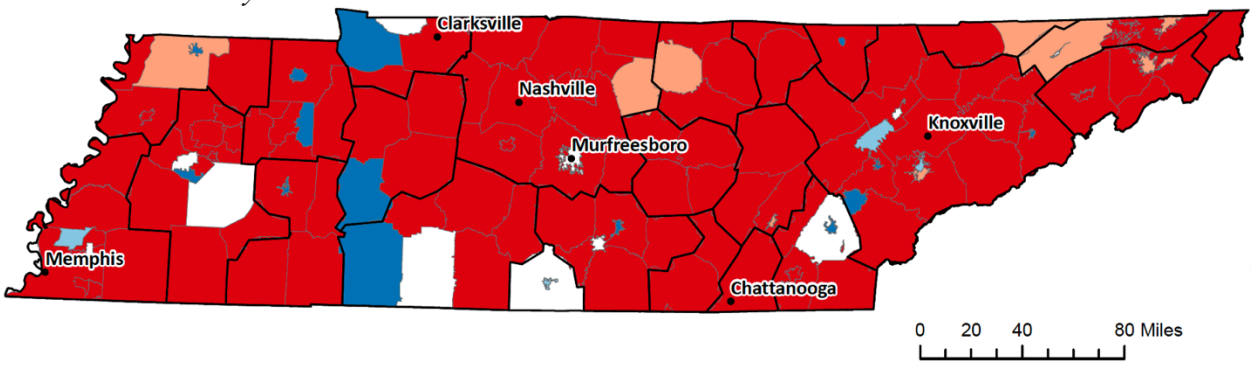
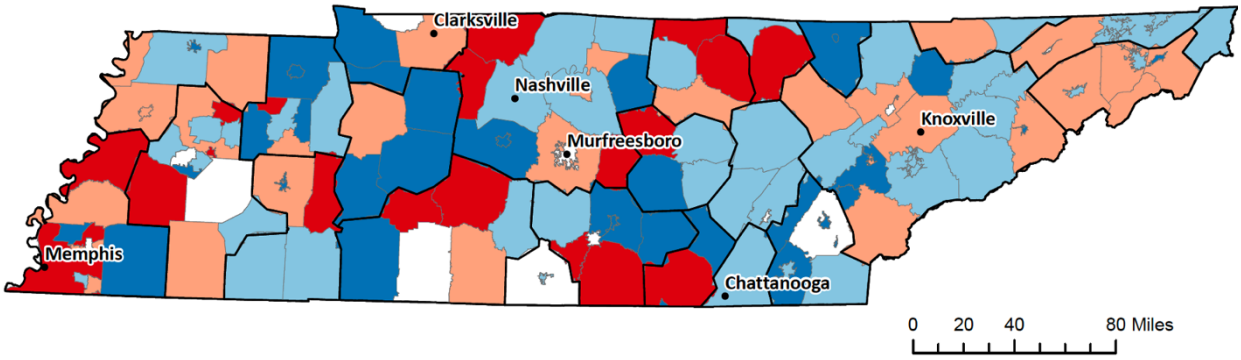


Figure 6. Perceived Staffing Challenges by District

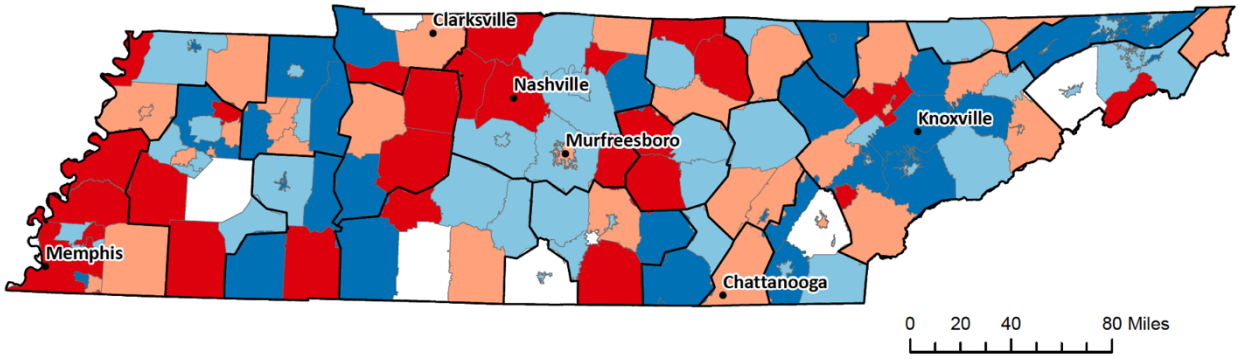
Panel A: Secondary Mathematics



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%	63%	37%
Avg. N. Students	590.7	627.6	527.7
Avg. Pct. Economically Disadvantaged	38%	36%	41%
Avg. Pct. Students with Disabilities	15%	16%	14%
Avg. Pct. English Learner	5%	5%	6%
Avg. Pct. Female	48%	48%	48%
Avg. Pct. Asian	2%	2%	2%
Avg. Pct. Black	24%	18%	36%
Avg. Pct. Hispanic	11%	10%	12%
Avg. Pct. Native American	<1%	<1%	<1%
Avg. Pct. Pacific Islander	<1%	<1%	<1%
Avg. Pct. White	62%	69%	50%
Avg. Std. Math Achievement	0.07	0.12	-0.02
Avg. Std. Reading Achievement	-0.06	-0.02	-0.12
Avg. Pct. Teachers with Masters	50%	53%	43%
Avg. Teacher Yrs. Experience	11.37	11.74	10.74
Avg. CWIFT Adjusted Base Salary	$46,990	$47,579	$45,964
Avg. 2019 Attrition Rate	15%	13%	19%
Pct. City	32%	24%	46%
Pct. Suburban	16%	18%	13%
Pct. Town	16%	18%	13%
Pct. Rural	36%	41%	29%
Pct. Elementary School	47%	46%	49%
Pct. Charter	5%	1%	12%
N Schools	1740	1098	642

Note. Our state sample includes all Tennessee 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 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. To construct our measure of achievement, we standardize student test scores on TNReady (Grades 3-8) and end of course assessments (EOCs) (Grades 9-12) within grade, subject, and year and use them to create a subject by school by year average test score for the TNReady and EOCs separately. We use the school's 2018-19 average TNReady test score as our measure of achievement. If a school does not offer TNReady, we use the average EOC score. 65 and 70 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). 14 schools did not report base salaries. Attrition rates are calculated using percent of the schools' teachers in 2018-19 that did not return to that school in 2019-20. 32 schools did not have teacher information for the 2018-19 schools year. 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	609	167	442
Pct. Vacant Teaching Positions	1.42%	0.96%	1.73%
Schools			
Avg. Number of Vacancies	0.56	0.33	0.75
Avg. Pct. Vacant Positions	1.56%	1.01%	2.03%
Pct. With 0 Vacancies	74%	82%	68%
Pct. With 1 Vacancy	14%	11%	17%
Pct. With 2 Vacancies	6%	4%	8%
Pct. With 3+ Vacancies	6%	3%	7%
N. Schools	1098	510	588

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

	Percent Vacant Positions	Has Vacant Position Indicator
Commuting Zone	0.49%	1.42%
District	19.56%	16.73%
School	79.95%	81.85%

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.

Table 4. Public Secondary School Vacancy Predictor Characteristics

	Has Vacancies	No Vacancies	Difference
EPP Grads in CZ in Last 3 Yrs.	7.928	8.842	-0.914
	(7.223)	(9.253)	
Early Car. Tchs. who Went to HS in CZ Last 3 Yrs.	3.405	3.725	-0.320***
	(0.946)	(0.912)	
EPP Grads in 25 Mi. in Last 3 Yrs.	8.465	7.729	-0.736
	(9.358)	(6.486)	
Early Car. Tchs. who Went to HS in 25 Mi. Last 3 Yrs.	2.780	2.479	-0.301***
	(0.966)	(0.887)	
CWIFT Adjusted District Base Salary	$47,172	$47,466	-$294
	($3,466)	($4,007)	
District Salary Annualized Rate of Change	1.467	1.485	-0.018
	(0.555)	(0.431)	
Std. School Working Conditions	-0.289	0.127	-0.416***
	(1.052)	(0.927)	
School Attrition Rate (Last 3 Yrs.)	20.03%	14.45%	5.58%***
	(9.45%)	(6.36%)	
N Schools	180	394	574

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 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 495 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 Percent Vacant Teaching Positions and Geographic Predictors of Vacancies in Public Secondary Schools

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPP Grads in CZ in Last 3 Yrs.	-0.027	-0.025	-0.025	-0.028				
	(0.020)	(0.021)	(0.020)	(0.021)				
Early Car. Tchs. who Went to HS in CZ Last 3 Yrs.	-0.375	-0.330	-0.280	-0.180				
	(0.284)	(0.280)	(0.274)	(0.285)				
EPP Grads in 25 Mi. in Last 3 Yrs.					-0.001	0.003	0.000	-0.004
					(0.029)	(0.030)	(0.030)	(0.029)
Early Car. Tchs. who Went to HS in 25 Mi. Last 3 Yrs.					-0.605*	-0.669**	-0.606*	-0.514
					(0.322)	(0.328)	(0.330)	(0.328)
Log. of CWIFT Adjusted District Base Salary		3.496	3.646	3.205		3.751	3.900	3.564
		(3.395)	(3.269)	(3.154)		(3.539)	(3.435)	(3.351)
District Salary Annualized Rate of Change		-1.315*	-1.357**	-1.179*		-1.473**	-1.483**	-1.276*
		(0.703)	(0.670)	(0.702)		(0.668)	(0.649)	(0.690)
Std. School Working Conditions			-0.381*	-0.285			-0.377*	-0.288
			(0.213)	(0.215)			(0.213)	(0.214)
School Attrition Rate (Last 3 Yrs.)				0.116*				0.110*
				(0.062)				(0.060)
Observations	574	574	574	574	574	574	574	574
Adj R Squared	0.092	0.105	0.112	0.129	0.095	0.112	0.118	0.133

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, 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. 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 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 6. Estimated Relationships between Indicator for Vacant Teaching Positions and Geographic Predictors of Vacancies in Public Secondary Schools

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPP Grads in CZ in Last 3 Yrs.	-0.002	-0.002	-0.002	-0.002				
	(0.002)	(0.002)	(0.002)	(0.002)				
Early Car. Tchs. who Went to HS in CZ Last 3 Yrs.	-0.032	-0.025	-0.019	-0.011				
	(0.028)	(0.028)	(0.028)	(0.027)				
EPP Grads in 25 Mi. in Last 3 Yrs.					-0.002	-0.002	-0.002	-0.002
					(0.002)	(0.002)	(0.002)	(0.002)
Early Car. Tchs. who Went to HS in 25 Mi. Last 3 Yrs.					-0.039	-0.040*	-0.032	-0.024
					(0.024)	(0.024)	(0.024)	(0.024)
Log. of CWIFT Adjusted District Base Salary		-0.059	-0.04	-0.078		-0.056	-0.036	-0.066
		(0.302)	(0.289)	(0.277)		(0.297)	(0.286)	(0.272)
District Salary Annualized Rate of Change		-0.077	-0.084	-0.068		-0.087*	-0.091*	-0.072
		-0.054	-0.051	(0.049)		(0.051)	(0.049)	(0.047)
Std. School Working Conditions			-0.039	-0.031			-0.040	-0.032
			(0.025)	(0.025)			(0.024)	(0.025)
School Attrition Rate (Last 3 Yrs.)				0.010**				0.010**
				(0.004)				(0.004)
Observations	574	574	574	574	574	574	574	574
Adj R Squared	0.117	0.119	0.135	0.15	0.118	0.121	0.137	0.151

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, 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. 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 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 12,683 first year teachers from the 2017-18, 2018-19, and 2019-20 school years. 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 3,718 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 A. 6,613 first year teachers (52%) attended a Tennessee Educator Preparation Program (EPP). We calculate the geodetic distance from the address of their EPP to their teaching placement for these teachers in Panel B.

Figure 3 Note. Sample includes 574 secondary (schools that offer grades above 5th grade) traditional public schools. Red line represents mean value and dotted lines represent values one standard deviation from the mean. EPP, HS, and CZ are abbreviations for educator preparation program, high school, and commuting zone respectively. Panels A and C and Panels B and D include EPP graduates with secondary education certifications and 1st year teachers in secondary schools 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 495 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 include the 588 secondary schools (schools that offer grades above 5th grade) that had at least one administrator report the number of vacant teaching positions on the Tennessee Educator Survey.

Figure 5 Note. Total respondents: 137 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 districts. Total respondents for secondary social studies: 129. Total respondents for elementary education: 135. 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 CZ in Last 3 Yrs.	7.928	8.842	-0.914
	(7.223)	(9.253)	
Early Car. Tchs. who Went to HS in CZ Last 3 Yrs.	3.405	3.725	-0.320***
	(0.946)	(0.912)	
EPP Grads in 25 Mi. in Last 3 Yrs.	7.729	8.465	-0.736
	(6.486)	(9.358)	
Early Car. Tchs. who Went to HS in 25 Mi. Last 3 Yrs.	2.479	2.780	-0.301***
	(0.887)	(0.966)	
CWIFT Adjusted District Base Salary	$47,172	$47,466	-$294
	($3,466)	($4,007)	
District Salary Annualized Rate of Change	1.467	1.485	-0.018
	(0.555)	(0.431)	
Std. School Working Conditions	-0.289	0.127	-0.416***
	(1.052)	(0.927)	
School Attrition Rate (Last 3 Yrs.)	20.03%	14.45%	5.58%***
	(9.45%)	(6.36%)	
Total Students	823.1	691.9	131.2***
	(532.4)	(468.1)	
Avg. Std Math Achievement	0.056	0.313	-0.257***
	(0.730)	(0.649)	
Pct. Economically Disadvantaged	39.58%	33.98%	5.60%***
	(17.09%)	(14.73%)	
Pct. Students with Disabilities	15.90%	14.53%	1.37%*
	(11.25%)	(6.58%)	
Pct. Female	47.52%	48.39%	-0.87%**
	(5.42%)	(4.36)	
Pct. English Learners	3.90%	1.61%	2.29%***
	(7.26%)	(2.94%)	
Pct. Asian	1.64%	1.51%	0.13%
	(2.08%)	(2.28%)	
Pct. Black	25.52%	12.26%	13.26%***
	(28.20%)	(17.71%)	
Pct. Hispanic	10.80%	6.78%	4.02%***
	(12.51%)	(7.23%)	
Pct. Indigenous Persons	0.40%	0.42%	-0.02%
	(0.50%)	(0.45%)	
Pct. Pacific Islander	0.22%	0.17%	0.05%**
	(0.38%)	(0.25%)	
Pct. White	61.41%	78.87%	-17.46%***
	(32.65%)	(20.83%)	
N Schools	180	394	574

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 495 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 standardize student test scores on math TNReady (Grades 3-8) and end of course assessments (EOCs) (Grades 9-12) within grade and them to create a school average test score for the TNReady and EOCs separately for the 2018-19 school year. If a school does not offer TNReady, we use the average EOC score as the school's measure of math achievement.

Table A2. 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 CZ in Last 3 Yrs.	-0.029	-0.030	-0.033			
	(0.021)	(0.021)	(0.021)			
Early Car. Tchs. who Went to HS in CZ Last 3 Yrs.	-0.260	-0.215	-0.126			
	(0.262)	(0.256)	(0.265)			
EPP Grads in 25 Mi. in Last 3 Yrs.				0.001	-0.002	-0.006
				(0.028)	(0.029)	(0.028)
Early Car. Tchs. who Went to HS in 25 Mi. Last 3 Yrs.				-0.640**	-0.584*	-0.496
				(0.321)	(0.323)	(0.318)
Log. of District Base Salary	1.368	0.120	-0.766	1.220	0.103	-0.807
	(3.626)	(3.616)	(3.308)	(3.686)	(3.604)	(3.333)
District Salary Annualized Rate of Change	-1.380**	-1.455**	-1.285*	-1.525**	-1.568**	-1.374**
	(0.636)	(0.617)	(0.650)	(0.611)	(0.605)	(0.642)
Std. School Working Conditions		-0.380*	-0.282		-0.377*	-0.285
		(0.212)	(0.214)		(0.211)	(0.212)
School Attrition Rate (Last 3 Yrs.)			0.118*			0.112*
			(0.063)			(0.061)
Observations	574	574	574	574	574	574
Adj R Squared	0.102	0.110	0.127	0.109	0.115	0.130

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, 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. 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. 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 A3. 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 CZ in Last 3 Yrs.	-0.002	-0.002	-0.002			
	(0.002)	(0.002)	(0.002)			
Early Car. Tchs. who Went to HS in CZ Last 3 Yrs.	-0.029	-0.023	-0.015			
	(0.029)	(0.029)	(0.028)			
EPP Grads in 25 Mi. in Last 3 Yrs.				-0.002	-0.002	-0.003
				(0.002)	(0.002)	(0.002)
Early Car. Tchs. who Went to HS in 25 Mi. Last 3 Yrs.				-0.043*	-0.035	-0.027
				(0.024)	(0.024)	(0.024)
Log. of District Base Salary	-0.434	-0.614	-0.691	-0.447	-0.621	-0.704*
	(0.465)	(0.460)	(0.437)	(0.455)	(0.447)	(0.423)
District Salary Annualized Rate of Change	-0.086	-0.099*	-0.085*	-0.098*	-0.108**	-0.090*
	(0.054)	(0.052)	(0.050)	(0.053)	(0.051)	(0.049)
Std. School Working Conditions		-0.039	-0.030		-0.040	-0.032
		(0.025)	(0.025)		(0.024)	(0.024)
School Attrition Rate (Last 3 Yrs.)			0.010**			0.010**
			(0.004)			(0.004)
Observations	574	574	574	574	574	574
Adj R Squared	0.120	0.138	0.154	0.123	0.140	0.155

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, 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. 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. 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 A4. 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 CZ in Last 3	-0.027	-0.025	-0.025	-0.028				
Yrs.	(0.020)	(0.021)	(0.020)	(0.021)				
New Tchs. who Went to	-0.375	-0.330	-0.280	-0.180				
HS in CZ Last 3 Yrs.	(0.284)	(0.280)	(0.274)	(0.285)				
EPP Grads in 25 Mi. in					-0.001	0.003	0.000	-0.004
Last 3 Yrs.					(0.029)	(0.030)	(0.030)	(0.029)
New Tchs. who Went to					-0.605*	-0.669**	-0.606*	-0.514
HS in 25 Mi. Last 3 Yrs.					(0.322)	(0.328)	(0.330)	(0.328)
Log. of CWIFT Adjusted		3.496	3.646	3.205		3.751	3.900	3.564
District Base Salary		(3.395)	(3.269)	(3.154)		(3.539)	(3.435)	(3.351)
District Salary Annualized		-1.315*	-1.357**	-1.179*		-1.473**	-1.483**	-1.276*
Rate of Change		(0.703)	(0.670)	(0.702)		(0.668)	(0.649)	(0.690)
Std. School Working			-0.381*	-0.285			-0.377*	-0.288
Conditions			(0.213)	(0.215)			(0.213)	(0.214)
School Attrition Rate				0.116*				0.110*
(Last 3 Yrs.)				(0.062)				(0.060)
City	0.811	0.458	0.380	0.448	0.846	0.480	0.407	0.475
	(0.762)	(0.752)	(0.719)	(0.686)	(0.791)	(0.773)	(0.746)	(0.715)
Town	0.103	-0.444	-0.249	-0.075	0.316	-0.217	-0.056	0.093
	(0.683)	(0.767)	(0.726)	(0.735)	(0.857)	(0.890)	(0.848)	(0.860)
Rural	0.026	-0.403	-0.284	-0.172	0.153	-0.278	-0.182	-0.092
	(0.538)	(0.588)	(0.565)	(0.544)	(0.500)	(0.551)	(0.529)	(0.511)
High School	0.944	0.883	0.973	0.717	0.825	0.778	0.868	0.638
	(1.040)	(1.021)	(1.030)	(1.118)	(1.033)	(1.022)	(1.038)	(1.108)
300-600 Total Students	-1.247	-1.208	-1.282	-1.204	-1.280	-1.244	-1.322	-1.239
	(0.846)	(0.841)	(0.825)	(0.816)	(0.829)	(0.818)	(0.801)	(0.795)
600-900 Total Students	-1.992*	-1.986*	-2.161**	-2.063*	-2.066*	-2.081**	-2.254**	-2.144**
	(1.064)	(1.048)	(1.053)	(1.044)	(1.055)	(1.034)	(1.034)	(1.027)
900-1200 Total Students	-2.740**	-2.622*	-2.888**	-2.645*	-2.653*	-2.539*	-2.818**	-2.591*
	(1.375)	(1.351)	(1.382)	(1.401)	(1.345)	(1.319)	(1.351)	(1.372)
Greater than 1200 Total	-3.213**	-3.237**	-3.588**	-3.287**	-3.274**	-3.322**	-3.659**	-3.370**
Students	(1.479)	(1.433)	(1.465)	(1.509)	(1.474)	(1.424)	(1.457)	(1.498)
Avg. Std Math	-0.043	-0.111	0.086	0.090	-0.192	-0.267	-0.072	-0.056
Achievement	(0.749)	(0.767)	(0.792)	(0.807)	(0.808)	(0.827)	(0.860)	(0.869)
Pct. Economically	0.002	-0.007	-0.014	-0.019	-0.006	-0.015	-0.021	-0.024
Disadvantaged	(0.026)	(0.025)	(0.024)	(0.023)	(0.025)	(0.025)	(0.025)	(0.024)
Pct. Students with	0.051	0.049	0.055	0.055	0.048	0.045	0.051	0.050
Disabilities	(0.069)	(0.063)	(0.065)	(0.070)	(0.069)	(0.063)	(0.065)	(0.069)
Pct. Female	-0.064	-0.065	-0.071	-0.065	-0.059	-0.060	-0.065	-0.060
	(0.097)	(0.095)	(0.093)	(0.081)	(0.097)	(0.095)	(0.093)	(0.083)
Pct. English Learners	0.128**	0.085	0.059	0.053	0.124*	0.072	0.050	0.045
	(0.065)	(0.074)	(0.086)	(0.089)	(0.064)	(0.070)	(0.082)	(0.085)
Pct. Asian	0.018	0.029	0.043	0.025	-0.013	-0.007	0.008	-0.006
	(0.088)	(0.072)	(0.072)	(0.066)	(0.091)	(0.072)	(0.071)	(0.067)
Pct. Black	0.039**	0.050***	0.047***	0.028	0.042**	0.054***	0.050***	0.030
	(0.015)	(0.018)	(0.017)	(0.024)	(0.016)	(0.018)	(0.017)	(0.024)
Pct. Hispanic	-0.046	-0.031	-0.022	-0.031	-0.044	-0.027	-0.020	-0.029
	(0.031)	(0.038)	(0.041)	(0.043)	(0.032)	(0.038)	(0.041)	(0.043)
Pct. Indigenous Persons	-0.102	0.0320	-0.0805	-0.187	-0.049	0.087	-0.027	-0.148
	(0.501)	(0.520)	(0.478)	(0.472)	(0.476)	(0.487)	(0.444)	(0.437)
Pct. Pacific Islander	0.561	0.718	0.497	0.741	0.617	0.810	0.591	0.813
	(0.562)	(0.495)	(0.524)	(0.546)	(0.594)	(0.514)	(0.551)	(0.567)
Observations	574	574	574	574	574	574	574	574
Adj R Squared	0.092	0.105	0.112	0.129	0.095	0.112	0.118	0.133

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.

Table A5. 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 CZ in Last 3	-0.002	-0.002	-0.002	-0.002				
Yrs.	(0.002)	(0.002)	(0.002)	(0.002)				
New Tchs. who Went to	-0.032	-0.025	-0.019	-0.011				
HS in CZ Last 3 Yrs.	(0.028)	(0.028)	(0.028)	(0.027)				
EPP Grads in 25 Mi. in					-0.002	-0.002	-0.002	-0.002
Last 3 Yrs.					(0.002)	(0.002)	(0.002)	(0.002)
New Tchs. who Went to					-0.039	-0.040*	-0.031	-0.024
HS in 25 Mi. Last 3 Yrs.					(0.024)	(0.024)	(0.024)	(0.024)
Log. of CWIFT Adjusted		-0.059	-0.040	-0.078		-0.056	-0.036	-0.066
District Base Salary		(0.302)	(0.289)	(0.277)		(0.297)	(0.286)	(0.272)
District Salary Annualized		-0.077	-0.084	-0.068		-0.087*	-0.091*	-0.072
Rate of Change		(0.054)	(0.051)	(0.049)		(0.051)	(0.049)	(0.047)
Std. School Working			-0.039	-0.031			-0.040	-0.032
Conditions			(0.025)	(0.025)			(0.024)	(0.025)
School Attrition Rate				0.010**				0.010**
(Last 3 Yrs.)				(0.004)				(0.004)
City	0.058	0.050	0.040	0.046	0.058	0.050	0.041	0.047
	(0.066)	(0.064)	(0.062)	(0.063)	(0.067)	(0.064)	(0.062)	(0.063)
Town	-0.008	-0.030	-0.007	0.008	-0.001	-0.021	-0.001	0.012
	(0.075)	(0.080)	(0.076)	(0.076)	(0.074)	(0.079)	(0.076)	(0.076)
Rural	0.029	0.014	0.029	0.038	0.034	0.019	0.032	0.040
	(0.071)	(0.075)	(0.072)	(0.072)	(0.071)	(0.074)	(0.071)	(0.071)
High School	0.042	0.042	0.053	0.031	0.035	0.036	0.048	0.027
	(0.056)	(0.057)	(0.057)	(0.060)	(0.056)	(0.056)	(0.056)	(0.059)
300-600 Total Students	0.036	0.035	0.030	0.037	0.032	0.032	0.026	0.034
	(0.062)	(0.063)	(0.060)	(0.061)	(0.060)	(0.061)	(0.059)	(0.060)
600-900 Total Students	0.075	0.072	0.056	0.064	0.069	0.065	0.050	0.060
	(0.072)	(0.0726)	(0.070)	(0.069)	(0.071)	(0.072)	(0.069)	(0.068)
900-1200 Total Students	0.045	0.050	0.025	0.046	0.048	0.053	0.026	0.047
	(0.083)	(0.083)	(0.090)	(0.096)	(0.083)	(0.082)	(0.089)	(0.095)
Greater than 1200 Total	0.170*	0.172*	0.134	0.160	0.164*	0.165*	0.127	0.153
Students	(0.097)	(0.096)	(0.096)	(0.099)	(0.098)	(0.096)	(0.096)	(0.099)
Avg. Std Math	-0.065	-0.064	-0.040	-0.040	-0.072	-0.071	-0.046	-0.045
Achievement	(0.044)	(0.044)	(0.044)	(0.046)	(0.044)	(0.044)	(0.043)	(0.045)
Pct. Economically	0.001	0.001	-0.000	-0.0001	0.000	0.000	-0.001	-0.001
Disadvantaged	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Pct. Students with	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.002
Disabilities	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)
Pct. Female	-0.002	-0.002	-0.003	-0.002	-0.002	-0.002	-0.003	-0.002
	(0.006)	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)	(0.006)	(0.005)
Pct. English Learners	0.012	0.009	0.005	0.005	0.012	0.008	0.005	0.005
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Pct. Asian	-0.013	-0.013	-0.012	-0.013	-0.015	-0.015	-0.013	-0.015
	(0.011)	(0.010)	(0.010)	(0.010)	(0.011)	(0.010)	(0.010)	(0.010)
Pct. Black	0.003**	0.004**	0.003**	0.002	0.004***	0.004***	0.004***	0.002
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Pct. Hispanic	0.001	0.002	0.003	0.003	0.001	0.003	0.003	0.003
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Pct. Indigenous Persons	0.023	0.032	0.019	0.009	0.026	0.035	0.021	0.010
	(0.043)	(0.043)	(0.041)	(0.042)	(0.044)	(0.044)	(0.043)	(0.043)
Pct. Pacific Islander	0.117*	0.131*	0.106	0.127*	0.119*	0.136*	0.110	0.130*
	(0.069)	(0.070)	(0.070)	(0.070)	(0.070)	(0.070)	(0.070)	(0.070)
Observations	574	574	574	574	574	574	574	574
Adj R Squared	0.117	0.119	0.135	0.150	0.118	0.121	0.137	0.151

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.

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 factor loadings of each item in the table below.

Survey Item	Factor Loading
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.	0.192
Staff at this school have an effective process for solving problems.	0.200
Teachers are encouraged to participate in school leadership roles.	0.178
I feel supported by other teachers at this school.	0.165
Our school staff is a learning community in which ideas and suggestions for improvement are encouraged.	0.196
The principal at my school communicates a clear vision for this school.	0.181
The staff feels comfortable raising issues and concerns that are important to them with school leaders.	0.179
I like the way things are run at this school.	0.195
School leadership effectively handles student discipline and behavioral problems.	0.180
Students treat adults with respect at this school.	0.173
Students in my school are often threatened and bullied.	-0.112
I feel safe at my school.	0.176
I feel prepared to respond to any type of emergency situation that may occur at my school.	0.163
Teachers in my school are allowed to focus on teaching students with minimal interruptions.	0.176
My individual planning time is sufficient.	0.100
My collaborative planning time is sufficient.	0.111
Teachers with demonstrated effectiveness in teaching have opportunities to lead instructional improvement efforts in my school.	0.173
This school provides meaningful opportunities for parents to partner with staff in the school to support student learning.	0.171
Parents respond to my suggestions for helping their child.	0.137
My curriculum/instructional materials are easy to use.	0.109
I am able to deliver high quality lessons by using the curriculum/instructional materials as designed.	0.111

I am able to use assessments and tasks provided by curriculum/instructional materials without having to modify or develop my own.	0.101
My curriculum/instructional materials are engaging to my students	0.126
Teachers at my school have high expectations for all students.	0.160
The processes used to conduct my teacher evaluation are fair to me.	0.153
In general, the teacher evaluation process used in my school has led to improvements in my teaching.	0.157
In general, the teacher evaluation process used in my school has led to improvements in student learning.	0.160
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.	0.171
School leadership proactively seeks to understand the needs of teachers and staff.	0.185
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.	0.145
Feel responsible to help each other do their best.	0.162
Help maintain discipline in the entire school, not just their classroom.	0.174
Take responsibility for improving their school.	0.180
Implement effective instructional strategies.	0.161
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.	0.154
My professional learning experiences this year have been closely aligned to the feedback I received on my evaluation.	0.159
My professional learning has been closely aligned to the instructional materials I use in class.	0.143
In general, the professional learning I have received this year has led to improvements in my teaching.	0.152
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)	-0.118
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)	-0.058
Numeric Open Response	
About how many minutes per week during school hours do you have for individual planning/prep time?	0.016
About how many minutes per week during school hours do you spend meeting with other teachers to discuss instruction?	0.003
About how many minutes per week during school hours do you spend on other school business (school improvement planning, administrative duties)?	-0.027