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Massachusetts Study of Teacher Supply and Demand

Trends and Projections

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Executive Summary

Although historically less attention has been paid to the study of educator quantity, in recent years growing concerns about teacher shortages have motivated state policymakers to turn their attention to the supply and demand of teachers (Motoko, 2015). However, to the extent that states report on teacher supply and demand, the approaches have varied considerably (Lindsay, Wan, & Gossin-Wilson, 2009). Conducting studies of teacher supply and demand is complicated by the fact that the available indicators of teacher supply, demand, shortage, and surplus are complex and often paint an ambiguous picture of whether and where problems exist, which can create more confusion than clarity for state leaders addressing the issue (Behrstock, 2009; Berg-Jacobson & Levin, 2015; Cowan, Goldhaber, Hayes, & Theobald, 2015). Gaining a clear understanding of teacher supply and demand in Massachusetts is especially important. Despite a recent increase in the number of individuals completing teacher preparation programs in fields exhibiting shortages (i.e., special education), there is still unmet demand in these areas (ESE, 2013). Moreover, the demographics of the teacher workforce do not reflect the population of students served, with minority teachers consistently underrepresented (ESE, 2011, 2013; Owen, 2010).

In April 2015, the Massachusetts Department of Elementary and Secondary Education (ESE) commissioned American Institutes for Research (AIR) to develop a comprehensive set of 10-year projections of teacher supply and demand in order to inform planning for future workforce needs. This included state-level projections both in the aggregate, as well as for a variety of disaggregated categories, including assigned program area, teacher race and age, and geographic areas across the state. AIR collaborated with representatives from ESE's Office of Planning and Research as well as the Center for Educator Effectiveness to develop research questions that target the needs of policymakers and teacher-preparation programs.

The study examined the following:

- Aggregate projections of annual demand
- Aggregate projections of annual supply
- Detailed supply and demand projections by program area
- Detailed supply and demand projections by teacher demographic groups
- Detailed supply and demand projections by region

The results of these analyses, including supporting tables and figures, are contained within this report. In addition, the results of each analysis are tied to relevant policy implications.

Data Sources

The research team at AIR worked closely with ESE to identify and obtain appropriate extant data for the study analyses. Data were drawn from publicly available databases[1], including the following:

- **School and District Profiles**. These online profiles include aggregate school- and district-level data on a number of different elements, including student enrollment, college enrollment and program completion, teacher and student characteristics, and teacher retention. To complete the project analyses, the research team used the data on which these reports are based.[2]
- **2014 Lists of Massachusetts Schools and Districts by Accountability and Assistance Level**. This dataset contains a list of school districts linked to the regional District and School Assistance Centers (DSAC) that serve these districts.
- **Center for Disease Control (CDC) Wide-Ranging Online Data for Epidemiologic Research (WONDER)**. This online database includes the birth counts in Massachusetts by county for the years 2002 through 2013, and the county fertility rate in 2013.
- **U.S. Census Population Data**. The U.S. Census Bureau's *Annual County Resident Population Estimates* report contains data on the population of females by county and age level. For this study, estimates for counties in Massachusetts were obtained for April 2010 through July 2014.
- **National Center for Education Statistics (NCES) Common Core of Data**. Collected annually by NCES, this resource contains fiscal and non-fiscal data on U.S. public schools. This information is obtained through administrative data that state education agencies maintain and NCES reports at both the school and district levels. For this study, the AIR research team used data on the district-level locale codes and the latitude and longitude of district offices.
- **NCES Comparable Wage Index (CWI)**. The CWI is an indicator of the cost of teacher labor for a given geographic area, known as a labor market, relative to other labor markets. Areas with higher labor costs are expected to have to pay higher salaries to attract and retain teachers.

Research Questions

This study was motivated by a number of research questions that were developed jointly by AIR's research team and ESE. The questions ask about the supply and demand for teachers, both generally and disaggregated by key groupings. The questions were:

[1] Table A1 in Appendix A includes Internet links to the locations of these data sources.
[2] The reports that were used included the following: Employment of Education Preparation Completers by Program/Program Characteristics/Year, Ed Prep Candidate Enrollment by Race/Gender, Student Enrollment by Grade/Race/Gender, Staffing Retention Rates, Staffing Age Report, Selected Populations Report, Race/Ethnicity and Gender Staffing Report, Teacher by Program Area Report, and Teacher Data Report.

1. What is the projected annual demand for teachers in Massachusetts over the next 10 years based on pupil–teacher ratios and projections of student enrollment?
2. What is the projected annual supply of teachers in Massachusetts over the next 10 years, and what is the composition of these projections when broken out by components of supply that include retained teachers, new entrants, and those transferring in and out of districts?
3. What are the projections for the annual supply and demand of teachers in Massachusetts for the next 10 years by program area?
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    a. What are the supply and demand projections by DSAC region?
    b. What are the supply and demand projections by NCES locale (i.e., city, suburb, town, and rural)?
    c. What are the supply and demand projections by location of the state's major educator preparation programs?
    d. What are the supply and demand projections by the state's largest metropolitan areas?

Key Findings

Research Question 1: Statewide Projections of Annual Demand

- Student enrollment, and therefore demand for teachers, is projected to decrease over the next 10 years by approximately 5.77 percent.

Research Question 2: Statewide Projections of Annual Supply

- Annual supply is expected to decline over the next 10 years by a little less than 2 percent.
- The slower expected rate of decline of supply compared to demand indicates that in 10 years (by 2023–24) there will be a surplus in the supply of teachers compared to the demand by approximately 4 percent.
- The trend over time in the number of retained teachers largely mirrors the overall trend in supply; meanwhile the number of new entrants has decreased over time, indicating a potential constriction of the teacher pipeline; and the number of teachers transferring—either across districts or into the state from elsewhere—has increased over time.

Research Question 3: Detailed Supply and Demand Projections by Program Area

- Demand for teachers in all four program areas—general education (GenED), special education (SPED), English language learners (ELLs), and career/vocational/technical education (CTE)—is expected to decline. The declines in demand are most profound for the SPED, ELL, and CTE, which are each expected to drop by more than 10 percent.
- While the supply of GenED teachers is expected to increase, leading to a surplus, the supplies of ELL and SPED teachers are expected to decline by more than 20 percent. The decline in supply for these two categories is expected to outpace the corresponding decline in demand, leading to projected shortages of ELL and SPED teachers. The expected decline in the supply of CTE teachers is less than the corresponding decline in demand, leading to an expected surplus for this group.

Research Question 4: Detailed Supply and Demand Projections by Teacher Demographic Groups

- Demand for minority teachers is expected to increase, while demand for White teachers is expected to decrease.
- The supply of minority teachers is not expected to change appreciably over time. Given an expected increase in demand and unchanging supply, there is expected to be a shortage of minority teachers. In contrast, the supply of White teachers is expected to decline at a slightly slower rate than demand, leading to an expected slight surplus of White teachers in later projected years.
- By age, the demand for teachers under 26, 26 to 32, and 49 to 56 are each expected to decline by more than 10 percent, with the decline in the 49 to 56 age group being the largest in both absolute (5,678 full-time equivalent teachers) and relative terms (46 percent). Large demand increases are also expected for the 41 to 48 and over 64 age groups.
- Under 26 is the only age group for which the supply of teachers expected to not meet demand in 10 years. This may be particularly worrisome, as this group makes up the largest portion of teachers newly entering the field and a large portion of the teacher pipeline.

Research Question 5: Detailed Supply and Demand Projections by Region

- Demand for teachers by region is projected to decline for all regions except the Commissioner's Districts, where demand is expected to be relatively steady over time. Demand in the Berkshires + region, central region, and southeast region is expected to decline for each by more than 10 percent between 2013–14 and 2023–24, well above the statewide projected decline of 5.77 percent.

- While demand in the Commissioner's Districts is expected to decline the least, the supply in this region is expected to decline the most, leading to teacher shortages. There are also slight projected shortages in the Greater Boston region, though these are expected to shrink over time. In all other regions, supply is expected to meet demand over the next 10 years.
- Other notable geographic areas expected to show deficits in the supply of teachers compared to the demand are districts in cities and the Lowell–Lawrence metropolitan area.

Introduction

In recent years, concerns have been growing across the country that there are not enough educators—especially teachers—to meet school and district hiring demands. Massachusetts has often encountered this issue with regard to mathematics, science, English language learners, and special education teachers (U.S. Department of Education, 2015). Previous studies suggest that these shortages will persist, despite recent increases in the numbers of teacher preparation program graduates specializing in historically high-need subject areas (ESE, 2011).

The Massachusetts Department of Elementary and Secondary Education (ESE) has a strong track record of taking action to address these concerns and has prioritized strategies to ensure that teacher supply meets demand. In the second core strategy of its 2015 strategic plan, ESE set objectives to expand statewide recruitment to increase effective supply, foster diversity in the workplace to address the shortage in minority teachers, and improve teacher preparation programs to ensure that new high-quality teachers are not in short supply (ESE, 2015). Its streamlined online recruitment tool (aMAzing Educators), the Massachusetts Advocates for Diversity in Education task force (ESE, 2014), and other important initiatives demonstrate ESE's commitment to develop policies that would improve the availability of effective teachers, especially those in areas with specific shortages. Clear, accurate, and timely teacher supply and demand projections will help ESE to achieve these objectives by providing a complete picture of its teacher workforce needs over the next decade.

Toward this end, in April 2015, ESE commissioned AIR to conduct a study to investigate patterns of teacher supply and demand to inform policy concerning the instructional labor force. The conceptual approach, data sources, analytic methods, and findings of the study are presented in this report.

Study Objectives

The primary objective of this study was to develop a comprehensive set of 10-year projections of teacher supply and demand in order to inform planning for future workforce needs. The projections of this study were estimated both in the aggregate and by a number of disaggregated categories, including teacher characteristics, geographic regions, and locales. The research team pursued this work in two key study phases:

1. **Data preparation for analysis.** AIR's research team initiated the study by obtaining, cleaning, and preparing the data for analysis. The data included both the factors that are direct indicators of supply and demand—such as enrollment, pupil–teacher ratios and counts of teachers—and those that, in theory, are related to or influence teacher supply and demand—such as demographic characteristics of students and teachers. The primary purpose of this phase was to ensure that there were no gaps or errors in the data that might prevent the research team from obtaining accurate results. While much of this work was conducted at the beginning of the study timeline, the research team considered this an ongoing task and continually examined the data for issues.

2. **Analysis to address research questions, testing validity of results, and write-up of findings.** The research team then analyzed the available data. This was an iterative process where multiple models were generated to produce the results. Models were compared based on the accuracy of their predictions of historical data and were altered and refined until a set of satisfactory models were decided upon. Results from these models were used to draw conclusions about anticipated levels of teacher supply and demand and to describe implications for policymakers and teacher preparation programs.

Research Questions

Below are the research questions that this study addressed in order to estimate future trends in teacher supply and demand:

1. What is the projected annual demand for teachers in Massachusetts over the next 10 years based on pupil–teacher ratios and projections of student enrollment?
2. What is the projected annual supply of teachers in Massachusetts over the next 10 years, and what is the composition of these projections when broken out by components of supply that include retained teachers, new entrants, and those transferring in and out of districts?
3. What are the projections for the annual supply and demand of teachers in Massachusetts for the next 10 years by program area?
4. What are the supply and demand projections of teachers in Massachusetts for the next 10 years by demographic group?
    a. What are the supply and demand projections of teachers by race/ethnicity?
    b. What are the supply and demand projections of teachers by age?
5. What are the supply and demand projections of teachers in Massachusetts for the next 10 years by state region and locale?
    a. What are the supply and demand projections by DSAC region?
    b. What are the supply and demand projections by NCES locale (i.e., city, suburb, town, and rural)?
    c. What are the supply and demand projections by location of the state's major educator preparation programs?
    d. What are the supply and demand projections by the state's largest metropolitan areas?

Report Organization

The remainder of the report is organized as follows.

Section 1 outlines the conceptual approach of the study, detailed information about the data sources used to conduct the analyses, and descriptions of the key analytic methods. Section 2 includes the key findings for each research question addressed by the study as well as potential policy implications of the reported results. Section 3 discusses some general limitations of developing demand and supply projections and what can be inferred from the results. The final section of the report describes opportunities for future study.

Section 1. Data and Methods

The AIR research team, through consultation with ESE and independent testing of a variety of approaches, identified the most appropriate methods for producing accurate projections, given the data made available for the study. The following section describes the specific data sources and methods used to address each research question.

Conceptual Approach

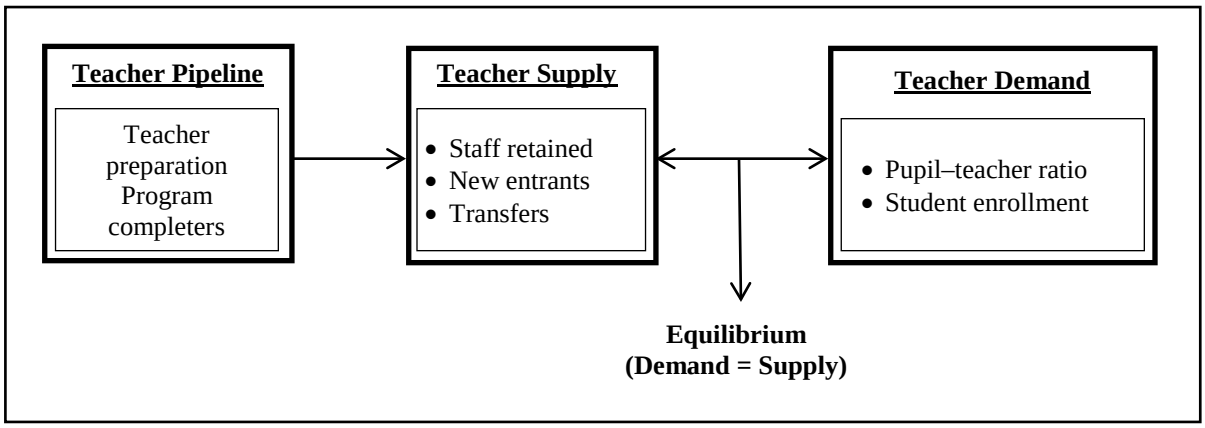
Before delving into the data and methods used for this study, the conceptual approach for investigating the supply and demand of teachers in Massachusetts is described. The AIR research team began by considering the components of supply and demand and how they each contribute to an overall understanding of whether shortages or surpluses will exist. Specifically, the following three broad categories of supply and demand components were considered:

- **Teacher Pipeline**: This includes all individuals who have completed teacher education programs housed in Massachusetts institutions of higher education (IHEs) and recently entered the state's teacher workforce, those who have entered the teacher workforce from alternative routes to certification, or those who were prepared in another state but came to Massachusetts to teach. By analyzing the pipeline component, one can identify trends in those who choose to become certified as a teacher and their entrance into the teacher workforce.
- **Teacher Supply**: This is the current pool of teachers actively certified and employed in Massachusetts' public schools. This pool of teachers includes both those retained from the previous year and those newly entering the teacher workforce.
- **Teacher Demand**: This is the number of teachers in demand based on the number of students enrolled and the ratio of pupils to teachers.

Together, the first two categories represent the potential supply of teachers. That is, the potential supply consists of the present pool of teachers and those individuals who are preparing to become teachers. In addition, there is movement within the teacher supply category. Teachers may transfer between districts, or temporarily fall out of the active teacher pool to enter back into the pool at a later period. By comparing the pool of active teachers, or effective supply, to the demand for teachers, one can assess whether there is a shortage (i.e., when demand is higher than supply) or a surplus (i.e., when supply is higher than demand). While data exists on the total number of teachers, the number of new teachers entering the Massachusetts public school system from teacher preparation programs, and the number of teachers retained each year within a given school district, the data used for this study does not include information on teacher mobility, or teachers leaving one district to enter into the teacher pool in another district. We attempted to estimate the number of transferring teachers but were limited in terms of how much we can say about this component of teacher supply.

Figure 1 illustrates the conceptual framework that informed this study, including the different components of educator supply and demand and how they relate to one another.

Figure 1. Conceptual Approach for Assessing Teacher Supply and Demand



General Approach to the Analysis

To address the research questions, the AIR research team adopted the general approach of analyzing historical data on supply and demand to identify trends over time and apply these to future years. Much of the analysis used a regression-based approach, which is described in more detail in Appendix A. Projections were made at the district level and were then aggregated to the level of the unit of analysis. For example, to analyze statewide trends of supply and demand, estimates for all districts in our sample were aggregated. To analyze regional trends, however, only the estimates for those districts within a particular region were aggregated.

The following sections describe the data sources and methodologies used to address each research question. The methodologies as well as the limitations of our analysis are also discussed in more detail in Appendix A.

Data Sources

There were a variety of data sources used to analyze the research questions (see Table 1), including primarily public reports made available on the ESE Profiles website, data from the National Center for Education Statistics (NCES), as well as population data from the Center for Disease Control (CDC), and U.S. Census Bureau. A brief description of each data source is presented below, and Table 1 presents the data sources used for each research question.[3]

- **School and District Profiles.** These online profiles include aggregate school- and district-level data on a number of different elements, including student enrollment, college enrollment and program completion, teacher and student characteristics, and teacher retention. The following sub-bullet points describe each report used from the School and District Profiles.
  - **Enrollment by Grade Report**. This report includes student enrollment for Grades K–12 in school years 2003–04 through 2014–15.

[3] Table A1 in Appendix A includes Internet links to the locations of these data sources.

  - **Enrollment by Select Populations Report**. This report includes student enrollment by selected populations of students, including students with disabilities and students eligible for free or reduced price lunch in school years 2008–09 through 2014–15.
  - **Enrollment by Race/Gender Report**. This report includes student enrollment by race/ethnicity and gender in fiscal years 2008–09 through 2014–15.
  - **Teacher Data Report**. This report includes full-time equivalent counts of teachers by district in fiscal years 2008–09 through 2013–14.
  - **Ed Prep Employment by Year and Program**. This report includes the number of program completers overall and by teacher preparation program and the percent of these individuals employed in a public school in Massachusetts in the school years 2011–12 through 2013–14.
  - **Staff Retention Report**. This report includes staff counts of retained teachers and total teachers in school years 2008–09 through 2013–14.

- **2014 Lists of Massachusetts Schools and Districts by Accountability and Assistance Level**. This report shows assigned districts a District and School Assistance Center (DSAC) region in conjunction with consultation with the Department of Elementary and Secondary Education (ESE).
- **CDC Wide-Ranging Online Data for Epidemiologic Research (WONDER).** This online database includes the birth counts in Massachusetts by county for years 2002–2013 and the county fertility rate in 2013.
- **U.S. Census Population Data.** This includes the Annual County Resident Population Estimates report containing data from April 2010 through July 2014, which provides county female population by age in Massachusetts in 2014.
- **NCES Common Core of Data (CCD).** Collected annually by NCES, this resource contains fiscal and non-fiscal data on U.S. public schools. This information is obtained primarily through administrative data that state education agencies maintain and NCES reports at both the school and district levels. For this study, we used data on the district-level locale codes,[4] and the latitude and longitude of district offices.
- **NCES Comparable Wage Index (CWI).** The CWI is an indicator of the cost of labor for a given geographic area, known as a labor market, relative to other labor markets. Areas with higher labor costs are expected to have to pay higher salaries to attract and retain teachers.

[4] The NCES categorizes schools and districts in 12 urban-centric locale types based on population and proximity to urban areas as follows: City-Large, City- Midsize, City-Small, Suburb-Large, Suburb-Midsize, Suburb-Small, Town-Fringe, Town-Distant, Town-Remote, Rural-Fringe, Rural-Distant, and Rural-Remote. Additional information on these data can be found at https://nces.ed.gov/ccd/aboutCCD.asp

Table 1. Data Sources by Research Question

Research Question	School and District Profiles	ESE Accountability and Assistance Level Data	NCES CCD	NCES CWI	CDC WONDER Data	U.S. Census Data
Research Question 1: What is the projected annual demand for teachers in Massachusetts over the next 10 years based on pupil–teacher ratios and projections of student enrollment?	●	●			●	●
Research Question 2: What is the projected annual supply of teachers in Massachusetts over the next 10 years, and what is the composition of these projections when broken out by components of supply that include retained teachers, new entrants, and those transferring in and out of districts?	●	●	●	●		
Research Question 3: What are the projections for the annual supply and demand of teachers in Massachusetts for the next 10 years by program area?	●	●	●	●	●	●
Research Question 4: What are the supply and demand projections of teachers in Massachusetts for the next 10 years by demographic group?	●	●	●	●	●	●
1. What are the supply and demand projections of teachers by race/ethnicity?						
2. What are the supply and demand projections of teachers by age?						
Research Question 5: What are the supply and demand projections of teachers in Massachusetts for the next 10 years by region and locale?	●	●	●	●	●	●
1. What are the supply and demand projections by Massachusetts District and School Assistance Center (DSAC) region?						
2. What are the supply and demand projections by NCES locale (i.e., city, suburb, town, and rural)?						
3. What are the supply and demand projections by location of the state's major educator preparation programs?						
4. What are the supply and demand projections by the state's largest metropolitan areas?						

Methods

Research Question 1

What is the projected annual demand for teachers in Massachusetts over the next 10 years based on pupil–teacher ratios and projections of student enrollment?

To calculate projections of annual demand for public school teachers in Massachusetts, the AIR research team first defined aggregate demand as a function of two components: (1) the target pupil–teacher ratio a district wishes to maintain, and (2) the total count of students who are enrolled in the district. Overall demand can be expressed as student enrollment divided by the pupil–teacher ratio, as shown by the equation defined in Figure 2, which serves as the underpinning of the demand projections.

Figure 2. Equation Used to Estimate Demand Based on Enrollment and Pupil–Teacher Ratios

$$\boldsymbol{Projected\ Demand} = \frac{Projected\ Student\ Enrollment}{Projected\ Pupil–Teacher\ Ratio}$$

Student Enrollment

Several approaches exist for creating student enrollment projections. These include models based on simple averages from previous years; a growth model based on historical year-over-year changes in enrollment; a growth model based on grade progression ratios (GPRs, which are the average proportions of students who progress from grade to grade each year); and regression-based models where enrollment is estimated as a function of those factors thought to influence the number of students enrolled (e.g., historical enrollment trends, birth rates, and so on). The AIR research team chose to use GPRs, which have previously been shown to be accurate for making projections as far as 10 years into the future (Berk & Hodgins, 2008; Minnesota Department of Education, 2015; Berg-Jacobson & Levin, 2015). This method relies on calculating projections based on a series of GPRs, which are the calculated proportions of students that move from one grade level to the next each year and those born five years earlier who enter kindergarten. GPRs for birth to kindergarten and every other successive pair of grades were used to calculate the projected number of students in each grade up to 10 years into the future.[5]

Pupil–Teacher Ratios

In order to project teacher demand, a target pupil–teacher ratio for each district was set at the average of the most recent three years observed (2011–12 through 2013–14). This approach of using a static ratio on which to calculate the demand projections is based on the assumption that districts will attempt to maintain these average pupil–teacher ratios over the next 10 years. Results using this assumption were considered more legitimate than other assumptions

[5] A more detailed summary of the methods used to project enrollment can be found in Appendix A.

associated with regression models and projections of pupil–teacher ratios based on historical trends.[6]

Research Question 2

What is the projected annual supply of teachers in Massachusetts over the next 10 years, and what is the composition of these projections when broken out by components of supply that include retained teachers, new entrants, and those transferring in and out of districts?

The AIR research team began by defining total supply of teachers as the number of teachers who will be employed in the state of Massachusetts over the next 10 years, under the assumption that trends in the number of teachers over the past six years remain constant. This estimation of total supply in each year is conceptualized as the sum of teachers from three broad categories: those who are retained in their teaching position from the previous year, those who are newly entering the teaching workforce, and those who transfer across districts or into Massachusetts from out of state. While data on the total number of teachers, retained teachers, and new entrants were readily available and used to address this research question, data on transferring teachers were not available. Therefore, to estimate the number of transferring teachers, retained and newly entering teachers were subtracted from the total number of teachers (see Figure 3).

Figure 3. Equation Used to Estimate Supply Based on Retained Teachers, New Entrants, and Transfers

Transferring Teachers *= Total Teacher Supply – Retained Teachers – New Entrants*

Projections of total supply, numbers of retained teachers, and numbers of newly entering teachers were estimated using a regression-based approach that modeled each of these as a function of factors believed to influence supply. For example, district enrollment and the percent of students eligible for free or reduced price lunch were included to take into account the effect of scale and student need on teacher supply. The inclusion of a time trend in the model allowed the research team to apply outcomes to future years to project supply and its components for the next 10 years. A detailed discussion on the specific models used as well as a description of extra steps required for the estimation of new entrants can be found in Appendix A.

Research Question 3

What are the projections for the annual supply and demand of teachers in Massachusetts for the next 10 years by program area?

[6] Modeling the pupil–teacher ratio as a function of several factors and predicting trends for future years assumes that historical trends in pupil–teacher ratios based on the estimated relationships would persist over the next 10 years. However, the predictions resulting from the models that were run yielded much larger changes in pupil–teacher ratios over future years than were thought to be realistic; therefore, this assumption was not considered as reasonable in assuming the districts will maintain their average ratio over recent years.

Demand and supply projections by program area categories were estimated with methods similar to those used to address Research Questions 1 and 2. However, due to limitations in the data readily available, additional steps were required to estimate these projections.

Demand projections by program area were calculated by first projecting the estimated proportion of teachers across program area categories over time using a regression-based modeling approach. The projected demand from Research Question 1 was then multiplied by the estimated proportion of teachers by program area to calculate the projected demand by program area. Detailed descriptions of the methods used to project demand by program area are included in Appendix A.

As with supply for Research Question 2, a regression-based modeling approach was used to make projections of the supply of teachers by program area.[7] Details regarding the models used for this analysis can also be found in Appendix A.

Research Question 4

What are the supply and demand projections of teachers in Massachusetts for the next 10 years by demographic group?

Demand and supply projections by race and age categories were estimated using methods similar to those described in Research Question 3. Specifically, demand projections by race and age categories consisted of a two-step process where multiple regressions were first used to make projections of proportions of teachers in race and age categories over time, which were then applied to the overall demand estimates from Research Question 1. Supply projections were also similarly estimated using regression models of teachers in the various race and age categories in historical years as supply, and estimated models were used to make projections for future years. In addition, analyses of the supply subcomponents (e.g., retained, new entrants, and transfers) were also conducted. Detailed descriptions of the methodology for making supply and demand projections by race and age categories can be found in Appendix A.

Research Question 5

What are the supply and demand projections of teachers in Massachusetts for the next 10 years by region and locale?

Demand and supply projections by DSAC regions, NCES locales, IHE areas, and major metropolitan areas were derived from the results produced by Research Questions 1 and 2. As the projections for these research questions were estimated at the district level, the results for Research Question 5 simply represent the aggregation of projections for districts in each of the relevant categories. For example, projections by DSAC region are the aggregation of the projections for each district in each of these regions.

[7] The supply subcomponent of retained teachers was also analyzed, but because of additional uncertainty in these measurements they are not reported in the main body of this report. Additional details on this analysis can be found in Appendix A.

Section 2. Results

Research Question 1: Statewide Projections of Annual Demand

What is the projected annual demand for teachers in Massachusetts over the next 10 years based on pupil–teacher ratios and projections of student enrollment?

To answer this question the AIR research team considered two components of teacher demand: student enrollment and pupil–teacher ratios. Specifically, the team calculated student enrollment projections for 2014–15 to 2023–24 based on eight years of historical data and using a GPR method.[8] The following section reports projected enrollment trends over time and across DSAC regions. It also reports on the pupil–teacher ratios in 2013–14 and average ratios by region across the most recent three years of data (i.e., 2011–12 through 2013–14). In addition, using the enrollment projections and three-year average ratios, the AIR research team created demand projections for 2014–15 through 2023–24. Finally, the validity of these results (by comparing actual and projected values from previous years) is reported in this section.

Enrollment Projections

Projections in student enrollment offer policymakers a glimpse into the future need Massachusetts will face in terms of the numbers of teachers that must be produced by IHEs and attracted into the public education workforce.

Table 2 displays the average annual projected percent change in statewide and regional enrollments between 2013–14 and 2023–24, and the overall projected percent and absolute changes over this same time period. As is shown in Table 2, the AIR research team projects that enrollment will decline an average of 0.59 percent each year from 2013–14 to 2023–24, resulting in a cumulative decrease in enrollments of 5.79 percent during this 10-year period. Put in absolute terms, the AIR research team projects that statewide Massachusetts will be serving 51,236 fewer students in 10 years. This trend is consistent across DSAC regions, though there is variation in the magnitude of the projected decline. For example, the Southeast region is expected to decline the most in absolute terms (19,021 fewer students), while the Greater Boston region is projected to decline the least (2,630 fewer students). In relative terms, enrollment is expected to shrink the most for the Berkshires +, where enrollment is projected to decline by 11.29 percent. In contrast, enrollment in the Greater Boston region is expected to drop by 1.38 percent.

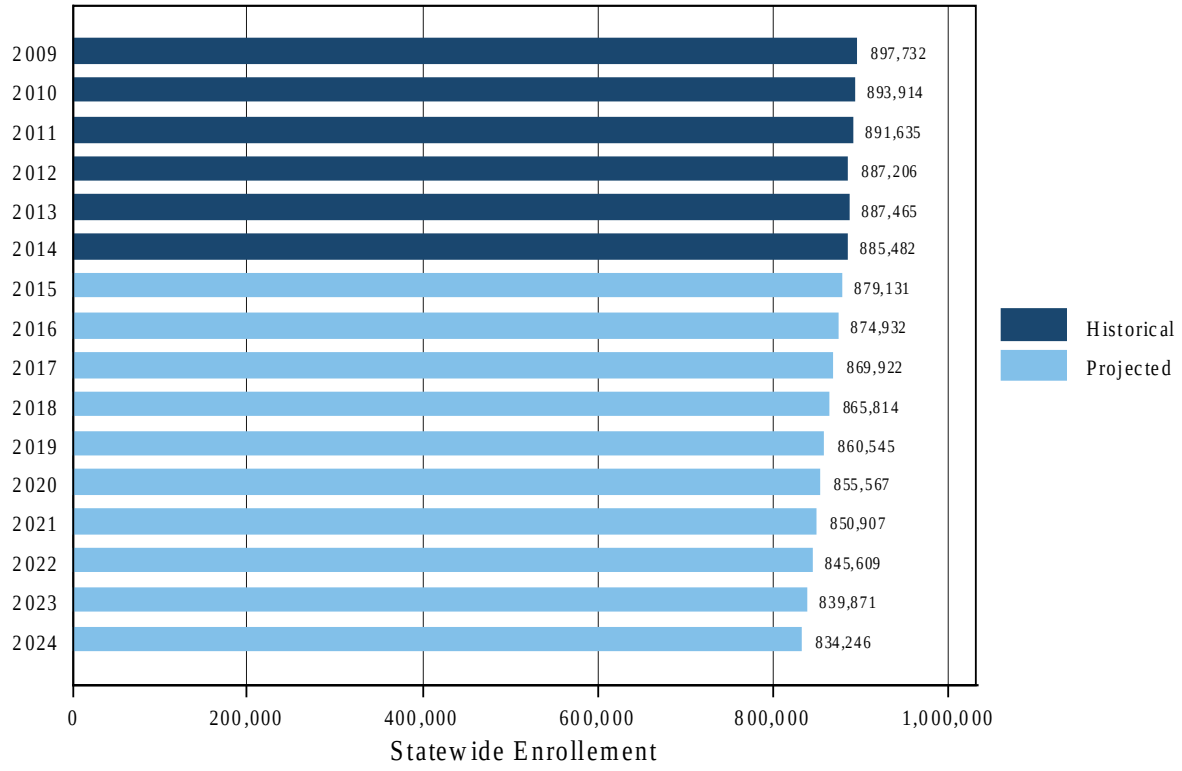
[8] See the Data and Methods section for additional detail on this method.

Table 2. Projected Percent and Absolute Changes in Enrollment Statewide and by DSAC Region, 2013–14 Through 2023–24

DSAC Region	Average Annual Percent Change 2013–14 Through 2023–24	Overall Percent Change 2013–14 Through 2023–24	Overall Absolute Change 2013–14 Through 2023–24
Berkshires +	-1.19%	-11.29%	-3,762
Central	-1.01%	-9.65%	-10,756
Commissioner's Districts	-0.26%	-2.53%	-4,670
Greater Boston	-0.14%	-1.38%	-2,630
Northeast	-0.52%	-5.13%	-6,861
Pioneer Valley	-0.80%	-7.74%	-3,536
Southeast	-1.07%	-10.20%	-19,021
Statewide	-0.59%	-5.79%	-51,236

Although the projected drops in enrollment may look large, when considered as part of a statewide trend over time, the decline seems less dramatic. In fact, as can be seen in Figure 4, statewide enrollment has been declining steadily for the past six years, declining 1.4 percent overall (12,250 students).

Figure 4. Historical and Projected Statewide Enrollment, 2008–09 Through 2023-24



Pupil–Teacher Ratios

Before demand projections are discussed, it is important to consider trends in pupil–teacher ratios. As outlined in the Data and Methods section, the demand projections are based on the assumption that statewide pupil–teacher ratios will remain constant over the next 10 years. In order to account for possible shocks in the most recent historical year of data, the AIR research team chose to hold pupil–teacher ratios constant at an average of the most recent three historical years (2011–12 through 2013–14). Moreover, the declining enrollment trend suggests that the statewide demand for teachers is also likely to decline. While policies related to pupil–teacher ratios can affect demand, these ratios tend to be fairly stable over time. To this end, student enrollment trends can be expected to be the primary driver of future demand.

Table 3 displays regional and statewide ratios in 2013–14, the three-year average, and the difference between the two. As can be seen in the table, there is generally a very small difference between the two ratios. In most regions the three-year average ratio is larger than the 2013–14 ratio, suggesting that, in general, ratios declined over the past three years. The exception is in the Commissioner's Districts, where ratios appear to have increased over the past three years. Although these differences are slight, the AIR research team believes that a three-year average is most appropriate as it takes into account these trends over time.

Table 3. Average Pupil–Teacher Ratios, 2013–14, Three–Year Average (2011–12 to 2013–14), and Comparison Statistic Statewide by DSAC Region

DSAC Region	Average Ratio in 2013–14	Three-Year Average Ratio	Difference Between 2013–14 Ratio—Three-Year Average Ratio
Berkshires +	11.79	11.92	-0.13
Central	13.62	13.80	-0.18
Commissioner's Districts	13.53	13.16	0.37
Greater Boston	12.88	13.05	-0.17
Northeast	13.29	13.45	-0.16
Pioneer Valley	12.15	12.36	-0.21
Southeast	13.54	13.71	-0.16
Statewide	13.21	13.27	-0.06

Demand Projections

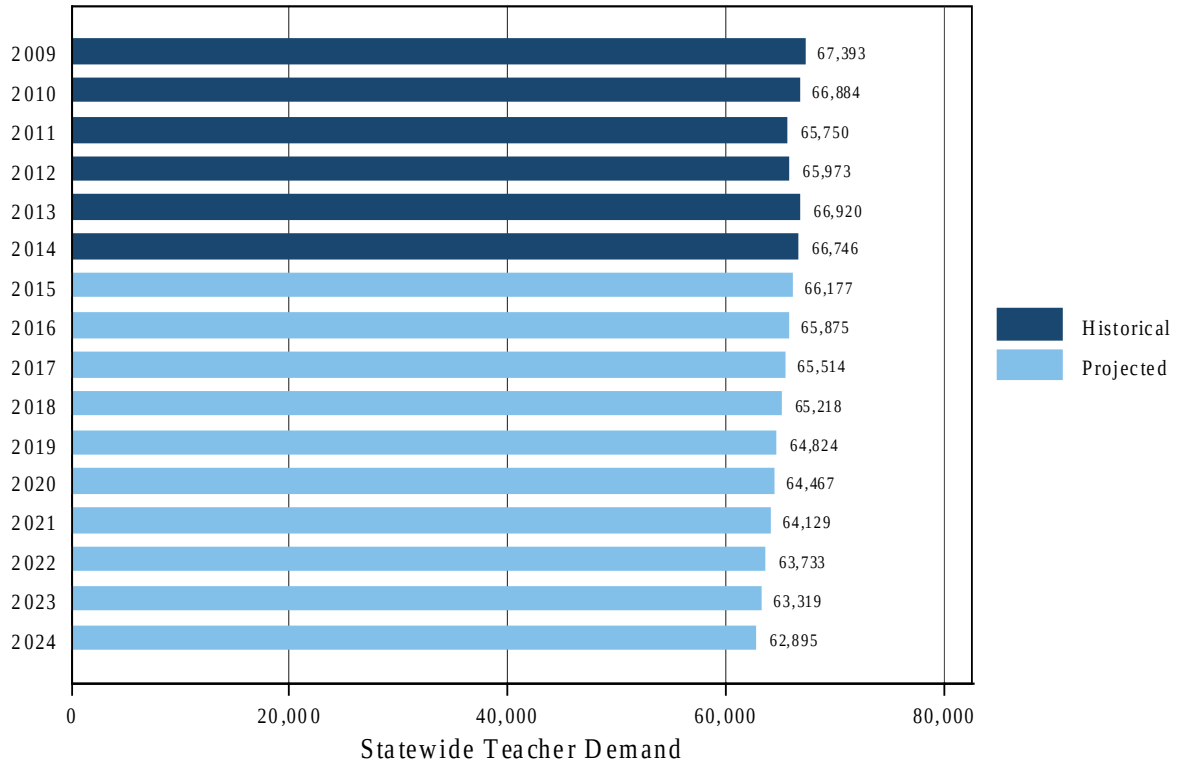
Using the projected enrollments and holding pupil–teacher ratios constant at the average of the most recent three years, demand projections were estimated at the district level. These projections represent an estimate of how demand for teachers will change over the next 10 years, and will be used in conjunction with supply projections to inform a discussion of potential shortages or surpluses.

Figure 5 displays the historical and projected trends in demand from 2008–09 to 2023–24. As expected, the trends in demand closely resemble the trends in student enrollment. The AIR research team projects that demand will decline an average of 0.59 percent each year from 2013–14 through 2023–24, declining in total about 5.77 percent over the 10-year period. Put in

absolute terms, it is projected that statewide the teacher labor market will demand 3,851 fewer full-time equivalent (FTE) positions in 10 years.

As with enrollment projections, it may be helpful to consider the statewide projected trends alongside the historical staffing trends. As can be seen in Figure 5, FTEs have been declining statewide over the last six years.

Figure 5. Historical and Projected Statewide Demand for Teachers in Terms of FTEs, 2008–09 Through 2023–24



The overall trend of declining statewide aggregate teacher demand may be welcome news for state policymakers concerned about teacher shortages. However, as demand declines, teacher supply also may decline, and there may still be a slight imbalance when the two are compared. Moreover, the reported trends are an aggregate of many varied trends at the district level. While teacher demand may be declining at the state level, this may not be the case for all districts, and some may, in fact, be struggling to meet demand. This may be especially true for districts serving high-need student populations and rural districts, which tend to face the greatest recruitment challenges (for a more detailed discussion of demand by region and locale, see answers to Research Question 5).

Validity of Results

As the estimates of future teacher demand are driven by enrollment projections, the AIR research team assessed the validity of these projections by using the same method to estimate enrollment projections in previous years and then comparing these with the actual enrollment counts for those years. Specifically, the team projected enrollment for 2004–05 through 2013–14 and

compared the results to historical values. This comparison was made by first aggregating enrollment projections to the state level and then calculating the statewide percent error in each year of the projections.

The projections for years one through eight were slightly higher than the actual values, with the largest error of 1.06 percent occurring in 2008–09. Although this validity testing suggests that AIR's method tends to have a positive bias, in the most recent two years the projections proved to be slightly lower than the historical values. Therefore, the pattern suggests that error in enrollment projections using this method tends to hover around zero, oscillating above and below over time.[9]

Research Question 2: Statewide Projections of Annual Supply

What is the projected annual supply of teachers in Massachusetts over the next 10 years, and what is the composition of these projections when broken out by components of supply that include retained teachers, new entrants, and those transferring in and out of districts?

To answer this question, the AIR research team used regression analysis to project overall teacher supply from 2014–15 through 2023–24. Projections were made of staff counts and FTEs from 2014–15 through 2023–24 based on models using the previous six years of historical data (2008–09 through 2013–14).

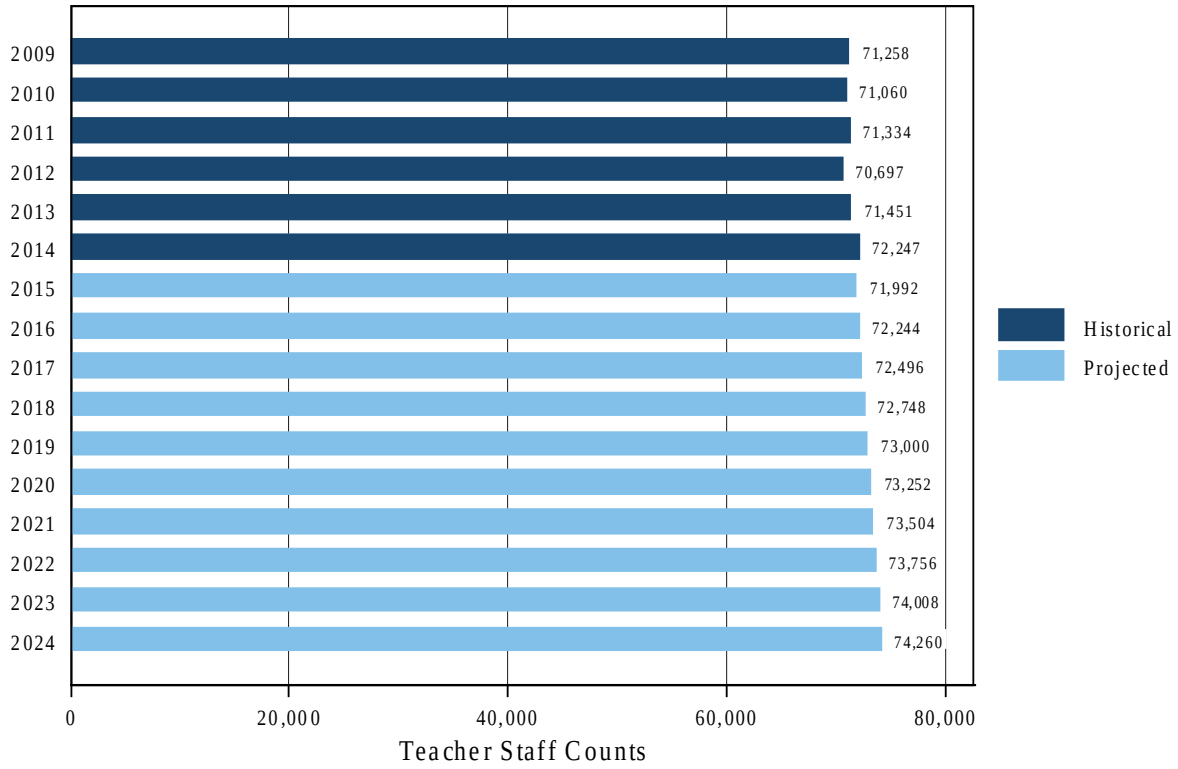
In addition, three components of overall teacher supply were examined: projections of retained teachers, new entrants, and transfers from other districts or from outside the public education system.

Total Supply

As explained in the section Data and Methods, overall teacher supply in each district was measured in two ways. The AIR research team first considered the total teacher staff count, or the actual number of people serving as teachers regardless of the total FTEs they represented. Figure 6 shows that the total number of teachers is expected to increase by 2,013 from 2013–14 through 2023–24, representing a change of 2.8 percent over the period (equal to an average increase of 0.2 percent per year).

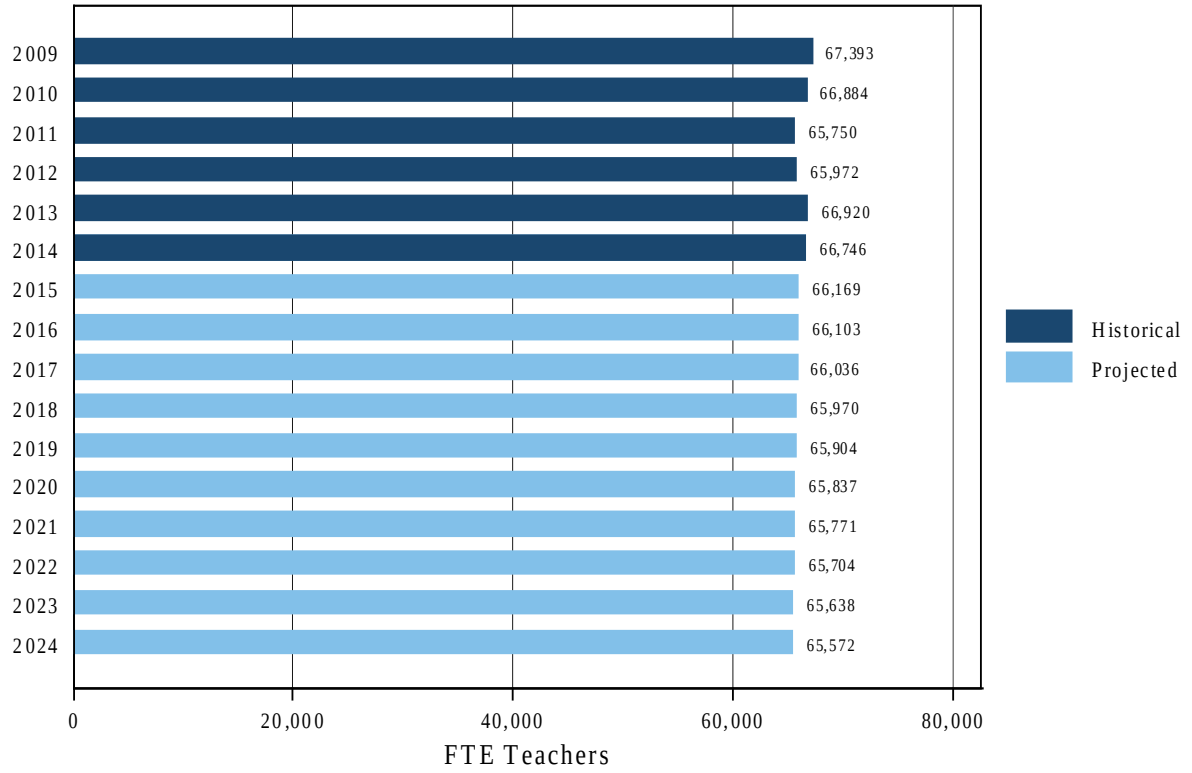
[9] Additional details on these metrics, including a detailed list of average percent errors (APEs) and mean absolute percent errors (MAPEs) for all analyses can be found in Appendix C.

Figure 6. Historical and Projected Statewide Supply of Teachers in Terms of Staff Counts, 2008–09 Through 2023–24



However, to the extent that there are many teachers serving in a part-time capacity, these projections will overstate the total amount of services actually provided by teachers. In fact, as is shown in Figure 7, total statewide teacher FTEs are expected to decline by 1,174 from 2013–14 through 2023–24, equal to a drop of 1.8 percent over the period (or an average of 0.2 percent per year).

Figure 7. Historical and Projected Statewide Supply of Teachers in Terms of FTEs, 2008–09 Through 2023–24



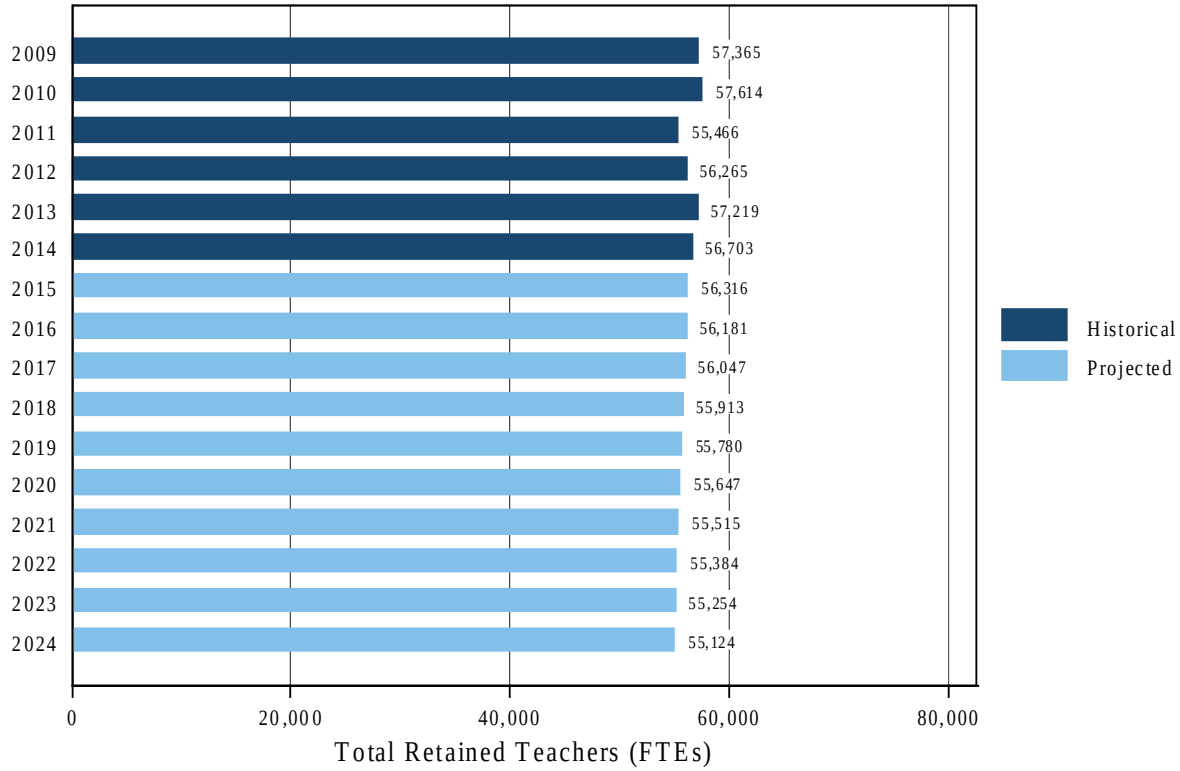
It is noteworthy that the teacher count and FTE supply projections are trending in opposite directions. This difference is even visible in the historical data, where in 2013–14 the number of FTEs was around the historical average, while the number of teachers measured by staff counts was at its historical maximum. This difference may suggest an increase in the number of part-time teachers over time or more generally a decrease in the average teacher caseload.[10]

Retention

It may be helpful for policymakers to consider from what sources the overall projected supply is expected to come, and if the projected trends in these supply components differ. Retained teachers are one such component. As can be seen in Figure 8, retained teachers are expected to decline by 1,579 teacher FTEs from 2013–14 through 2023–24 (equal to a 2.8 percent drop over the period, or 0.3 percent per year on average).

[10] Policymakers may want to further investigate this finding, perhaps through a more comprehensive study comparing teacher staff counts and FTEs not only over time but also across regions. For example, are prospective teacher preparation program candidates observing that teaching is increasingly becoming a part-time profession in particular regions of the state, and, if so, is this influencing their enrollment decision?

Figure 8. Historical and Projected Statewide Supply of Retained Teachers in Terms of FTEs, 2008–09 Through 2023–24



The fact that the projected trend for retained teachers is aligned with the aggregate supply projection trends is not surprising, given that retained teachers comprise a majority of overall teacher supply; this analysis finds that the share of statewide teacher supply made up by retained teachers remains relatively constant over time, averaging 85.2 percent over the historical period 2008–09 through 2013–14. Therefore, the trend in retained teachers will tend to drive the aggregate trend in teacher supply.

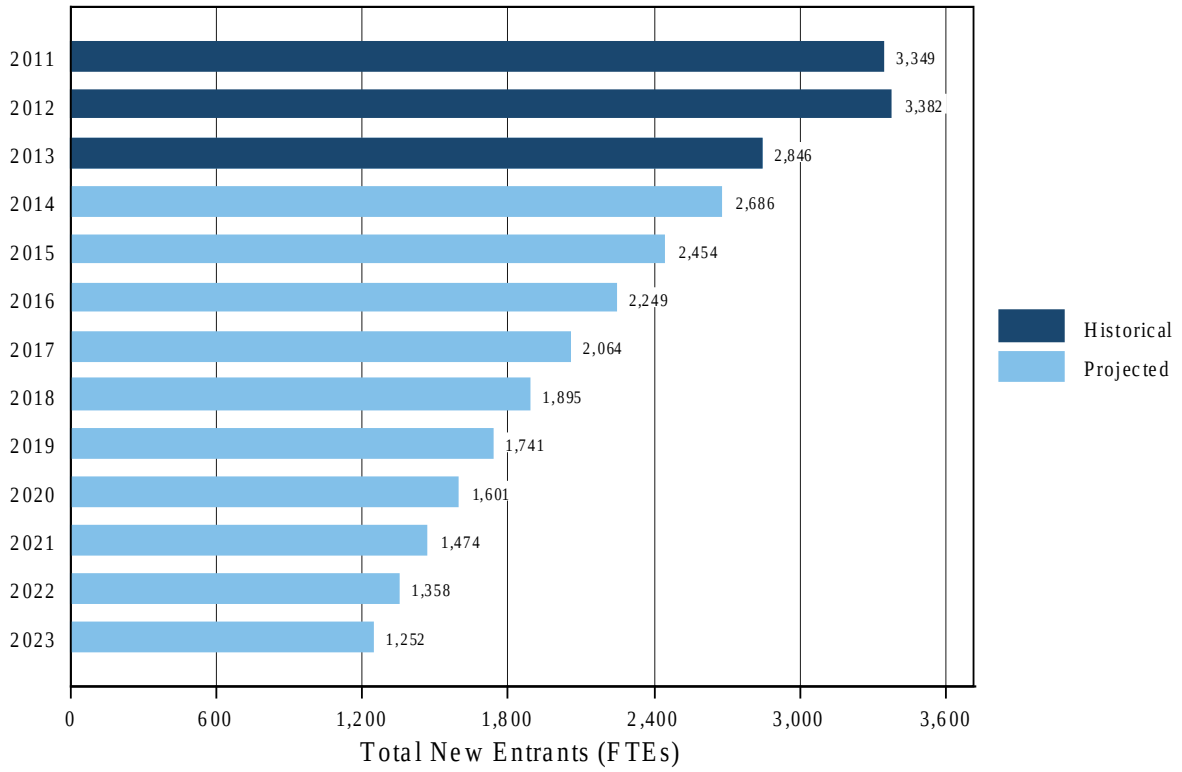
While retained teacher FTEs are expected to decline, this change is very slight. Nonetheless, underlying this statewide aggregate trend is a collection of district-level trends that may vary widely. In particular, districts serving large populations of high-need students may, in fact, be facing greater retention challenges than the aggregate results suggest. Policymakers may want to consider further investigation of differential retention trends by district student needs to better understand potential retention challenges that exist in the state.

New Entrants

The results of this analysis show a projected trend of newly entering teachers that is decreasing over time (Figure 9). Specifically, the number of new entrant teacher FTEs is expected to decline by 1,594 from 2012–13 through 2022–23 (equal to 56.0 percent over the period, or 7.9 percent per year, on average). Moreover, new entrants are projected to make up an increasingly smaller share of overall teacher supply. Over the three-year period for which there is have historical data (2010–11 through 2012–13), new entrants accounted on average for 4.8 percent of all teachers. In 2014–15, new entrants are expected to make up approximately 3.7 percent of the overall

yearly supply of teachers. By 2022–23, the share of supply made up by new entrants is expected to fall to around 1.8 percent, a drop of 3 percentage points from the historical average.

Figure 9. Historical and Projected Statewide Supply of New Entrant Teachers in Terms of FTEs, 2008–09 Through 2023–24



Although the results suggest dramatic decreases in the FTEs of newly entering teachers in coming years, it is important to keep in mind that these findings are based on only three years of historical data. Moreover, the district-level estimates of new entrants are based on several assumptions, which is cause to interpret the specific figures with caution.[11] Nonetheless, given these results, policymakers may want to monitor the number of newly entering teachers over the next few years. If new entrants do start declining as the analysis suggests, this may be cause for policy action. While new entrants represent the smallest share of supply for any given year, depressed numbers of new entrants year after year will have cumulative effects on the supply of teachers over time.

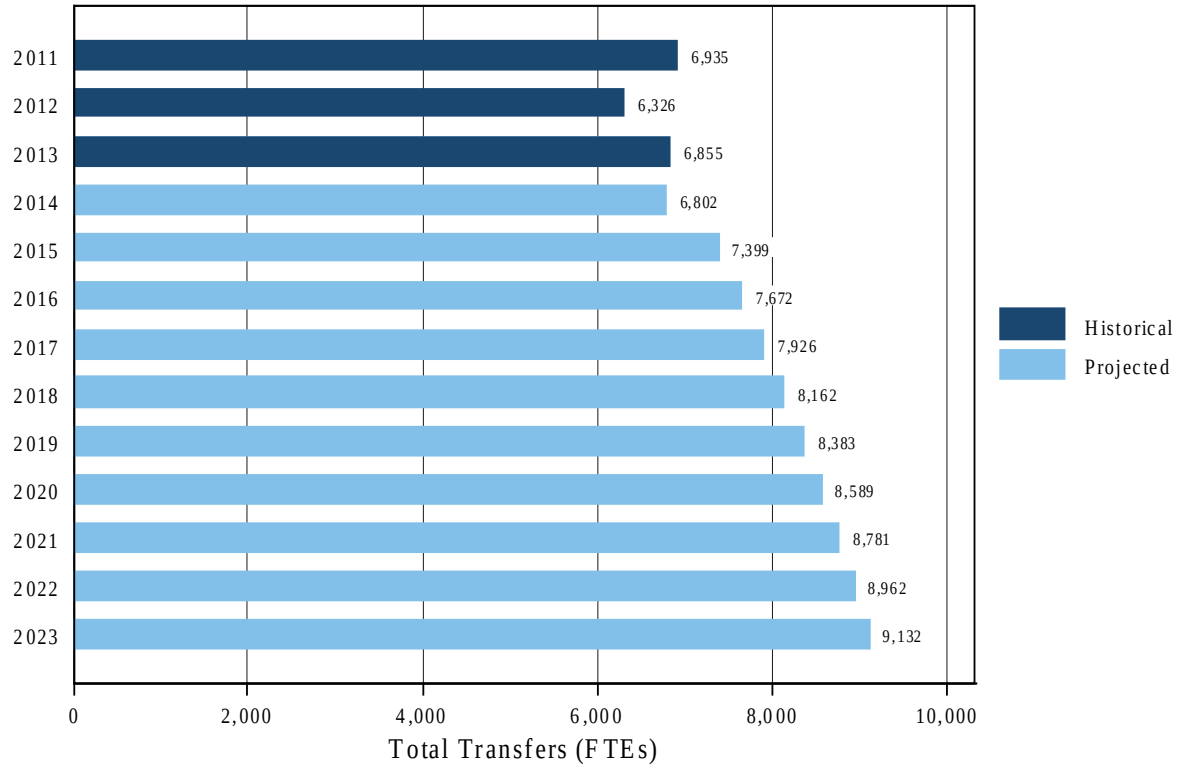
Because retention—as a percentage of total teachers—has remained relatively constant over time, the recent decline in new entrants has likely been offset by teachers either transferring across districts or into the state from somewhere else (e.g., other states, private schools). If trends persist, it is expected this will also be the case in future years. Therefore, policymakers also may want to consider this third component of supply in any policy discussions about the pipeline of teachers.

[11] See the Data and Methods section for additional detail on the assumptions underlying the projections.

Transfers

The analysis findings suggest that there will be an increasing trend in the number of transfer teacher FTEs over the coming years (Figure 10). Specifically, the number of transfer FTEs is expected to increase by 2,277, or 33.2 percent from 2012–13 through 2022–23. Over the historical period from 2010–11 to 2012–13, transferring teachers made up 10.1 percent of the overall supply of teacher FTEs, on average. However, by 2022–23 the share of supply made up by transferring teachers is expected to grow by almost 3 percentage points, to more than 12.9 percent.

Figure 10. Historical and Projected Statewide Supply of Transferring Teachers in Terms of FTEs, 2008–09 Through 2023–24



This component of supply is the only group for which no raw data were readily available. Given that transferring teachers are projected to increase the fastest among the three supply components, a better understanding of this group would be tremendously beneficial. For example, it would be good to know to what extent this supply component is composed of teachers transferring across districts within the state, rather than entering from outside the state's public education sector (e.g., from outside the state or another sector). The first group represents a reshuffling of the existing pool of teachers, while the second group represents new or returning teaching staff. This distinction is important to understand as this reshuffling may place a burden on high-need districts (i.e., lower performing, high poverty), which are left trying to find replacement teachers for those who choose to transfer. On the other hand, teachers coming from out of state or from the within-state reserve pool add to the effective supply of teachers. If a large number of teachers are coming from these sources, then the drop in new entrants may not be as troubling. Policymakers may want to consider investigating this issue further, possibly through a

comprehensive study of teacher mobility, which would identify more detailed trends in transfers across districts or even across schools. The results of such a study could inform any statewide strategies concerning teacher supply and contribute to a better overall understanding of sources of teacher supply across the state.

Validity of Results

The AIR research team conducted a number of tests to determine the validity of the estimated supply projections. Specifically, the AIR team considered the average percent errors (APEs) and mean absolute percent errors (MAPEs) for all supply projections based on a comparison of actual and projected values. The AIR team also considered the 95 percent confidence intervals around the supply projections, including overall teacher supply (in terms of both FTEs and staff counts), as well as new entrants and retained teachers (staff counts only).[12]

Average Percent Errors (APEs) and Mean Absolute Percent Errors (MAPEs)

When projected and actual supply estimates in historical years were compared, it was found that, in general, there was very little error in any supply projections. Specifically, all of the MAPEs were well below the 7.5 percent threshold.[13] In terms of bias, most of the supply components had a downward bias, suggesting that these projections may be under-predicting supply in future years. The only exception was for new entrants, which had an upward bias, possibly suggesting an over-prediction of the number of new entrants. These biases could have implications on the analysis comparing supply and demand, and thus on any expected shortages or surpluses.

Confidence Intervals

As an additional test of the error in projections, the AIR research team also considered the 95 percent confidence intervals around the district average supply projections. It was found that for most analyses, the supply projections more than tripled from 2014–15 to 2023–24. These results suggest that there should be less confidence in the projections farther out in projected years. However, the relative sizes of the intervals were generally modest for most projections in the final projected year.[14]

[12] Due to the fact that transfers are calculated deterministically by backing out the figures using the estimated overall teacher supply and retained and new entrant components, there are no confidence intervals to consider for this component of supply.

[13] There is no industry standard for an acceptable amount of bias and inaccuracy that the AIR research team is aware of, although others have suggested some guidelines. On the one hand, Berk and Hodgins (2008) suggested that an MAPE of more than 10 percent indicate that future projections should be interpreted with caution. On the other hand, the Minnesota Teacher Supply and Demand Report (Minnesota Department of Education, 2015) found that for three- and five-year enrollment projections, the best method tested produced MAPEs no higher than 5 percent. With these reports in mind, the AIR research team has chosen to consider a MAPE of 7.5 percent high enough to warrant caution.

[14] Additional details on validation testing and these metrics can be found in Appendix C.

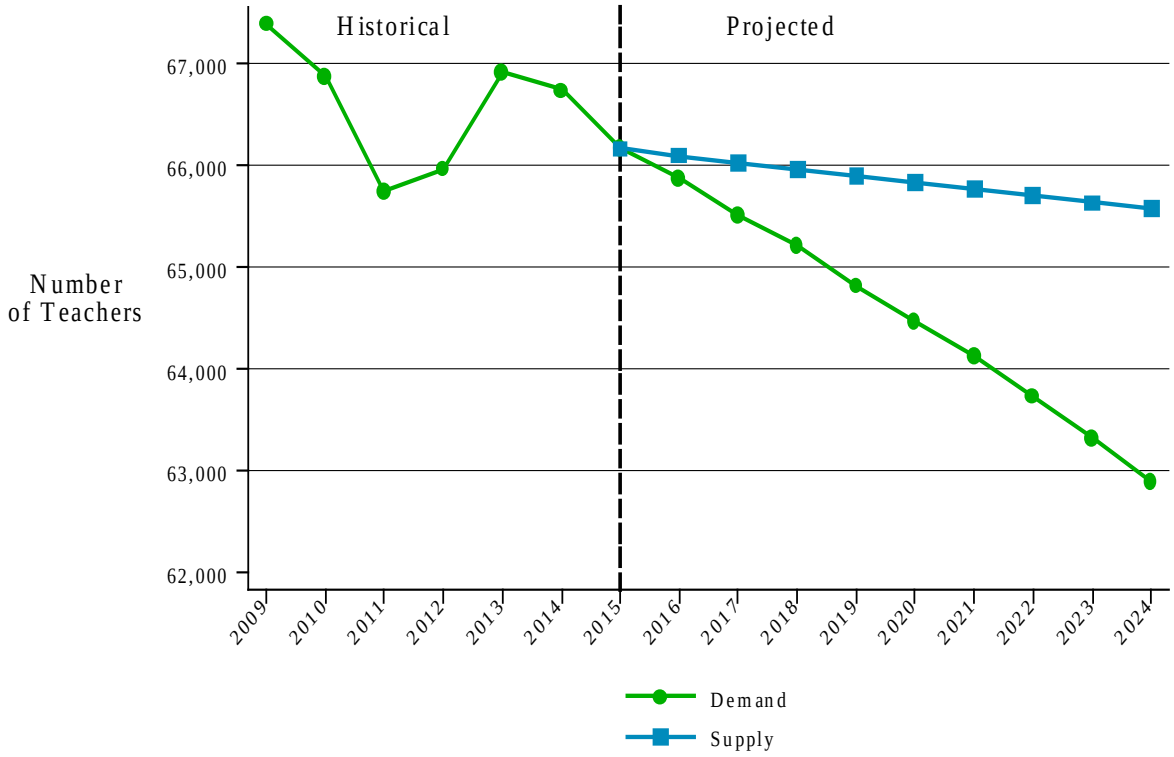
Research Question 1 and 2: Comparing Aggregate Supply and Demand

In an effort to determine whether statewide shortages or surpluses of teachers are expected, the AIR research team compared the aggregate supply and demand projections, displayed in Table 4 and Figure 11. The findings suggest that it should expected to see a surplus of overall teacher FTEs on the order of 228 (or 0.35 percent in relative terms) starting in 2015–16, which will steadily increase to 2,677 FTEs (or 4.26 percent in relative terms) by 2023–24.

Table 4. Projected Statewide Demand and Supply of Teachers in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	66,169	66,177	-8	-0.01%
2015–16	66,103	65,875	228	0.35%
2016–17	66,036	65,514	522	0.80%
2017–18	65,970	65,218	752	1.15%
2018–19	65,904	64,824	1,080	1.67%
2019–20	65,837	64,467	1,370	2.13%
2020–21	65,771	64,129	1,642	2.56%
2021–22	65,704	63,733	1,971	3.09%
2022–23	65,638	63,319	2,319	3.66%
2023–24	65,572	62,895	2,677	4.26%

Figure 11. Historical and Projected Statewide Supply and Demand for Teachers in Terms of FTEs, 2008–09 Through 2023–24



These results suggest that the state will experience a statewide surplus of teachers over most of the next 10 years, which may be encouraging to policymakers. However, it is important to bear in mind that these reported trends in demand and supply are an aggregate of many varied trends at the district level. There may, in fact, still be inequitable access to teachers in specific districts, and while surpluses may be clustered in particular districts, others may face shortages. This question may be partially answered with the results from Research Question 5, which examines these trends by DSAC regions, locales, areas surrounding the IHEs (which are the largest producers of newly prepared teachers), and major metropolitan areas.

Research Question 3: Detailed Supply and Demand Projections by Program Area

What are the projections for the annual supply and demand of teachers in Massachusetts for the next 10 years by program area?

While considering demand and supply projections in the aggregate can be a valuable overall gauge of potential teacher shortages or surpluses, it can also mask different demand and supply trends that exist across a variety of categories of teachers. To illuminate this potential variation, for Research Question 3, the AIR research team considered how these trends in demand and supply vary for teachers in different program areas.

In particular, we estimated the projected demand for teachers in general education (GenED), special education (SPED), career/vocational/technical education (CTE), and English language

learner education (ELL), respectively. This section reports on key findings from these analyses, including projected future trends in demand, as well as projections over time for SPED and ELL teachers.

The AIR research team also estimated supply for teachers in each program area; this section reports on projected future trends in supply over time.[15] In addition, this section reports on the comparison of demand and supply by program area, including program areas expected to experience surpluses and shortages. Finally, there are reports on the validity of these results based on a comparison of actual and projected values created with historical data, and a review of the 95 percent confidence intervals surrounding the regression-based estimates of the team's projections.[16]

Demand Projections by Program Area

The AIR team first estimated demand projections by program area. Table 5 displays the average projected percent change in statewide demand for each program area between 2013–14 and 2023–24, and the overall projected percent and absolute changes over this same time period. As is shown in the table, AIR projects that demand will decline for all four program areas, following the aggregate trend, though there is variation in the magnitude of the projected decline across the areas. For example, demand for CTE teachers[17] is expected to decline the most in relative terms, dropping by 19.10 percent in total over this time period, while demand for GenED teachers is only projected to decline by 3.83 percent. It may be useful to keep in mind differences in the number of teachers in each program area. For example, though GenED teacher demand is expected to decline far less in relative terms than SPED teacher demand, in *absolute* terms the declines are larger for GenED versus SPED (2,101 and 1,173, respectively).

Table 5. Projected Percent and Absolute Changes in Statewide Demand by Program Area, 2014–15 Through 2023–24

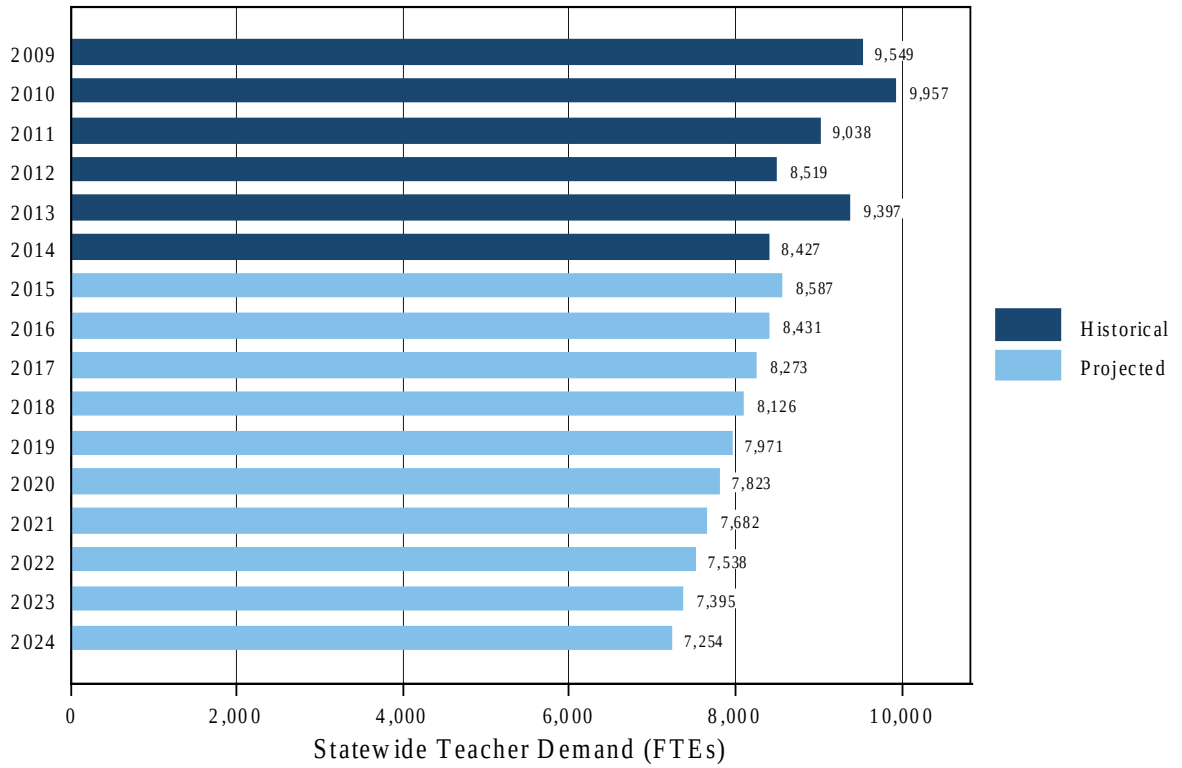
Program Area	Average Annual Percent Change 2013–14 Through 2023–24	Overall Percent Change 2013–14 Through 2023–24	Overall Absolute Change 2013–14 Through 2023–24
General Education	-0.39%	-3.83%	-2,101
Special Education	-1.48%	-13.91%	-1,173
English Language Learners	-1.37%	-12.91%	-197
Career/Vocational/ Technical Education	-2.10%	-19.10%	-370

When considering these projected trends alongside historical staffing trends in each program area, it is found that some program areas are relatively stable in historical years, while others tend to be more volatile. For example, as can be seen in Figures 12 and 13, the historical staffing

[15] The AIR team also estimated projections of retained teachers by program area. See Appendix B for additional findings.
[16] Additional exhibits displaying Research Question 3 findings not presented in this report, including figures and tables, are available upon request.
[17] Please note that throughout this section when "teachers" are referred to, the reference is to FTEs, not staff counts.

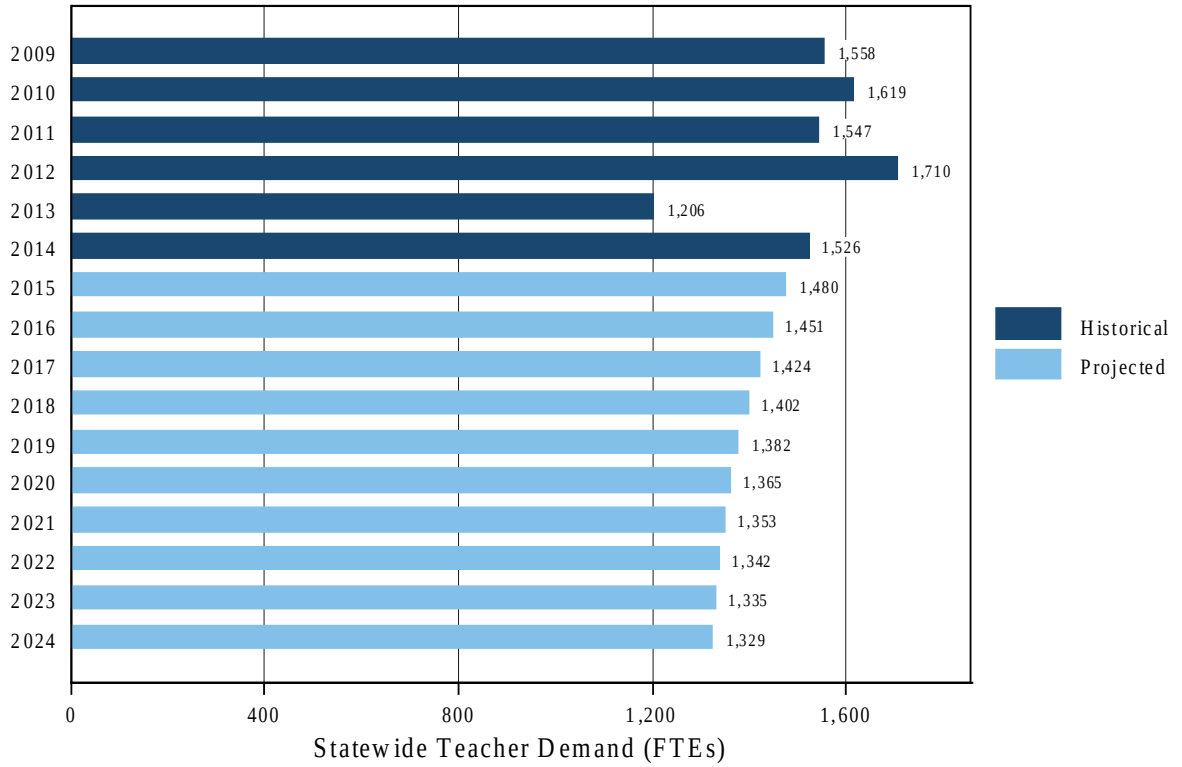
trends for SPED and ELL teachers are quite volatile. Over the last six years, SPED FTEs have ranged between 8,427 (2013–14) and 9,957 (2009–10). Likewise, ELL FTEs have ranged between 1,206 (2012–13) and 1,710 (2011–12) over the same period.[18]

Figure 12. Historical and Projected Statewide Demand for Special Education Teachers in Terms of FTEs, 2008–09 Through 2023–24



[18] It should be noted that because these projections are based on an average historical trend, the AIR team sees gradual changes in future years. An inherent limitation to the method AIR used is not being able to accurately forecast future shocks, but it is, for the most part, an unavoidable limitation. Without a clear understanding of the observed historical shocks, the most conservative thinking is to assume that these trends will smooth out in future years and approach the average.

Figure 13. Historical and Projected Statewide Demand for English Language Learner Teachers in Terms of FTEs, 2008–09 Through 2023–24



Despite the observed volatility, these results suggest that demand for SPED and ELL teachers will decline in future years, in some cases quite dramatically. Policymakers may want to investigate further to determine how these projected declines are distributed across the state, possibly by partnering with districts to better understand needs with respect to program area.

Supply Projections by Program Area

The AIR research team also estimated projections of teacher supply by program area. Table 6 displays the average projected percent change in statewide teacher supply for each program area between 2013–14 and 2023–24, and the overall projected percent and absolute changes over the same period. As shown in the table, projected supply will decline for the majority of program areas, following the aggregate trend. In relative terms, the supplies of ELL and SPED teachers are expected to decline the most over the period, 26.44 and 20.43 percent, respectively. CTE teacher supply is also expected to decline, but less severely in relative terms, at 7.86 percent. While the supply of teachers in the three specialized program areas is expected to decline, based on AIR's projections, the supply of GenED teachers is actually expected to grow 7.19 percent over the next 10 years.[19]

[19] This is noteworthy because findings in Research Question 2 suggested that FTEs are projected to decline but that staff counts are actually projected to increase. The fact that GenED FTEs are following the staff count trend may suggest that relatively few GenED teachers are serving at less than one FTE, or, conversely, that SPED, CTE, and ELL teachers are more likely to serve in a part-time capacity.

Table 6. Projected Percent and Absolute Changes in Statewide Supply by Program Area, 2014–15 Through 2023–24

Program Area	Average Annual Percent Change 2013–14 Through 2023–24	Overall Percent Change 2013–14 Through 2023–24	Overall Absolute Change 2013–14 Through 2023–24
General Education	0.70%	7.19%	3,945
Special Education	-2.26%	-20.43%	-1,722
English Language Learners	-3.04%	-26.44%	-403
Career/Vocational/ Technical Education	-0.81%	-7.86%	-152

One interpretation of the program-area specific supply projections is that future declines in teacher supply are expected to be primarily among non-GenED teachers. See Appendix B for additional findings from this analysis.

Comparing Supply and Demand by Program Area

In an effort to determine if there are expected shortages or surpluses in any particular program area in future years, the AIR research team compared the supply and demand projections for each year through 2023–24.

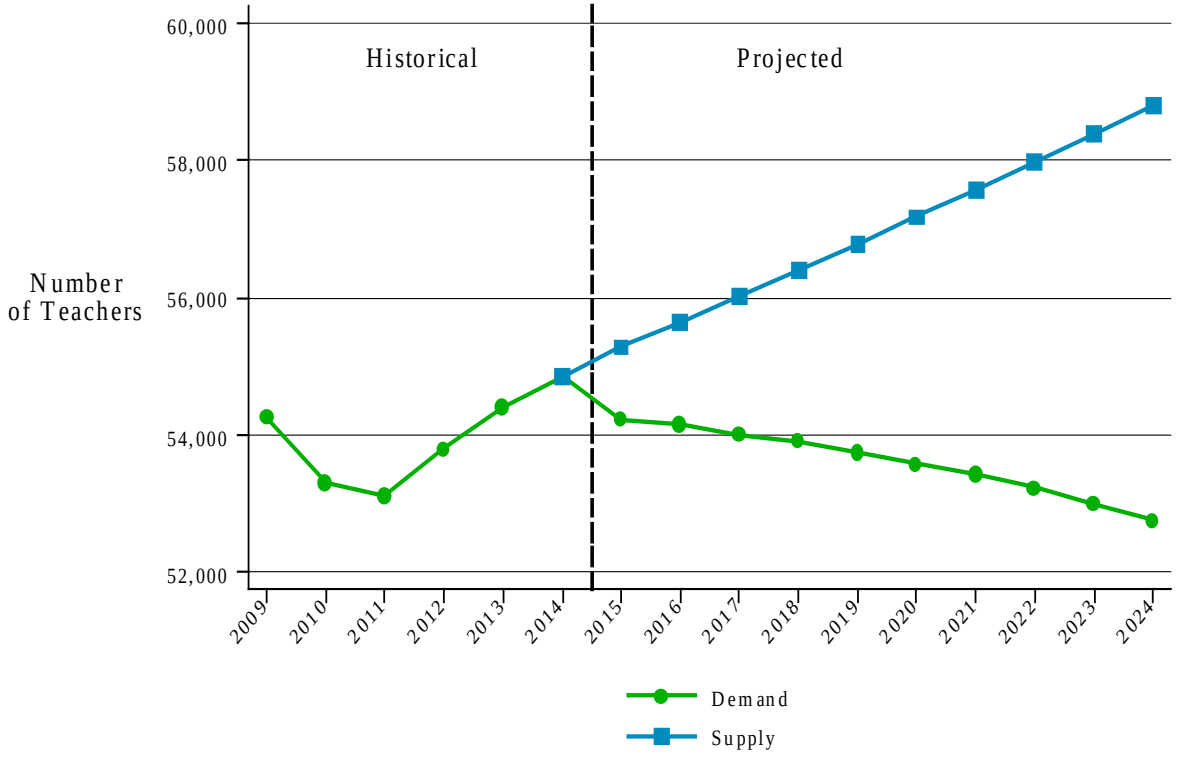
Expected Surpluses

For those program areas expected to experience a surplus (i.e., GenED and CTE), it was found that projected surpluses tend to grow over time. The demand for GenED teachers is projected to decline over the next 10 years, while supply is projected to grow. Consequently, as shown in Table 7 and Figure 14, there is an expected statewide surplus of 1,058 FTEs (supply exceeds demand by 1.95 percent) in 2014–15, which is projected to grow to 6,046 FTEs (11.46 percent) by 2023–24.

Table 7. Projected Statewide Demand and Supply of General Education Teachers in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	55,276	54,218	1,058	1.95%
2015–16	55,644	54,138	1,506	2.78%
2016–17	56,017	54,001	2,016	3.73%
2017–18	56,396	53,910	2,485	4.61%
2018–19	56,780	53,731	3,049	5.67%
2019–20	57,170	53,573	3,597	6.71%
2020–21	57,566	53,423	4,143	7.76%
2021–22	57,968	53,217	4,751	8.93%
2022–23	58,377	52,988	5,388	10.17%
2023–24	58,791	52,745	6,046	11.46%

Figure 14. Historical and Projected Statewide Supply and Demand for General Education Teachers in Terms of FTEs, 2008–09 Through 2023–24

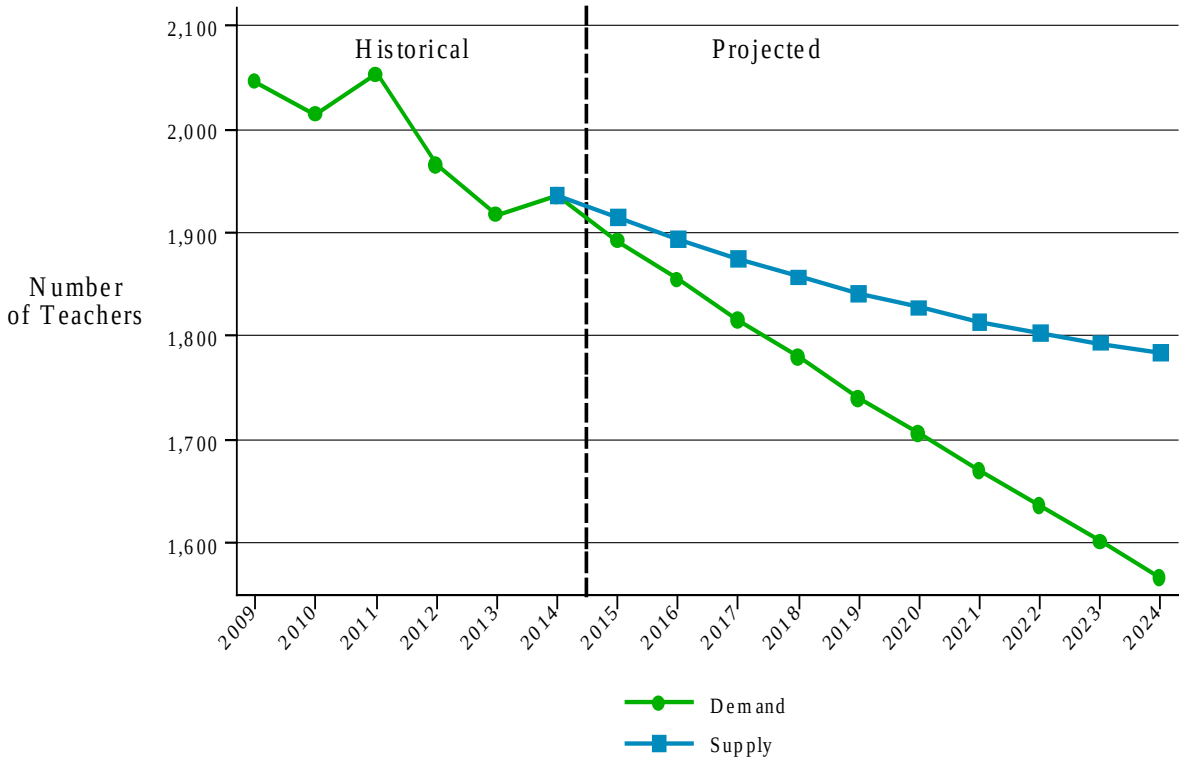


In contrast, both the demand and supply of CTE teachers are projected to decline over the next 10 years, but at differing rates. As shown in Table 8 and Figure 15, there is an expected surplus of 22 FTEs (1.16 percent) in 2014–15 that is projected to grow to 218 FTEs (13.89 percent) by 2023–24.

Table 8. Projected Statewide Demand and Supply of Career/Vocational/Technical Education Teachers in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	1,914	1,892	22	1.16%
2015–16	1,893	1,855	39	2.09%
2016–17	1,874	1,815	59	3.25%
2017–18	1,857	1,779	77	4.35%
2018–19	1,841	1,740	101	5.80%
2019–20	1,827	1,706	121	7.09%
2020–21	1,814	1,671	143	8.55%
2021–22	1,803	1,636	166	10.17%
2022–23	1,793	1,601	191	11.94%
2023–24	1,784	1,567	218	13.89%

Figure 15. Historical and Projected Statewide Supply and Demand for Career/Vocational/Technical Education Teachers in Terms of FTEs, 2008–09 Through 2023–24



These surpluses may suggest that recruitment and retention is healthy among teachers in these program areas, and no additional support will be needed if historical trends persist. However, any shock in future years, such as a change in statewide policy or a large staffing change (e.g., offers for early retirement, reductions in force) could certainly impact these results. This is especially

important to keep in mind for CTE teachers, who make up a very small part of the teacher workforce and therefore may be more affected by any shocks or policy decisions regarding CTE education. In addition, the statewide projections presented here represent an aggregation of individual district-level projections. It is possible that, although statewide there is an expected surplus, there may be individual districts that will experience shortages.

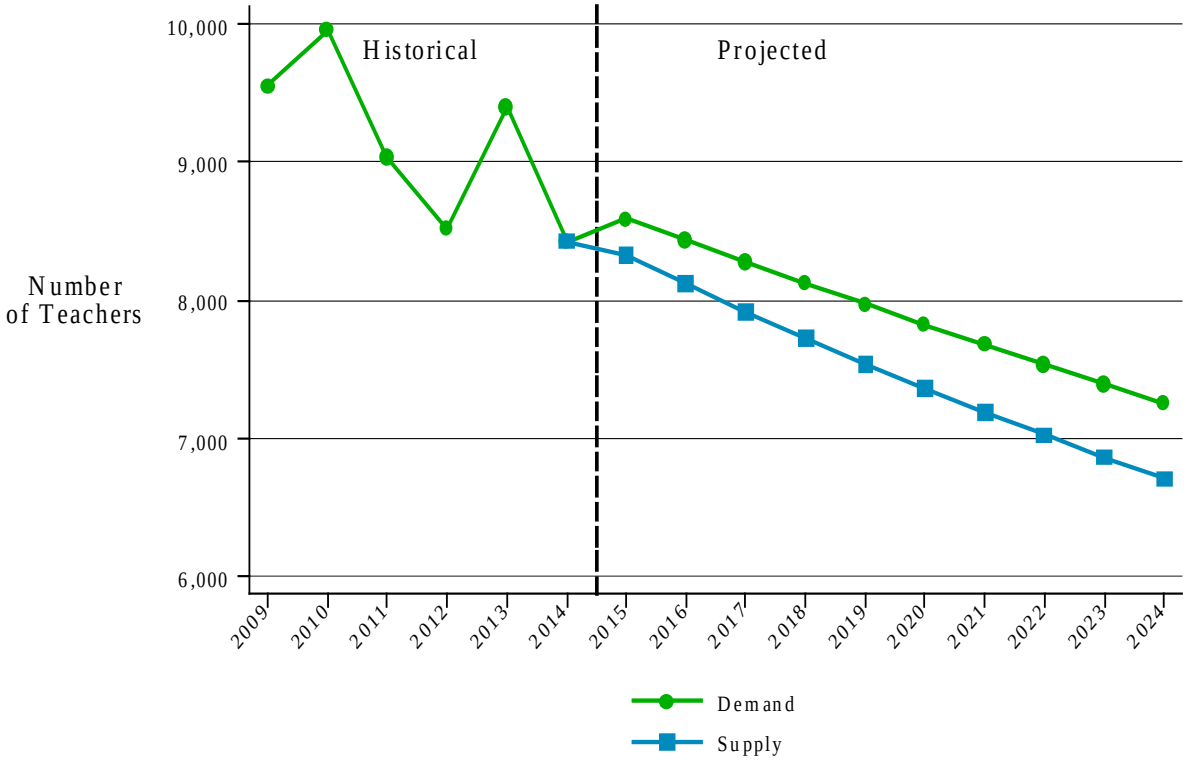
Expected Shortages

For those program areas expected to experience a shortage (i.e., SPED and ELL), the AIR research team found that the projected shortages tend to grow over time. Both the demand and supply for SPED teachers is projected to decline over the next 10 years, but supply is expected to decline at a faster rate. Specifically, there is an expected statewide shortage of 262 FTEs (3.06 percent) in 2014–15 that is projected to grow to 549 FTEs (7.57 percent) by 2023–24 (Table 9 and Figure 16). The projected rapid decline in both supply and demand of SPED teachers is striking. In many ways the decline in supply is more reasonable than the decline in demand, which will be driven largely by the number of special education students, which is expected to decline at a rate similar to the general population of students. If that decline in demand is overstated, the projected shortage could be greater than presented here.

Table 9. Projected Statewide Demand and Supply of Special Education Teachers in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	8,324	8,587	-262	-3.06%
2015–16	8,115	8,431	-317	-3.76%
2016–17	7,913	8,273	-360	-4.35%
2017–18	7,720	8,126	-406	-5.00%
2018–19	7,534	7,971	-437	-5.48%
2019–20	7,355	7,823	-468	-5.98%
2020–21	7,183	7,682	-499	-6.50%
2021–22	7,018	7,538	-520	-6.90%
2022–23	6,858	7,395	-536	-7.25%
2023–24	6,705	7,254	-549	-7.57%

Figure 16. Historical and Projected Statewide Supply and Demand for Special Education Teachers in Terms of FTEs, 2008–09 Through 2023–24

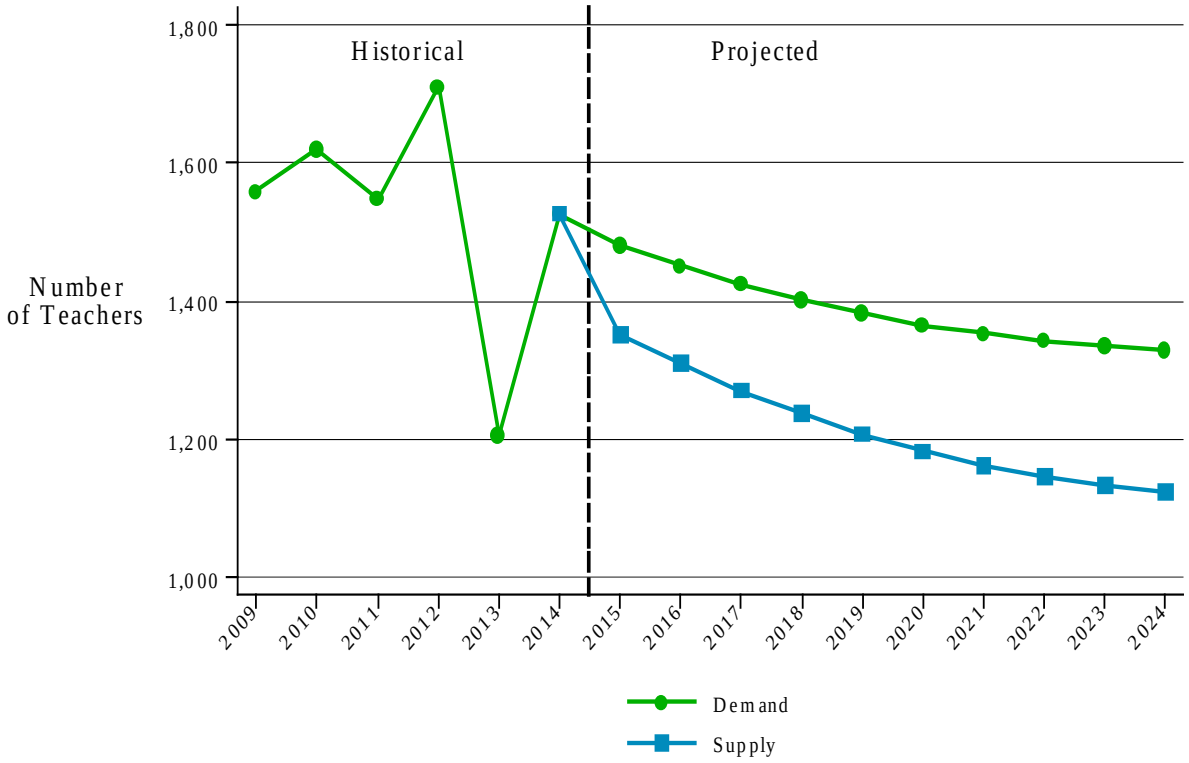


Similarly, both the demand and supply of ELL teachers are projected to decline over the next 10 years, but at differing rates. Specifically, there is an expected shortage of 128 FTEs (8.68 percent) in 2014–15 that is projected to grow to 207 FTEs (15.54 percent) by 2023–24 (Table 10 and Figure 17).

Table 10. Projected Statewide Demand and Supply of English Language Learner Education Teachers in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	1,352	1,480	-128	-8.68%
2015–16	1,309	1,451	-142	-9.80%
2016–17	1,270	1,424	-154	-10.81%
2017–18	1,237	1,402	-166	-11.81%
2018–19	1,207	1,382	-174	-12.63%
2019–20	1,182	1,365	-183	-13.38%
2020–21	1,162	1,353	-191	-14.14%
2021–22	1,145	1,342	-198	-14.72%
2022–23	1,132	1,335	-203	-15.20%
2023–24	1,123	1,329	-207	-15.54%

Figure 17. Historical and Projected Statewide Supply and Demand for English Language Learner Education Teachers in Terms of FTEs, 2008–09 Through 2023–24



These shortages may suggest that statewide support to recruit and retain SPED and ELL teachers is needed. This finding for SPED teachers is in line with findings in previous workforce reports conducted in Massachusetts (ESE 2011; 2013). However, both of these program areas experienced quite a bit of volatility in the past six years, and these projections are by design based on an average trend and will not project similar shocks. Therefore, if the volatility seen in historical years can be expected in future years, there are limits to what inferences can be drawn from these projections. Shocks in future years could also affect the accuracy of results for GenED and CTE teachers. Moreover, the projections presented here also represent an aggregation of projections at the district level, and so, although statewide there is a net shortage, there may be variation in the needs of individual districts.

To the extent that policymakers intend to pursue strategies for recruiting teachers in particular program areas, they may want to further investigate the root cause of the observed shocks in SPED and ELL historical data. In addition, they may want to engage with districts to better understand whether experiences are aligned with statewide trends. In particular, districts that tend to serve a larger population of SPED and ELL students typically also serve large populations of low-income students. These districts may face much greater shortages than is discernable from aggregate trends.

Validity of Results

Demand Projections

The AIR research team conducted a number of tests to determine the validity of the estimated demand and supply projections by program area. Specifically, the team considered the average percent errors (APEs) and mean absolute percent errors (MAPEs) for both demand and supply projections based on a comparison of actual and projected values obtained with historical data, as well as the 95 percent confidence intervals around the predicted proportions that drive the demand projections, and the 95 percent confidence intervals around the predicted supply projections for districts on average.

Average Percent Errors (APEs) and Absolute Percent Errors (MAPEs)

When the AIR team compared projected to actual demand estimates in the historical data, it was found that GenED projections had the lowest bias as measured by APEs and general error as measured by MAPEs, , at 0.1 and 0.5 percent, respectively. ELL projections had the largest APE and MAPE at 4.6 and 7.8 percent, respectively. Given that the MAPE was above 7.5 percent, these projections should be interpreted with caution. In terms of bias, GenED, CTE, and ELL projections appear to be over-predicting demand, on average, while SPED projections appear to be under-predicting demand. This could have implications for the identified shortages and surpluses. On the one hand, if demand is over-predicted, then it is possible to infer shortages may be smaller and surpluses larger. On the other hand, because SPED demand is under-predicted, on average, it is possible to infer that the expected shortages may, in fact, be larger than reported.

Confidence Intervals

Similar to the findings for the aggregate supply projections, confidence intervals around the demand proportion projections by program area grew substantially from 2014–15 to 2023–24. Given the large growth in intervals over time, the AIR research team suggests that the earlier years of projections should be relied on more heavily in any discussions of policy implications. Moreover, in the first projected year, all intervals are generally modest in size, with only ELL teachers rising above +/- 10 percent. However, by the final projected year the intervals are quite large for both CTE and ELL teachers. This further supports the notion that over time one should be less confident in the projections, especially for CTE and ELL teachers.

Supply Projections

The AIR research team next calculated the APEs and MAPEs by program area by using predicted and actual supply in historical years. In addition, the AIR team evaluated the 95 percent confidence intervals around district average program area supply estimates.

Average Percent Errors (APEs) and Absolute Percent Errors (MAPEs)

When the AIR research team compared projected and actual demand estimates in historical years, it was found that, as was the case with the proportion projections, GenED projections have the lowest APE and MAPE, at less than 0.1 percent and 0.4 percent respectively, and ELL projections have the largest, 1.3 and 8.4 percent, respectively. Given that the MAPE for ELL is

above 7.5 percent, these projections should be interpreted with caution. In terms of bias, all program area supply projections appear to be over-predicting, on average, based on the direction of the APEs (all positive). This could have implications for the identified shortages and surpluses. However, since, in general, demand projections also have an upward bias, the impact of the bias on the calculated supply demand differences (surplus/shortage) may be negligible. For example, if CTE teacher demand tended to over-predict by 0.6 percent, on average, and supply tended to over-predict by 0.5 percent, on average, than, although both may be higher than reported, the difference between the two would be largely unchanged. The exception to this are the SPED projections, which exhibit a downward bias for demand and an upward bias for supply, suggesting that the projected shortages may actually be larger than reported.

Confidence Intervals

As expected, the confidence intervals around the average supply estimates also grow consistently over the projected years. Specifically, it was found that intervals around the CTE supply estimates had the largest growth, nearly quadrupling over the projected years. On the other hand, the SPED and ELL confidence intervals grew least, although still substantially, almost doubling over projected years. Given the growth in intervals over time, the AIR research team suggests that the earlier years of projections be relied on more heavily in any discussions of policy implications. Moreover, when considering the relative size of the intervals, SPED, CTE, and ELL projections all have very large intervals in the final projected year, indicating less certainty in projected supply of teachers in these program areas.[20]

[20] Additional details on validation testing and these metrics can be found in Appendix C.

Research Question 4: Detailed Supply and Demand Projections by Race and Age

What are the supply and demand projections of teachers in Massachusetts for the next 10 years by demographic group?

The AIR research team first estimated projected demand for teachers in a variety of racial and ethnic categories. This section reports on key findings from these analyses, including estimated proportions of minority (i.e., non-White) teachers, and projected future trends in demand for minority (i.e., non-White) and White teachers.

The AIR team next estimated projected supply for teachers by race, including projections of all supply components by race.[21] This section reports key findings from these analyses, including a summary of projected trends in supply by race. In addition, this section reports on the comparison of demand and supply by race, including expected surpluses and shortages for minority and White teachers.

For the second part of this research question, the AIR research team estimated demand projections by age groups split into seven categories,[22] and key findings from those analyses are presented here by age category. In addition, projected supply for teachers by age was estimated, including projections of all supply components by age. These supply projections also are summarized in this section. In addition, this section reports on the comparison of demand and supply by age, including expected surpluses and shortages for teachers in each age category.

Finally, this section reports on the validity of these results based on a comparison of actual and projected values derived from historical data, and presents the 95 percent confidence intervals surrounding the regression-based estimates.[23]

Research Question 4a: Demand and Supply Projections by Race

Demand Projections by Race

The AIR research team first estimated demand projections by the race of the teacher. As outlined in the Data and Methods section, in order to do this, regression models were used to predict proportions of teachers[24] by race, and these proportions were applied to the demand estimates in Research Question 1. Projections were initially tested in each of the race categories, but it was found that projections for the individual categories were not reliable. The research team determined that projecting a combined minority category instead was more appropriate. This

[21] The data available for this study included the following seven race categories: (1) African American, (2) Asian, (3) Hispanic, (4) Native American, (5) Native Hawaiian, (6) Pacific Islander, (7) multi-race, non-Hispanic, and (7) White.

[22] The seven age categories are as follows: (1) under 26, (2) 26–32, (3) 33–40, (4) 41–48, (5) 49–56, (6) 57–64, and (7) over 64.

[23] Additional exhibits displaying Research Question 4 findings not presented in this report, including figures and tables, are available upon request.

[24] Please note that throughout this section when "teachers" are referred to, the reference is to FTEs, not staff counts.

lack of reliability may be due in part to the fact that all minorities made up only 2.8 percent of all teachers in Massachusetts, on average, over the past six years.

As can be seen in Table 11, the share of teachers who are minority is expected to increase over time to approximately 3.3 percent of the active teaching workforce by 2023–24. This is met by an expected complementary decline in White teachers.

Table 11. Projected Percent of Minority and White Teachers, 2014–15 Through 2023–24

Year	Percent Minority Teachers	Percent White Teachers
2014–15	2.92%	97.08%
2015–16	2.96%	97.04%
2016–17	3.01%	96.99%
2017–18	3.05%	96.95%
2018–19	3.09%	96.91%
2019–20	3.14%	96.86%
2020–21	3.18%	96.82%
2021–22	3.23%	96.77%
2022–23	3.28%	96.72%
2023–24	3.33%	96.67%

As expected, and as seen in Table 12, this increase in the share of minority teachers over time amounts to an increase in demand of 0.90 percent per year, or 9.34 percent in total between 2013–14 and 2023–24. This results in an absolute expected increase of 405 minority teachers over a period in which it is projected that numbers of teachers overall will decrease. During the same time period, the demand for White teachers is expected to decline by more than 4,200.

Table 12. Projected Percent and Absolute Changes in Statewide Demand by Teacher Race, 2014–15 Through 2023–24

Race	Average Annual Percent Change 2013–14 Through 2023–24	Overall Percent Change 2013–14 Through 2023–24	Overall Absolute Change 2013–14 Through 2023–24
All Minority	0.90%	9.34%	405
White	-0.70%	-6.81%	-4,250

The projected growth in demand in Table 12 assumes that the share of teachers who are of a minority race is a reasonable proxy of demand for these teachers. This assumption is supported by the fact that the expected increase in demand is consistent with statewide initiatives to increase the number of minority teachers (ESE, 2014). The results in Table 12 would seem to suggest that these efforts are seeing some success, at least in the aggregate. However, the historical trends on which these projections are based may also, in part, reflect shifts in the demographics of the teacher workforce that are driven by the racial makeup of both those leaving and entering the active pool of teachers. Policymakers may want to investigate population data and teacher mobility further to better understand the observed changing demographics.

Supply Projections by Race

In contrast to the demand results by race, supply by race is expected to decrease over time for both minority and White teachers. As can be seen in Table 13, the supply of minority teachers is expected to decline an average of 0.05 percent per year between 2013–14 and 2023–24, and 0.48 percent in total (equal to 21 minority teachers) over the same time period. White teachers, however, are expected to decrease at a faster rate than minority teachers, declining by 3,315 teachers (5.31 percent) over the time period. The expected result is an increase of the share of minority teachers over time, which is consistent with the estimated proportions used to calculate projected demand.

Table 13. Projected Percent and Absolute Changes in Statewide Supply by Teacher Race, 2013–14 Through 2023–24

Race	Average Annual Percent Change 2013–14 Through 2023–24	Overall Percent Change 2013–14 Through 2023–24	Overall Absolute Change 2013–14 Through 2023–24
All Minority	-0.05%	-0.48%	-21
White	-0.54%	-5.31%	-3,315

Comparing Supply and Demand Projections by Race

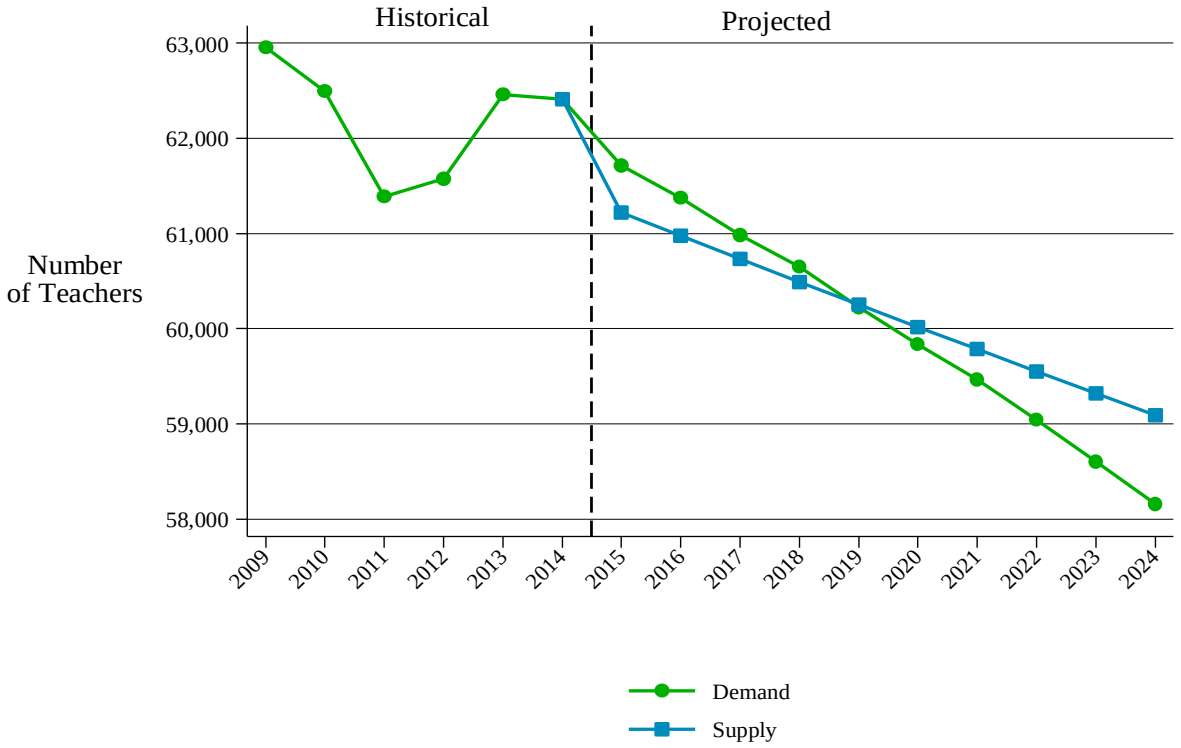
In an effort to determine if there are expected shortages or surpluses in minority or White teachers in future years, supply and demand projections for each were compared. It is expected there will be a surplus of White teachers and a shortage of minority teachers (Table 14 and Figure 18).

Specifically, for White teachers, the projections indicate a shortage of 496 teachers (-0.80 percent) in the first projected year, which is expected to shrink over the following two years. This is expected to change to a surplus in later projected years, where supply will increasingly exceed demand from a surplus of 30 (0.05 percent) teachers in 2018–19 to 934 (1.61 percent) in 2023–24.

Table 14. Projected Statewide Demand and Supply of White Teachers in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	61,219	61,715	-496	-0.80%
2015–16	60,975	61,376	-401	-0.65%
2016–17	60,732	60,981	-249	-0.41%
2017–18	60,492	60,648	-156	-0.26%
2018–19	60,254	60,224	30	0.05%
2019–20	60,017	59,838	179	0.30%
2020–21	59,783	59,465	318	0.53%
2021–22	59,551	59,041	510	0.86%
2022–23	59,321	58,602	719	1.23%
2023–24	59,093	58,159	934	1.61%

Figure 18. Historical and Projected Statewide Supply and Demand for White Teachers in Terms of FTEs, 2008–09 Through 2023–24



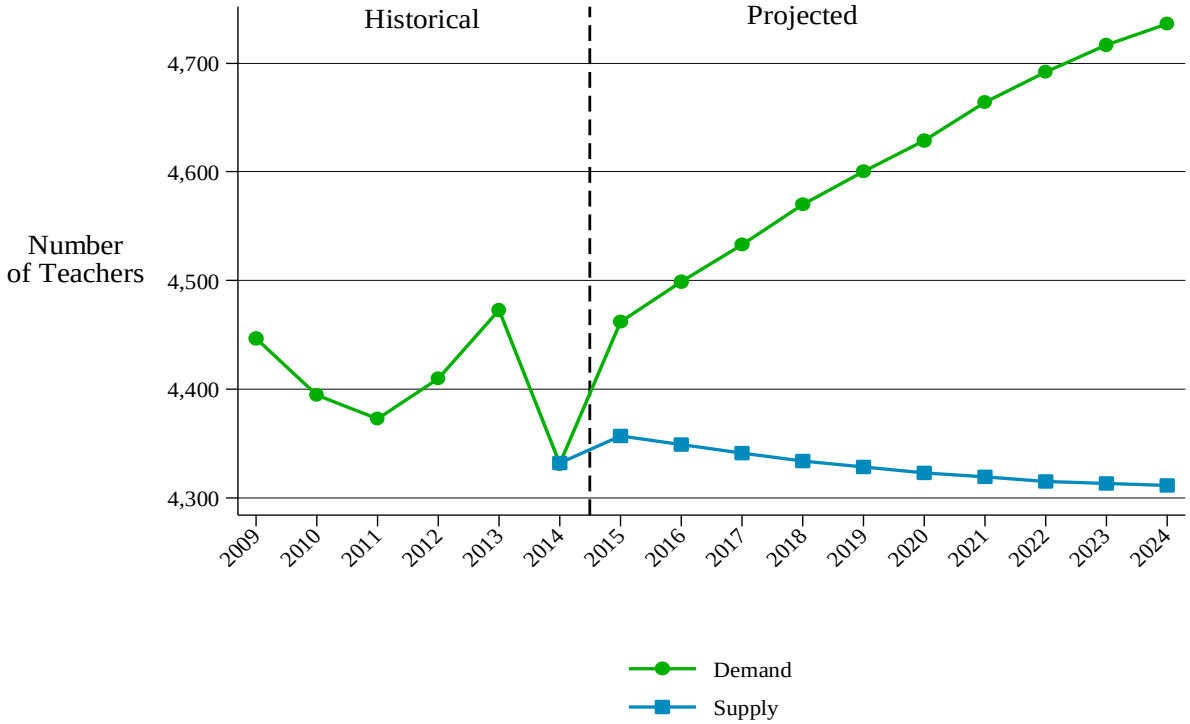
Given the relatively small size of the projected shortages and surpluses above, these results suggest that the demand and supply of White teachers will be relatively balanced over the projected years.

On the other hand, given that the demand for minority teachers is projected to increase, while supply is projected to decline, the AIR research team expects to see a slight shortage of minority teachers (Table 15 and Figure 19). Specifically, a shortage of 105 teachers in 2014–15 (2.35 percent) is projected, which will grow slightly to 425 teachers (8.98 percent) by 2023–24.

Table 15. Projected Statewide Demand and Supply of Minority Teachers in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	4,357	4,462	-105	-2.35%
2015–16	4,349	4,499	-150	-3.34%
2016–17	4,341	4,533	-192	-4.23%
2017–18	4,334	4,570	-236	-5.16%
2018–19	4,328	4,600	-272	-5.91%
2019–20	4,323	4,629	-307	-6.62%
2020–21	4,319	4,664	-345	-7.40%
2021–22	4,315	4,692	-376	-8.02%
2022–23	4,313	4,717	-405	-8.58%
2023–24	4,311	4,736	-425	-8.98%

Figure 19. Historical and Projected Statewide Supply and Demand for Minority Teachers in Terms of FTEs, 2008-09 Through 2023-24



The projected shortage of minority teachers appears largely due to the sharp projected increase in demand, given that there is a much smaller relative decline in expected supply of minority teachers. It is important to note that ESE seems to be concerned with this issue, given it is already implementing initiatives to increase the diversity of its teacher workforce. Moreover, this aggregate finding is in line with findings an earlier workforce report conducted in Massachusetts (ESE 2011).

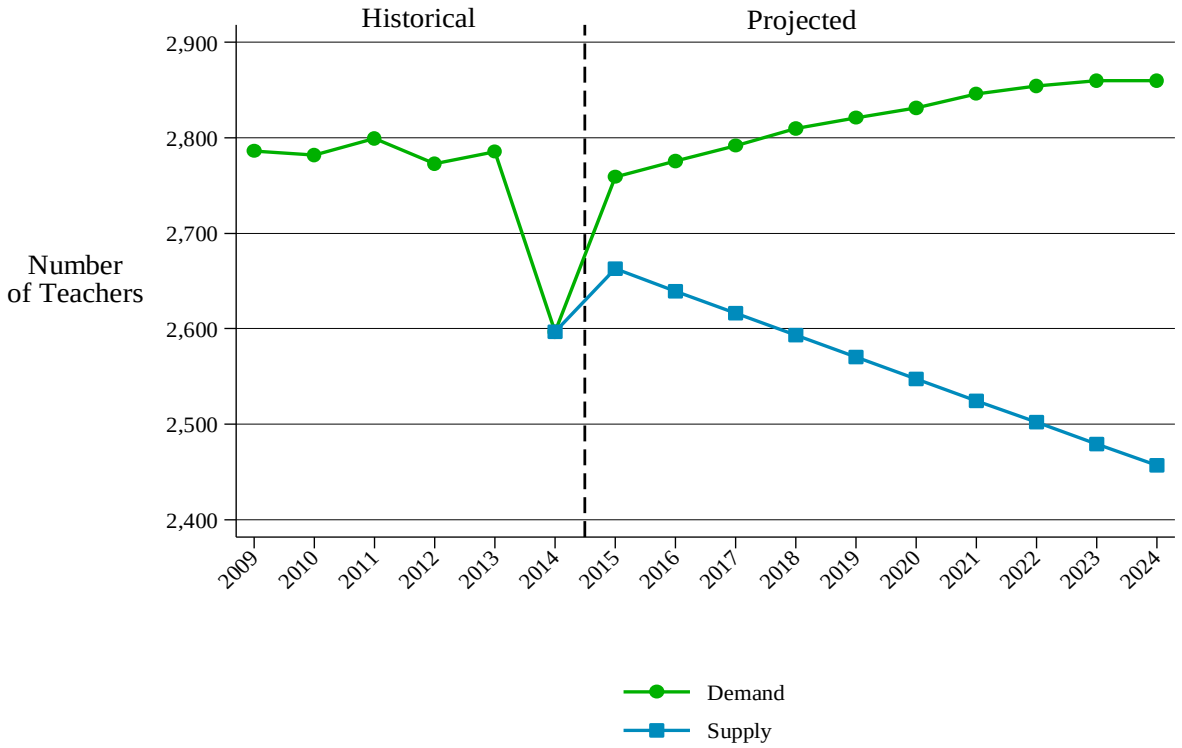
Given the small proportion of minority teachers statewide, it is possible that a few high-minority regions are driving the results presented above. To determine if this is the case, the research team also analyzed the minority teacher demand and supply projections by DSAC region, with shortages being found in all regions except the Southeast. The projected shortages in the Berkshires +, Commissioner's Districts, and Northeast regions show expected increasing trends and exceed the statewide average shortage in the final projected year. In contrast, expected surpluses of White teachers were found in all regions except the Commissioner's Districts, with the Greater Boston and Northeast regions expecting to see both shortages and surpluses over the 10-year projection period, 2014-15 to 2023-24.

In general, the above results suggest that the regional trends in the projected demand and supply of minority and White teachers follow the aggregate trends, with a few exceptions. However, as the Commissioner's Districts region employs the majority of minority teachers, the results in this region warrant closer examination. The expected shortages of minority teachers in this region results from the fact that the demand for these teachers is expected to increase while the supply is expected to decline. Specifically, the results suggest there will be an expected shortage of 96 teachers (3.47 percent) in the Commissioner's Districts in 2014-15 which will grow to 403 teachers (14.08 percent) by 2023-24 (Table 16 and Figure 20).

Table 16. Projected Statewide Demand and Supply of Minority Teachers in Terms of FTEs and Absolute and Relative Differences in the Commissioner's Districts Region, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	2,663	2,759	-96	-3.47%
2015–16	2,639	2,776	-137	-4.93%
2016–17	2,616	2,792	-176	-6.32%
2017–18	2,593	2,810	-217	-7.72%
2018–19	2,570	2,821	-252	-8.93%
2019–20	2,547	2,831	-284	-10.05%
2020–21	2,524	2,846	-321	-11.30%
2021–22	2,502	2,854	-352	-12.34%
2022–23	2,479	2,860	-381	-13.32%
2023–24	2,457	2,860	-403	-14.08%

Figure 20. Historical and Projected Statewide Supply and Demand for Minority Teachers in Terms of FTEs in the Commissioner's Districts Region, 2008-09 Through 2023-24

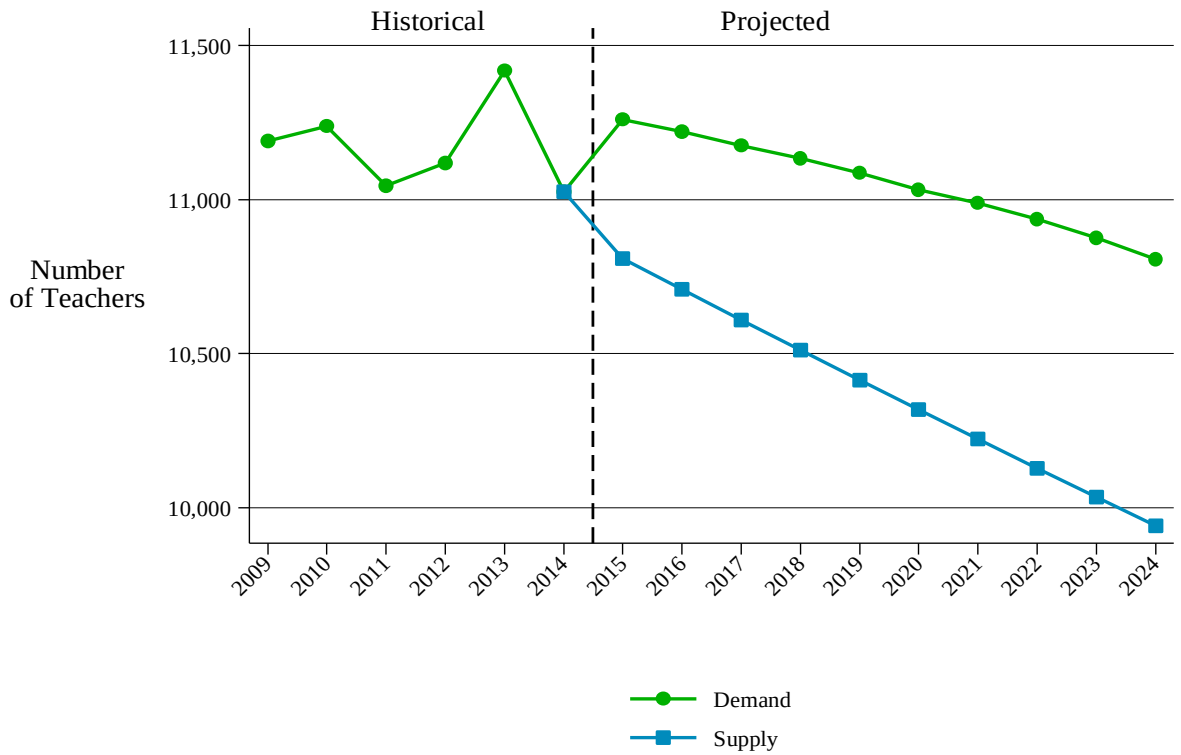


Alternatively, the slightly increasing shortages of White teachers expected for this region are due to both by the initial year projections and the fact that demand for these teachers is expected to decline at a slower rate than the supply of these teachers. Specifically, this results in an expected shortage of 451 teachers (4.01 percent) in 2014-15 which will grow to 865 teachers (8 percent) by 2023-24 (Table 17 and Figure 21).

Table 17. Projected Statewide Demand and Supply of White Teachers in Terms of FTEs and Absolute and Relative Differences in the Commissioner's Districts Region, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	10,809	11,260	-451	-4.01%
2015–16	10,709	11,220	-511	-4.55%
2016–17	10,610	11,175	-565	-5.05%
2017–18	10,512	11,135	-624	-5.60%
2018–19	10,414	11,086	-671	-6.05%
2019–20	10,318	11,032	-714	-6.47%
2020–21	10,223	10,990	-768	-6.99%
2021–22	10,128	10,936	-808	-7.39%
2022–23	10,034	10,877	-842	-7.74%
2023–24	9,942	10,806	-865	-8.00%

Figure 21. Historical and Projected Statewide Supply and Demand for White Teachers in Terms of FTEs in the Commissioner's Districts Region, 2008-09 Through 2023-24



These results suggest that the expected shortages of minority teachers in the Commissioner's Districts will be larger than the statewide average, and given the relatively larger population of minority teachers in this region, it is likely driving the aggregate results that were found. However, these results also suggest that this region is expected to experience shortages regardless of teacher race. This finding is discussed in more detail later in this section.

Validity of Results by Race

As with previous research questions, the AIR research team conducted a number of tests to determine the validity of the estimated demand and supply projections by race. Specifically, the average percent errors (APEs) and mean absolute percent errors (MAPEs) for both demand and supply projections were calculated based on comparisons of actual and projected values in historical years. In addition, for the average district, the 95 percent confidence interval around the predicted proportions that drive the demand and supply projections was considered.

Demand Projections

Average Percent Errors (APEs) and Mean Absolute Percent Errors (MAPEs)

When the predicted proportions are applied to the overall demand, the APEs and MAPEs for the demand estimates indicate the models generally do a good job of predicting demand for historical years. However, the APE for the minority demand model of 0.69 indicates a possible upward bias of the projections. In other words, demand for minority teachers was potentially overestimated. This indicates that the projected shortage of minority teachers is potentially

overstated. The MAPE for White teachers is below 0.10 percent, and the MAPE for minority teachers is below 1 percent, indicating the models have low overall error.

Confidence Intervals

The 95 percent confidence intervals around the projected proportions of White teachers are larger in absolute terms than those of their minority counterparts, and as a percentage above and below the point estimates, the confidence intervals are actually tighter for White teachers. However, for both teacher categories, the confidence intervals are large enough to cast some doubt on the overall projected trends over time. Additionally, the size of the confidence intervals for both minority and White teachers grow by a factor of four over time, indicating more precision in estimates in earlier years.

Supply Projections

Average Percent Errors (APEs) and Mean Absolute Percent Errors (MAPEs)

For the models predicting supply of both minority and White teachers, APEs are very small and close to zero, at -0.02 and 0.05, respectively, indicating very little upward or downward bias is evident in the projections. The MAPEs for the models of supply of White and minority teachers indicate the supply models have slightly more error than the demand models with, MAPEs of 0.6 percent for White teacher supply and about 1.4 percent for minority teacher supply. However, both of these models are well within the standard for what could be considered a good fit.[25]

Confidence Intervals

The confidence intervals for supply of minority teachers indicate that for an average district, the trend in the supply of minority teachers over time is quite uncertain. For an average district, the 95 percent confidence intervals are quite large in the final projected year, while for White teachers the relative size in the final projected year is more modest. However, for the district average estimates for both minority and White supply, confidence intervals are more than three times larger in 2023–24 compared with 2014–15.

Research Question 4b: Demand and Supply Projections by Age

Demand Projections by Age

To develop demand projections across age group categories, the AIR research team first estimated the proportion of total teachers expected to fall into each of the age categories over time. The estimated proportions by age group are shown in Table 18. As can be seen, the two age groups expected to show the largest proportion increases over time are 41–48 and over 64. The group showing the largest decline is 49–56. Although it is easy to understand why the over 64 age group is projected to increase—the recent recession may have led to a decrease in the retirement rate—it is less easy to explain why we see a dramatic increase in those 41–48 and a decrease in those 49–56.

[25] Additional details on these metrics can be found in Appendix C.

Table 18. Projected Percent of Teachers by Age Groups, 2014–15 Through 2023–24

Year	% Under 26	% Age 26–32	% Age 33–40	% Age 41–48	% Age 49–56	% Age 57–64	% Over 64
2014–15	3.34%	16.72%	20.53%	22.69%	19.21%	15.71%	1.79%
2015–16	3.16%	16.62%	20.66%	23.47%	18.33%	15.73%	2.02%
2016–17	3.00%	16.50%	20.77%	24.24%	17.47%	15.73%	2.28%
2017–18	2.86%	16.37%	20.86%	25.00%	16.63%	15.71%	2.58%
2018–19	2.73%	16.22%	20.92%	25.73%	15.81%	15.67%	2.91%
2019–20	2.62%	16.07%	20.96%	26.45%	15.01%	15.62%	3.28%
2020–21	2.52%	15.90%	20.97%	27.13%	14.24%	15.55%	3.70%
2021–22	2.43%	15.72%	20.96%	27.78%	13.48%	15.46%	4.17%
2022–23	2.36%	15.53%	20.92%	28.40%	12.75%	15.35%	4.69%
2023–24	2.29%	15.32%	20.86%	28.97%	12.05%	15.23%	5.27%

After calculating the expected proportions for each age category over time, these were applied to the demand estimates from Research Question 1 to determine the overall number of FTEs expected to be in each category. The average percent change, overall percent change, and overall absolute change from 2013–14 to 2023–24 for each age category are found in Table 19. As can be seen, there is quite a bit of variation in demand trend by age group over time. In five of the seven categories, the overall absolute percent change from 2013–14 to 2023–24 is greater than 10 percent, with the largest percent change in the over 64 group, which is expected to increase by about 164 percent. However, because the number in this group was the smallest to begin with, this represents an increase of only 1,821 FTEs. In line with the results presented above, a large increase in the 41–48 age group and a large decrease in the demand for teachers in the 49–56 age group were found. Figures depicting these changes over time can be viewed in Figures B1 and B2 in Appendix B.

Table 19. Projected Percent and Absolute Changes in Statewide Demand by Teacher Age, 2013–14 Through 2023–24

Age Group	Average Annual Percent Change 2013–14 Through 2023–24	Overall Percent Change 2013–14 Through 2023–24	Overall Absolute Change 2013–14 Through 2023–24
Under 26	-3.24%	-28.54%	-892
Age 26–32	-1.59%	-14.82%	-1,879
Age 33–40	-0.12%	-1.23%	-175
Age 41–48	2.07%	22.76%	3,188
Age 49–56	-5.90%	-45.59%	-5,678
Age 57–64	-0.27%	-2.73%	-252
Over 64	10.20%	163.69%	1,821

It is important to keep in mind that the above projections represent demand by age to the extent that the trends in proportions of each group reflect the needs or preferences of districts with respect to age. While in other analyses, such as demand by program area, this was more intuitive, this particular case is more nuanced. On the one hand, districts may be in need of more

experienced and qualified teachers who tend to be in older age groups, and the historical distribution by age may be driven in part by a desire to retain these same individuals over time. Both of these are expressions of demand, and could be reflected in the proportion trends. On the other hand, the observed changes in proportions are certainly driven in part by the advancement in age of the workforce, as well as other factors such as the economy and retirements, factors that would not reflect district demand. As such, policymakers may want to partner with districts to better understand what may be primarily behind the proportion trends.

Supply Projections by Age

Rather than estimate proportions of teachers, the supply projections broken out by age use historical counts of teachers by age group to estimate future expected counts of teachers. As with the demand projections, the supply projections for the 41–48 and over 64 age groups show the largest 10-year increases both in relative and absolute terms. The largest decrease in supply over the period is for the 49–56 age group. While overall supply is expected to decrease over time, the sum of supply across the age groups is increasing over time. This suggests some of the supply categories, particularly those showing substantial increases, may be overestimated. The annual average and overall percent changes, as well as the overall absolute change between 2013-14 and 2023-24 are found in Table 20.

Table 20. Projected Percent and Absolute Changes in Statewide Supply by Teacher Age, 2013–14 Through 2023–24

Age Group	Average Annual Percent Change 2013–14 Through 2023–24	Overall Percent Change 2013–14 Through 2023–24	Overall Absolute Change 2013–14 Through 2023–24
Under 26	-4.24%	-35.53%	-1,110
Age 26–32	-0.72%	-7.01%	-890
Age 33–40	1.39%	14.76%	2,088
Age 41–48	3.47%	40.68%	5,700
Age 49–56	-5.24%	-41.65%	-5,187
Age 57–64	-0.03%	-0.30%	-28
Over 64	11.55%	198.24%	2,205

As with demand projections, the AIR research team found that the supply of teachers in the over 64 age group is projected to grow sharply over the next 10 years. However, as previously suggested, this growth may be due in part to the recession and a corresponding drop in the rate of retirement in reaction to financial instability. Therefore, to the extent that it is expected the financial health in the state will generally improve, and that the effects of the recession will wane, it is also expected that retirements will increase over time. Future financial health of the economy is not captured in these projections, so policymakers may want to monitor these numbers over the coming years for a drop in teachers of retirement age.

Comparing Supply and Demand Projections by Age

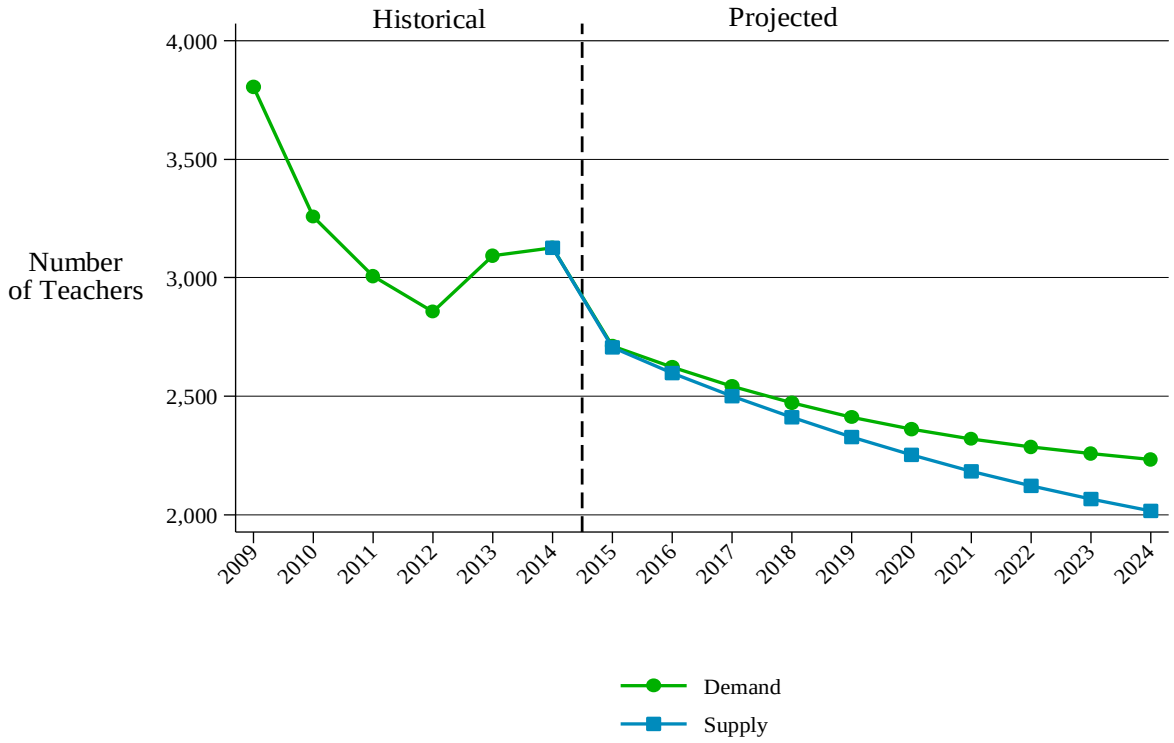
In an effort to determine if there are expected shortages or surpluses among teachers in different age groups in future years, the supply and demand projections for each were compared. In

general, projected supply is expected to exceed demand (suggesting a surplus) in most of the projected 10 years for all but two age groups (i.e., under 26 and ages 57–64). Moreover, demand is expected to exceed supply (shortage) in all 10 projected years for only the under 26 group. The results for the under 26 group can be seen in Table 21 and Figure 22, and additional tables and figures displaying these findings can be found in Appendix B.

Table 21. Projected Statewide Demand and Supply of Teachers Under 26 Years of Age in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	2,705	2,713	-8	-0.28%
2015–16	2,598	2,622	-24	-0.92%
2016–17	2,500	2,541	-41	-1.63%
2017–18	2,410	2,473	-63	-2.56%
2018–19	2,327	2,412	-85	-3.51%
2019–20	2,252	2,361	-109	-4.60%
2020–21	2,184	2,320	-136	-5.87%
2021–22	2,122	2,285	-163	-7.15%
2022–23	2,066	2,257	-191	-8.48%
2023–24	2,015	2,233	-218	-9.78%

Figure 22. Historical and Projected Statewide Supply and Demand for Teachers Under 26 Years of Age in Terms of FTEs, 2008–09 Through 2023–24



However, it should be noted that, given the uncertainty surrounding the factors contributing to the supply and demand by age, and the possibility that those of retirement age may begin to retire over the coming years, an in-depth analysis of shortages and surpluses by age based on these projections may be inappropriate.

Validity of Results by Age

Demand Projections

Average Percent Errors (APEs) and Mean Absolute Percent Errors (MAPEs)

For the analysis of results validity of the proportions of teachers in different age groups, the APEs and MAPEs for the models by age group were examined. The results indicate a good fit, with the models for the middle-age groups having a better fit than the lowest and highest age groups, which have substantially fewer numbers of teachers within those categories. The three categories showing the largest bias, as indicated by APEs are the under 26, 26–32, and over 64 groups, which each have APEs near -2.5, indicating downward bias in the estimates. This is particularly relevant for the over 64 category, for which the dramatic increase may be understated. The demand model with the largest MAPE is the under 26 model, with a MAPE of 5.0 percent, which is still well below the cutoff for what the team considers a good fit of 7.5 percent.

Confidence Intervals

The 95 percent confidence intervals surrounding the district average predicted point estimates were examined, and this analysis indicates substantial uncertainty in predictions as time goes on, particularly for the youngest and oldest age groups (i.e., under 26 and over 64 categories). Additionally, for six of seven categories, the confidence intervals grow by more than three times from 2014–15 to 2023–24, with the largest increase in the over 64 category

Supply Projections

Average Percent Errors (APEs) and Mean Absolute Percent Errors (MAPEs)

The APEs and MAPEs for supply are quite similar to those for demand. As with demand, the age category with the largest MAPE is the under 26 category, which has a MAPE of 5.88 percent for the supply model. This MAPE still falls below the team's threshold for a good fit of 7.5 percent.

Confidence Intervals

As with demand by age, the analysis of confidence intervals of supply by age category indicates that confidence intervals are growing over time, and this growth is largest for the 41–48 age group, where the intervals more than triples over the projected years. However, when the relative sizes of the intervals are considered it is found that they are largest in the final projected year for the under 26 group, and the intervals for the over 64 group also are quite large.[26]

Research Question 5: Detailed Supply and Demand Projections by Region

What are the supply and demand projections of teachers in Massachusetts for the next 10 years by state region and locale?

To address Research Question 5, the AIR research team considered how the trends in supply and demand found in Research Questions 1 and 2 vary by DSAC region and NCES locale, as well as in the geographic area surrounding key IHEs and by major metropolitan area.

The team first aggregated demand and supply for teachers for each of these groupings of districts. The results of this analysis are presented in detail in Appendix B. This section reports on key findings from a comparison of these aggregated supply and demand estimates for each district grouping.[27]

Comparing Supply and Demand Projections

A comparison of the supply and demand projections reported for Research Question 5 shows there to be relatively few expected shortages. However, while there are few instances of expected

[26] Additional details on these metrics can be found in Appendix C.
[27] Additional figure and tables displaying Research Question 5 findings not presented in this report, including bar figures and tables, are available upon request.

teacher shortages, namely in the Commissioner's Districts and in city locale districts, they are in areas that traditionally serve high proportions of disadvantaged and underperforming student populations, making these findings particularly concerning for policymakers.

Table 22 reconciles the supply and demand projections by region for the period 2014–15 to 2023–24. Here it is seen that only the Commissioner's Districts are expected to maintain a persistent and increasing shortage of teachers over time. In contrast, the Greater Boston area shows an initial shortage equal to that of the Commissioner's Districts, which is expected to decrease over time, while all other areas are expected to experience consistently increasing surpluses.

Figure 23 shows the difference in predicted supply and demand over time for the Commissioner's Districts. Because this area represents the largest districts in the state and tends to serve more disadvantaged student populations, this finding may be particularly concerning to policymakers as the teacher shortages could lead to higher student–teacher ratios, less qualified teachers for the high-need districts in this area, or both.

Table 22. Relative Difference Between Supply and Demand by DSAC Region, 2014–15 Through 2023–24

Year	Berkshires +	Central	Commissioner's Districts	Greater Boston	Northeast	Pioneer Valley	Southeast
2014–15	3.73	1.11	-3.73	-3.73	3.90	5.03	2.31
2015–16	4.79	1.59	-4.34	-3.55	4.73	5.56	3.32
2016–17	5.41	2.26	-4.91	-3.22	5.52	6.04	4.62
2017–18	6.16	2.64	-5.53	-2.98	6.32	6.40	5.78
2018–19	7.05	3.44	-6.05	-2.66	7.16	6.89	7.20
2019–20	7.88	4.01	-6.53	-2.33	7.92	7.26	8.55
2020–21	8.64	4.40	-7.13	-1.97	8.79	7.58	9.95
2021–22	9.68	5.04	-7.60	-1.64	9.74	7.84	11.52
2022–23	10.61	5.56	-8.03	-1.20	10.65	8.29	13.17
2023–24	11.16	6.05	-8.34	-0.77	11.65	8.97	14.78

Note. Relative Difference = (Supply-Demand)/Demand.

Figure 23. Historical and Projected Statewide Supply and Demand for Teachers in the Commissioner's Districts in Terms of FTEs, 2008–09 Through 2023–24

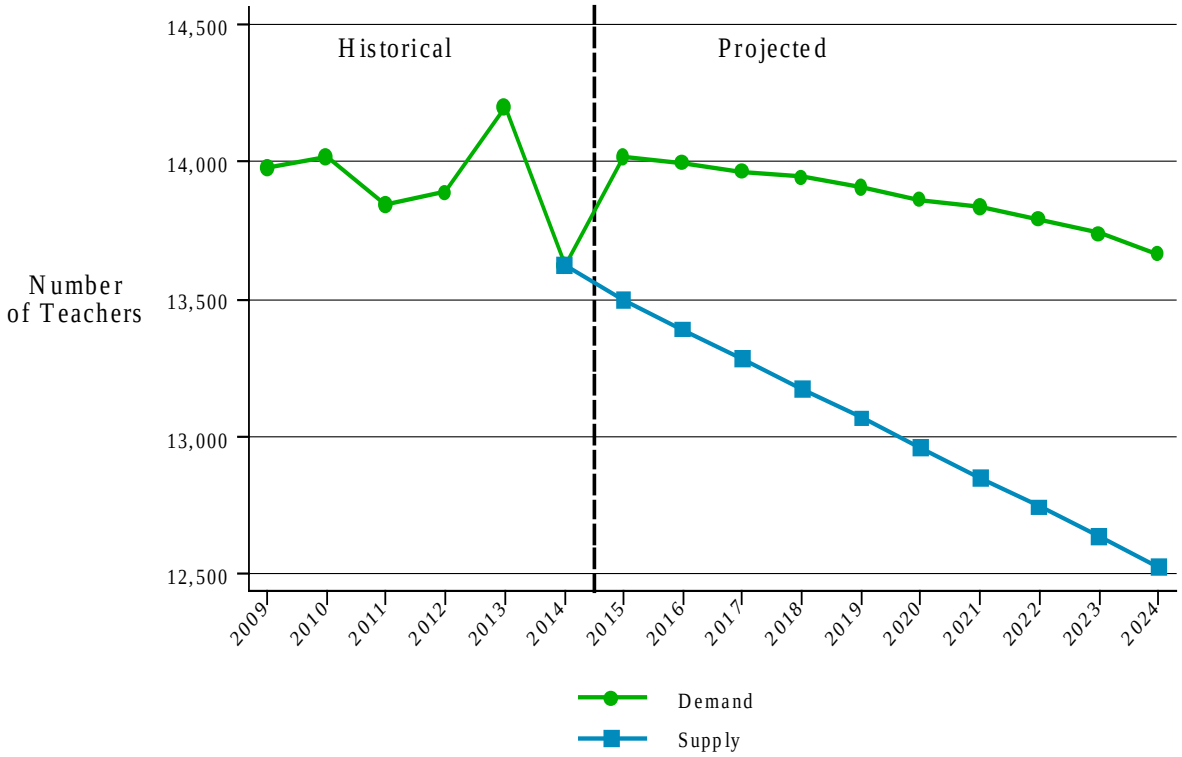


Table 23 shows the relative differences between supply and demand by NCES locale. Not surprisingly, the City locale also shows a shortage of teachers, which grows over time, as many of the largest urban districts are located both in City locales and the Commissioner's District

region. As with the Commissioner's Districts, City locales tend to have districts serving students with relatively higher needs. Again, this makes the shortage of teachers in these areas particularly concerning; while three out of the four locales show expected surplus trends, the one locale that is expected to have shortages over the foreseeable future is where a shortage might have the largest impact on those students with higher needs.

Table 23. Relative Difference Between Supply and Demand by Locale, 2014–15 Through 2023–24

Year	City	Suburb	Town	Rural
2014–15	-2.82	0.06	1.51	3.90
2015–16	-3.25	0.53	2.63	4.72
2016–17	-3.60	1.12	3.48	5.57
2017–18	-4.03	1.62	4.43	6.22
2018–19	-4.27	2.23	5.49	7.29
2019–20	-4.48	2.81	6.36	8.09
2020–21	-4.79	3.37	7.44	8.93
2021–22	-4.97	4.02	8.72	9.86
2022–23	-5.10	4.69	10.64	10.82
2023–24	-5.07	5.37	12.18	11.72

Note. Relative Difference = (Supply-Demand)/Demand.

As shown in Table 24, none of the areas surrounding the top five IHEs show teacher shortages of any substantial magnitude. The results by IHE area do not show particularly large teacher surpluses either, indicating that teacher supply and demand is relatively balanced within these areas.

Table 24. Relative Difference Between Supply and Demand by IHE Area, 2014–15 Through 2023–24

Year	American International	Boston University	Bridgewater State	Salem State	Lesley University
2014–15	2.26	0.01	-1.03	-1.62	-0.91
2015–16	3.26	0.35	-0.87	-1.60	-0.86
2016–17	4.08	0.90	-0.59	-1.39	-0.74
2017–18	4.90	1.33	-0.40	-1.42	-0.66
2018–19	5.83	1.91	-0.09	-1.16	-0.50
2019–20	6.71	2.48	0.20	-1.06	-0.32
2020–21	7.38	3.00	0.48	-1.01	-0.15
2021–22	8.14	3.67	0.85	-0.87	0.12
2022–23	8.95	4.43	1.26	-0.78	0.42
2023–24	9.90	5.14	1.69	-0.70	0.84

Note. Relative Difference = (Supply-Demand)/Demand.

Table 25 shows the relative difference between supply and demand by major metropolitan area. Of the four major metropolitan areas, Lowell–Lawrence shows the largest expected teacher shortage. The projection for this area suggests a shortage of 6.93 percent in 2014–15 that grows

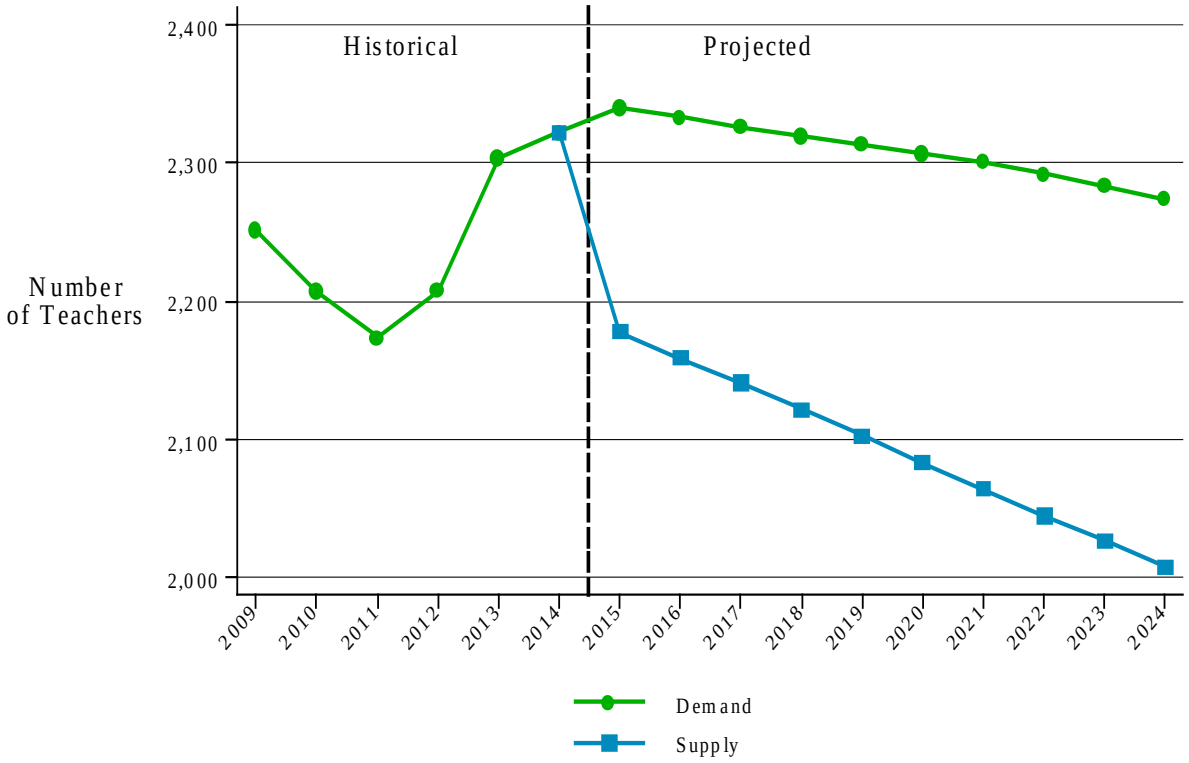
to almost 12 percent by 2023–24. Figure 24 shows the projected supply and demand trends underlying the shortages expected for Lowell–Lawrence. Worcester is also expected to experience an increasing teacher shortage over time, growing from 0.79 percent in 2014–15 to 1.76 percent by 2023–24, but the size of the projected shortage is much smaller than that of Lowell–Lawrence. In contrast to the expected trends found for Lowell–Lawrence and Worcester, the results suggest that Springfield will experience an increasing surplus over the period, while there is expected to be a small but gradually increasing surplus in Boston.

Table 25. Relative Difference Between Supply and Demand by Major Metropolitan Area, 2014–15 Through 2023–24

Year	Boston	Worcester	Springfield	Lowell–Lawrence
2014–15	0.04	-0.79	3.41	-6.93
2015–16	0.03	-0.93	4.42	-7.47
2016–17	0.16	-0.89	5.26	-8.00
2017–18	0.18	-1.20	6.08	-8.54
2018–19	0.45	-1.03	7.02	-9.16
2019–20	0.65	-1.19	7.93	-9.71
2020–21	0.77	-1.48	8.60	-10.29
2021–22	1.06	-1.57	9.32	-10.77
2022–23	1.44	-1.76	10.09	-11.24
2023–24	1.75	-2.01	10.99	-11.72

Note. Relative Difference = (Supply-Demand)/Demand.

Figure 24. Historical and Projected Statewide Supply and Demand for Teachers in the Lowell–Lawrence Metropolitan Area in Terms of FTEs, 2008–09 Through 2023–24



Validity of Results

As with previous analyses, to assess the validity of the results presented for Research Question 5, the AIR research team compared the actual and projected values for historical years and calculated the relative difference between the two (i.e., APEs and MAPEs).[28] The metrics for both supply and demand for each of the groupings reported for Research Question 5 were calculated. Notable findings are reported below, and a full listing of the corresponding APEs and MAPEs for these analyses can be found in Appendix C.

Demand Projections

When the APE and MAPE measures for the demand projections are considered, it was found that no MAPEs rise above 5 percent, indicating that the error in AIR' projections is relatively small. In general, the errors tend to be in the regions with the largest populations and in metropolitan areas. The largest MAPE was 4.65 percent, found in the Greater Boston region. The MAPEs were also higher for the Lowell–Lawrence and Worcester metropolitan areas at 3.39 percent and 2.69 percent, respectively. In contrast, there were MAPEs as low as 0.44 percent (suburban locales) and 0.79 percent (the area around Boston University).

[28] Note that the team did not analyze confidence intervals as the results for Research Question 5 or rely on the same regression models used to address Research Question 2. For additional information on the validity of these results, see Research Question 2 and Appendix C.

With respect to bias measured using APEs, there tend to be more positive biases, indicating that in general AIR's projections tend to be higher than the actual value in historical years. These biases ranged from less than 0.00 percent to slightly higher than 4 percent.

Supply Projections

On the supply side, the APEs and MAPEs were even lower. Specifically, the MAPEs tended to be lowest among IHEs and metro areas, and largest among locales, ranging from less than 0.44 percent in the Springfield metropolitan area to 2.71 percent in suburban locales. Moreover, the biases were, for the most part, positive, indicating that projections tend to be larger than the actual values. However, given that the calculated errors are so low, bias in either direction is in most cases negligible.

The fact that the bias for both demand and supply projections tended to be positive suggests that, on average, these projections may be lower than the estimates imply. However, because both are biased in the same direction, this lessens the concern that the comparison between supply and demand could be impacted by bias in the model.

Note that in some instances the relative magnitudes of the supply and demand biases are rather different. For example, the APE for demand for the Greater Boston region is 4.3 percent while the APE for supply is -0.4 percent. This indicates that demand is likely to be underestimated to a greater degree than supply, and subsequently that demand in Greater Boston may be higher than projections show; given that Greater Boston is already expected to have slightly lower supply than demand, the projected shortage could be a bit larger.

Section 3. Study Limitations

It is important to acknowledge the limitations encountered in conducting this study and the constraints that these limitations produce in drawing conclusions from the results. The study limitations took several forms, including limitations presented by the data, as well as projection limitations inherent both in the specific methods chosen for this study and more generally in making projections from statistical models.

Data Limitations

The data used in in this study was limited in a few fundamental ways. First, most of the data used was aggregated from the school level to the district level, leading to a lack of granularity that individual data would offer. This limited the types of questions that could be answered, which potentially led to less clarity in the results. For example, because data on retention only indicates the total number of teachers retained, it is not possible to determine whether the teachers that were not retained exited the workforce entirely or transferred to another district within the state. Similarly, a lack of readily available data on the numbers of new teachers entering a district from an IHE necessitated a series of assumptions pertaining to the transition of teacher preparation program completers into the workforce (e.g., which districts program completers found employment).

Projection Limitations

There are inherent limitations to the methods chosen for this study, as well as in all projections made with statistical models more generally. To begin, many of the projections created for this study were based on linear regressions that estimate an average trend taking into account a number of factors. If the available historical data are particularly volatile, the projected average trend, which smooth out this volatility, will not be able to accurately reflect similar volatile patterns in future years.

Moreover, projections based on historical trends are inherently limited to the assumption that these past trends will persist in the future. Unexpected events that lead to sharp changes in the metric being projected, or shocks, are by nature inconsistent with the past trends. Therefore, a projection cannot anticipate these events and will be in error to extent that they occur. In addition, if policymakers act on the projections presented here in an effort to avoid undesirable future outcomes (i.e., teacher shortages), these acts themselves might (hopefully) impact future trends, which will invalidate the projections.

Finally, all projections are susceptible to a certain amount of error. The APEs and MAPEs and 95 percent confidence intervals presented in the Results section of this report illustrate the level of error found in particular analyses, and should be considered alongside all of the projections that are presented.

Section 4. Opportunities for Future Study

The findings presented in this study are intended to inform the work of policymakers in Massachusetts. However, there are certainly questions that could not be answered. To this end, the following section includes a summary of possible opportunities for future research. Specifically, the state would benefit from an analysis of supply and demand by specific and consistently assigned subjects, an analysis of teacher mobility conducted at the individual level, and an analysis of the teacher pipeline conducted in partnership with teacher preparation programs.

Demand and Supply by Subject

An analysis of teacher demand and supply projections by subject is important because the aggregate supply and demand trends indicating surpluses may actually mask shortages for particular subjects. This is illustrated by the fact that while these projections suggest the state can expect a surplus of teachers *in aggregate*, a shortage of teachers in specific program areas such as special education and English language learners can also be expected. In turn, it is entirely possible that this is the case for particular subject areas as well. Moreover, subject–specific projections would allow policymakers and IHEs to better target recruitment efforts toward candidates in subjects most likely to show shortages and support districts to better recruit teachers in these subjects.

In fact, the AIR research team's initial intention was to include in this report an analysis of projected demand and supply by subject area. However, through careful examination of the available staffing data, it was found that the numbers of teachers by subject is quite volatile in historical years. Through conversations with ESE, it was determined that this volatility was likely a result of policy allowing districts flexibility in how they classified individual teacher assignments by subject each year. In particular, the use of the subject area category "Core–All subjects" as an alternative blanket category for which a wide variety of subject areas could be coded presented a data issue that this study could not overcome. For example, it was observed that between school years 2008–09 and 2011–12 teachers classified as "Core–All subjects" constituted an average of 38 percent of all teacher FTEs in Boston. However, between school years 2012–13 and 2013–14, "Core–All subjects" teachers accounted for only 11 percent of the reported total for the district, on average.

Rather than this reflecting a true change in the FTEs of teachers assigned to this subject, it was determined that this was likely influenced by a decision to consider the *same* teachers as assigned in more detailed subject categories (e.g., English language arts, mathematics, reading) rather than "Core–All subjects" after 2001–12. Moreover, based on further evaluation, it was the team's understanding that this sort of reclassification was equally likely for all districts and all years, and therefore its implications on projections based on historical trends were substantial. Without a clear method of separating out "true" changes in subject assignment from reclassifications, it was determined that the raw data could not be used to make supply and demand projections by subject. Furthermore, to the team's knowledge, there is no alternative centralized data source at the state level that contains more specific subject assignments not plagued by this issue.

AIR's recommendation is that policymakers work to ensure that teacher-assigned subjects are consistently reported in the future and to possibly work directly with districts in order to understand the extent to which reclassification has taken place in past years. Such actions would support any future study of teacher demand and supply by subject area.

Teacher Mobility Analysis

Understanding the movements of teachers within a state, whether across districts or schools, is crucial if policymakers wish to have a complete picture of teacher demand and supply. While within-state mobility of teachers from district to district does not affect calculations of the aggregate statewide supply of teachers, it can substantially impact individual districts. Moreover, high-need schools tend to have the biggest challenges with recruiting and retaining teachers, further exacerbating the inherent challenges facing these schools. A comprehensive analysis of teacher mobility would give policymakers the information they need to provide targeted supports to these districts. However, this sort of analysis was beyond the scope of the current study primarily because it would require more granular individual-level data that the research team did not have access to.

The present study did analyze the proportion of teachers retained, and it estimated those entering from preparation programs. This allowed a proportion of transferring teachers to be calculated, though more granular data would be required to determine the characteristics of individuals in this group. Previous workforce reports in Massachusetts include analysis of the retention rates of first-year teachers, the "reason for leaving" for teachers who left within two years, and teacher mobility by years of service and teacher characteristics (ESE, 2011, 2013; Owen, 2010). Policymakers may want to consider conducting an updated and comprehensive study that considers the mobility of teachers in more detail, including analyzing the progression of new teacher cohorts five years after they enter the workforce, or determining the characteristics of schools that transferring teachers tend to exit and enter.

Teacher Pipeline Analysis

A complete picture of the pipeline of new teachers is an important part of any analysis of teacher demand and supply. To the extent that teacher shortages are expected, any strategies to avoid such shortages would require an understanding of who is entering the workforce and where they come from. For example, to what extent are new entrants employed in high-need schools completing traditional teacher preparation programs as opposed to alternative routes to certification? What are the characteristics of individuals prepared to teach who have not joined the workforce in Massachusetts? Are a significant number of new teachers entering the workforce from out of state, and where are they entering the workforce?[29] Answering questions like these can support a thoughtful discussion of strategies designed to increase the supply of teachers and address expected teacher shortages.

[29] A previous study conducted by members of the research team addressed some of these types of questions in Oklahoma (Berg-Jacobson & Levin, 2015).

While the present study did some analysis of new entrants, the team was limited in what it could say about the teacher pipeline overall. Some of these specific limitations are described in detail in Section 3, but in general they stemmed primarily from an inability to say with certainty if an individual completing a teacher preparation program would enter the workforce, or where this individual would find employment. Previous workforce reports in Massachusetts provide some additional analysis, including reporting on the distribution of program completers by program type and subject area, the employment rate of recent graduates one year following graduation, and the distance between a candidate's graduating program and first employing school (ESE, 2011, 2013). These reports present a possible starting point for a more comprehensive analysis. However, conducting an updated and more in-depth analysis would require linking teacher staffing data with teacher preparation program completer data and employment outcome data, likely at the individual level. Such an analysis would allow researchers to describe the supply of newly prepared teachers with more precision, as well as ascertain the alternative professions employing those prepared to teach in Massachusetts.

Conclusion

For the present study, AIR's research team used publicly available data, primarily consisting of ESE data published in their School/District Profiles reports, to conduct analyses addressing the five research questions in this study. These analyses produced aggregate 10-year projections of teacher supply and demand, and disaggregated 10-year projections by teacher assigned program area, teacher demographics, and for particular regions and locales.

While aggregate supply in Massachusetts is projected to meet demand over the next 10 years, there are areas where shortages are expected to occur if corrective action is not taken. These potential shortage areas are particularly concerning due to their impact on the teacher pipeline and the impact on high-need student populations. The team concluded these issues warrant particular consideration by Massachusetts policymakers and practitioners:

- **Expected Teacher Pipeline:** The results of the present study indicate sharp declines in the number of newly entering teachers, and more generally teachers under 26 (one of the groups for which a shortage was projected). These declines in newly entering and younger teachers have potentially serious consequences for the teacher pipeline, as these groups represent a primary source of new teachers. Moreover, the projected declines in teacher preparation program completion may have implications on the state's strategic objective to improve teacher preparation, which includes revising the program approval process, a teacher performance assessment, and updating professional standards for teaching.
- **Impact on High-Need Populations**: The results pertaining to expected shortages in specific program areas (ELL and SPED), regions (the Commissioner's Districts), and locales (city districts) suggest there will be negative impacts disproportionately affecting special needs and disadvantaged student populations. The state clearly recognizes a need for targeting strategies to the lowest performing districts and schools, as evidenced by their strategic plan, and these results may have implications on this work. Moreover, the expected shortage of minority teachers certainly has implications on the state's goal to increase diversity in the teacher workforce, which might also impact students with the highest needs.[30]

It is the research team's hope that by considering the projections of supply and demand presented in this report, policymakers are better positioned to develop and implement strategies to address teacher shortages in future years.

[30] For example, shortages of teachers of color may disproportionately impact students of color, as teachers of color are more likely to work in high-need urban schools (Achinstein, Owaga, Sexton, & Freitas, 2010).

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Appendix A. Technical Description of Methods

Data Sources

Table A1. Internet Links to Study Data Sources

Data Source/Report		Link to Source
Massachusetts Department of Elementary and Secondary Education (ESE) School and District Profiles	Enrollment by Grade Report	http://profiles.doe.mass.edu/state_report/enrollmentbygrade.aspx
	Enrollment by Select Populations Report	http://profiles.doe.mass.edu/state_report/selectedpopulations.aspx
	Enrollment by Race/Gender Report	http://profiles.doe.mass.edu/state_report/enrollmentbyracegender.aspx
	Teacher Data Report	http://profiles.doe.mass.edu/state_report/teacherdata.aspx
	Ed Prep Employment by Year and Program	http://profiles.doe.mass.edu/state_report/epppempratebyyear.aspx
	Staff Retention Report	http://profiles.doe.mass.edu/state_report/staffingRetentionRates.aspx
2014 Lists of Massachusetts Schools and Districts by Accountability and Assistance Level		http://www.mass.gov/edu/government/departments-and-boards/ese/programs/accountability/support-for-level-3-4-and-5-districts-and-schools/district-and-school-resource-centers-dsac/overview-and-eligibility-for-dsac.html
Centers for Disease Control and Prevention (CDC) Wide-Ranging Online Data for Epidemiologic Research (WONDER)		http://wonder.cdc.gov/
U.S. Census Population Data		http://www.census.gov/popest/data/counties/asrh/2014/CC-EST2014-ALLDATA.html
National Center for Education Statistics (NCES) Common Core of Data (CCD)		https://nces.ed.gov/ccd/
NCES Comparable Wage Index (CWI)		https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2006865

General Approach—Regression-Based Projections

As many of the research questions were addressed, at least in part, through regression-based projections, it is helpful to have a basic understanding of this approach. In essence, a linear regression identifies an average linear relationship between an outcome of interest (or the quantity that is being predicted, which in the case of both supply and demand is the number of teachers) and one or more predictor variables (that is, the factors that may be related to the outcome of interest) that best fit the observed data. Multiple linear regressions allow one to estimate a relationship between an outcome variable and a predictor variable while controlling for other factors. For our purposes, we use multiple regression to generate models that accurately estimate the supply and demand components of interest. Within each model we include a time trend, which allows us to apply the models to future years to predict changes in supply and demand over time, while holding all other variables constant.

The benefit of using this approach for projections is that it allows projections to vary based on factors of interest. For example, we can allow the time trends to vary by region to understand whether certain regions of the state have experienced different patterns of supply or demand. However, there also are limitations to this approach. In particular, projections based on observational units with small counts in historical years are generally more prone to error. This issue has been documented previously in a report using data from Washington State that noted projections based on counts of 1,000 or less, particularly 100 or less, are problematic (Berk & Hodgins, 2008). Although this finding was not presented in the context of regression analysis, we also have found that models attempting to predict supply or demand for smaller populations contain more errors. In addition, future shocks—or specific events that change the time trend—are inherently difficult to anticipate with a high degree of accuracy, and projections therefore cannot easily or reliably account for these shocks.[31]

Research Question 1: Enrollment Projections

The study team adopted a model for projecting student enrollments that relied on "grade progression ratios" (or GPRs). As the name of the method implies, these ratios represent the percentages of students who progress from grade to grade each year or from birth to kindergarten five years later. Enrollment projections were calculated at the county level. This was done for two practical reasons. First, birth and population data were only available at the county level (these data were not available at the district level). Second, although the GPR method requires data on student progression between each consecutive pair of grades from K to 12, not all districts serve every grade. For example, some districts only serve the elementary grades (K to 5), so that progressions from fifth grade to sixth grade require students to change to a different school district. In these cases, an enrollment projection between these grades could not be calculated for districts that did not serve both grades. However, once the enrollment data were aggregated to the county level, every county was found to serve all grades. In turn, the district-

[31] Shocks impacting trends of supply and demand could be policy changes impacting teacher supply and demand, such as maximum class-size policies, sudden changes in economic growth such as recessions or periods of strong growth, rapid demographic changes, or many other factors that can change quickly, which could impact teacher supply and demand.

level enrollment data (for Grades K–12) were first aggregated to the county level to accommodate the calculation of grade-level enrollment projections, which were then prorated across the constituent districts in each county using historical district-level shares of countywide enrollment.

Calculation of GPRs for Grades K–1 Through 11–12

We used the following equation to calculate the progression ratio from Grade *x* in Year 1 to Grade *y* in Year 2:

$$\text{GPR}x\text{-}y = \frac{y \text{ Enrollment in Year 2}}{x \text{ Enrollment in Year 1}}$$

A GPR was calculated for each consecutive K–12 grade combination (e.g., Grade K–1, 1–2) for the 2003–04/2004–05 through 2013–14/2014–15 school year pairs, and overall progressions for each grade combination used to project enrollment were created by taking the average GPRs over these years.

Calculating Birth to Kindergarten GPRs

To calculate the progression ratios from birth to kindergarten, birth counts five years prior were used in place of "Year 1" enrollment. Specifically, it was assumed that kindergarten enrollment in a given year represents the proportion of children born five years earlier that will progress to kindergarten. The equation used to calculate the birth–K GPRs is the same as that presented above, and the average across the previous six years (2009–10/2010–11 through 2013–14/2014–15) was used in projection models.

Estimating Births for Years in Which No Data Are Available

To calculate 10-year projections, birth counts were needed for years where these data are unavailable because either these years are in the future or the birth estimates have yet to be published. Specifically, these data are not available for 2014 through 2019. To estimate birth counts for these years, the county-level population of women of child-bearing age (i.e., between 15 and 44 years of age) was calculated for future years (2015 through 2019) based on 2014 population data, and this population for each year was multiplied by the county fertility rate[32] in the most recent year available, which was 2013.

Calculating Projected Enrollment

Finally, to calculate 1-year to 10-year enrollment projections, average GPRs were paired with the most recent cohort of students in a given grade to forecast enrollment in a future period. For example, students in first grade in the last year of observed data (2013–14) will be in fourth grade when calculating three-year projections.[33] The GPRs estimate the proportion of students in

[32] The fertility rate is defined as the number of births divided by the number of females age 15–44 in the given year.
[33] Note that although 2014–15 enrollment data were available to the research team, other data sources were not; thus, projections for these analyses begin in 2014–15.

a given cohort that will progress forward during those three years. Table A2 displays the equation used to calculate 10-year projections:

Table A2. Calculations for 10-Year Forecasts (From the 2013–14 School Year)

Grade in 10 Years	Status in 2013–14	Calculations for 2023–24 Forecast
12	Grade 2	grade 2*gpr2-3*gpr3-4*gpr4-5*gpr5-6*gpr6-7*gpr7-8* gpr8-9* gpr9-10*gpr10-11*gpr11-12
11	Grade 1	grade 1*gpr1-2*gpr2-3*gpr3-4*gpr4-5*gpr5-6*gpr6-7*gpr7-8*gpr8-9*gpr9-10*gpr10-11
10	Grade K	grade K*gprK-1*gpr1-2*gpr2-3*gpr3-4*gpr4-5*gpr5-6*gpr6-7*gpr7-8*gpr8-9*gpr9-10
9	Born 2009	births2009*Birth-K*gprK-1*gpr1-2*gpr2-3*gpr3-4*gpr4-5*gpr5-6*gpr6-7*gpr7-8*gpr8-9
8	Born 2010	births2010*Birth-K*gprK-1*gpr1-2*gpr2-3*gpr3-4*gpr4-5*gpr5-6*gpr6-7*gpr7-8
7	Born 2011	births2011*Birth-K*gprK-1*gpr1-2*gpr2-3*gpr3-4*gpr4-5*gpr5-6*gpr6-7
6	Born 2012	births2012*Birth-K*gprK-1*gpr1-2*gpr2-3*gpr3-4*gpr4-5*gpr5-6
5	Born 2013	births2013*Birth-K*gprK-1*gpr1-2*gpr2-3*gpr3-4*gpr4-5
4	Born 2014	Females aged 15–44 in 2014*Fertility rate in 2013*Birth-K*gprK-1*gpr1-2*gpr2-3*gpr3-4
3	Born 2015	Females aged 14–43 in 2014*Fertility rate in 2013*Birth-K*gprK-1*gpr1-2*gpr2-3
2	Born 2016	Females aged 13–42 in 2014*Fertility rate in 2013*Birth-K*gprK-1*gpr1-2
1	Born 2017	Females aged 12–41 in 2014*Fertility rate in 2013*Birth-K*gprK-1
K	Born 2018	Females aged 11–40 in 2014*Fertility rate in 2013*Birth-K

Note. GPR = grade progression ratios.

In order to report projected enrollment at the district level, the proportion of total county enrollment made up by each member district was calculated using the most recent year of available data, which was 2014–15. These proportions were then used to prorate the county-level projected enrollment for each of the member districts in each projected year from 2014–15 through 2023–24.[34]

Prekindergarten and Ungraded Enrollments

Although the research team projected enrollment for Grades K–12, it did not do so for prekindergarten or ungraded students (e.g., non K–12 special education). We made this decision for a number of reasons. First, our projection methodology relied on estimating the number of students progressing from grade to grade (see discussion of the GPR approach above). Second, enrollment in prekindergarten, unlike kindergarten, is not compulsory and preschool enrollment data are not consistently available in all communities in which it is offered. For these reasons,

[34] Although there are enrollment data available for 2015, we do not have retention data available for this year. Thus, we begin projecting demand in 2015, the first year for which we do not have data from all relevant sources.

estimating the average progression of prekindergarten students to kindergarten is problematic and would require making potentially inaccurate assumptions. Similarly, estimating progression rates from birth to prekindergarten would require questionable assumptions regarding the numbers of children entering prekindergarten at various ages in different locations. Third, a similar issue exists for ungraded students, in that they do not exist as a regular part of Grades K–12, and thus could not be incorporated into the grade progression methodology without making assumptions. For these reasons, we chose not to include enrollments in these grades in our projections.

Research Question 2: Supply Projections

Projections of total supply, numbers of retained teachers, and numbers of newly entering teachers were estimated using a regression-based approach, which modeled each of these as a function of factors believed to influence supply. What follows is a detailed description of the specific models used to create these projections and address Research Question 2.

Total Supply

Using both the total number of teachers and total teacher full-time-equivalents (FTEs) in a given district as measures of supply, the research team created projections for the 10-year period, from 2014–15 to 2023–24. These projections were created using a regression analysis to forecast the total number of teachers and teacher FTEs in future years. Specifically, in separate regressions the total number of teachers and total teacher FTEs were modeled as a function of a yearly time trend, District and School Assistance Center (DSAC) region, an interaction between the time trend and region, institution of higher education (IHE) area,[35] an interaction between IHE area and the time trend, major metropolitan area, an interaction between metropolitan area and the time trend, National Center for Education Statistics (NCES) locale, the interaction between locale and the time trend, enrollment, enrollment squared, the proportion of students receiving free/reduced-price lunch,[36] and the interaction between free/reduced-price lunch proportion and total students. The model is presented in Box A1, with total teacher FTEs as the dependent variable. The same model was used to project the total number of teachers.

Box A1. Model Used to Project Total Teacher Supply

Total Teacher FTEs *= f(Time Trend, Region, Time X Region, Enrollment, Enrollment^2, % Free Lunch, % Free Lunch X Enrollment, IHE Area, IHE Area X Time, Metro Area, Metro Area X Time, Locale, Locale X Time)*

DSAC region, IHE area, metropolitan area, locale, and the interactions between those variables and time were included to account for the differences in supply across those different geographic areas and to allow the time trends for those areas to vary over time. Enrollment (squared) was

[35] IHE areas are the geographic areas surrounding the five institutions of higher education with the most education preparation program completers. The geographic area is defined as a 45-minute drive from the IHE.
[36] The percentage of students eligible for free/reduced-price lunch is used here as a proxy for the population of students in poverty.

included to account for the differences in supply across districts of varying sizes and to account for the possibility that the supply-enrollment relationship is nonlinear. The inclusion of the percentage of free/reduced-price lunch students is to account for differences in supply across districts with varying rates of student poverty. Finally, the inclusion of the interaction between students in poverty and enrollment is to allow the effect of students in poverty to vary by district size. The set of variables included in the model was based on both theoretical justification as well as testing of competing models to improve model fit.

For the primary measure of supply, the number of FTEs was used, rather than a total count of teachers. This decision was made to take into consideration the varying level of service that each teacher provides, including those serving in part-time roles, and ultimately more accurately reflect the total supply. The use of staff counts would assume that all staff provide equal levels of service and mask the extent to which some teachers work only part time (i.e., it would overestimate the number of FTE teachers providing services). However, as discussed next, it also was necessary to create a secondary measure of projected teacher supply based on the total number of teachers.

Components of Supply

Although total teacher FTEs was the primary measure of supply used to address Research Question 2, the research team also created projections of the total number of teachers and the individual components of supply, including numbers of retained teachers, new entrants, and teachers transferring across districts or from out of state. Projections were calculated for the numbers of retained and newly entering teachers, while the projected number of transferring teachers was calculated based on taking the difference between the total projected number of teachers and the sum of the projections of the other two components (numbers retained and newly entering). The teacher count projections for the three components were then used to calculate shares of total teacher supply, which were then applied to the total projected teacher FTEs. This process is discussed below in the section Harmonizing Staff Counts and Fulltime Equivalents (FTEs). In addition, the methods used to project each component of teacher supply are discussed further below.

Retained Teachers

The projected number of retained teachers was calculated by estimating a regression model that was used to forecast the total numbers of retained teachers in future years. Specifically, total numbers of retained teachers were modeled as a function of a yearly time trend, the total number of teachers, teacher age, teacher race/ethnicity, DSAC region, interactions of the time trend and total teachers, the time trend and region, total teachers and region, and time, region and total teachers, the percentage of students eligible for free/reduced-price lunch, and the interaction between the percentage of these students and total teachers, IHE area, metropolitan area, and locale, and the interactions between those three geographic groupings and the time trend. The model is presented in Box A2.[37]

[37] Additional models, including additional student characteristics, were tested, but the inclusion of these variables did little to improve the performance of the model.

Box A2. Model Used to Project Number of Retained Teachers

***Number of Retained Teachers** = f(Time Trend, Total Teachers, Teacher Age, Teacher Race/Ethnicity, Region, Time X Total Teacher, Time X Region, Total Teacher X Region, Time X Region X Total Teacher, % Free Lunch, % Free Lunch X Total Teacher, IHE Area, IHE Area X Time, Metro Area, Metro Area X Time, Locale, Locale X Time)*

As with the total supply model, the inclusion of DSAC region, IHE area, metropolitan area, and locale, as well as the interaction between those geographic variables and time, is to account for the differences in supply across geographic areas and to allow the time trend for those areas to differ. The inclusion of total teachers is to account for differences in supply across districts of varying size, while also accounting for varying supply for districts with different pupil-teacher ratios. Furthermore, due to the fact that the number of teachers retained is a function of total number of teachers, a three-way interaction between region, time trend, and total teachers is included to allow for the effect of region to vary over time as well as by district size. The inclusion of the percentage of free/reduced-price lunch students is to account for differences in supply across districts with varying rates of student poverty. Finally, the inclusion of the interaction between students in poverty and total teachers is to allow the effect of students in poverty to vary by district size.

New Entrants

Data for new entrants into the teacher profession are only readily available by the IHE (or teacher preparation program) where new entrants were trained, rather than by district. Data on new entrants by IHE consist of the number of program completers by IHE and an estimate of the proportion of program completers hired by Massachusetts public schools. Therefore, new entrants were calculated as the number of program completers multiplied by the proportion hired by public schools in Massachusetts. Because data on the number of new entrants in a given district are not available, in order to calculate these figures, the research team assumed that the majority of new entrants would join the workforce in a district within the vicinity (i.e., within a 45-minute drive) of the IHE where they completed their training. This approach is based on the tendency for newly certified teachers to take positions at a school near their IHE, as noted in the ESE workforce report (ESE, 2013) and other research (Boyd, Lankford, Loeb, & Wyckoff, 2009). The method used to estimate the number of new entrants by district is described in detail below in the section Distributing New Entrants by District.

Once new entrants by district were calculated, a regression model was used to predict the total number of new entrants in future years. Specifically, total numbers of new entrants were modeled as a function of a yearly time trend, total enrollment, enrollment squared, DSAC region, an interaction between region and enrollment and region and enrollment squared, IHE area, metropolitan area, and locale, as well as the interaction between these geographic areas and the time trend. The model is presented in Box A3.

Box A3. Model Used to Project New Entrants

Number of New Entrants *= f(Time Trend, Region, Enrollment, Enrollment^2, Region X Enrollment, Region X Enrollment^2, IHE Area, IHE Area X Time, Metro Area, Metro Area X Time, Locale, Locale X Time)*

As with the total supply model, the inclusion of enrollment (squared) is to account for differences in supply across districts of varying sizes and for the possibility that the new entrant-enrollment relationship is nonlinear. The DSAC region is included to account for differences in supply across regions. Interactions between region and enrollment (squared) are included to allow for the effect of the region to vary by district size. IHE area, metropolitan area, and locale, as well as the interactions with those geographic areas and the time trend, were included to account for differences in supply across geographic area and to allow time trends to vary by geographic area.

Because many of the districts have small values for new entrants, the use of a linear functional form often resulted in a negative projection of the number of new entrants for future years. To mitigate this, Poisson regression was used, which has the advantage of restricting the value of projections to be greater than zero.[38] It should be noted that due to the fact that only three years of historical data were available on which to base future projections, the forecasts of new entrants must be interpreted with caution.

Harmonizing Staff Counts and Fulltime Equivalents (FTEs)

Although the primary analyses for this study considered only FTE counts of teachers, the data used to address some analyses were only available in staff counts; specifically, the data on supply components, including retained teachers and new entrants. As a result, steps were taken to harmonize the FTE-based aggregate results and the more granular staff count-based results.

First, projections were calculated based on staff count data using the methods described earlier in this report. For each projected year, we then calculated the proportion of overall teachers that were retained and constituted new entrants. The complementary proportion was then calculated for the third component, transfer teachers. Then, using the projections of total teachers based on FTE counts, we applied the calculated staff count proportions to these projections. For example, the proportions of retained teachers and new entrants projected in 2016 were 85 percent and 4 percent, respectively, so that the proportion of transfer teachers was calculated to make up the remaining 11 percent. These proportions were applied to the overall projected FTE count of teachers in 2016 of 66,170, yielding supply measures in FTE terms of retained, new entrants, and transfers of approximately 56,320, 2,250, and 7,400, respectively, for that year. A similar method was used to estimate FTE projections for supply components in the disaggregated analysis in Research Question 4.

[38] In addition, to improve the fit of the model, the natural log of enrollment and its square were used.

Distributing New Entrants by District

To estimate the number of individuals newly entering a given district from a teacher preparation institution, new entrants were assigned a district based on travel time from their preparation institution to each district. The assignment method is based on the assumption that the majority of new entrants join the workforce in a district within the vicinity of the institution where they completed their training. Specifically, assignment of new entrants to districts was governed by a travel time cutoff indicating whether an institution and district are in the same vicinity.

Calculation of travel times required data on the latitude and longitude coordinates of each institution and district in the state. The research team used one of two methods for determining latitude and longitude coordinates: (1) by entering the name of the teacher preparation institution and "Massachusetts" into the Stata program *mqgeocode* (the preferred method), and (2) by entering the institution's name into Google Maps and retrieving the coordinates one at a time (the less efficient method used when mqgeocode failed to locate the latitude and longitude for an institution).

The latitude and longitude for individual districts were obtained from the NCES Common Core of Data database. District latitude and longitude values were collected for the school years 2007–08 through 2012–13. For the majority of districts, the latitude and longitude values varied slightly over the years. It seemed improbable that so many districts physically changed location over the time period; therefore, the mode of the latitude and longitude for a given district across years was used as the latitude and longitude in the case where there was a single mode. Where there was not a single mode, the mean value of the latitude and longitude for a given district was used as the latitude and longitude.

Using latitudes and longitudes, travel times and distances were calculated for each combination of district and institution using the Stata program *mqtime*.[39] New entrants were then assigned to districts under the assumption that 75 percent of new entrants are hired by districts located within a 45-minute drive of the institution where they were trained. The total number of students for districts within the drive time cutoff area and those outside the area was calculated, and new entrants were assigned proportionally based on the share of total enrollment inside or outside the drive time area. For example, if District 1, which has an enrollment of 1,000, is within a 45-minute drive of Institution A, which matriculated 100 total new program completers, and the total enrollment of all districts within the 45-minute cutoff of Institution A is 10,000, the number of new entrants from Institution A that will go to District 1 is 0.75*100*(1,000/10,000), or 7.5. For districts outside the 45-minute cutoff, 0.75 in the previous equation was replaced with 0.25, and the total district enrollment represented the total enrollment outside, rather than inside, the cutoff area. Once the new entrants from each institution were assigned to each district, the total number of new entrants for a given district was totaled.

[39] Additional information on the Stata commands used to calculate travel times can be found here: http://www.stata-journal.com/article.html?article=dm0083.

Research Question 3: Demand and Supply by Program Area

Demand and supply projections by program area categories were estimated with methods similar to those used to address Research Questions 1 and 2. However, due to limitations in the data readily available, additional steps were required to estimate these projections. What follows is a detailed description of these methods.

Demand

Demand projections by program area were calculated by first projecting the proportions of teachers across program area categories over time, and applying those projected proportions to the aggregate projections of demand estimated in Research Question 1. These projections were created using regression analysis to project the proportion of teachers in each program area category in future years. Specifically, this proportion was estimated as a function of a yearly time trend, DSAC region, the time trend interacted with the region, the total number of students in the district, the percentage of students who receive free or reduced-price lunch, the percentages who are African American and Hispanic, the district locale (city, suburb, town, or rural), and whether or not a district was vocational/technical. The model is presented in Box A4.

Box A4. Model Used to Project Proportions of Teachers by Program Area Category

Proportion of Teachers in Given Category *= f(Time Trend, Region ,Time X Region, Enrollment, % Free Lunch, % African American, % Hispanic, Locale, Vocational/Technical)*

The inclusion of the yearly time trend, DSAC region, and the interaction between these two variables is to account for differential patterns of supply over time, across regions, and across regions over time. The inclusion of enrollment (squared) is to account for the differences in supply across districts of varying sizes and for the possibility that the supply-enrollment relationship is nonlinear. The inclusion of the percentage of free/reduced-price lunch and minority students is to account for differences in supply across districts with varying rates of these types of students. The inclusion of the locale variable is to account for differences in supply across different levels of relative district urbanicity. Finally, a variable indicating whether or not a district was vocational/technical was included to account for the inherent systemic differences in the numbers of career/vocational/technical teachers in these districts.

Because proportions are being estimated by the regression model, and proportions by definition are numbers between 0 and 1, a special functional form called a fractional logit model was used. Predicted outcomes from logit models are constrained to be between 0 and 1. In this case the model is a fractional logit model because the outcome variable is a proportion rather than a binary categorical variable.

Supply

As with the supply projections in Research Question 2, the estimation of supply was based on teacher FTEs, rather than counts of teachers.

Total Supply by Program Area

The projected supply of teachers by program area is defined as the number of teacher FTEs in different program area groups. These projections were created using regression analysis to forecast the number of teachers in each program area category in future years. Specifically, FTE counts by these categories were modeled as a function of a yearly time trend, DSAC region, an interaction between the time trend and region, the total number of teachers, the percentage of students receiving free or reduced-price lunch, the percentages of African-American and Hispanic students, the total number of teachers interacting with the three student characteristic percentages, and whether or not a district was vocational/technical. The model is presented in Box A5.

Box A5. Model Used to Project Supply by Program Area Categories

FTEs by Subject or Program Area Category *= f(Time Trend, Region, Time X Region, Total Teachers, % Free Lunch, % African American, % Hispanic, % Free Lunch X Total Teacher, % African American X Total Teacher, % Hispanic X Total Teacher, Vocational/Technical*)

As with the aggregate supply model, the inclusion of the yearly time trend, DSAC region, and the interaction between these two variables is to account for the differential patterns of supply over time, across regions, and across regions over time. The inclusion of total teachers is to account for differences in supply across districts of varying size. The inclusion of the percentages of free/reduced-price lunch, African-American, and Hispanic students is to account for differences in supply across districts with varying rates of these types of students. The inclusion of the interaction between these student populations and total teachers is to allow the effect of these populations to vary by district size. In addition, because the numbers of teachers in various program area categories are often quite small or zero, a Poisson regression model was used to restrict predicted counts of teachers to be above zero. Finally, a variable indicating whether or not a district was vocational/technical was included to account for the inherent systemic differences in the numbers of career/vocational/technical teachers in these districts.

Retained Teachers

Due to the fact that data on FTEs of retained teachers by program area were not available, a multistep process was used to estimate these projections. The first step was to estimate statewide average retention rates by program area category. These estimates were created using a regression analysis to estimate an average retention rate for each category for historical years. Specifically, the retention rate was modeled as a function of the proportion of teachers who are in the various program area categories.[40] Additional variables about the types of students in the districts were added to the model as they seemed to significantly influence estimated retention rates. The model used to predict the retention rate by race and age groups is shown in Box A6.

[40] The percentage of general education teachers was omitted from the retention rate model to serve as the reference group.

Box A6. Model Used to Project Retention Rates by Program Area Categories

Retention rate by program area*= f(% special education, % CTE, % ELL, LEP student %, special education student %, Vocational/Technical)*

Because the retention rates are proportions, fractional logit models were used (previously described earlier in this section). Using this model, the retention rate for each group was estimated by predicting the retention rate of a hypothetical district if all teachers were in a particular program area. These estimated retention rates for hypothetical districts represent the estimated statewide average retention rates for teachers within a particular program area category.

Once average retention rates were calculated, the number of retained teachers in each district was estimated by applying the average retention rate to FTEs of teachers in the given program area. The total estimated retention was calculated by adding up the estimated retained FTEs across the categories. The aggregated estimates were then adjusted using a ratio of the estimated aggregated retention counts to actual retention measured in FTEs.[41] For example, if the sum of the estimated retained FTEs across program area categories in a given district was higher than the actual retained FTEs, then the estimated retention in each category was decreased according to the calculated ratio, such that the sum of retained FTEs across categories equaled the actual retained FTEs as shown in the data. Occasionally, this method resulted in a larger number of retained FTEs than total FTEs for a given category with a high retention rate. When this occurred, the estimated FTEs retained were capped at the total FTEs for the category, and the additional number or retained FTEs were reapportioned to categories of teachers with lower retention rates.

Once retention by program area for each district was estimated, the following Poisson regression, similar to that used to predict retention in Research Question 2, was used to predict the number retained by program area categories for future years. The model is presented in Box A7.

Box A7. Model Used to Project Retained Teachers by Program Area Categories

Retained FTEs By Program Area *= f(Time Trend, Region, Time X Region, Total Teachers, % Free Lunch, % Free Lunch X Total Teachers, Total African-American Teacher Count, Time X Total African-American Teacher Count, Total Hispanic Teacher Count, Time X Total Hispanic Teacher Count, Vocational/Technical)*

As with the aggregate retained teachers model, a yearly time trend, DSAC region, and the interaction between these two variables are included so that the models can account for differential patterns of retained teachers over time, across regions, and across regions over time. The total number of teachers over time was included so that the differences across districts of varying size can be accounted for in the models. The inclusion of the percentage of free/reduced-price lunch students helped to account for differences across districts with varying rates of

[41] The data for retention use numbers of teachers rather than FTEs. In order to convert the number of retained teachers to retained FTEs, the retained number of teachers was multiplied by the ratio of total FTEs to total number of teachers.

student poverty. The inclusion of the interaction between students in poverty and total teachers allows the effect of students in poverty to vary by district size. The overall FTEs of African-American and Hispanic teachers also was included for the model, predicting retention to account for districts with unusually high or low numbers of minority teachers, such as Boston. Finally, total teachers and minority teachers were log transformed in the above model to improve overall fit.

Research Question 4: Demand and Supply by Race and Age Categories

Demand and supply projections by race and age categories were estimated using methods similar to those described in Research Question 3, although additional analyses of supply subcomponents also were conducted. What follows is a detailed description of these methods.

Demand

Demand projections by race and age were calculated by first projecting the proportions of teachers in the various race and age categories over time, and then applying those projected proportions to the aggregate projections of demand estimated in Research Question 1. These projections were created using regression analysis to forecast the proportion of teachers in each race and age category in future years. Specifically, this proportion was estimated as a function of a yearly time trend, DSAC region, the time trend interacted with the region, the total number of students in the district, the percentage of students who receive free or reduced-price lunch, the percentages of students who are African American and Hispanic, district locale (city, suburb, town, or rural), and a dummy variable for the Boston Public Schools district. The model is presented in Box A8.

Box A8. Model Used to Project the Proportion of Teachers by Race and Age Categories

Proportion of Teachers in Given Category *= f(Time Trend, Region ,Time X Region, Enrollment, % Free Lunch, % African American, % Hispanic, Locale, Boston)*

The inclusion of the time trend, DSAC region, and the interaction between these two variables is to account for the differential patterns of supply over time, across regions, and across regions over time. Enrollment and its square are included to account for the differences in supply across districts of varying sizes and for the possibility that this relationship is nonlinear. The inclusion of the percentage of free/reduced-price lunch students and minority students is to account for differences in supply across districts with varying rates of these types of students. The locale variable is included to account for differences in the level of relative district urbanicity. Even though region and locale were included, the models did not do a particularly good job of predicting proportions for Boston—particularly for minority teachers. As such, a dummy variable was included for Boston. Because proportions serve as the outcome being estimated by the regression model, a special functional form called a fractional logit model was used.

Supply

As with the supply projections in Research Question 1, the estimation of supply was based on teacher FTEs, rather than teacher counts. Subcomponents of supply—retained, newly entering, and transferring teachers—also were estimated. Because the available data did not disaggregate retained teachers and new entrants by race and age, additional steps were required to estimate these subcomponents of supply by race and age categories. As such, additional assumptions were made lending additional error to these projections. Because of the additional uncertainty in these measurements, we have chosen not to present the results of these breakdowns in the main text.

Total Supply

The projected supply of teachers by race and age is defined as the number of FTEs in different race and age groups. These projections were created using regression analysis to forecast teacher FTEs in each race and age category in future years. Specifically, teacher FTEs in each category were modeled as functions of a yearly time trend, DSAC region, an interaction between the time trend and region, the total number of teachers, the percentage of students receiving free or reduced-price lunch, percentages of African-American and Hispanic students, and the total number of teachers interacted with these three student characteristic percentages. The model is presented in Box A9.

Box A9. Model Used to Project Supply by Race and Age Categories

> ***FTEs by Race or Age Category*** *= f(Time Trend, Region, Time X Region, Total Teachers, % Free Lunch, % African American, % Hispanic, % Free Lunch X Total Teacher, % African American X Total Teacher, % Hispanic X Total Teacher)*

As with the aggregate supply model, the inclusion of the time trend, DSAC region and the interaction between these two variables is to account for the differential patterns of supply over time, across regions, and across regions over time. Total teachers are included to account for differences in supply across districts of varying size. Inclusion of percentages of free/reduced-price lunch students and minority students is to account for differences in supply across districts with varying rates of these types of students. Inclusion of the interaction between these student populations and total teachers is to allow the effect of these student populations to vary by district size. Finally, because the numbers of minority teachers and teachers in various age categories are often quite small or zero, a Poisson regression model was used to restrict predicted counts of teachers by age and race categories to be above zero.

Retained Teachers

Due to the fact that data on FTEs of retained teachers by race and age are not available, a multistep process was used to estimate these projections. The first step was to estimate statewide average retention rates by race and age category. These estimates were created using a regression analysis to estimate an average retention rate for each race and age category for historical years. Specifically, the retention rate was modeled as a function of the proportion of teachers who are

in the various age and race categories.[42] Additional variables about the types of students in the districts were added to the model for race, as they seemed to significantly impact the estimated retention rates. The inclusion of additional variables did yield substantial changes to the estimated retention rates by age categories and therefore were excluded. The models used to predict the retention rate by race and age groups are shown in Box A10.

Box A10. Models Used to Project Retention Rates by Race and Age Categories

Retention Rate by Race*= f(% African American, % Asian, % Hispanic, % American Indian, % Hawaiian/Pacific Islander, % Multiracial, African American Student %, Hispanic Student %, Free/Reduced Lunch Student %)*

Retention Rate by Age Group *= f(% Age Under 26, % Age 26-32, % Age 33-40, % Age 41-48, % Age 57-64, % Age Over 64)*

Because the retention rates are proportions, fractional logit models were used. Using this model, the retention rates for each group were estimated by making predictions for a hypothetical district if all teachers were in a particular race or age category, while holding other covariates constant. These estimated retention rates for hypothetical districts represent the estimated statewide retention rates for teachers within a particular race or age category.

Once average retention rates were calculated, the number of retained teachers in each district was estimated by applying the average retention rate by race and age category to FTEs of teachers in the given category. The total estimated retention was calculated by adding up the estimated retained FTEs across the categories. The aggregated estimates were then adjusted using a ratio of the estimated aggregated retention counts to actual retention measured in FTEs.[43] The procedure for adjusting retention counts is presented in more detail in the description of retention by subject area for Research Question 3 earlier in this appendix.

Once retention by race and age for each district was estimated, the following Poisson regression, similar to that used to predict retention in Research Question 2, was used to predict the number retained by race and age categories for future years. The model is presented in Box A11.

Box A11. Model Used to Project Retained Teachers by Race and Age Categories

Retained FTEs By Race and Age *= f(Time Trend, Region, Time X Region, Total Teachers, % Free Lunch, % Free Lunch X Total Teachers, Total Minority Teachers)*

As with the aggregate retained teachers model, the yearly time trend, DSAC region, and the interaction between these two variables are included so that the models can account for

[42] The percentage of White teachers was omitted from the retention rate-by-race model to serve as the reference group. The percentage of teachers ages 49–56 was omitted from the retention rate-by-age group model to serve as the reference group.

[43] The data for retention use numbers of teachers rather than FTEs. In order to convert the number of retained teachers to retained FTEs, the retained number of teachers was multiplied by the ratio of total FTEs to total number of teachers.

differential patterns of retained teachers over time, across regions, and across regions over time. The total number of teachers over time was included to control for the differences across districts of varying size. The inclusion of the percentage of free/reduced-price lunch students helped to account for differences across districts with varying rates of student poverty. The interaction between students in poverty and total teachers is included to allow for the effect of students in poverty to vary by district size. The overall FTEs of minority teachers also was included for the model predicting minority retention to account for districts with abnormally high or low numbers of minority teachers, such as Boston. Finally, total teachers and minority teachers were log transformed in the above model to improve overall fit.

New Entrants

As with retention, estimates for FTEs of new entrants by race and age first had to be calculated, as there were no data available for program completers or percentage employed by race and age.

Numbers of new entrants by race for particular institutions were calculated using the average proportion of students by race enrolled in each institution from 2010–11 to 2012–13. Although the distribution of institutional enrollments across race does not perfectly reflect the distribution of education preparation program completers or new entrants by race, it is the best information at our disposal that can be used as a proxy. In addition, the proportion of new entrants by race estimated using the enrollment characteristics is similar to the estimates of proportions of new entrants by race in Massachusetts using the NCES Schools and Staffing Survey (SASS) data from 2011–12.[44]

Once new entrants by race were determined by institution, they were apportioned to districts in the same manner as in Research Question 2. After determining the estimated historical counts of new entrants by race for each district, regression analysis was used to predict new entrants by race in future years using the same models used in the prediction of new entrants in Research Question 2.[45]

The number of new entrants by age group was estimated using the state-aggregated proportion of teachers in given age categories with less than two years of experience generated from the SASS data. Age categories in the SASS data do not correspond to the age categories used in the ESE data made available for this report. Therefore, Excel was used to estimate a cumulative distribution function of the proportion of new entrants below a given age. The estimates of new entrants below a given age could then be used to estimate the proportion of new entrants in each age category. Additional documentation on this process is available upon request.

The average proportion of new entrants in each age category was applied to the estimated number of new entrants by district, calculated in Research Question 2, to estimate the number of new entrants by age group. Because only statewide data were available on proportions of new

[44] SASS is a collection of related questionnaires used to provide descriptive data about the context of elementary and secondary education, and covers a wide range of topics. More information on this data source can be found here: https://nces.ed.gov/surveys/sass/.
[45] For more details on this model, see the section New Entrants above.

entrants by age, the proportion of new entrants in each age category is assumed to be the same across all districts.

Districts Excluded From Analysis

Over the course of preparing the data for analysis, 106 districts were excluded for various reasons. Of these excluded districts, 81 were charter districts found in the data over the six historical years used in the study analyses. The decision to exclude all charters was made for a few practical reasons. The first of these was that the unique nature of policies in charter districts with respect to data collection and reporting suggested that numbers reported by these districts may not be reliable over time, and thus should be excluded to ensure that data were comparable over historical years. In addition, many of these charters were not operational across all six years of historical data at our disposal (2008–09 through 2013–14), and the closing and opening of these districts could have distorted the historical data (the sudden addition and removal of their staff could have caused shocks). Finally, no Comparable Wage Index (CWI) data are available for charter districts, and thus they could not be included in any regression that controlled for CWI, which is true for many of our selected models.

In addition to the 81 excluded charters, another 19 districts also were excluded for a variety of reasons as follows:

- **District Not Found in All Six Years**: As with many charters, an additional seven districts were not found in all six historical years of data, and many of these were not found in the most recent year. Thus, these districts also were excluded.
- **District Not Found in 2015:** Even if districts were found in all six historical years used for study analyses, in some cases districts were not found in the 2014–15 enrollment data.[46] Four districts were excluded for this reason.
- **Incomplete Historical Data**: An additional eight districts were excluded because they did not have complete data for all required metrics in all years of historical data. These metrics include CWI data, NCES locale data, or total teacher staff counts data.

[46] Recall that although 2014–15 enrollment data were available, 2014–15 staffing data were not; consequently, 2014–15 was projected for all analyses.

A summary of the non-charter excluded districts is displayed in Table A3.

Table A3. Non-charter Excluded Districts

District Name	District Code	Reason for Exclusion
Barnstable	20000	Not found in 2014–15
Ayer	190000	Not in all six historical years
Boxborough	370000	Not found in 2014–15
Carver	520000	No staff count data in 2010
Chatham	550000	Not in all six historical years
Freetown	1020000	Not in all six historical years
Granville	1120000	Not in all six historical years
Harwich	1260000	Not in all six historical years
Lakeville	1460000	Not in all six historical years
Provincetown	2420000	No staff count data in 2011
Shirley	2700000	Not in all six historical years
Williamsburg	3400000	No staff count data in 2013
MA Academy of Math and Science	4680000	No CWI data
Ayer Shirley School District	6160000	No CWI data
Monomoy Regional School District	7120000	No CWI data
Somerset Berkley Regional School District	7630000	No CWI data
North Shore Regional Vocational Technical	8540000	Not found in 2014–15
Essex Agricultural Technical	9130000	Not found in 2014–15
Massachusetts Virtual Academy at Greenfield Commonwealth Virtual School	39010000	No NCES locale data

Appendix B. Additional Findings and Exhibits

Research Question 3: Demand and Supply Projections by Program Area

Retained Teachers

The research team also estimated projections of the supply of retained teachers over the next 10 years by program area. First, statewide average retention rates by race and age category were created using a regression analysis to estimate an average retention rate for each race and age category for historical years. These retention rates were then applied to FTEs of teachers in the given category to calculate the number of retained FTEs in each district. Then projections were estimated using a regression-based approach.

We found that most program areas were expected to have generally similar retention rates. Specifically, general education, special education, and career/vocational/technical education (CTE) teachers had average estimated retention rates that were between 86 and 91 percent. This was in line with the overall statewide average retention rate of about 85 percent.

In contrast, English language learner (ELL) teachers were estimated to have a lower average retention rate of about 55 percent. However, as can be seen in Table B1, the confidence interval around this estimate was relatively large, suggesting that the estimated retention rate and the corresponding projections of retained ELL teachers should be interpreted with caution.[47]

Table B1. Average Estimated Teacher Retention Rates by Program Area

Program Area	Estimated Average Retention Rate	95% Confidence Interval–Lower Bound	95% Confidence Interval–Upper Bound
General Education	86%	85%	88%
Special Education	91%	86%	95%
English Language Learners Education	55%	13%	96%
Career/Vocational/Technical Education	88%	84%	93%

Using the retention rates above, we then estimated projections of retained teachers in each program area. Due to the fact that the majority of the teacher population is retained year to year, it is not surprising that the projections of retained teachers generally follow the same trends as the supply projections overall (Table B2). For example, the projected trend for general education teachers is similar to the overall projected trend over the next 10 years.

[47] See the Appendix A for more details on the methods used to estimate these retention rates.

Table B2. Projected Percent and Absolute Changes in Statewide Supply of Retained Teachers by Program Area, 2014–15 Through 2023–24

Program Area	Average Annual Percent Change: 2014–15 Through 2023–24	Overall Percent Change: 2014–15 Through 2023–24	Overall Absolute Change: 2014–15 Through 2023–24
General Education	0.74%	7.65%	3,572
Special Education	-2.07%	-18.94%	-1,428
English Language Learners Education	-2.64%	-23.45%	-187
Career/Vocational/Technical Education	-0.56%	-5.44%	-93

Research Question 4a: Demand and Supply Projections by Race

As an additional analysis related to demand and supply projections by race, the research team estimated projections of retained teachers, new entrants, and transfers by race. The retained teacher projections were created in much the same way as they were for Research Question 3. To estimate new entrant projections by race, we first estimated new entrants based on the average proportion of students by race enrolled in each institution of higher education (IHE) and then created projections at the district level using a regression-based approach. Finally, we estimated transfers based on the total teacher, retained teacher, and new entrant projections. The assumptions and methods used for these analyses are described in more detail in the Data and Methods section and Appendix A of this report.

Retained Teachers

As seen in Table B3, the number of retained minority teachers is expected to decrease annually by almost 0.5 percent, on average, between 2013–14 and 2023–24, which will result in an overall decline of more than 4 percent in total over the same time period. The decline of 128 retained minority teachers outpaces the overall decline in the supply of minority teachers, which is expected to decline by only 21 teachers from 2014–15 to 2023–24. Moreover, the decline in the retention of minority teachers is faster than the decline in the retention of White teachers, which is only expected to change by 0.37 percent per year, or 3.65 percent overall.

Table B3. Projected Percent and Absolute Changes in Statewide Supply of Retained Teachers by Race, 2014–15 Through 2023–24

Race	Average Annual Percent Change: 2014–15 Through 2023–24	Overall Percent Change: 2014–15 Through 2023–24	Overall Absolute Change: 2014–15 Through 2023–24
All Minority	-0.46%	-4.50%	-128
White	-0.37%	-3.65%	-1,968

The estimated trends for all minorities versus Whites are not all that surprising when we consider the average estimated retention rates for specific race categories versus that of White teachers. As shown in Table B4, African-American, Asian, and Hispanic teachers all have much lower average estimated retention rates than White teachers. Furthermore, these findings may be

driving the overall decline in the supply of minority teachers as retention constitutes the largest share of overall supply.

Table B4. Estimated Average Retention Rates for Minority and White Teachers

Race	Estimated Average Retention Rate	95% Confidence Interval–Lower Bound	95% Confidence Interval–Upper Bound
African American	65%	24%	107%
Asian	63%	16%	111%
Hispanic	72%	43%	100%
Native American	100%	96%	104%
Native Hawaiian, Pacific Islander	94%	49%	138%
Multirace, Non-Hispanic	70%	17%	122%
White	87%	87%	88%

New Entrants

The supply of newly entering teachers also was analyzed by race (Table B5). Specifically, we found that minority new entrants are expected to decline by an average of 6.69 percent each year between 2012–13 and 2022–23, or by approximately 50 percent in total over the period. Although these changes seem large in relative terms, they amount to a drop of only 173 teachers. In fact, new entrants are a very small proportion of total supply in general, making up only 4.8 percent of all teachers over the past three years. The supply of White new entrants also is expected to decline. Specifically, we found that newly entering White teachers are expected to decline by an average of 7.19 percent each year between 2012–13 and 2022–23, or approximately 52.6 percent (equal to 1,317 teachers) in total over the same time period.

Table B5. Projected Percent and Absolute Changes in Statewide Supply of New Entrants by Race, 2012–13 Through 2022–23

Race	Average Annual Percent Change: 2012–13 Through 2022–23	Overall Percent Change: 2012–13 Through 2022–23	Overall Absolute Change: 2012–13 Through 2022–23
All Minority	-6.69%	-50.04%	-173
White	-7.19%	-52.59%	-1,317

These results suggest that the projected decline in new entrants statewide is consistent for both White and minority new entrants. However, it is important to bear in mind that the data upon which the new entrant projections were based only consisted of three years of historical data, so these projections should be interpreted with caution.

Transfers

We found that the supply of minority teachers transferring into districts, either from other districts or elsewhere (i.e., those who did not transfer from a teacher preparation program) is expected to grow (Table B6). Specifically, minority transfer teachers are projected to increase

2.23 percent, on average, each year between 2012–13 and 2022–23, growing 24.62 percent in total, or 278 teachers over the period. The supply of White transfer teachers is expected to increase at a much slower average annual rate of 0.61 percent, amounting to an increase of 348 teachers over the period.

Table B6. Projected Percent and Absolute Changes in Statewide Supply of Transfers by Race, 2012–13 Through 2022–23

Race	Average Annual Percent Change: 2012–13 Through 2022–23	Overall Percent Change: 2012–13 Through 2022–23	Overall Absolute Change: 2012–13 Through 2022–23
All Minority	2.23%	24.62%	278
White	0.61%	6.03%	348

Research 4b: Demand and Supply Projections by Age

Demand Projections by Age

Figures B1 and B2 present demand projections by age for the 41–48 and 49–56 age groups.

Figure B1. Historical and Projected Statewide Demand for Teachers Ages 41 to 48 in Terms of FTEs, 2008–09 Through 2023–24

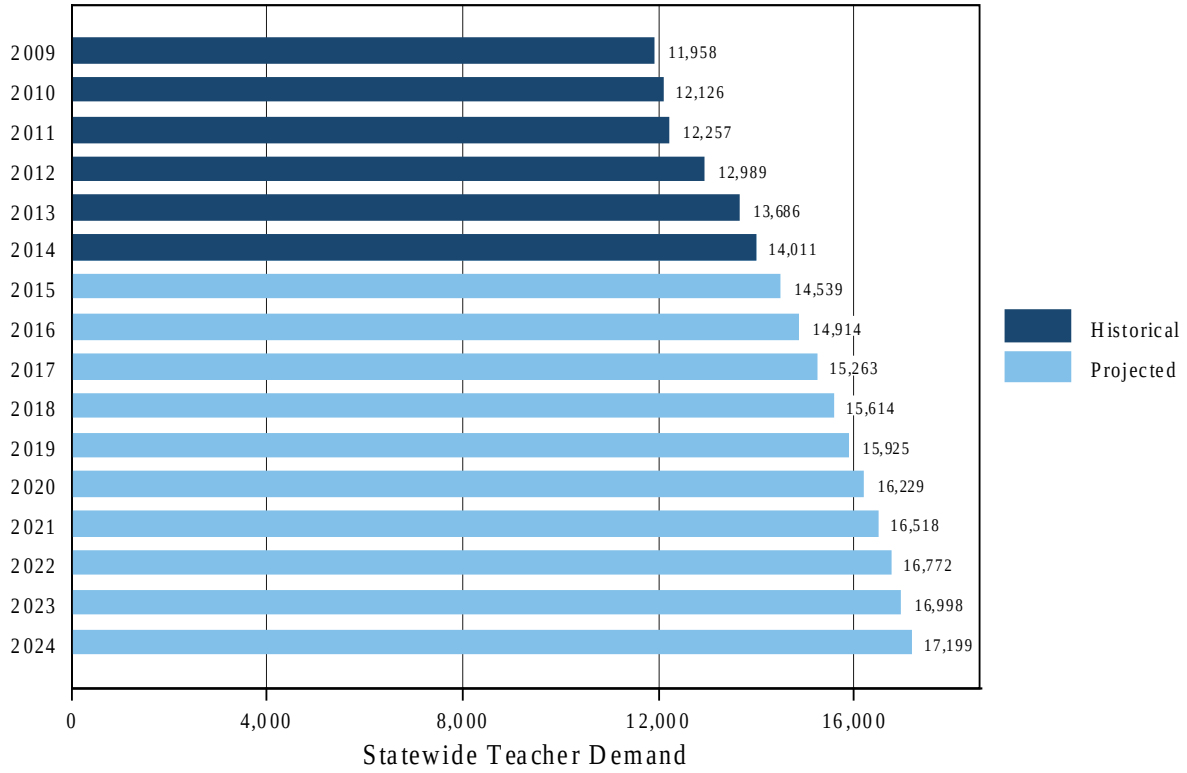
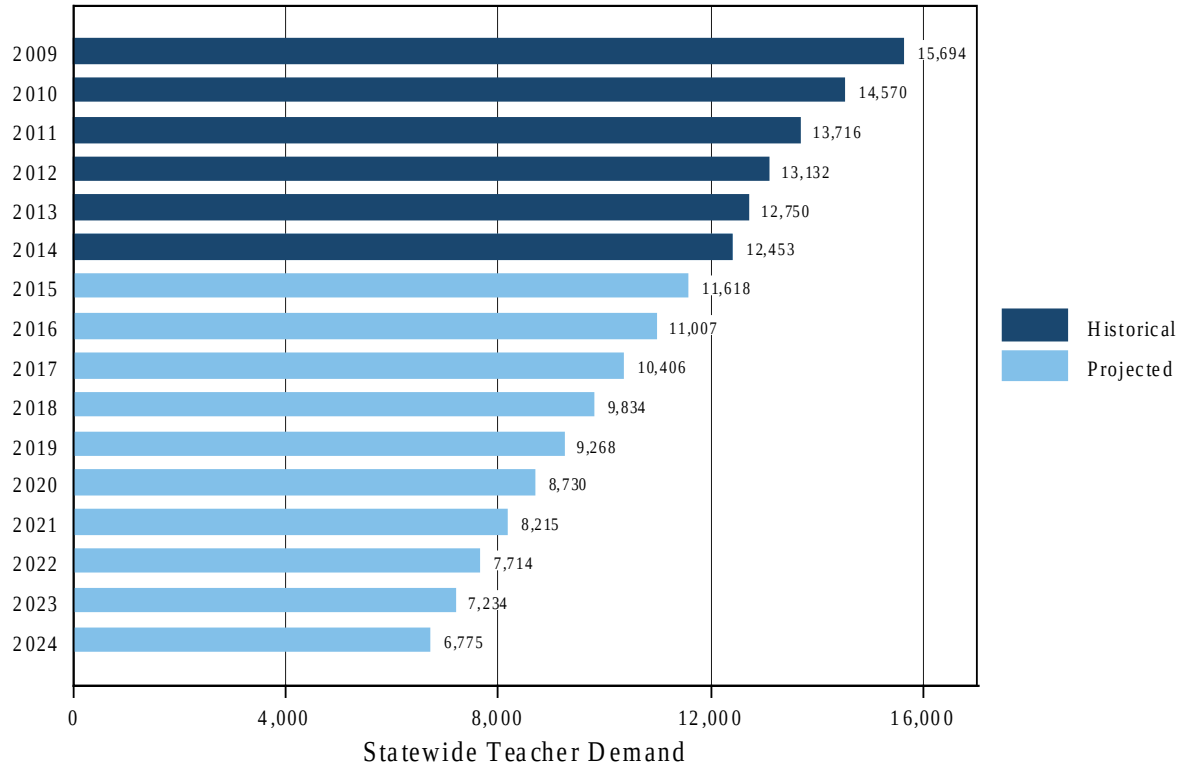


Figure B2. Historical and Projected Statewide Demand for Teachers Ages 49 to 56 in Terms of FTEs, 2008–09 Through 2023–24



Comparing Supply and Demand by Age

The following tables and figures present the comparison of demand and supply projections for each age group not presented in the main body of the report.

Table B7. Projected Statewide Demand and Supply of Teachers Ages 26 to 32 in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	12,456	12,301	155	1.26%
2015–16	12,378	12,177	200	1.65%
2016–17	12,301	12,034	267	2.22%
2017–18	12,225	11,893	332	2.79%
2018–19	12,150	11,728	422	3.60%
2019–20	12,077	11,561	516	4.46%
2020–21	12,004	11,391	613	5.38%
2021–22	11,933	11,204	729	6.51%
2022–23	11,863	11,007	855	7.77%
2023–24	11,793	10,804	990	9.16%

Figure B3. Historical and Projected Statewide Supply and Demand for Teachers Ages 26 to 32 in Terms of FTEs, 2008–09 to 2023–24

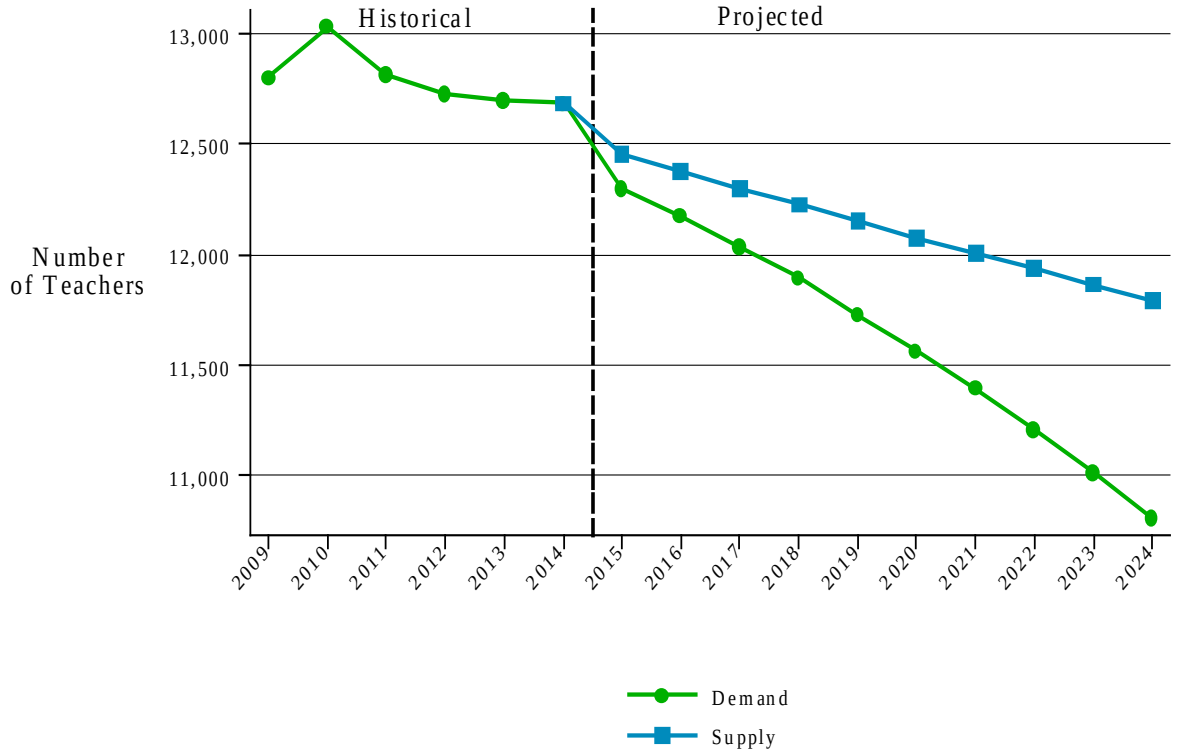


Table B8. Projected Statewide Demand and Supply of Teachers Ages 33 to 40 in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	14,343	14,265	78	0.55%
2015–16	14,537	14,306	231	1.61%
2016–17	14,735	14,319	416	2.91%
2017–18	14,937	14,332	605	4.22%
2018–19	15,143	14,308	835	5.84%
2019–20	15,353	14,277	1,076	7.54%
2020–21	15,567	14,235	1,332	9.36%
2021–22	15,786	14,166	1,619	11.43%
2022–23	16,009	14,078	1,930	13.71%
2023–24	16,236	13,973	2,262	16.19%

Figure B4. Historical and Projected Statewide Supply and Demand for Teachers Ages 33 to 40 in Terms of FTEs, 2008–09 to 2023–24

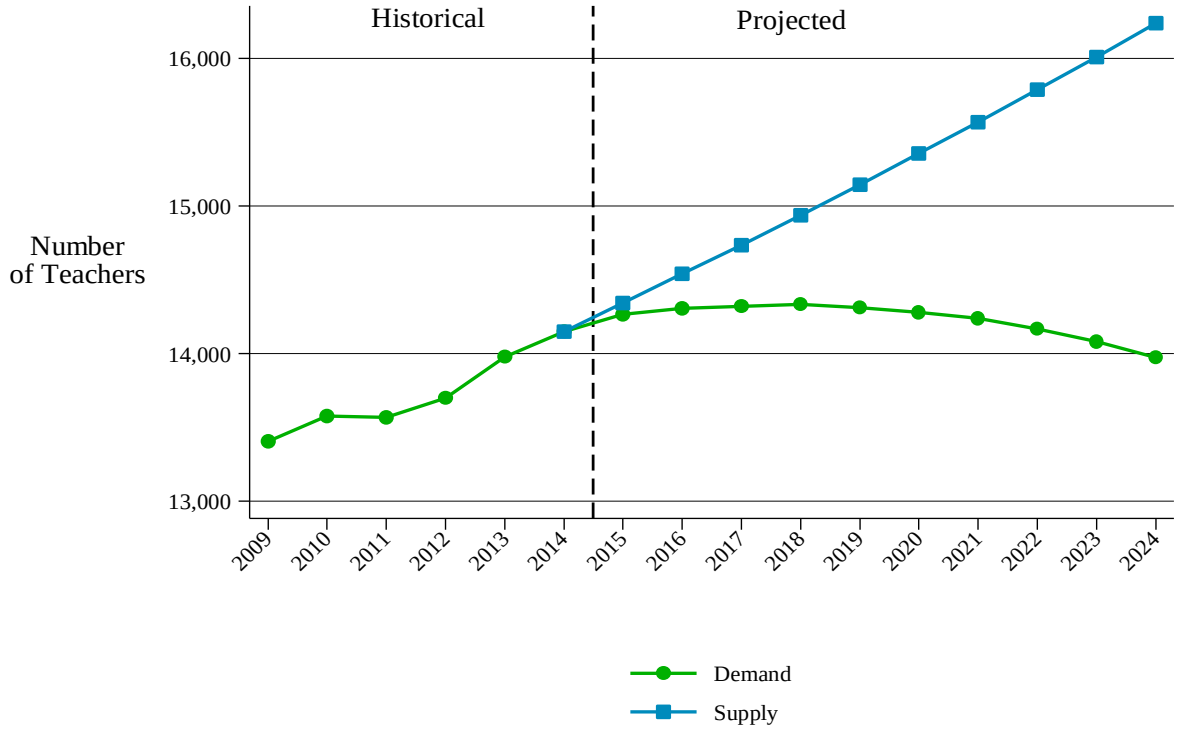


Table B9. Projected Statewide Demand and Supply of Teachers Ages 41 to 48 in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	14,369	14,539	-170	-1.17%
2015–16	14,869	14,914	-45	-0.30%
2016–17	15,390	15,263	127	0.83%
2017–18	15,933	15,614	319	2.04%
2018–19	16,498	15,925	573	3.60%
2019–20	17,088	16,229	859	5.29%
2020–21	17,703	16,518	1,185	7.17%
2021–22	18,344	16,772	1,573	9.38%
2022–23	19,013	16,998	2,015	11.86%
2023–24	19,710	17,199	2,512	14.60%

Figure B5. Historical and Projected Statewide Supply and Demand for Teachers Ages 41 to 48 in Terms of FTEs, 2008–09 to 2023–24

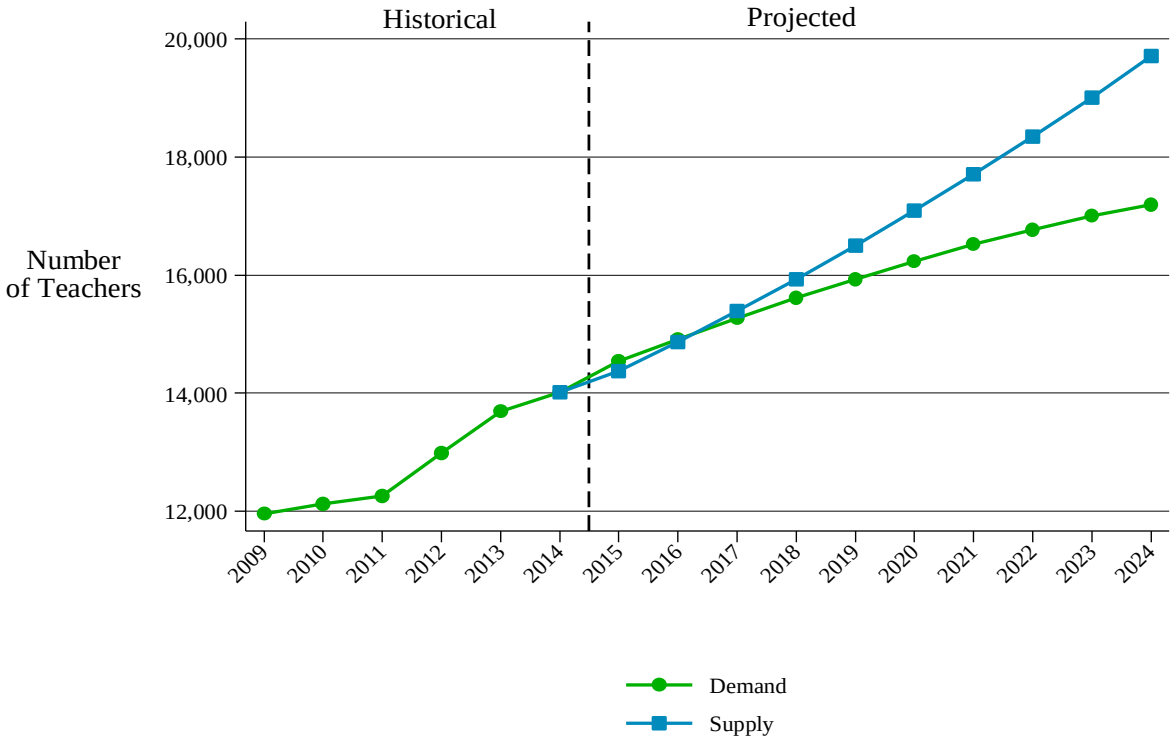


Table B10. Projected Statewide Demand and Supply of Teachers Ages 49 to 56 in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	11,445	11,618	-173	-1.49%
2015–16	10,877	11,007	-130	-1.18%
2016–17	10,338	10,406	-67	-0.65%
2017–18	9,827	9,834	-7	-0.07%
2018–19	9,342	9,268	74	0.80%
2019–20	8,882	8,730	153	1.75%
2020–21	8,446	8,215	231	2.81%
2021–22	8,032	7,714	318	4.12%
2022–23	7,639	7,234	405	5.60%
2023–24	7,266	6,775	490	7.24%

Figure B6. Historical and Projected Statewide Supply and Demand for Teachers Ages 49 to 56 in Terms of FTEs, 2008–09 to 2023–24

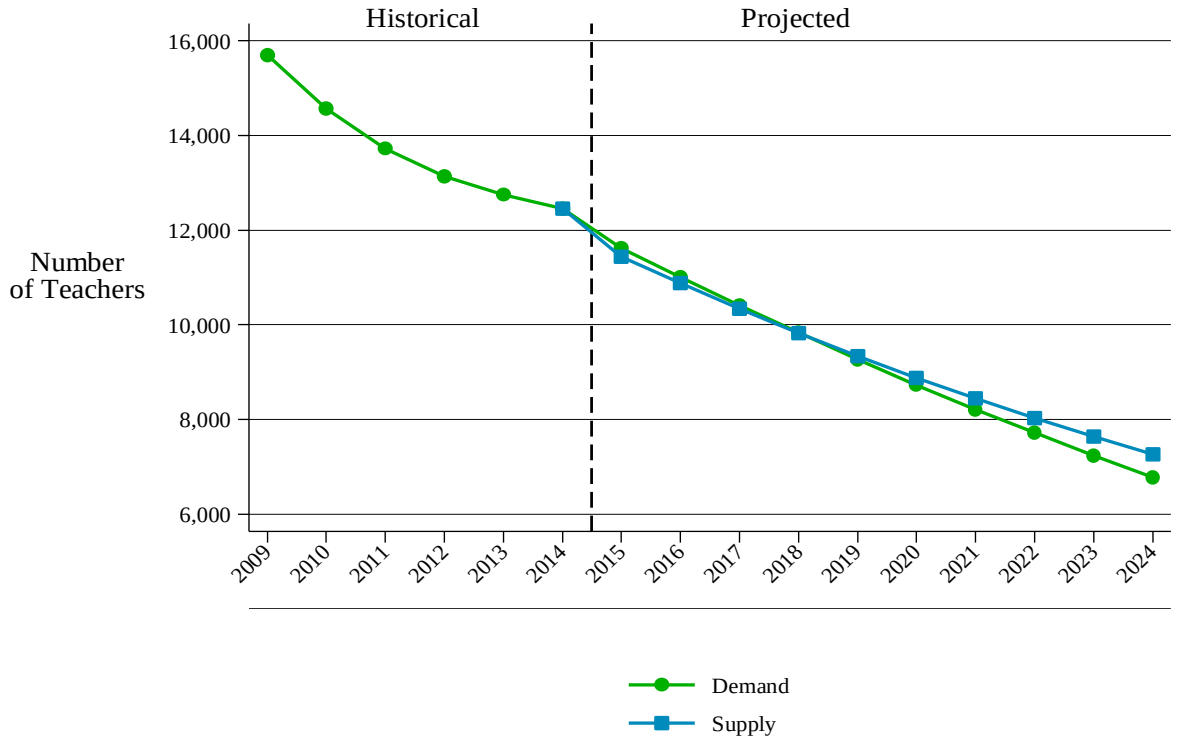


Table B11. Projected Statewide Demand and Supply of Teachers Ages 57 to 64 in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	9,412	9,573	-161	-1.68%
2015–16	9,385	9,553	-168	-1.76%
2016–17	9,359	9,515	-156	-1.64%
2017–18	9,334	9,477	-143	-1.51%
2018–19	9,310	9,415	-106	-1.12%
2019–20	9,286	9,350	-64	-0.68%
2020–21	9,264	9,278	-14	-0.15%
2021–22	9,242	9,189	54	0.59%
2022–23	9,222	9,088	134	1.47%
2023–24	9,202	8,977	225	2.50%

Figure B7. Historical and Projected Statewide Supply and Demand for Teachers Ages 57 to 64 in Terms of FTEs, 2008–09 to 2023–24

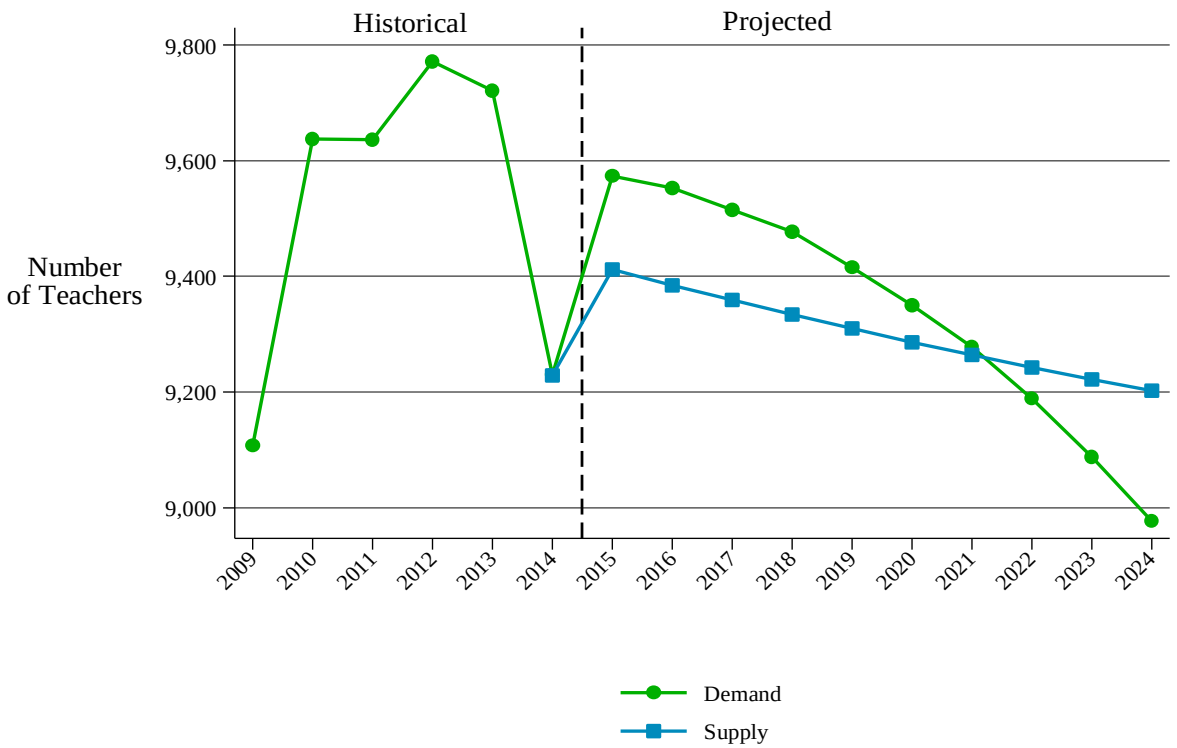
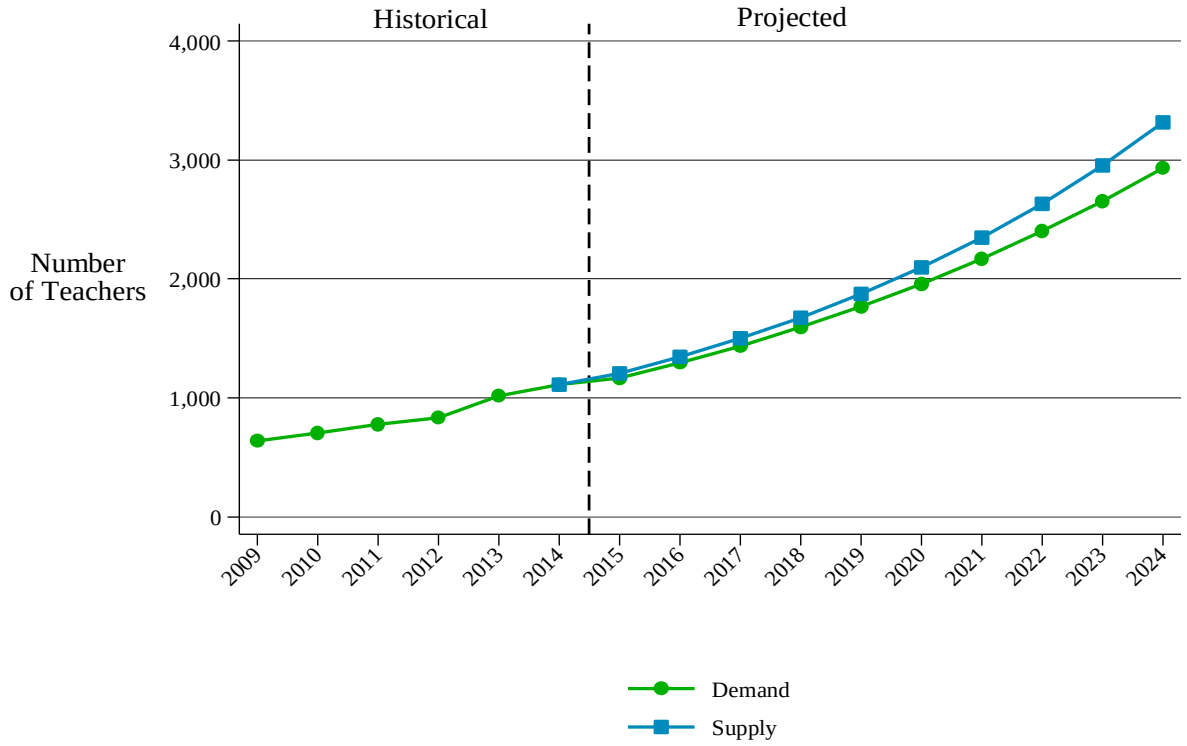


Table B12. Projected Statewide Demand and Supply of Teachers Over 64 Years of Age in Terms of FTEs and Absolute and Relative Differences, 2014–15 Through 2023–24

Year	Projected Supply	Projected Demand	Absolute Difference Between Supply and Demand	Relative Difference Between Supply and Demand
2014–15	1,205	1,167	38	3.25%
2015–16	1,344	1,295	48	3.73%
2016–17	1,500	1,437	63	4.41%
2017–18	1,676	1,595	81	5.09%
2018–19	1,874	1,767	107	6.03%
2019–20	2,098	1,959	138	7.05%
2020–21	2,350	2,172	178	8.19%
2021–22	2,634	2,404	230	9.58%
2022–23	2,955	2,657	298	11.21%
2023–24	3,317	2,933	384	13.10%

Figure B8. Historical and Projected Statewide Supply and Demand for Teachers Over 64 Years of Age in Terms of FTEs, 2008–09 to 2023–24



Research Question 5: Demand and Supply Projections by Region

The demand and supply projections underlying the surpluses and shortages reported in the Results section are presented and discussed below.

Demand Projections

The resulting disaggregated demand trend projections for specific regions of the state and locales are very much in line with the aggregate trend in demand in the results found for Research Question 1. With few exceptions, demand is projected to decline over the next 10 years in these disaggregated categories. Moreover, as with the aggregate projected decline in demand, these trends are relatively modest. The largest total relative changes in projected demand are seen in the analysis by DSAC region—particularly in the Berkshires+, Central, and Southeast regions where projected demand is expected to fall by more than 10 percent from 2013–14 to 2023–24. However, the general consistency of findings suggests that, at least with respect to demand, there is relatively little variation across the state.

DSAC Region

Table B13 contains the results of the projected demand trends by DSAC region. Of all of the analyses addressing Research Question 5, the demand projections by DSAC region tend to be the most divergent from the aggregate statewide trend. Although a decline in demand from 2013–14 to 2023–24 is projected for most regions, in some cases this decline is almost twice as large in

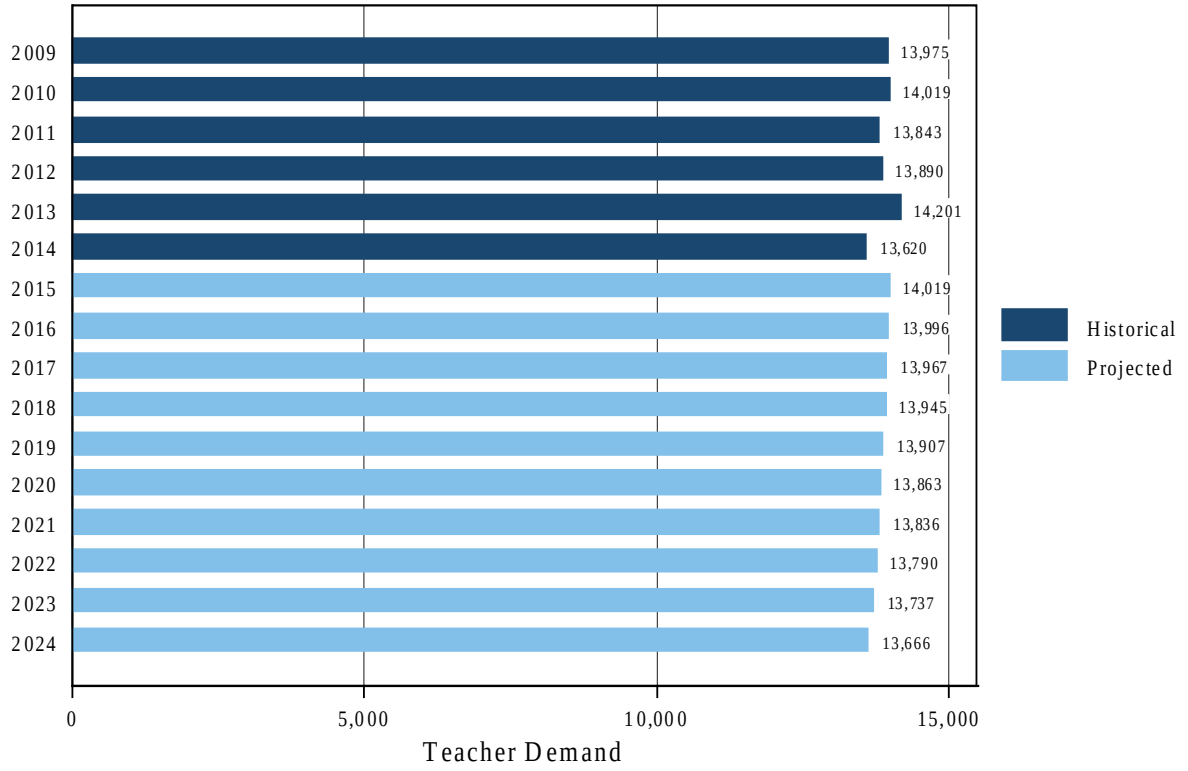
relative terms as the statewide projection. Specifically, over this period we project an absolute decline in demand of 346 FTEs (equal to 12.26 percent) in the Berkshires+ region, which marks the largest projected drop among the DSAC regions. The declines are similarly large for the Central and Southeast regions over the same time period, at 668 FTEs (10.72 percent) and 1,213 FTEs (11.17 percent), respectively.

In addition, this is the only analysis related to Research Question 5 for which a projected future trend in demand differs somewhat from the aggregate trend. Specifically, we project that demand in the Commissioner's Districts will increase an average of 0.04 per year between 2013–14 and 2023–24, resulting in an absolute increase of 46 FTEs (0.34 percent) over the period. As can be seen in Figure B9, this rise is likely due to the fact that, in the two most recent years, this region experienced some volatility in staffing (i.e., there was a marked decrease in the number of FTEs from 2012–13 to 2013–14). As a result of this drop, the first projected year of demand is generally in line with the historical average number of teachers, but somewhat larger than the last historical year (2013–14). Therefore, although the first projected year represents an increase over the last, each subsequent projected year shows a slight decline over the previous projected year.

Table B13. Projected Percent and Absolute Changes in Statewide Demand by DSAC Region, 2013–14 Through 2023–24

DSAC Region	Average Annual Percent Change: 2013–14 Through 2023–24	Overall Percent Change: 2013–14 Through 2023–24	Overall Absolute Change: 2013–14 Through 2023–24
Berkshires +	-1.30%	-12.26%	-346
Central	-1.13%	-10.72%	-878
Commissioner's Districts	0.04%	0.34%	46
Greater Boston	-0.15%	-1.52%	-222
Northeast	-0.58%	-5.65%	-563
Pioneer Valley	-0.97%	-9.30%	-350
Southeast	-1.18%	-11.17%	-1,538
Statewide	-0.59%	-5.77%	-3,851

Figure B9. Historical and Projected Demand for the Commissioner's Districts in Terms of FTEs, 2008–09 Through 2023–24



In general, these results suggest that demand is declining in regions as it is statewide. This finding should not be surprising as we project that enrollment will decline for all regions, as it has statewide. The slight variation we see in the Commissioner's Districts is more an indication of recent historical volatility than a different projected trend. However, this discrepancy is noteworthy because, to the extent that historical volatility is indicative of future volatility in staffing, there may be an error in our projections. This is because we are calculating demand based on three-year average pupil-teacher ratios, and thus smoothing out this volatility in projected years. For this reason, policymakers may want to monitor staffing trends in the Commissioner's Districts to see if this volatility continues over the next few years. Moreover, they may want to investigate the root cause of this volatility to better understand the dynamics influencing the above findings.

NCES Locale

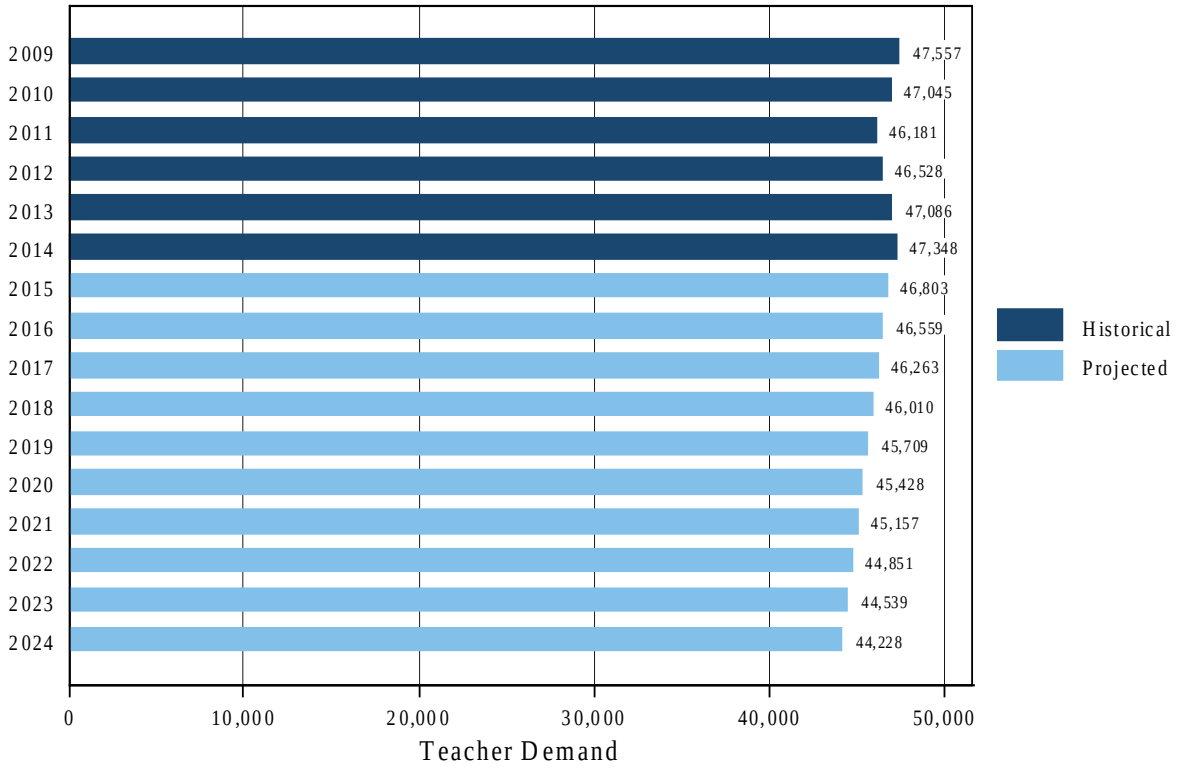
When considering demand projections by NCES locale, we find the results to be generally very much in line with the aggregate demand projections (Table B14). Specifically, teacher demand is projected to decline in most locales between 2013–14 and 2023–24. The largest projected relative change is for rural districts, which are projected to decline by 745 FTEs (10.54 percent) in total over the 10-year period. We also find that the largest absolute decline in demand will be for Suburb districts, which are expected to have a drop in demand of 3,120 FTEs (6.59 percent). Finally, a much smaller projected change in demand is calculated for City districts. Specifically, demand in these districts is expected to increase an average of 0.11 percent per year over the period, amounting to an overall increase of 122 FTEs (1.10 percent). Not surprisingly, this

pattern is similar to the trend for Commissioner's Districts (which consist entirely of urban districts). In addition, it is noteworthy that the projected decline in Suburb locales in absolute terms is nearly as large as projected declines statewide. This finding suggests that these districts are driving the statewide trend, which may not be surprising as they make up about 65 percent of all districts and, on average, about 70 percent of demand in historical years. Trends in historical and projected demand for districts in suburban locales can be seen in Figure B10.

Table B14. Projected Percent and Absolute Changes in Statewide Demand by NCES Locale, 2013–14 Through 2023–24

NCES Locale	Average Annual Percent Change: 2013–14 Through 2023–24	Overall Percent Change: 2013–14 Through 2023–24	Overall Absolute Change: 2013–14 Through 2023–24
City	0.11%	1.10%	122
Suburb	-0.68%	-6.59%	-3,120
Town	-0.95%	-9.11%	-108
Rural	-1.11%	-10.54%	-745
Statewide	-0.59%	-5.77%	-3,851

Figure B10. Historical and Projected Demand for Teachers in Suburb Locales in Terms of FTEs, 2008–09 Through 2023–24



As with the demand projections by region, these results suggest that expected demand by locale does not deviate from aggregate trends a great deal.

Top IHE Areas

Results of the demand projections by IHE geographic area around key IHEs mirror the aggregate demand projections (Table B15). All IHE areas are projected to see a small decline in demand over the next 10 years. In particular, districts in the area near the American International College are expected to see the largest decline, 0.79 percent, on average, each year between 2013–14 and 2023–24, with a total decline of 424 FTEs (7.62 percent) over the same period. The smallest projected decline is for districts in the area around Salem State University, with a projected decline of 0.13 percent, on average, each year between 2013–14 and 2023–24, and a total decline of only 348 FTEs (1.33 percent) over the same time period.

Table B15. Projected Percent and Absolute Changes in Statewide Demand by IHE Area, 2013–14 Through 2023–24

IHE Area	Average Annual Percent Change: 2013–14 Through 2023–24	Overall Percent Change: 2013–14 Through 2023–24	Overall Absolute Change: 2013–14 Through 2023–24
American International College	-0.79%	-7.62%	-424
Boston University	-0.35%	-3.41%	-1,368
Bridgewater State University	-0.57%	-5.52%	-1,422
Lesley University	-0.62%	-6.03%	-951
Salem State University	-0.13%	-1.33%	-348
Statewide	-0.59%	-5.77%	-3,851

Major Metropolitan Areas

Much like the results by IHE area, the results by major metropolitan area generally mirror the aggregate results (Table B16). The largest projected declines are in the Worcester and Springfield areas, which have projected declines in demand over the 10-year period of 805 FTEs (9.51 percent) and 642 FTEs (8.22 percent), respectively. The smallest decline is seen in the Lowell/Lawrence metropolitan area, which is expected to decrease by only 48 FTEs (2.06 percent) from 2013–14 to 2023–24.

Table B16. Projected Percent and Absolute Changes in Statewide Demand by Major Metropolitan Area, 2013–14 Through 2023–24

Major Metropolitan Area	Average Annual Percent Change: 2013–14 Through 2023–24	Overall Percent Change: 2013–14 Through 2023–24	Overall Absolute Change: 2013–14 Through 2023–24
Boston	-0.43%	-4.21%	-757
Worcester	-0.99%	-9.51%	-805
Springfield	-0.85%	-8.22%	-642
Lowell/Lawrence	-0.21%	-2.06%	-48
Statewide	-0.59%	-5.77%	-3,851

Supply Projections

Unlike the demand results, we find that future trends in projected supply by region and locale do deviate from the aggregate results in many cases. This deviation suggests that although predicted trends in demand are relatively consistent across the state, trends in supply vary quite a bit. This finding may point to a need for differentiated strategies to support districts from different parts of the state or locales in meeting their teacher demand. That said, projected changes in supply are generally more modest than the projected changes in demand, with very few overall percent changes falling above or below 5 percent. The largest projected changes in the analysis are by major metropolitan area, specifically in areas surrounding Worcester and Lowell/Lawrence.

DSAC Region

When considering supply projections by DSAC region, we find that most regions are expected to see a decline (Table B17). Specifically, in the Berkshires+, Central, Commissioner's Districts, Greater Boston, and Pioneer Valley regions, the supply of teachers is expected to decrease between 2013–14 and 2023–24, ranging from a decline of 44 FTEs (1.17 percent) in Pioneer Valley to 1,094 FTEs (8.03 percent) in the Commissioner's Districts. However, two regions, Northeast and Southeast, are expected to see overall increases in supply by 532 FTEs (5.34 percent) and 269 FTEs (1.69 percent), respectively. Although the Greater Boston region shows overall declines in the supply of teachers from 2013–14 to 2023–24, this is largely due to a discrepancy between the most recent year of historical data and the first projected year where there was a sharp projected decline. However, in each subsequent year of projected supply, the trend for Greater Boston is a gradual increase in teacher supply.

Table B17. Projected Percent and Absolute Changes in Statewide Supply by DSAC Region, 2013–14 Through 2023–24

DSAC Region	Average Annual Percent Change: 2013–14 Through 2023–24	Overall Percent Change: 2013–14 Through 2023–24	Overall Absolute Change: 2013–14 Through 2023–24
Berkshires +	-0.25%	-2.47%	-70
Central	-0.54%	-5.32%	-436
Commissioner's Districts	-0.83%	-8.03%	-1,094
Greater Boston	-0.22%	-2.27%	-333
Northeast	0.52%	5.34%	532
Pioneer Valley	-0.12%	-1.17%	-44
Southeast	0.19%	1.96%	269
Statewide	-0.18%	-1.76%	-1,174

The fact that the Commissioner's Districts are expected to see a decline in supply is noteworthy as these districts are projected to have a slight increase in demand in future years, suggesting that they may experience teacher shortages. This is all the more important when we consider that these districts represent a large proportion of statewide enrollment.

NCES Locale

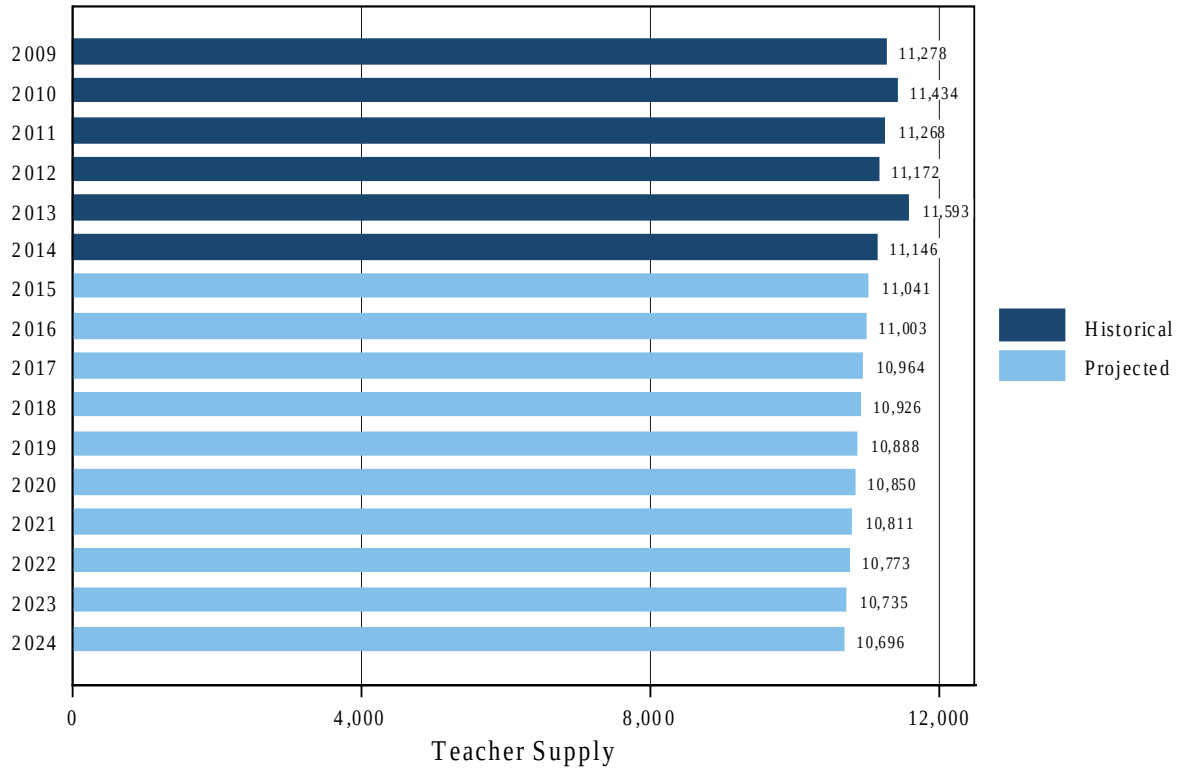
Turning our attention to supply projections by locale, we see that all but one locale is consistently aligned with the downward aggregate trend in supply, and the projected declines are generally very modest (Table B18). Only districts in towns are expected to see an increase in supply, although the increase is so small that the absolute change from 2013–14 to 2023–24 is almost negligible. Similarly, we note how small the projected decline is for districts in rural locales, where we project four fewer FTEs (0.05 percent) over the 10-year period. However, it is important to remember this figure represents an aggregation of the supply across these districts, and the projected supply trends may vary considerably from district to district.

Table B18. Projected Percent and Absolute Changes in Statewide Supply by NCES Locale, 2013–14 Through 2023–24

NCES Locale	Average Annual Percent Change: 2013–14 Through 2023–24	Overall Percent Change: 2013–14 Through 2023–24	Overall Absolute Change: 2013–14 Through 2023–24
City	-0.41%	-4.03%	-449
Suburb	-0.16%	-1.57%	-744
Town	0.20%	1.95%	23
Rural	<0.00%	-0.05%	-4
Statewide	-0.18%	-1.76%	-1,174

Given that demand is projected to increase slightly in cities over the first four projected years (2014–15 to 2017–18), the projected decline in supply may result in an expected shortage in this period. Moreover, as can be seen in Figure B11, unlike demand, supply is projected to steadily decline in all projected years for City districts. This finding supports the likelihood of a shortage, despite the fact that demand is expected to start declining after the fourth projected year. This finding is discussed in more detail later in this section.

Figure B11. Historical and Projected Supply of Teachers in City Locales in Terms of FTEs, 2008–09 Through 2023–24



Top IHE Areas

Projected supply in the geographic areas surrounding the top five IHEs also mirrors the declining aggregate supply trend (Table B19). Only districts in the area near the American International College are expected to see an increase in supply—though very slight—increasing by only 85 FTEs (1.52 percent) from 2014–15 to 2023–24. The largest decline is expected for districts near Lesley University, where supply is expected to drop by an average of 0.69 percent per year over the 10-year period, resulting in a total decline of 1,054 FTEs (6.68 percent).

Table B19. Projected Percent and Absolute Changes in Statewide Supply by IHE Area, 2013–14 Through 2023–24

IHE Area	Average Annual Percent Change: 2013–14 Through 2023–24	Overall Percent Change: 2013–14 Through 2023–24	Overall Absolute Change: 2013–14 Through 2023–24
American International College	0.15%	1.52%	85
Boston University	-0.18%	-1.78%	-714
Bridgewater State	-0.07%	-0.66%	-171
Lesley University	-0.69%	-6.68%	-1,054
Salem State University	-0.05%	-0.50%	-131
Statewide	-0.18%	-1.76%	-1,174

The size of the projected decline for districts near Lesley University is noteworthy because the expected drop in demand for these districts over the period is slightly smaller, suggesting there may be shortages in these districts. However, the expected difference is so slight that it may prove to be negligible. This finding is discussed further below.

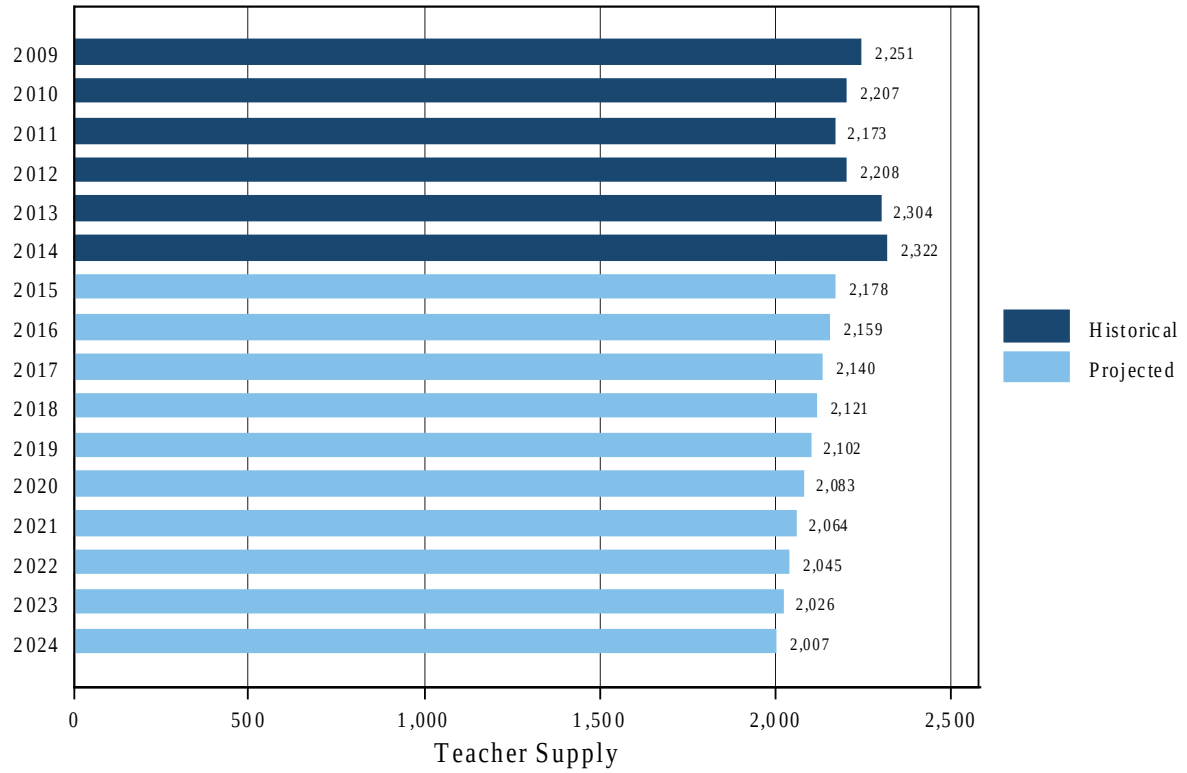
Major Metropolitan Areas

We also calculated aggregated supply projections for groups defined by those districts in the major metropolitan areas of the state (Table B20). We found that most of these areas are expected to see a decline in supply between 2013–14 and 2023–24. Specifically, the Boston, Worcester, and Lowell/Lawrence metropolitan areas are all expected to decline, with the largest change in Worcester, where a decrease of 959 FTEs (11.32 percent) is expected over the period. The change seen in Lowell/Lawrence is, in part, explained by the large discrepancy between the most recent year of historical data and the first year of projected data (Figure B12). Although the trend over projected years of supply for Lowell/Lawrence is still likely to decline, the average year-over-year trend for projected years is much smaller when the most recent year of historical data is omitted. Only the Springfield metropolitan area is expected to see a modest increase in supply of 146 FTEs (1.87 percent) over the period.

Table B20. Projected Percent and Absolute Changes in Statewide Supply by Major Metropolitan Area, 2013–14 Through 2023–24

Major Metropolitan Area	Average Annual Percent Change: 2013–14 Through 2023–24	Overall Percent Change: 2013–14 Through 2023–24	Overall Absolute Change: 2013–14 Through 2023–24
Boston	-0.26%	-2.53%	-455
Worcester	-1.19%	-11.32%	-959
Springfield	0.19%	1.87%	146
Lowell/Lawrence	-1.43%	-13.55%	-315
Statewide	-0.18%	-1.76%	-1,174

Figure B12. Historical and Projected Supply of Teachers in the Lowell/Lawrence Area in Terms of FTEs, 2008–09 Through 2023–24



The size of the decline in supply for districts in the Worcester metropolitan area is noteworthy because it is larger than the projected decline in demand for these districts. This drop suggests there may be shortages over the projected years. This finding will be discussed further below.

Appendix C: Validation Testing

The research team conducted a number of tests to determine the validity of the estimated projections. Specifically, we considered the average percent errors (APEs) and mean absolute percent errors (MAPEs) for all projections based on a comparison of actual and projected values. We also considered the 95 percent confidence intervals around the regression-based projections as applicable. Below is a detailed summary of these tests and the results for each analysis.

Average Percent Errors (APEs) and Mean Absolute Percent Errors (MAPEs)

To test for the bias and accuracy of our projections, we compared projected values with actual values in historical years. Specifically, we calculated two metrics commonly used to assess validity, the APE, and MAPE. APEs generally are used to determine whether projected values are biased in a particular direction, while MAPEs are used to assess the magnitude of the discrepancy. The equations we used to calculate these metrics are displayed in Box C1.

Box C1. Equations Used to Calculate the APE and MAPE Metrics

$$APE = \frac{(predicted - actual)}{actual}$$

$$MAPE = \frac{|(predicted - actual)|}{actual}$$

While no industry standard exists for an acceptable amount of bias and inaccuracy that we are aware of, others have suggested some guidelines. Berk and Hodgins (2008) suggest that a MAPE of more than 10 percent suggests that future projections should be interpreted with caution. The *Minnesota Teacher Supply and Demand Report* found that for three- and five-year enrollment projections, the best method tested produced MAPEs no higher than 5 percent. With these reports in mind, we have chosen to consider a MAPE of 7.5 percent high enough to warrant caution.

The results of these tests for each projection analysis are displayed in Table C1. The metrics below represent APEs and MAPEs calculated at the level of analysis and averaged across all historical years. The only exception to this are enrollment projections, for which the error in each historical projected year is given. Those MAPEs that exceed the 7.5 percent threshold have been bolded in red.

Table C1. Relative Difference between the Projected and Actual Measures by Research Question (Averages Taken Across All Projected Years Except for Enrollments)

Research Question and Analysis	APE	MAPE
RQ1: 1-Year Enrollment Projections	0.38%	0.38%
RQ1: 2-Year Enrollment Projections	0.74%	0.74%
RQ1: 3-Year Enrollment Projections	0.82%	0.82%
RQ1: 4-Year Enrollment Projections	1.07%	1.07%
RQ1: 5-Year Enrollment Projections	0.93%	0.93%
RQ1: 6-Year Enrollment Projections	0.71%	0.71%
RQ1: 7-Year Enrollment Projections	0.34%	0.34%
RQ1: 8-Year Enrollment Projections	0.35%	0.35%
RQ1: 9-Year Enrollment Projections	-0.08%	0.08%
RQ1: 10-Year Enrollment Projections	-0.28%	0.28%
RQ2: Supply Total	-0.11%	0.79%
RQ2: Supply Teacher Counts	-0.06%	0.40%
RQ2: Supply Retention	-0.01%	0.40%
RQ2: Supply New Entrants	0.46%	4.13%
RQ3a: General Education Demand	0.12%	0.50%
RQ3a: Special Education Demand	-1.07%	4.11%
RQ3a: CTE Demand	0.13%	1.49%
RQ3a: ELL Demand	4.64%	**7.84%**
RQ3b: General Education Supply	0.01%	0.38%
RQ3b: Special Education Supply	0.16%	3.45%
RQ3b: CTE Supply	0.46%	2.01%
RQ3b: ELL Supply	1.29%	**8.42%**
RQ3b: General Education Retained	0.05%	0.34%
RQ3b: Special Education Retained	0.18%	3.68%
RQ3b: CTE Retained	0.44%	1.84%
RQ3b: ELL Retained	1.24%	**8.17%**
RQ4a: Minority Demand	0.69%	0.88%
RQ4a: White Demand	-0.06%	0.07%
RQ4a: Minority Supply	0.05%	1.40%
RQ4a: White Supply	-0.02%	0.56%
RQ4a: Minority Retention	0.02%	1.19%
RQ4a: White Retention	-0.01%	0.89%
RQ4a: Minority New Entrants	0.37%	5.71%
RQ4a: White New Entrants	0.29%	4.15%
RQ4b: Demand Under 26	-2.73%	5.03%
RQ4b: Demand 26–32	-2.54%	2.54%

Research Question and Analysis	APE	MAPE
RQ4b: Demand 33–40	1.06%	1.16%
RQ4b: Demand 41–48	1.71%	1.71%
RQ4b: Demand 49–56	0.53%	1.38%
RQ4b: Demand 57–64	0.11%	2.68%
RQ4b: Demand Over 64	-2.48%	3.21%
RQ4b: Supply Under 26	0.20%	5.88%
RQ4b: Supply 26–32	-0.20%	0.85%
RQ4b: Supply 3–-40	-0.04%	0.51%
RQ4b: Supply 41–48	-0.13%	1.18%
RQ4b: Supply 49–56	0.25%	1.28%
RQ4b: Supply 57–64	0.20%	2.65%
RQ4b: Supply Over 64	0.12%	1.80%
RQ4b: Retention Under 26	0.35%	6.54%
RQ4b: Retention 26–32	-0.19%	1.16%
RQ4b: Retention 33–40	-0.03%	0.76%
RQ4b: Retention 41–48	-0.14%	1.47%
RQ4b: Retention 49–56	0.24%	1.61%
RQ4b: Retention 57–64	0.19%	2.57%
RQ4b: Retention Over 64	0.14%	2.34%
RQ4b: New Entrants Under 26	0.17%	3.95%
RQ4b: New Entrants 26–32	0.17%	3.95%
RQ4b: New Entrants 33–40	0.17%	3.95%
RQ4b: New Entrants 41–48	0.17%	3.95%
RQ4b: New Entrants 49–56	0.17%	3.95%
RQ4b: New Entrants 57–64	0.17%	3.95%
RQ5a: Demand Berkshires +	1.17%	1.20%
RQ5a: Demand Central	2.41%	2.41%
RQ5a: Demand Commissioner's	2.32%	2.58%
RQ5a: Demand Greater Boston	-4.28%	4.31%
RQ5a: Demand Northeast	1.24%	1.24%
RQ5a: Demand Pioneer Valley	1.60%	1.60%
RQ5a: Demand Southeast	0.99%	0.99%
RQ5a: Supply Berkshires +	0.01%	1.14%
RQ5a: Supply Central	-0.78%	0.99%
RQ5a: Supply Commissioner's	0.02%	1.05%
RQ5a: Supply Greater Boston	-0.36%	1.01%
RQ5a: Supply Northeast	0.25%	0.61%
RQ5a: Supply Pioneer Valley	0.30%	0.94%

Research Question and Analysis	APE	MAPE
RQ5a: Supply Southeast	0.07%	1.42%
RQ5b: Demand City	0.50%	1.79%
RQ5b: Demand Suburb	0.17%	0.44%
RQ5b: Demand Town	1.93%	1.93%
RQ5b: Demand Rural	1.75%	1.75%
RQ5b: Supply City	-1.22%	1.38%
RQ5b: Supply Suburb	0.17%	0.87%
RQ5b: Supply Town	-2.71%	2.71%
RQ5b: Supply Rural	0.32%	0.87%
RQ5c: Demand American Int. C.	1.80%	1.80%
RQ5c: Demand Boston U.	-1.64%	1.81%
RQ5c: Demand Bridgewater St.	0.00%	0.79%
RQ5c: Demand Salem St.	-1.24%	1.86%
RQ5c: Demand Lesley U.	-0.75%	0.79%
RQ5c: Supply American Int. C.	0.01%	0.72%
RQ5c: Supply Boston U.	0.01%	0.90%
RQ5c: Supply Bridgewater St.	0.01%	1.09%
RQ5c: Supply Salem St.	0.01%	0.89%
RQ5c: Supply Lesley U.	0.01%	0.77%
RQ5d: Demand Boston	-1.56%	1.73%
RQ5d: Demand Worcester	2.79%	2.79%
RQ5d: Demand Springfield	2.20%	2.20%
RQ5d: Demand Lowell/Lawrence	-0.36%	3.32%
RQ5d: Supply Boston	0.01%	0.79%
RQ5d: Supply Worcester	0.00%	0.44%
RQ5d: Supply Springfield	0.00%	0.36%
RQ5d: Supply Lowell/Lawrence	0.04%	1.67%

95 Percent Confidence Intervals

A 95 percent confidence interval is a common metric used to assess uncertainty or error in an estimated parameter. Specifically, Valerie J. Easton and John H. McColl's Statistics Glossary v1.1 defines a confidence interval as "an estimated range of values which is likely to include an unknown population parameter, the estimated range being calculated from a given set of sample data."[48] The "95 percent" indicates the probability that the point estimate will fall within the given range of values if additional intervals were calculated using independent samples.

[48] For additional detail, see http://www.stats.gla.ac.uk/steps/glossary/confidence_intervals.html.

For the present study, these point estimates are actually projected values of supply and demand in future years based on a sample of historical data. Moreover, we report intervals for a district-level average across all districts, rather than an interval for a particular district or in the aggregate. For example, if we report a 95 percent confidence interval for a demand projection as 5.3 percent above or below the average point estimate, this means that "true" demand on average in the projected year is likely within that range.

Put simply, the width of these intervals are one measure of the extent of our uncertainty in the reported projections. Given the fact that uncertainty in projections inherently grow larger over time, we can expect to see these intervals also grow in width over time.

Research Question 1—Validity of Results

Due to the fact that the projections created to address Research Question 1 were not based on a regression model or estimated parameter, we cannot report confidence intervals for these results. However, in addition to the APEs and MAPEs reported earlier in this appendix, we conducted additional tests of the validity of our enrollment projections. The results of these tests are discussed later in this appendix.

Research Question 2—Validity of Results

When we considered the 95 percent confidence intervals around the aggregate supply projections (Table C2), we found that for most analyses they more than tripled in size (or grew over 200 percent) from 2014-15 to 2023-24. In fact, the total teacher staff count projections had the largest growth of 228 percent over this time period. These results suggest that we should be less confident in the projections the farther out we get in projected years. This is somewhat to be expected, and reflects a more general limitation of projections. Given this we would suggest that the earlier years of projections be given more weight in any discussions of policy implications.

Moreover, to consider the relative size of these confidence intervals we calculated the percentage above or below the average point estimate of the confidence interval bounds. While the relative sizes of the intervals were generally modest for most projections in the final projected year, the new entrant projections grew to 16 percent above or below the point estimate. This suggests that the true value may be 16 percent above or below the reported projection, and may be reason to interpret the results of this analysis with caution.

Table C2. 95% Confidence Intervals for Projected Supply of Teachers by Component, 2014–15 and 2023–24

Supply Projections/Year	Average Point Estimate	95% Confidence Interval–Lower Bound	95% Confidence Interval–Upper Bound	Percent Above/Below Estimate	Growth of Interval Over Time
Total Teachers (Staff Counts)					
2014-15	223.6	220.0	227.1	+/- 2%	3.28
2023-24	231.4	219.6	243.1	+/- 5%	
Total Teachers (FTEs)					
2014-15	205.3	201.8	208.7	+/- 2%	3.05
2023-24	203.9	193.4	214.4	+/- 5%	
Retained Teachers (Staff Counts)					
2014-15	189.3	186.8	191.8	+/- 1%	3.53
2023-24	192.8	183.8	201.7	+/- 5%	
New Entrants (Staff Counts)					
2014-15	8.2	7.8	8.5	+/- 4%	2.05
2023-24	4.3	3.6	5.0	+/- 16%	

Research Question 3—Validity of Results

Demand Projections

Similar to the findings for the aggregate supply projections, confidence intervals around the demand proportion projections by program area grew substantially from 2014-15 to 2023-24 (Table C3).[49] The intervals around the ELL projections experienced the largest growth, more than quadrupling over the projected years. In contrast, the intervals around the SPED projections grew least, though still by a substantial amount, more than tripling. Given the large growth in intervals over time, we would suggest that the earlier years of projections should be relied upon more heavily in any discussions of policy implications.

Moreover, to consider the relative size of these confidence intervals we calculated the percentage above or below the average point estimate of the confidence interval bounds. In the first projected year all intervals are generally modest, with only ELL teachers rising above +/- 10 percent. However, by the final projected year the intervals are quite large for both CTE and ELL teachers, +/- 42 and 32 percent respectively. SPED intervals are also a bit larger, growing to +/- 14 percent. This further supports the notion that over time we can be less confident in the projections, especially for CTE and ELL teachers.

[49] Please note that the metric projected for this analysis is itself a proportion, and that the point estimate and bounds are presented in Table C3 as decimals.

Table C3. 95% Confidence Intervals for Projected Proportions of Teachers by Program Area, 2014–15 and 2023–24

Program Area Proportion/Year	Average Point Estimate	95% Confidence Interval–Lower Bound	95% Confidence Interval–Upper Bound	Percent Above/Below Estimate	Growth of Interval Over Time
GenED					
2014–15	0.82	0.81	0.83	+/- 1%	3.28
2023–24	0.83	0.80	0.85	+/- 3%	
SPED					
2014–15	0.12	0.12	0.13	+/- 4%	3.18
2023–24	0.12	0.10	0.13	+/- 14%	
CTE					
2014–15	0.049	0.045	0.054	+/- 8%	3.43
2023–24	0.045	0.030	0.059	+/- 32%	
ELL					
2014–15	0.010	0.009	0.012	+/- 11%	4.89
2023–24	0.014	0.008	0.020	+/- 42%	

Supply Projections

As we would expect, the confidence intervals around the average supply estimates also grow consistently over the projected years (Table C4). Specifically, we found that intervals around the CTE supply estimates had the largest growth, nearly quadrupling over the projected years. On the other hand, the SPED and ELL confidence intervals grew least though still substantially, almost doubling over projected years. Given the growth in intervals over time, we would suggest that the earlier years of projections be relied upon more heavily in any discussions of policy implications.

Moreover, when considering the relative size of the intervals, SPED, CTE, and ELL projections all have very large intervals in the final projected year, +/- 26, 42, and 49 percent respectively. These large confidence intervals indicate less certainty in projected supply of teachers in these program areas.

Table C4. 95% Confidence Intervals for Projected Supply of Teachers by Program Area, 2014-15 and 2023-24

Program Area FTEs/Year	Average Point Estimate	95% Confidence Interval–Lower Bound	95% Confidence Interval–Upper Bound	Percent Above/Below Estimate	Growth of Interval Over Time
GenED					
2014–15	170.2	166.5	173.9	+/- 2%	3.66
2023–24	181.1	167.5	194.6	+/- 7%	
SPED					
2014–15	25.6	22.7	28.5	+/- 11%	1.84
2023–24	20.6	15.2	26.0	+/- 26%	
CTE					
2014–15	5.9	5.3	6.5	+/- 10%	3.71
2023–24	5.6	3.2	7.9	+/- 42%	
ELL					
2014-15	4.1	3.2	5.0	+/- 22%	1.83
2023-24	3.4	1.7	5.0	+/- 49%	

Retained Teacher Projections

We also examined the 95 percent confidence intervals for the projections of retained teachers by program area and in general, these metrics followed the trends for overall supply, though the confidence intervals were consistently tighter in the final projected year (Table C5).

Table C5. 95% Confidence Intervals for Projected Supply of Retained Teachers by Program Area, 2014-15 and 2023-24

Program Area FTEs/Year	Average Point Estimate	95% Confidence Interval–Lower Bound	95% Confidence Interval–Upper Bound	Percent Above/Below Estimate	Growth of Interval Over Time
GenED					
2014–15	145.7	142.7	148.7	2%	3.42
2023–24	155.0	144.8	165.1	7%	
SPED					
2014–15	23.3	20.9	25.7	10%	1.81
2023–24	19.1	14.7	23.4	23%	
CTE					
2014–15	5.3	4.7	6.0	12%	3.14
2023–24	5.1	3.1	7.2	40%	
ELL					
2014–15	2.3	1.8	2.7	20%	2.05
2023–24	2.0	1.1	2.9	46%	

Research Question 4a—Validity of Results by Race

Demand Projections

Table C6 below shows the confidence intervals around the predicted point estimates for the proportions of teachers who are minority and white for the school years ending in 2014-15 and 2023-24. As can be seen, although the confidence intervals around the estimates of White teachers are larger in absolute terms than those of their minority counterparts, as a percentage of the point estimates the confidence intervals are actually tighter for White teachers.

However, for both teacher categories, the confidence intervals are large enough to cast some doubt on the overall predicted trends over time. This can be most easily seen in graphs of the point estimates and confidence intervals found in Figures C1 and C2. While the average trend is for the proportion of minority teachers to increase over time and the proportion of White teachers to decrease over time, confidence intervals indicate that decreases in the proportion of minority teachers and increases in the proportion of White teachers are certainly possible. Additionally, by 2023-24 the upper and lower bounds of the confidence intervals on the average proportion of minority teachers in districts are within +/– 33 percent of the point estimate, which suggests substantial uncertainty in the predictions. The size of the confidence intervals for both minority and White teachers grow by a factor of four over time, indicating more precision in earlier estimates.[50]

[50] Please note that the metric projected for this analysis is itself a proportion, and that the point estimate and bounds are presented in Table C6 as decimals.

Table C6. 95% Confidence Intervals for Projected Proportions of Teachers by Teacher Race, 2014-15 and 2023-24

Race Proportion/Year	Average Point Estimate	95% Confidence Interval–Lower Bound	95% Confidence Interval–Upper Bound	Percent Above/Below Estimate	Growth of Interval Over Time
All Minority					
2014-15	0.029	0.027	0.032	+/- 10%	3.98
2023-24	0.034	0.022	0.045	+/- 33%	
White					
2014-15	0.971	0.968	0.973	+/- 0.3%	3.97
2023-24	0.967	0.955	0.978	+/- 1.1%	

Figure C1. Confidence Intervals for the Average Projected Proportion of Minority Teachers, 2008-09 Through 2023-24

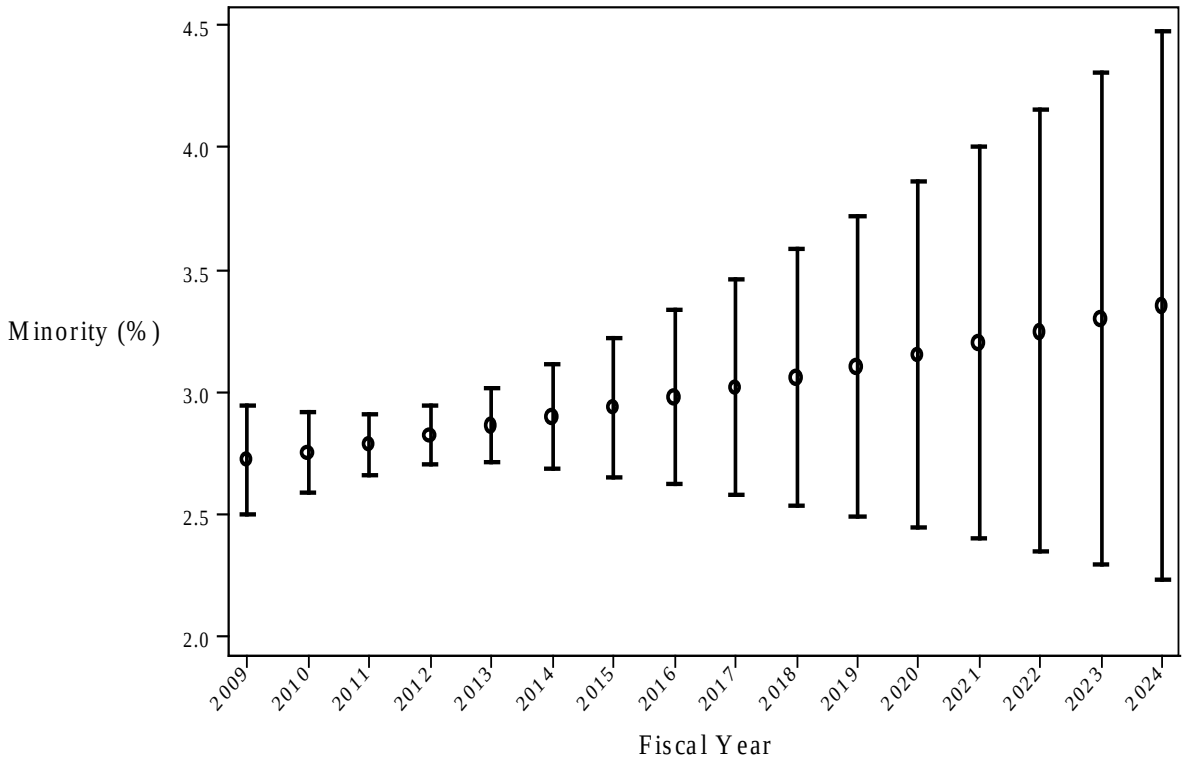
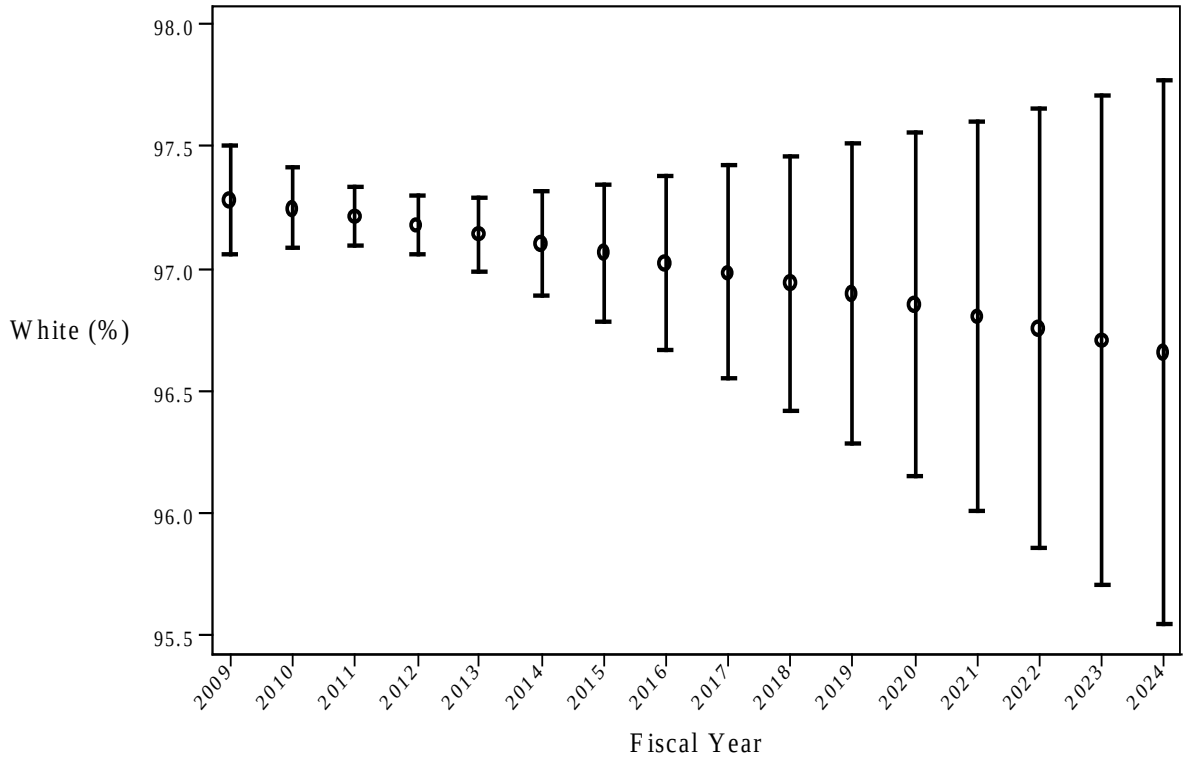


Figure C2. Confidence Intervals for the Average Projected Proportion of White Teachers, 2008-09 Through 2023-24



Supply Projections

The confidence intervals for supply of minority teachers indicate that for an average district, the trend in the supply of minority teachers over time is quite uncertain (Table C7). For an average district, the point estimates indicate the number of minority teachers should stay steady over time at around 13.3 to 13.4. However the 95 percent confidence intervals increase from +/-9 percent above and below the estimate to +/-28% around the estimate, indicating substantial increase in uncertainty over time. For White teachers, there is much more confidence in the point estimates as confidence intervals increase from +/- 1 percent around the estimate to +/- 4 percent. For the district average estimates for both minority and White supply, confidence intervals are more than three times larger in 2023-24 compared to 2014-15.

Table C7. 95% Confidence Intervals for Projected Supply of Teachers by Race, 2014-15 and 2023-24

Race FTEs/Year	Average Point Estimate	95% Confidence Interval–Lower Bound	95% Confidence Interval–Upper Bound	Percent Above/Below Estimate	Growth of Interval Over Time
All Minority					
2014-15	13.4	12.2	14.5	+/- 9%	3.2
2023-24	13.3	9.5	17.0	+/- 28%	
White					
2014-15	189.6	187.2	192.1	+/- 1%	3.1
2023-24	183.0	175.5	190.6	+/- 4%	

Retained Teachers

It is first important to bear in mind the confidence intervals around the estimated retention rates which drive the results of this analysis were quite large for all minorities (Table B4). This indicates a great deal of error in these estimated rates, and since the estimations of retained teachers by race are based on these average rates, this error has implications on the accuracy of this analysis. Given this, we suggest the results be interpreted with caution.

We also considered the 95 percent confidence intervals for the projections of retained teachers by race and in general, these metrics followed the trends for overall supply, though the confidence intervals were tighter in the final projected year and grew less over the projected years for retained minority teachers (Table C8).

Table C8. 95% Confidence Intervals for Projected Supply of Retained Teachers by Race, 2014-15 and 2023-24

Retained Teachers/Year	Average Point Estimate	95% Confidence Interval–Lower Bound	95% Confidence Interval–Upper Bound	Percent Above/Below Estimate	Growth of Interval Over Time
All Minority					
2014-15	8.9	8.7	9.1	+/- 2%	2.84
2023-24	8.5	7.9	9.0	+/- 7%	
White					
2014-15	164.7	161.9	167.5	+/- 2%	3.11
2023-24	160.8	152.2	169.4	+/- 5%	

New Entrants

We also considered the 95 percent confidence intervals for the projections of new entrants by race. As with the retained teacher projections, these metrics generally followed the trends for overall supply, with the confidence intervals growing over the projected years. However, the intervals were much larger in the final projected year for both minority and White teachers

(Table C9). This was especially true for White teachers, which had substantially larger intervals than those in the total supply analysis.

Table C9. 95% Confidence Intervals for Projected Supply of New Entrants by Race, 2013-14 and 2022-23

New Entrants/Year	Average Point Estimate	95% Confidence Interval–Lower Bound	95% Confidence Interval–Upper Bound	Percent Above/Below Estimate	Growth of Interval Over Time
All Minority					
2014-15	1.0	1.0	1.1	+/- 8%	2.48
2023-24	0.5	0.3	0.7	+/- 37%	
White					
2014-15	7.4	6.7	8.1	+/- 10%	2.38
2023-24	3.7	2.0	5.4	+/- 47%	

Research Question 4b—Validity of Results by Age

Demand Projections

We also examined the 95 percent confidence intervals surrounding the district average predicted point estimates (Table C10). This analysis indicates substantial uncertainty in predictions as time goes on, particularly for the youngest and oldest age groups (i.e., under 26 and over 64 categories), which have confidence interval bounds 36 and 45 percent above and below the average point estimate, respectively. Additionally, for six of seven categories the confidence intervals grow by more than three times from 2014-15 to 2023-24, with the largest increase in the over 64 category, where confidence intervals increase by a factor of almost 12.[51]

[51] Please note that the metric projected for this analysis is itself a proportion, and that the point estimate and bounds are presented in Table C10 as decimals.

Table C10. 95% Confidence Intervals for Projected Proportions of Teachers by Age, 2014-15 and 2023-24

Age Group/Year	Average Point Estimate	95% Confidence Interval–Lower Bound	95% Confidence Interval–Upper Bound	Percent Above/Below Estimate	Growth of Interval Over Time
Under 26					
2014-15	0.033	0.031	0.036	+/- 7%	3.6
2023-24	0.025	0.016	0.034	+/- 36%	
Age 26-32					
2014-15	0.167	0.160	0.174	+/- 4%	3.5
2023-24	0.166	0.143	0.190	+/- 16%	
Age 33-40					
2014-15	0.206	0.200	0.212	+/- 3%	3.3
2023-24	0.228	0.207	0.248	+/- 9%	
Age 41-48					
2014-15	0.225	0.223	0.234	+/- 2%	4.2
2023-24	0.318	0.294	0.341	+/- 7%	
Age 49-56					
2014-15	0.194	0.187	0.201	+/- 4%	2.3
2023-24	0.132	0.116	0.148	+/- 12%	
Age 57-64					
2014-15	0.159	0.153	0.165	+/- 4%	3.4
2023-24	0.168	0.148	0.188	+/- 12%	
Over 64					
2014-15	0.018	0.016	0.020	+/- 12%	11.8
2023-24	0.058	0.032	0.084	+/- 45%	

Supply Projections

As with demand by age, the analysis of confidence intervals of supply by age category indicates that confidence intervals are growing over time (Table C11). This growth is largest for the group 41 to 48 group where the intervals more than triples over the projected years. However, when the relative sizes of the intervals are considered we see that they are largest in the final projected year for the under 26 group, reaching 39 percent above and below the average point estimate. The intervals for the over 64 group also are quite large, at 25 percent above and below the point estimate in the final projected year.

Table C11. 95 Percent Confidence Intervals for Projected Supply of Teachers by Age, 2014–15 and 2023–24

Age Group/Year	Average Point Estimate	95% Confidence Interval–Lower Bound	95% Confidence Interval–Upper Bound	Percent Above/Below Estimate	Growth of Interval Over Time
Under 26					
2014–15	8.4	7.6	9.1	+/- 9%	2.4
2023–24	6.2	3.8	8.7	+/- 39%	
Age 26-32					
2014–15	38.5	37.2	39.8	+/- 3%	2.2
2023–24	36.5	32.3	40.6	+/- 11%	
Age 33–40					
2014–15	44.4	43.2	45.6	+/- 3%	2.7
2023–24	50.3	45.8	54.7	+/- 9%	
Age 41–48					
2014–15	44.5	43.6	45.5	+/- 2%	3.7
2023–24	61.1	56.7	65.5	+/- 7%	
Age 49–6					
2014–15	35.5	34.6	36.3	+/- 2%	1.1
2023–24	22.5	20.7	24.3	+/- 8%	
Age 57–64					
2014–15	29.2	28.3	30.0	+/- 3%	2.1
2023–24	28.5	25.8	31.2	+/- 9%	
Over 64					
2014–15	3.7	3.5	4.0	+/- 7%	8.7
2023–24	10.3	7.7	12.8	+/- 25%	

Research Question 5—Validity of Results by Region

As with Research Question 1, the demand projections created to address Research Question 5 were not based on a regression model or estimated parameter, and thus we cannot report confidence intervals for these results. In addition, due to the fact that supply projections in Research Question 5 are based entirely on the projections created to address Research Question 2, no additional confidence intervals could be analyzed for these projections. However, the APEs and MAPEs for all Research Question 5 analyses are reported earlier in this appendix.

Additional Test of Enrollment Projection Validity

In addition to considering the APEs and MAPEs of the enrollment projections, we also compared our projections to the statewide aggregated enrollment projections calculated by ESE for the same projected years. Figure C3 displays the AIR historical and projected enrollments and those reported by ESE. As you can be seen in the figure, AIR projections are only slightly different than ESE projections. In fact, when the enrollment projections are compared, AIR projections are

an average of 0.9 percent lower than ESE projections, and at most 1.8 percent lower in the final projected year. Figure C4 displays this relative difference for each of the projected years.

Given these results, one could consider our aggregated projections and those generated by ESE as lower and upper bound enrollment estimates, respectively. However, the ESE figures do not have the same granularity and therefore do not allow for reporting across the same contrasts included in our analysis.

Figure C3. Comparison of ESE and AIR Enrollment Projections, 2008-09 Through 2023-24

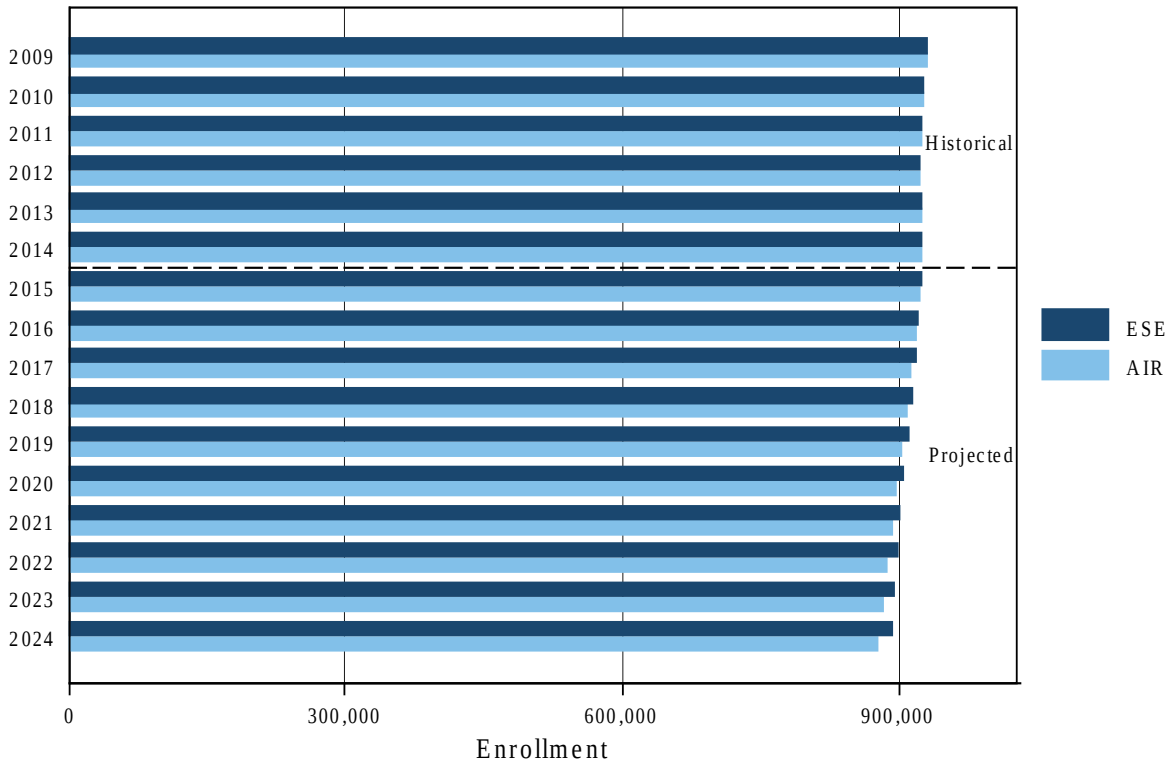
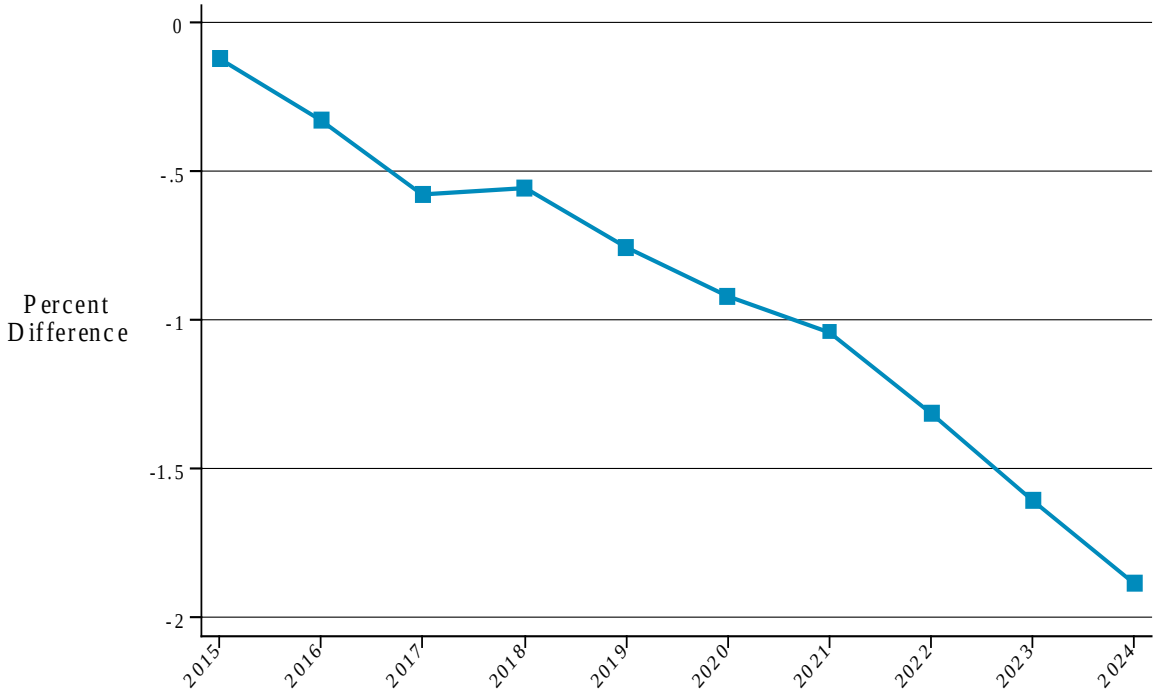


Figure C4. Relative Differences in AIR and ESE Projections, 2014-15 Through 2023-24



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