



## **Research Analysis**

### **Supply-Demand Analysis of the Labor Market for Public School Teachers: Current Research Practices and Potential for Improving Planning and Policy Deliberation**

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**Note:**

*This Research Analysis was commissioned specifically for the Association of Public and Land-grant Universities' project Improving State Need Assessments of Secondary Science and Mathematics Teachers: Challenges, Possibilities, and Recommendations to provide a review of key literature related to developing teacher supply and demand estimates. The author surveys a broad range of studies and indicates the lessons that can be learned from each. The Research Analysis thus provides much of the theoretical background for the larger project of which it is a part.*

*Particularly important contributions of the Research Analysis are its discussion of the value and limitations of “mechanical” or demographic-based estimation models of teacher supply and demand and its assessment of the ability of “behavioral” or econometric estimation models to provide projections that are more sensitive to economic and policy considerations. Two additional insights in the paper are also worth emphasizing: that public policies can indeed influence the teacher supply and demand equation in significant ways and that the discussion of teacher supply and demand cannot be isolated from a consideration of teacher quality. Indeed, the author suggests that measures of the relative quality of science and mathematics teachers from one school or district to the next may be a better indicator of the level of need for teachers than direct measures of supply and demand.*

*Finally, the Research Analysis includes an Appendix in which it discusses supply and demand estimates in other occupations, with particular emphasis on the health professions.*

*Although this discussion will be of value to readers with broad interests in the teacher supply and demand issue, it will be of particular value for those interested in the more technical methodological discussion of the issues involved.*

## **Introduction**

Policy makers and education officials charged with managing the nation's public elementary and secondary schools make heavy use of enrollment and teacher employment forecasts. Future projections of the supply of and demand for public school teachers are employed to ensure that (1) there are enough teachers to staff the nation's elementary and secondary schools in light of enrollment projections, and (2) the teaching staff is sufficiently trained to meet substantive subject area goals and priorities. Such forecasts require assessments of broad demographic trends as well as subtle analyses of the factors motivating teachers, potential teachers, and students beyond compulsory attendance age cutoffs. That is to say, forecasting the future contains both mechanical elements driven by forces determined outside of the education arena as well as behavioral analysis in assessing the responses of teachers and students to the parameters set by policy makers and educational administrators.

In addition to highlighting future gross employment needs, supply-demand analyses as commonly applied are often quite useful in uncovering potential areas of concern to local, state, and national policy makers. For example, detailed analyses of the age distribution of the current teacher workforce in conjunction with age-specific analysis of teacher attrition may reveal coming teacher shortages associated with a pending wave of retirements. Inter-school analyses of teacher job mobility often reveal cross-school heterogeneity in the stability of the teaching workforce, and often in identifiable measures of teacher quality (e.g., experience, certification, or

the incidence of out-of-field teaching assignments). In addition, with sufficiently disaggregated data, these forecasting tools can be used to study relative needs for teachers in different subfields. Such field-specific analysis is particularly important for forecasting supply and demand for hard-to-staff sub-fields such as high school mathematics, special education, and physics.

This paper presents a review of the state-of-the-art of teacher demand and supply forecasts with a special eye on the demand and supply of mathematics and science teachers. I begin with a general presentation of the structure of such analyses. In its most reductive form, supply-demand analyses of teacher labor markets forecast enrolment assuming a fixed policy environment, forecast the supply of teachers from the existing stock of public school teachers, and identify the demand for new hires by the difference between needs implied by enrolment, and supply from the continuing workforce. With sufficient data on teaching assignment and credentials, such analyses are often applied to specific subject areas, districts, and even schools.

While quite straightforward, within this framework are a number of subtle empirical relationships that may be influenced by the policy and managerial choices of educational officials. For example, teacher supply from continuing teachers decreases with year-to-year teacher attrition rates. Existing research has shown that a number of factors, such as the relative pay of teachers and workplace conditions are significantly related to attrition rates. Moreover, these relationships are heterogeneous for teachers in different, age, gender, and racial/ethnic groups. As a further example, the supply of teachers from those who have not taught in the past year is determined by policy choices (the degree of stringency of certification criteria, teacher salaries, avenues for alternative certification), as well as forces beyond the control of education policy makers (the state of the economy, salary levels outside of teaching). Thus, supply-

demand analysis broadly defined must include a discussion of focused research on the determinants of these choice points for existing and potential teachers.

I begin by first reviewing the model structure underlying most supply-demand projections. After reviewing the basic model, I turn to a discussion of existing national and state-level supply-demand analyses. At the national level, I review the methodology and results from the enrolment and teacher needs forecast calculated annually by the National Center for Education Statistics. I also review teacher needs estimates from the American Association for Employment in Education (AAEE) that rely on the opinions of informed observers to gauge trends in the relative scarcity of public school teachers in various specialties. State level analyses often make use of detailed administrative records on teachers and enrolment, are generally more detailed than national level studies, and are often conducted at various degrees of geographic detail. Below I discuss the general nature of these studies and highlight select findings from a few such analyses.

Much of the useful information in state-level analyses is contained in the descriptive analysis used to document trends in the characteristics of the teacher workforce and summary measures of quality, such as the proportion of teachers certified, the proportion of teachers assigned out of field, and the proportion of teachers who are novices. Budding shortages in specific subject areas often emerge in these standard quality measures rather than in position vacancy rates, as schools and districts do whatever they have to do to fill vacant positions and as a consequence vacancy rates are usually quite low in most schools. Disparities in the incidence of out-of-field or under-prepared teachers, however, are readily observable and often reveal specific shortages in some schools (for example, schools with large minority populations) and at certain times. Thus, I recommend that states identify a set of key quality measures for teachers,

measure them consistently across years, and monitor them for temporal and regional staffing problems.

In addition to the descriptive analysis, the formal forecasting tools also provide much useful information. At a minimum they provide estimates of hiring needs in future years, with short term projections that are quite accurate, and mid-term and long-term projections that are less so. However, these models can also be used to simulate supply from continuing teachers and new hiring needs under alternative policy choices, such as alternative student-teacher ratios, reductions in teacher attrition, etc.

Where these models fall short is in their ability to simulate the impact of changes in policy and market conditions that influence the occupational and labor supply choices of existing and potential teachers. Specifically, changes in teacher salaries relative to salaries in non-teaching occupations, trends in student achievement, or the presence of in-service training programs all impact the entry and attrition choices of the pool of potential teachers. Current supply-demand analyses rarely incorporate such behavioral factors into the modeling, and certainly do not simulate the impacts of altering such levers on future teacher supply. Supply-demand analyses in other professions (discussed in the appendix) suffer from similar shortcomings. Nonetheless, there is a growing body of research analyzing the empirical relationships between these factors and the choices that teachers and potential teachers make. I close the paper with a discussion of the research on the determinants of teacher attrition as well as the determinants of new teacher entry. For a number of reasons discussed below, there is considerably more research on attrition than entry. However, the entry choice appears to be quite important, as the economic factors (in particular, relative salary and the improved labor market prospects for women) motivating entry bear directly on the average “quality” of new

teachers and the nature of the flow of new teacher labor that replenishes the nation's teacher workforce.

While the existing research on the determinants of these transitions does not permit decisive estimates of the responsiveness of attrition and entry to existing policy parameters, one can certainly glean the relative importance of these factors and assess the likely ability to achieve certain goals. For example, if a district aims to reduce attrition by 10 percent, this body of research can indeed provide insight as to which employment conditions might be altered and what the likely impact on attrition may be. In conjunction with the supply-demand projections, declines in attrition rates can then be used to estimate how such an achievement would impact new hiring needs for the coming years. Such creative use of these disparate sources of information is certainly possible and should provide valuable and actionable information to state policy makers.

## **2. A prototypical teacher supply-demand analysis**

Teacher supply-demand analyses in practice are quite broad and often descriptive. At the national level, the NCES subsumes this analysis within a much broader set of projections of enrolment and staffing needs over the coming decade. At the state level, many of these studies include detailed summary statistics on the characteristics of teachers such as the age distribution, level of educational attainment, their undergraduate institutions, states where they completed their training, areas and level of certification, and the propensity to teach out of field. These studies also include enrolment trends by region and sometimes subject area. Thus, identifying a prototypical teacher supply-demand analysis is somewhat difficult, given the degree of cross-study heterogeneity in format and output.

Nonetheless, at the core of these studies are future enrolment projections and the derived demand for teachers, estimates of the future supply of continuing teachers, and estimates of needed new hires. In this section, I present a simple structure that captures the general forecast methods and highlights the data requirements for such forecasts.

#### *A. Forecasting the demand for teachers*

Teacher demand projections tend to be mechanical in the sense that the researcher makes a fixed assumption about the pupil-teacher ratio and, in conjunction with external population forecasts, mechanically projects the future required teacher workforce. For example, suppose that the current pupil-teacher ratio is given by  $R_{ta}$ , where  $t$  indexes time and the value of  $t$  corresponds to the current year and  $a$  indexes student age group. Typically, the grade categories are defined broadly to include children of elementary school age, children of middle-school age, and high school age children. Let  $P_{t+j,a}$  be the projected school age population for group  $a$  in year  $t+j$  (where  $j>0$ ). Finally, define  $E_{tg}$  as the proportion of children in age category  $a$  enrolled in public school. Assuming that the teacher/pupil ratios and the enrolment rates will remain constant into the future, demand for teachers  $j$  years from now to staff schools for children of age group  $a$  is given by the equation

$$(1) \quad Demand_{t+j,a} = \frac{E_{tg} P_{t+j,a}}{R_{ta}}$$

where the numerator,  $E_{tg} P_{t+j,a}$ , provides an estimate of total enrolment and dividing by the pupil-teacher ratio yields the required number of teachers.

As written, equation (1) assumes that the current enrolment rate and teacher-student ratio will remain constant into the future. If this is the standard operating assumption, analysts face the specification decision of whether to use the current-year values (which are more likely to reflect transitory departures from some underlying average value) or to take an average enrolment rate and teacher-student ratio for some time period (for example, the last five years). For projections at the state level, single year values are likely to be tabulated over a large enough population such that transitory departures from the true underlying tendencies are likely to be unimportant. For small-area projections (for example, a single school), it is perhaps more prudent to take an average over a larger time period. To be thorough, analysts should assess the sensitivity of enrolment projections to these alternative specification choices.<sup>1</sup>

In practice, all three elements of equation (1) could be forecast into the future. Enrolment rates may be trending either upwards or downwards and including information on this trend in the demand forecast would likely improve forecasting precision, especially for more distant years. Similarly, states may have information about pending policy changes to the student-teacher ratios that could easily be incorporated into future demand projections. There are a number of ways that such trends could be taken into account. One could calculate the average percentage changes in either enrolment rates or teacher-student ratios and use these percentage changes to interpolate these variables linearly into the future. Alternatively, one could use slightly more sophisticated econometric models to incorporate non-linear trends that may be revealed in the data.<sup>2</sup> Again, the sensitivity of future projections to these specifications choices

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<sup>1</sup> The discussion brings to mind an apocryphal story of a well-known academic who over the years has served as the Ph.D. advisor for countless empirical dissertations. This particular professor has a folded piece of paper taped to his door with the words “before knocking, lift and read” written on the outer flap. The inside contains the message “Do it both ways.”

<sup>2</sup> A simple model for estimating linear and higher-order trends in the data would be to fit a model over, say, the most recent 10 years where the dependent variable is the log of the variable being modeled and the key independent variable is a linear time trend set to one in the initial year. For example, in the enrolment rate model given by the

should be analyzed. In the study, one would like to establish that the underlying specification choices of the demand projections model do not qualitatively impact one's projections (i.e., that the forecasts are robust).

Such forecasts can also be extended to subject areas but may require specifying the target pupil-teacher ratio for subject area specialties as well as a targeted proportion of students doing the coursework. This may present problems when current staffing levels fall short of the desired level. For example, in an analysis of nationally-representative data presented below, I find that a small proportion of public secondary schools sometimes cancel class offerings in response to staffing shortages or increase average class size. In the presence of such coping strategies, applying the current pupil-teacher ratio to forecast demand for a specific sub-field will lead to underestimates of the current and future need for teachers. In the presence of a persistent staffing problem and under-enrolment in specific subject areas, accurately projecting teacher demand would require a pre-specification of the optimal teacher-pupil ratio and enrolment rate for the subject area and/or grade level in question. That is to say, a policy priority would have to be built into the forecast along with sufficient disclosure of the underlying assumptions generating projected demand levels. Of course, this will be particularly important in forecasting secondary school demand where students have greater discretion over their coursework.

Most demand analyses rely on external population projections either by the U.S. Census Bureau or by individual states. Many states calculate county-level population projections by age, and thus population projection data is available with sufficient detail to conduct geographically

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equation  $\ln(E_t) = \alpha + \beta \text{Trend}_t + \varepsilon_t$  the coefficient  $\beta$  yields the estimate of the derivative of the expected value of log enrolment with respect to the time trend, or  $1/E_t \cdot dE_t/d\text{Trend}$ , equal to the typical year-to-year percentage change. This average percent change could then be applied to base levels to project into the future. Incorporating non-linearities simply requires adding higher-order trend terms (for example,  $\text{Trend}^2$ ).

disaggregated forecasts.<sup>3</sup> In my reading of this literature, I found no studies that endogenized population growth. This would be important to the extent that county-level population trends were somehow dependent on the characteristics of local schools (a not too far-fetched hypothesis).

One could also imagine making the enrolment rate endogenous in the sense that factors under control of policy makers may influence the enrolment choices made by parents. For example, a decline in the pupil-teacher ratio may alter the balance between private and public schools and alter the age-specific enrolment rate. For children beyond compulsory school attendance age, dropout rates (and thus enrolment rates) may also depend on these factors. Again, most demand-supply studies assume that current enrolment rates will remain constant into the future.

Finally, pupil-teacher ratios are clearly within the control of policy makers, and in recent years have tended towards lower values nationwide. Existing demand-supply studies have made a number of different assumptions about these ratios. The NCES uses a simple linear regression with a sparse set of covariates to forecast future values of the pupil-teacher ratio for broad grade categories. Most state-level analyses assume current ratios into the future. Nonetheless, one could easily generate additional teacher-demand forecasts (and by extension net needed new hiring) by exploring the impact of alternative values of  $R_{it}$  on future teachers demand levels.

### *B. Decomposing teacher supply*

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<sup>3</sup> Of course, analysts can experiment with their own population projections. In fact, at the school level there are unlikely to be sufficient state-produced figures. If the research team chooses to employ its own population projections, the team should demonstrate with in-sample prediction error analysis that their own projection beats those of official state projections. A school-level analyses should take advantage of detailed information on grade-to-grade student attrition rates as well as grade-specific new student entrances rates to project future enrolment. Such an analysis using first-order Markov processes is essentially equivalent to the formal model of teacher supply that I discuss later in this section.

The supply of teachers in a given year can be separated into two broad groups: those who taught last year and continue teaching into the current year, and those who did not teach last year who are teaching this year. The first source of supply depends on both teacher characteristics (nearness to retirement, availability of outside opportunities) as well as workplace characteristics (the desirability of employment at a given school or in public school teaching more generally). The second supply group can be further decomposed into a number of alternative sources, including newly minted college graduates, former teachers who took some time out of the profession or out of the workforce altogether, as well as adults with prior careers who bridge into teaching through either traditional or alternative credentialing program. These supply sources will depend on the relative attractiveness of the teaching profession, but they may also be sensitive to factors that pertain specifically to new or reentering teachers, such as signing bonuses or student loan forgiveness programs. The lion's share of supply at a given point in time comes from continuing teachers. However, since new entrants are often considerably younger than continuing employees, new entrants are a considerably important source of future teacher supply, as today's new entrants are tomorrow's continuing workforce.

The supply of teachers in any given year can be conceived of as depending on a series of transition probabilities for existing teachers as well as for potential teachers. A transition probability describes the likelihood that an individual transitions from one state of being (for example, teacher in year  $t$ ) to another state of being (non-teacher in year  $t+1$ ). These probabilities will vary across broadly defined groups of teachers. For example, novice teachers have a relatively high likelihood of leaving teaching for alternative employment opportunities while older teachers have an elevated attrition rate associated with retirement. Transition

probabilities for non-teachers into teaching also vary across groups of potential teachers defined by age, gender, race, level of formal educational attainment, and other such traits.

To highlight the centrality of these transition probabilities to supply forecasts and hiring needs projections, here I work through a simple mechanical model of teacher supply that will frame much of the discussion to follow. Suppose that the supply of teachers is drawn from the adult college educated population. At a given point in time, we can split the active college-educated population into two occupational groups, public school teachers and everyone else (non-teachers). We can also divide the population into three age groups: relatively young college graduates, middle-aged college graduates, and older college graduates. Table 1 presents a matrix that lists the transition probabilities describing all possible year-to-year moves between age-occupation groups for our college age population. Listed along the stub of the table are the possible origin states in year  $t$  (younger teachers, middle-age teachers etc). Listed across the top rows are the potential destination states in year  $t+1$ . The defined transition probabilities are mutually exclusive and exhaustive. Thus, within a given row the transition probabilities must sum to one (that is to say, for a given origin age-occupation group one and only one of the transitions indicated by the destination possibilities must occur). Transitions that are logically impossible (for example, transiting up two age groups or down an age group) are assigned a value of zero.

Within the larger matrix are four sub-matrices of transition probabilities that merit separate discussion. The upper-left quadrant with elements given by  $TT_{ij}$  provide the likelihood that existing teachers will continue to teach next year. These probabilities are the building blocks for teacher retention rates, with the year-to-year retention rates by age given by the equations

$$\begin{aligned}
 \text{Retention}_y &= TT_{yy} + TT_{ym} \\
 \text{Retention}_m &= TT_{mm} + TT_{mo} \\
 \text{Retention}_o &= TT_{oo}
 \end{aligned}
 \tag{2}$$

where  $y$  indicates younger,  $m$  indicates middle-aged, and  $o$  indicates older.

Conversely, the upper-right hand quadrant (with elements given by  $TN_{ij}$ ) provides the transition probabilities out of teaching. The interpretation of these probabilities depends on the geographic level of analysis. At the national level, these exit transitions represent those who leave public school teaching altogether (what is commonly deemed teacher attrition). At the level of the state, those who leave public school teaching will include those who leave teaching altogether as well as those who leave to teach in public schools in other states (commonly referred to as teacher mobility). As we move to lower levels of disaggregation (for example, district or school level), the relative importance of teacher mobility increases. Moreover, at lower levels of disaggregation, exit probabilities are generally higher. Using the elements in table 1, the year-to-year exit probabilities for teachers by age are

$$\begin{aligned}
 \text{Exit}_y &= TN_{yy} + TN_{ym} \\
 \text{Exit}_m &= TN_{mm} + TN_{mo} \\
 \text{Exit}_o &= TN_{oo}
 \end{aligned}
 \tag{3}$$

Of course, for each group it must be the case that  $\text{Exit}_i = 1 - \text{Retention}_i$ .

The lower left quadrant of the table lists key transition probabilities for the “refresher” supply of teachers – i.e. teacher in year  $t+1$  that did not teach in year  $t$ . Empirically, the transition probabilities in this quadrant for the young are generally higher than the probabilities

for those in the middle and older age groups. Moreover, the choices driving these transition probabilities are often quite different. New younger teachers tend to be recent college graduates with no former teaching experience. While some new teachers from the middle and older age groups may also have no prior teaching experience, these teachers will be comprised disproportionately of former teachers that are either returning to the workforce or changing occupations after a spell outside of public school teaching. The key entry probabilities that may conceptually provide the basis for research on the reserve pool of teachers are given by the equations

$$\begin{aligned}
 (4) \quad \text{Entry}_y &= NT_{yy} + NT_{ym} \\
 \text{Entry}_m &= NT_{mm} + NT_{mo} \\
 \text{Entry}_o &= NT_{oo}.
 \end{aligned}$$

The final sub-matrix (the lower right hand corner) provides the likelihoods that those who are not teachers remain in their current occupations.

The connection between the transition probabilities matrix and teacher supply is made explicit in Table 2. In year  $t+1$  the supply of teachers within each age group comes from four sources: teachers retained from within the age group, new entrants from outside of the pool of continuing teachers within the age group, retained teachers who age upwards across age categories, and new entrants from outside of the pool of continuing teachers who age across categories between years  $t$  and  $t+1$ . If we define the variable  $Pop_{ij}^t$  as the college educated population in year  $t$ , in age group  $i$ , and occupation group  $j$ , then each of these sources of supply can be derived by multiplying the appropriate population total with the corresponding transition probability. Of course, the total supply of teachers is given by the sum across age groups.

This decomposition of supply into respective sources aids in highlighting three aspects of supply forecasts. First, heterogeneity in the transition probabilities into and out of teaching matter, and thus future projections require dynamic models of the evolving age structure of the teacher workforce. Thus, our forecasts of the supply of future teachers will be different in cases when the incumbent workforce is disproportionately distributed towards the older age groups relative to instances when the incumbent workforce is relatively young.

Second, supply from retentions and new recruits are to some degree separate animals that require individual research and modeling attention. Considering these separate sources of supply is quite important when trying to devise strategies for addressing persistent teachers shortages in certain schools and/or subject areas. This distinction is raised quite forcefully in a recent paper by Ingersoll and Perda (2009). In an analysis of the labor market for mathematics and science teachers, the authors compare the flow of recent hires into secondary school teaching positions relative to aggregate teacher attrition due to retirement, inter-school mobility, and teachers leaving the teaching profession pre-retirement. The authors note that new hires and teacher exits are roughly in balance across subject areas, yet that interviews with principals indicate persistent shortages in the fields of mathematics, certain science sub-disciplines, and special education. Cognizant of the important contribution of existing teacher retention to teacher supply, the authors advocate for a greater focus on teacher retention rather than generating new mathematics and science teachers as policy to address the staffing problems in these subject areas.

This position has its merits considering that roughly 90 percent of teachers in a given year are incumbent workers retained from the previous years (with new hires accounting for under 10 percent of the teaching workforce). Even small changes in retention rates will induce relatively large changes in supply given the proportional importance of existing teachers to the

overall composition of supply. Nonetheless, if a particular sub-discipline experiences structural supply shortages, the fact that new teacher hires are comparable in magnitude to the total teachers lost through attrition does not imply that the supply of new teachers is sufficient. In the face of rising enrolment levels (a pattern also documented in Ingersoll and Perda (2009)), addressing the supply shortage would require new hires in excess of teacher losses through attrition. More generally, however, both an increase in the rate at which college graduates transition into teaching (new hiring) as well as a decrease in the rate at which existing teachers transition out of teaching (teacher attrition) would increase the equilibrium or “steady-state” supply of teachers within a given specialty. The optimal balancing of policy efforts and resources across these two sources of supply will depend on how sensitive these supply sources are to factors under the control of policy makers. I address this latter issue in detail in reviewing the research pertaining to determinants of the occupational transition probabilities in Table 1.

Finally, the dependence of supply on underlying transition probabilities that vary by age group (and in a more complicated empirical framework, perhaps age, race and other such characteristics) highlights the key choice points and probabilistic relationships underlying the determination of supply at any given point in time. In fact, each of the transition probabilities presented in Table 1 (though primarily the transition probabilities in the two shaded sub-matrices) provides the dependent variables for research agendas that one could subsume under the heading of teacher supply analysis.

### *C. Forecasting future continuing supply and new hiring needs*

The structure laid out thus far provides the needed components for projections of continuing supply and the demand for new hires used in most teacher supply-demand analyses.

Begin by calculating enrolment forecasts and teacher demand as described in equation (1). Next, use the current employment levels of teachers by age in conjunction with estimates of age-specific retention rates (or equivalently, attrition rates) to project the number of teachers that will remain teachers for the next school year. For state-level projections, age-specific retention rates estimated with administrative data for the most recent year (or perhaps for the most recent two or three years) are likely to be sufficiently precise to generate reliable estimates of the supply of teachers from continuing faculty. At the school level however, estimating retention rates from a single year are likely to be quite imprecise, especially in small schools. There are several potential fixes to this problem. One would be to apply state level estimated retention rates to teachers of a given age range in specific schools. This of course, would fail to capture the differences across schools in retention rates that are documented below. A safer bet would be to estimate retention rates for specific schools using several years of data for the specific school. An alternative that would preserve the benefits of the larger sample size in state administrative databases would be to tabulate retention rates by teacher age and broad school characteristics (such as quintiles of the percent minority or quintiles of the distribution of student test scores). These specification choices aside, most analyses take retention rates as given and make no attempt to model how these rates may change with changes in compensation, workplace conditions, or other variables that teachers and potential teachers might consider in making future occupational choices.

Finally, tabulate the number of necessary new hires by calculating the difference between projected teacher demand and projected supply from continuing teachers. Such calculations are often silent with regards to the certification or hiring standards compromises that schools may have to make in order to meet these hiring needs. In practice, however, this assumption seems to

best reflect actual hiring behavior as teacher vacancy rates are consistently quite low. In other words, schools do what they have to do (i.e., exhaust the supply of new fully certified teachers and then lower hiring standards until all or most vacant position are filled) to meet new hiring needs. Conceptually, this new-hires total can be further decomposed into two components: a component associated with changes in enrolment and a component associated with replacing teacher exits.

Projections beyond one year require additional assumptions regarding the age distribution of new hires. A common choice is to assume that education officials will fill all vacant positions (a not too unreasonable assumption given that schools via a variety of compromises can usually fill most vacancies) in year  $t+1$  and to assume that the age distribution of new hires in year  $t+1$  (which of course is unobservable) will be the same as the age distribution of new hires in year  $t$  (which is observable). To be sure, the age distribution of new hires may be changing over time, and the assumption of a constant age profile may add further error to future supply forecasts. An alternative strategy may be to estimate trends in the age distribution of new hires and project out based on changes in recent years. Nonetheless, assuming a constant age distribution is relatively simple and is often used in supply-demand projections in other occupations (see the appendix review for several medical professions).

Subject to the assumption regarding the age distribution of future hires, one can then calculate the base age distribution and supply levels in year  $t+1$  for further projections into year  $t+2$ . Longer projections require subsequent iterations of this entire procedure.

#### *D. Data requirements*

The data required to perform teacher supply-demand analyses depend on (1) the desired geographic level of analysis, (2) the desired degree of disaggregation with regards to teaching

specialty, and (3) whether one wishes to project future demand and supply holding constant the policy environment or to forecast teacher market conditions under alternative hypothetical reforms, such as pay raises, alternative certification regimes, or changes in pupil-teacher ratios. Assuming for the moment that we are interested only in forecasts that assume a constant policy environment, data requirements include the following:

- Population projections for school age children, preferably broken down by elementary, middle, and high school age ranges,
- Current enrolment rates by age group
- Information on current pupil-teacher ratios by grade level, and in high school, by subject area (or alternatively, desired pupil teacher ratios that use total school enrolment as the base thereby incorporating optimal enrolment and class size into the projection)
- Estimates of the counts of the existing teacher workforce by age, gender, grade, and subject area
- Estimates of retention rates (defined either nationally, at the state level, or at the district or school level depending on the desired level of analysis) that vary by age, gender, and perhaps subject area and other teacher demographics
- Estimates of the age distribution for new teachers.

As was already mentioned, it is often assumed that education officials will do what is necessary to fill the shortfall between demand and supply and that the age distribution of these new hires will remain constant into the future. Thus, for the purposes of forecasting future hiring needs, one does not necessarily need information on the “reserve pool” of potential teachers.

One can envision more complex supply-demand analyses that would allow for the possibilities that the key transition probabilities laid out in Table 1 depend on such factors as the pay of teachers relative to their next best labor market opportunities, employment conditions at schools, certification hiring requirements, or the presence or absence of teacher induction and in-service training programs and support. With information on the responsiveness of these transition probabilities to these factors, one could potentially simulate market conditions under several alternative policy scenarios. For example, if we knew that teacher induction programs, such as providing mentors or extra resources for novice teachers, increased the retention probability for young teachers by a fixed amount, one could simulate hiring needs under the status quo and under the alternative scenario where such induction activities were made universal across all schools. Alternatively, one might be interested in simulating how granting teachers more control of curriculum content would increase future needs via the relationship between this particular workplace practice and the likelihood that teachers of all experience levels are retained from year to year. Alternatively, one might ask the question, “By how much would we need to increase the retention rates of mathematics and science teachers to reduce new hiring needs by x percent?”

All of the supply-demand analyses that I have reviewed follow the first relatively mechanical approach, where the status quo is assumed into the future and continuing supply and hiring needs are projected. Nonetheless, there are many serious studies of some of these transition probabilities and their dependence on such factors as relative pay and working conditions. I now turn to a discussion of this research beginning with existing national and state level supply-demand analyses that projects based on current conditions. I then review several

studies that attempt to analyze the determinants of the key transition probabilities driving teacher supply.

### **3. National-Level Studies of Teachers Supply and Demand**

The principal source of national projections of teacher supply and demand come from the *Projections of Education Statistics* series compiled by the National Center for Education Statistics. The 36<sup>th</sup> edition of this publication provides enrolment and teacher workforce projections through the year 2017 (NCES 2008a). Teacher demand and supply are forecasted using a model quite similar to that laid out in the discussion above. What distinguishes these calculations from other studies is the national focus. The NCES projections look at the aggregate supply and demand for teachers, regardless of the distribution of demand and supply across states (although these publications do provide some state level projections). This national focus means that the relevant transitions analyzed in forecasting teacher supply and demand are the transitions of adult college graduates of varying ages into and out of public school teaching. As we will soon see, state, district, and school level analyses require a more complex set of transition calculations to account for cross-school teacher mobility.

The NCES student enrolment projections combine Census Bureau population projections with NCES econometric forecasts of enrolment rates and pupil-teacher ratios. For overall teacher employment, the NCES uses two very simple time series regressions to project overall elementary and secondary school pupil-teacher ratios. For the elementary school regression, the specification is log-log and includes the relative salary of elementary school teachers and the size of state-level funding per student for elementary school students. State grant levels are negatively associated with the pupil-teacher ratio while a higher relative wage has a positive

association (with the interpretation that higher costs induce economizing on teachers). Projected elementary school teacher demand combines forecasted pupil-teacher ratios with forecasted enrolment using the formula laid out in equation (1) of the previous section.

The forecasting methodology for secondary school teacher demand is similar although the model specification used to forecast the student-teacher ratio is slightly different. For the secondary school equation, relative salary is not included in the specification while a variable measuring the overall enrollment rate for secondary school age children is added to the specification. Both included variables have the expected signs. The latest edition of these forecasts (NCES 2008a) projects a 9 percent increase in overall public school enrolment by 2017, and corresponding increases of 11.5 percent for K-8 and 4.3 percent for high school.

The NCES methods for projecting teacher supply from continuing teachers and needed new hires is described in detail in Hussar (2000). The NCES calculates age-specific one-year retention rates for teachers using data from the Statistics School and Staffing Survey (SASS) and the corresponding Teacher Follow-up Survey (TFS). The SASS provides microdata on public and private school teachers that when properly weighted can be used to generate estimates of the total teaching force and national representative estimates of teacher characteristics. The TFS re-interviews a sub-sample of teachers from the SASS sample one year later and is used to estimate cross-school mobility and teacher attrition (or equivalently, retention) rates. The one year retention rates are used to project the proportion of the base count of teachers in year  $t$  (estimated from the SASS data) that will still be working as teachers in year  $t+1$ . This total can then be compared to the estimated total needed teacher workforce, with the difference between the two providing the number of new teachers that need to be hired.

To project forward beyond the first projection year, data on the age distribution of new hires are used to apportion the hypothetical new hires across age groupings. Then the one-year retention rates can be used to project forward the continuing workforce. The difference between the sum of continuing teachers and the projected need provides the estimate of the number of new hires that need to occur in year  $t+2$ .

The latest projections indicate that new teacher hires will increase from 285,000 in 2005 to 364,000 in 2017. While this may seem like an awfully large amount of hiring, it is worth noting that in 2005 roughly 91 percent of teacher supply came from continuing teachers, with the remaining from new hires. By 2017, the NCES is projecting that 90.2 percent of teacher supply will be met by continuing teachers. Interestingly, the implied amount of hiring relative to the scale of the enterprise is not that unusual relative to what occurs in the private sector. National level estimates of the proportion of employed U.S. adults who will leave their current employer within one year range from 20 to 25 percent (Bansak and Raphael 2006). The comparable figure for public school teachers, including both those who change schools and those who leave teaching altogether, was 16.5 percent in 2004-2005 (NCES 2007).

Figure 1 presents estimates of the age-distribution for all teachers and new teachers (defined as teachers employed this year who did not work as public school teachers last year) for the 2003-2004 school year (the latest year available from SASS). As is evident from the figure, new teachers are considerably younger than teachers overall, with nearly 70 percent of the former below 40 years of age, compared with 42 percent of all teachers. This simple difference in the age-distribution suggests that the supply of new teachers is coming disproportionately from younger college graduates likely to have little or no past experience teaching. Nonetheless,

30 percent of the new hires are over 40 indicating that returning former teachers and people affecting mid-career changes are also an important source of supply.

Figure 2 presents NCEs estimates of the rate at which existing teachers leave public school teaching (the attrition rate) by age. As has been demonstrated in numerous studies, the relationship between age and attrition is u-shaped, with relatively high attrition among young, relatively inexperienced teachers, lower attrition rates for teachers in the middle age ranges, and relatively high attrition rates for older teachers approaching retirement. The heterogeneity in the relationship between age and the attrition probabilities is an important fact that will require special attention as the population of existing teachers ages. In addition, heterogeneity in the *responsiveness* of these transition probabilities by age may prove important to policy makers wishing to augment supply through greater retention.

Data from the *Projections of Education Statistics* in conjunction with results presented in several other NCEs publications (in particular, NCEs (2007) and NCEs (2008b)) can be used to assess the degree to which staffing problems for mathematics and science teachers are more severe than what is observed for other teachers. To begin, Figure 3 presents estimates of the overall one-year attrition rate for all public school teachers, public school mathematics and science teachers, and all other public school teachers for all available years of the TFS. While attrition is only one element in understanding supply, to the extent that mathematics and science teachers pose a particular staffing challenge, one might expect to observe higher attrition rates among this group. The figure reveals that with the exception of the year 2000-2001 the attrition rates of mathematics and science teachers tend to be lower than those for all other public school

teachers. This is also the conclusion reached in Ingersoll and Perda (2009) in separate comparisons of attrition rates for English teachers, mathematics teachers, and science teachers.<sup>4</sup>

To be sure, differences in attrition may be driven by average differences between mathematics teachers and other teachers in the age distribution or in some other characteristic. To explore whether this is the case, Table 3 presents comparisons of various traits for all teachers, for mathematics and science teachers, and for all other teachers working in public schools. While mathematics and science teachers are somewhat younger, the age distribution for this group is quite similar to the overall age distribution for teachers. Moreover, the distribution across pay categories is nearly identical, with mathematics teachers slightly more concentrated in lower paying categories. This latter finding is actually somewhat alarming, due to the fact that in the broader labor market for college graduates there are substantial premiums paid for technical mathematical and science training, while among teachers there is not. There is very little difference in the proportion of teachers with something other than the standard state certification, with mathematics and science teachers slightly more likely to have a standard certification. The one large difference observed in the table is that mathematics and science teachers are considerably more likely to work in secondary as opposed to elementary schools. Moreover, an extensive review of the research on teacher attrition found that attrition rates are consistently higher among secondary school teachers relative to elementary school teachers (Allen 2005). If this were the case, a comparison of attrition by field for secondary school teachers may yield results that differ from those presented in Figure 3.

The figures in Table 3 also shed some light on the question concerning whether the rate at which new mathematics and science teachers are entering the teaching profession differs from the comparable rate for teachers in other fields. Several of the variables listed in the table permit

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<sup>4</sup> The authors do not indicate whether the attrition rates are tabulated for secondary school teachers only.

drawing indirect inferences pertaining to this issue. First, if fewer college graduates are choosing to become mathematics and science teachers relative to teaching in other fields, one would expect the age distribution of mathematics and science teachers to be concentrated in the higher ranges, as there would be lesser infusions of new supply into this sub-specialty. In addition, if schools are experiencing particular difficulties in staffing mathematics and science classes, one might expect to see a greater proportion of teachers in mathematics and science without regular state certifications. As is evident in Table 3, neither of these patterns is observed in the data. If anything, mathematics and science teachers are slightly younger than all other teachers and are slightly more likely to have regular state certification. Based on these gross figures, it appears that the stock of mathematics and science teachers is being replenished at a rate comparable to that observed for other teachers. Moreover, mathematics and science teachers are no more likely to leave the teaching professions than others.

One manner in which the mathematics and science teacher workforce may be changing relative to other teachers that is not reflected in these tabulations concerns average academic aptitude. As we will see in our discussion of new teacher entry, there is substantial evidence suggesting that as the pay for teaching declines relative to the pay in other occupations open to college graduates, the relative ability of teachers as measured by performance on standardized tests declines. Although I was unable to find specific research on the next best employment alternatives for teachers by fields, it is probably safe to assume that the relative pay for mathematics and science teachers have declined by more than the relative pay for other teachers (below, I present empirical evidence regarding declining relative pay for teachers overall). If this is the case, schools may be meeting their staffing needs for all subjects (giving the illusion of comparability in the tabulations discussed thus far) but dipping further down into the academic

performance distribution for certain sub-specialties. While I was unable to find evidence either confirming or refuting such speculation, this is clearly an important adjustment valve in need of further research.

The issue of subject-area certification and teacher mismatch has been studied in greater depth by Seastrom et al. (2004). Using data from various years of the SASS, the authors estimate the proportion of teachers in middle school and high school that are “teaching out of field” by subject area. Figures 4 and 5 reproduce some of the results from this study. For the school years 1987-88 and 1999-00, each figure presents the percent of teachers in the subject area that have neither a major nor minor in their teaching area and that do not have a subject-area certification to teach in the field. Figure 4 presents tabulations for middle school teachers while figure 5 presented tabulations for high school teachers. There is a notable increase in the proportion of mathematics teachers teaching out of field among middle school mathematics teachers, but no such increase among science teachers. The higher level of aggregation among science teachers, however, may mask out-of-field teaching. For example, should a biology teacher teaching physics be considered as teaching within her subject area specialty? The general impression for high schools (Figure 4) is that the degree of out-of-field teaching is no greater in mathematics and science than in other subject areas (especially in high schools). Moreover, over the time period analyzed, there is little evidence of trends in these outcomes.<sup>5</sup>

The patterns investigated thus far look for evidence of staffing shortages by focusing on specific transition probabilities (for example, directly comparing attrition rates by field or inferring difference in entrance rates by comparing age distributions). An alternative tack would be to analyze the data fields in the SASS pertaining to each school principal’s response to

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<sup>5</sup> However, there is evidence of greater out-of-field teaching in schools where large proportions of the children come from poor families. I will discuss this issue in greater depth below along with the discussion of heterogeneity in demand-supply conditions across schools with different student socioeconomic compositions.

questions pertaining to teaching vacancies and the degree of difficulty in filling such vacancies. The benefit of this characterization is that it provides an overall measure of hiring difficulty and the compromises that schools may make to deal with these difficulties. On the downside, the summary measure does not allow us to distinguish the source of the staffing difficulties (i.e., excess attrition or low teacher entrance rates).

Table 4 presents school level responses to questions regarding (1) whether the school had vacant positions in specific sub-fields, and (2) for those with vacancies the degree of difficulty experienced in filling these vacancies. I tabulated these data from the school level file of the 1999-2000 SASS (the latest year with public use data files available on the ICPSR webpage). The tabulations are restricted to public secondary schools. The figures reveal that the majority of public high schools experienced mathematics vacancies. Only 39 percent of schools indicate that there were no mathematics vacancies in the survey year. This figure is quite low relative to all other fields with the exception of English teachers. Moreover, fully 26 percent of public high schools indicate that they had mathematics vacancies that were very difficult to fill or that they had a mathematics vacancy that they could not fill (the most of any sub-field). The comparable figures for other hard-to-staff fields are 23 percent for special education, 20 percent for foreign language teachers, and 17 percent for physics teachers. Schools indicate the greatest ease in filling English teacher and social studies teacher vacancies.

Further cross-tabulations of these data reveal particularly severe mathematics staffing problems in minority schools. This fact is documented in Table 5. The table presents estimates of the proportion of high schools that have a vacancy in each field that is either very difficult to fill or that could not be filled (the sum of the last two columns in Table 4). The table present separate tabulations for groups of high schools defined by the proportion of the student body that

is minority. Overall, the data reveal that the sub-fields with the greatest staffing difficulties are mathematics, special education, foreign languages, and physics (as in Table 4). The most striking patterns in the table, however, are the large differences across schools by the percent of students that are minority. For example, while 18 percent of schools with students that are less than 5 percent minority indicated difficulties in filling mathematics vacancies, the comparable figure for schools that are over 50 percent minority is 34 percent. Moreover, this gauge of mathematics staffing problems increases uniformly with the increase in the percent of students that is minority. Similar patterns are observed in all other sub-fields.

The final column of Table 5 presents the results of a test of whether the differences observed across schools defined by the percent of students who are minority are statistically significant. The figures in the last column of the table are estimates of the likelihood of observing the difference in the first four columns due to random variation alone.<sup>6</sup> When this figure is below 0.05, we would conclude that the differences we observe are statistically significant (that is to say, unlikely to result from sampling error). With the exception of the differences observed for foreign language and social studies teachers, all of the disparities are statistically significant.

One interesting pattern in Table 4 that I have yet to discuss is the very low proportion of schools that indicated that they had a vacancy that could not be filled. With the exception of special education vacancies (where 4 percent of schools indicated that they had unfilled vacancies) these figures never exceed 2 percent, even for mathematics vacancies. An interesting question that one might ask of the data is what is it that schools are doing to insure that nearly each vacant position is filled? Fortunately, the SASS includes questions on compromises that

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<sup>6</sup> To be precise, the figures in the last column are the p-values from F-tests of the null hypothesis that the proportion of schools experiencing hiring difficulties does not differ across the categories define across the top row of the table.

schools make in order to address vacant teaching positions. Table 6 presents tabulations of these fields. Specifically, the table stratifies schools into two groups: schools that had vacant positions in one to five of the sub-fields listed in Tables 4 and 5 and schools that had vacant positions in six or more of the eleven sub-fields. For each of these groups, the table presents the proportion of schools that indicated that they had to cancel planned course offerings, expand class size, hire unqualified teachers, add to other teacher's workload, re-assign existing teachers, assign administrators to teach classes, or use short or long-term substitutes. For each staffing compromise with the exception of using administrators to teach, schools with a higher number of vacancies are substantially and statistically significantly more likely to be forced to make such compromises. Interestingly, a sizable minority of high schools indicates that they cancel classes due to difficulty in filling vacancies.

Thus far, we have characterized national supply shortages using data gleaned primarily from the SASS and TFS data sets. An alternative source of data is to consult the impressions and opinions of those who train the nation's public school teachers. Such impressions are recorded in the annual report of the American Association for Employment in Education (AAEE) titled *Educator Supply and Demand in the United States*. For the past 30 years, the AAEE has fielded an annual survey of institutions of higher education (in 2006, the sample included 1,270 institutions). Surveys are completed by career service directors with responsibility for placing new teachers or deans or directors of teacher education at the university. Each respondent is asked to rank the relative scarcity of teachers in each of 68 fields. Respondents rank each field on a scale from one to five, with a value of one indicating considerable surplus and a value of five indicating considerable shortage. Unlike the NCES supply-demand analysis which projects new hiring needs based on the actual teacher workforce, turnover behavior, and enrolment

projections, the AAEE estimates relative demand conditions via the sentiments of those in the business of producing and placing new teachers. Figure 6 presents the composite relative scarcity score for all teachers and for mathematics and science teachers from the 2007 AAEE report. These figures represent the average response of survey respondents. Mathematics and science teachers are notably ranked as being in high demand (or in considerable shortage) relative to teachers overall. Mathematics teachers have the highest average score.

Interestingly, the AAEE indices appear to exhibit considerable stability over time. For example, in the 2006 report (the 30<sup>th</sup> anniversary of this data collection effort) it is noted that when the survey was first administered in 1976, respondents indicated that there were considerable shortages in the supply of mathematics, chemistry, and physics teachers, a pattern also evident in the most recent data. Moreover, the composite index indicating the overall scarcity of teachers moves very little between 1981 and the present and does not exhibit a trend (AAEE 2006). The stability of these rankings can be seen in Table 7, where I have assembled the average scores for the composite index of all teachers and for mathematics and science teachers for the years 2002 through 2007. The scarcity of mathematics and science teachers relative to the composite index is quite stable over time, as is the relative ordering of mathematics and science teachers within each year. Moreover, the correlation between the index values for each sub-field and the composite index is quite high (reported in the last row of the table). While the high correlation results in part from the fact that each field is an element of the index (in the latest data, respondents are asked to provide rankings for 68 separate fields), the strong correlation coefficient suggest that subject area scarcity moves in conjunction with teacher scarcity more generally.

How then does one reconcile the mixed signals from the SASS research with the impressions of those surveyed by the AAEE? Several possibilities come to mind. For one, it could be that there is a perennial shortage of mathematics and science teachers that is not worsening. A second possibility is that while the relative supply of mathematics and science teachers exhibits evidence of stability, the educational demands of the future workforce require that we increase the relative employment of mathematics and science teachers above historical levels. A third and perhaps more ominous possibility is that the declining average academic aptitude of science and mathematics teachers exceeds the declines observed for teachers overall (a pattern that cannot be addressed with the data discussed thus far). An additional possibility is that while there may not be a shortage nationally, there may be important school and district-specific shortages. In particular, it appears to be the case that teaching out of field is a particularly severe problem in schools that serve poor or generally less fortunate children. With such sentiments in mind, I now turn to a discussion of state-level and even further disaggregated supply-demand analyses.

#### **4. State and Local-Level Studies of Teachers Supply and Demand**

A wide variety of technical reports conducted by academics, research centers, and state education departments fall into the category of state-level analyses of teacher supply and demand. The emphasis varies from report to report, with some studies paying particular attention to projections of aggregate hiring needs, others devoted largely to descriptive analysis of current supply conditions that may hint at future hiring needs and potential staffing problems, some focusing on specific subject areas, and many focusing on geographic variation in relative teacher supply and the characteristics of schools that face persistent teacher shortages. Unlike

the national studies which generally make use of two surveys conducted by the Census Bureau, state-level analyses make heavy use of administrative data, often linked across different information systems and source state departments. In addition, the state-level analyses tend to be considerably more detailed on a number of dimensions.

One key difference between the level of detail in state and national studies concerns the different geographic levels of analysis. Many state supply-demand analyses, in addition to analyzing current and future market conditions for the state as a whole, also analyze the conditions facing educational policy makers at the district and even the school level. The importance of this ability to disaggregate is evident in Figure 7. The figure presents estimates from Reichardt (2003a) of teacher attrition rates (defined as the proportion of current teachers who will not be working next year) for Colorado measured at the level of the state, the district, and the school. Attrition at the school level can be due to either intra-district mobility, inter-district mobility within the state, inter-state mobility, or teachers leaving teaching altogether. Attrition at higher levels of aggregation will occur through fewer channels and thus should be lower relative to more disaggregated levels. Indeed, the figure reveals much higher attrition rates when measured at the school level than when measured at the level of the district or the state.

Another key difference between state-level analyses and the extant national-level studies is the degree to which state forecasts home in on specific subject area demand. Many state studies present subject area-specific estimates of enrolment-driven teacher demand, future supply from continuing teachers given the age distribution of the incumbent workforce, and new hires needed. Several studies rank the severity of the supply shortage by teacher subject area. In addition, a number of studies analyze how teacher shortages vary across school groups defined

by average test score, percentage of children receiving free lunch benefits, as well as the percentage of children from minority groups.

Reichardt (2003b) presents an excellent users guide for conducting state-level supply and demand analyses. The author presents a thorough discussion of the data needs for such studies, typical descriptive analyses that are easily interpreted and informative with regards to current demand-supply conditions, and the formal modeling and key elements needed to project teacher demand into the future.

The data employed in state-level studies often vary from study to study. However, there are common components that are observed in nearly all and that are likely to be the most informative.<sup>7</sup> All studies include enrolment forecasts, usually based on externally provided population forecasts and fixed assumptions regarding enrolment rates. Nearly all state-level studies make use of longitudinal administrative records for teachers that include school and subject-area teaching assignment; measures of teacher experience (either explicitly asked of teachers or constructed from administrative histories); teacher age, gender, and race; salary information; undergraduate institutions, majors, and minors; and teacher qualifications (level of educational attainment, types of certification, etc). When combined with school level information on student socioeconomic and demographic characteristics, these variables can be quite informative regarding the current distribution of teachers, areas where teacher quality problems are likely to be most severe, and areas that are likely to pose challenges to educational policy makers in the future. For example, many of these studies often tabulate the following information for teachers overall as well as by subject area:

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<sup>7</sup> The following discussion is based on my reading of the following analyses: Reichardt (2003), Reichardt (2002a, 2002b), SRI International (2006), Beaudin et al. (2000), Thompson and Beaudin (2004), Florida Department of Education (2007), Wechsler et al. (2007), and Maryland State Department of Education (2006). While there are certainly many additional state-level analyses, the structure and content appear to be fairly comparable, and thus the discussion is likely representative of what is possible with existing data sources.

- Age distribution of the current teacher workforce
- Proportion of teachers within five years of retirement
- Attrition rates by age
- Proportion of teachers under-prepared (using definitions that vary with state licensure and certification criteria)
- Proportion of teachers teaching out of field.

Some of the most informative tabulations in these studies show how the various teacher characteristics differ across schools by geographic area of the state, the proportion of low-income or minority students, or the general academic performance of the student body. As we have already seen in national data, such school characteristics are important predictors of relative teacher supply shortages, and similar patterns have been documented within states.

Independent of any forecasts regarding future need, it is often the case that subject area shortages are readily apparent from careful readings of these simple cross-tabulations. For example, cross-school disparities in teacher experience levels or the proportion of teachers assigned out of field often reveal key differences existing across schools within a state. Thus, the summary descriptive elements of these reports presented for the state and disaggregated to defined classes of districts and schools are likely to be particularly useful to education policy makers. Of course, these elements are often combined to generate future predicted supply of continuing teachers and, in conjunction with enrolment forecasts, future hiring needs. Nonetheless, much of the information embodied in formal projections is often readily apparent (and perhaps easier to interpret) in the descriptive statistics.

A number of the studies that I reviewed presented information specific to the demand and supply of mathematics and science teachers, although these particular subject areas are not always the principal focus of analysis. The Colorado analysis in Reichardt (2003) presents subject-area specific estimates of the proportion of teachers within five years of retirement, certification levels, and attrition rates. There is little evidence of relatively high attrition rates or high proportions nearing retirement for mathematics and science teachers in Colorado, and no difference in the proportion certified or teaching out of field. Reichardt's (2002a) analysis of Wyoming data finds comparable salaries and vacancy rates for mathematics and science and other positions, but it also find that mathematics and science teachers are slightly more likely to be novices and have slightly higher attrition rates. Reichardt's (2002b) analysis of Kansas finds little difference between mathematics and science teachers and other teachers in the proportion of veteran teachers, the proportion within five years of retirement, the proportion teaching out of field, and the proportion with master's degree.

The analysis of California data by SRI International (2006) focuses specifically on the market for mathematics and science teachers. The most powerful cross tabulations in this analysis show the strong association between the proportion of students who are minority and the proportions of mathematics and science teachers who are under-prepared. Similarly, the study shows much higher percentages of under-prepared teachers in schools with relatively low API scores. These measures of teacher quality improve in all school between 2000 and 2004, though the cross school relationships associated with the socio-demographic makeup of the student body remain.

The Office of Evaluating and Reporting for the Florida Department of Education (2007) presents a series of projections by subject area that closely match the methods discussed in the

first section of this review. These projections also include a simulation of the impact of mandated changes in class size on total teacher demand and likely new hires needed. Note that this simply requires altering the assumption regarding the time path of the student-teacher ratio. Nonetheless, such simulations provide fairly concrete information about how potential class size reductions alter staffing needs and help to determine the feasibility of such proposed changes. As it turns out, the subject area projections for Florida indicate future shortages of mathematics and science teachers.

The Maryland State Department of Education (2006) conducted a thorough analysis of the coming year need for new hires, an analysis which is updated each year. Applying historical attrition rates to the incumbent teacher workforce and making use of staffing needs implied by enrolment projections, the analysis estimates the demand for new hires by subject area. Subject areas are then ranked by the ratio of continuing teachers (projected) to needed new hires, with lower ratios indicating a more severe labor shortage. The physical sciences are predicted to have the most critical shortages, while mathematics teachers are also in short supply, though to a lesser extent. Biology teachers, on the other hand, are relatively abundant.

## **5. Usefulness of These National and State-Level Analyses to Policy Makers**

Clearly, much effort and resources are devoted to empirical analysis and description of the labor market for public school teachers. Researchers in academia, think tanks, and government have made creative use of administrative and survey data and are producing supply-demand analyses that have a fairly uniform and common set of tabulations and projections. Given all this effort, one might reasonably inquire about the purpose that this body of research

serves. More specifically, are there specific planning tasks and policy deliberations towards which the output of this research can be constructively applied?

Certainly, all-else-held-equal projections in conjunction with a fixed set of measures of teacher preparation can be used to identify emerging and perhaps structural staffing problems faced by schools, districts, and states. In fact, I would argue that some of the most useful output included in many supply-demand analyses is the most accessible and easy to interpret summary statistics. The following are particularly significant:

- Proportion of teaching slots that will need to be filled by new hires or the proportion that were recently filled by new hires
- Proportion of teachers in a given subject area that are novice, under-certified, or teaching out of field
- Proportion of teachers within five years of retirement or over a certain age

Such data are clearly positively associated with current or pending teacher shortages. In addition, age-adjusted measures<sup>8</sup> of attrition would provide indications of the relative extent to which teachers in the different subject areas are leaving teaching for alternative opportunities.

Developing such key summary measures for a state's workforce overall, by school district, by broad classes of schools, and by subject area would certainly provide actionable information for planning purposes. Separate tabulations of current levels and trends in these indicators by subject area would highlight particular subject area shortages. Ideally, states would want to measure a set of relative supply indicators consistently over time to benchmark the progress of efforts to meet the need for teachers in particular teaching sub-fields. I would argue that settling

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<sup>8</sup> Adjusting a particular outcome for age is common when there is a strong average empirical relationship between age and the outcome. For example, demographers frequently adjust mortality rates by age to facilitate comparisons across groups such as gender, race, or nationality. Age adjusting can be done quite simple by calculating weighted averages of age-specific attrition rates where each value is weighted by the overall proportion of teachers in the age range.

on a fixed set of indicators, measuring them consistently as far back as possible, and then sustaining a data reporting structure that tabulated these key indicators would be quite useful.

In addition to being useful in identifying developing shortages at the state level, the descriptive analysis in many supply-demand studies can be quite forceful in highlighting specific schools and districts that face particularly acute teacher supply problems. Irrespective of overall structural supply shortages, the disparities that are commonly documented across schools grouped by the proportion of children receiving free lunch benefits, the proportion minority, average API scores, or whatever other school-level variables are used to stratify institutions demonstrate forcefully how the market conditions faced by specific schools differ from the average conditions faced by schools in the state. In other words, it may be that all schools face a shortage of qualified mathematics teachers. However, if the quality indicators for the incumbent workforce or the proportion of positions sitting vacant are much higher in some schools than others, then policy makers have clear information regarding areas in need of improvement. Preferably, charting these disparities for the key indicators discussed above would permit assessing progress along equity dimensions as well as overall progress in meeting the labor needs of a state's public schools.

Existing supply-demand studies are also quite useful, and at the national level, fairly accurate in projecting overall teacher demand and new hiring needs. However, longer term projections are considerably more variable, as will be projections of all time horizons for smaller states and smaller units of analysis. For example, the NCES reports that in an analysis of past education statistics projections the absolute percent difference between the projections for classroom teachers and actual number of teachers was one percent for one year projections, 1.5 percent for

two-year projections, 2.7 percent for five year projections. 6.1 percent for ten year projections (NCES 2008). Clearly, forecasting errors will be larger for state-level projections<sup>9</sup> and even larger for projections for specific schools, given the greater variability in unpredictable behavior observed in smaller populations. However, using the projections from a careful supply-demand analysis as the first guess regarding next year's hiring needs, and even that for the year after next, is perhaps the best starting point provided that policy makers allow for either upward or downward flexibility associated with forecasting error.

One additional set of applications of these models that is little evidenced in existing studies yet could easily be accommodated within existing frameworks concerns using the models to perform hypothetical policy simulations. For example, suppose that California educators are considering extending the state's current class-size reduction efforts beyond third grade. One could easily simulate the new hiring needs under the status quo and under the alternative policy scenario. Further, the state may attempt to determine by how much it would need to reduce existing teacher attrition to meet the additional staffing needs associated with expanded class size reduction efforts. A set of hypothetical projections associated with alternative attrition rates would provide this information and would also provide a target towards which state district officials and school principals could work towards. Of course, large policy changes often induce behaviors and consequences that are unanticipated and often unintended, and thus the uncertainty surrounding such simulations is inherently greater than the forecasting error associated with a status quo projection. Nonetheless, such creative use of these models (which frankly, does not require technical modeling skills beyond those already used to produce the base report) can

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<sup>9</sup> I was unable to find any systematic assessment of the forecast errors in state-level supply demand analyses of teachers labor markets.

provide a starting point for in-depth policy analysis about the feasibility and requirements of possible reforms.

Thus, the potential usefulness of supply demand analysis, especially the descriptive analysis, is far-reaching. That being said, policymakers and planners may also have many important questions that existing studies cannot answer. In particular, any “what if” questions that depend on the mobility behavior of teachers or the propensity of recent college graduates or mid-career professionals to enter teaching cannot be answered by the mechanical demographic projections that constitute existing supply-demand analyses. For example, suppose we wish to boost supply by improving new teacher induction programs or increasing the proportion of schools that provide such options to new teachers. Absent behavioral research on the relationship between the presence of such programs (and the particular elements of these efforts) and the likelihood that new teachers leave teaching, one could not simulate the effect of such expansions on future teacher supply. Doing so would require an estimate of how the transition probability of young teachers into non-teaching occupations responds to the presence and characteristics of induction programs.

As another example, suppose that a state commissions a supply-demand analysis which indicates that next year the state will need to hire 5,000 new teachers. Stipulating to this number, one can envision two broad alternative scenarios regarding the hiring strategies of education officials. First, the state could increase starting salaries, offer signing bonuses and housing assistance, or implement student-loan forgiveness programs of sufficient generosity such that in combinations these efforts yield 5,000 fully qualified (however this is defined) new teachers. Alternatively, policy makers can hold all compensation characteristics constant, hire all available qualified teachers, and then lower various hiring standard until all 5,000 positions are filled. Or,

states can pursue some combination of the two, increasing incentives for new teachers while maintaining flexibility in hiring standards to accommodate needs. Faced with these options, one could imagine a number of questions that policy makers might ask of a supply-demand model that would impact their decision-making and short to medium term planning. For example, how many additional qualified teachers would the loan-forgiveness program generate? How about a signing bonus of a given size? If we relax standard x, y, or z, how many additional teachers would this generate? Or to commingle with the previous example, how could we alter the retirement system or the treatment of new teachers to induce higher retention rates with the aim of obviating the need to hire 5,000 new teachers?

Answering such questions would require that we have information regarding the determinants of the transition probabilities discussed in the first section of this paper and the policy levers available to education decision makers. Fundamentally, this is an analysis of how the behavior of current and potential teachers responds to workplace conditions, the terms of employment, and the incentives that these factors generate. I now turn to a discussion of the existing research on such behavioral responses and some discussion regarding how this research could be incorporated into existing supply demand projections.

## **6. Modeling the Transition Behavior of Teachers and Potential Teachers**

Aside from the enrolment forecasts that are based on population projections and the proportion of children within given age categories that enroll in public schools, the transition probabilities out of teaching (the teacher attrition rates) and the transition probabilities into teaching (the teacher entry rates) are the key behavioral outcomes used in supply-demand analyses. The teacher attrition probability is defined specifically as the proportion of a given

population of teachers (defined by age, state, district, school etc.) that leave their teaching assignment (which also can be defined at various levels of geography) either over the course of a school year or between school years. This proportion can be applied to any individual teacher chosen at random and interpreted as the likelihood that the individual will leave his or her assignment. Of course, there are personal characteristics as well as job characteristics that will cause the actual probability for a given teacher to deviate from the average for his or her respective group. Thus, with adequate research evidence, the attrition probability for a specific teacher can be refined. For example, gender, age, and ethnicity have all been shown to impact the attrition probability. In addition, workplace autonomy, administrative support, and pay relative to the next best alternative also impact teacher mobility behavior.

The teacher entry rate is defined as the proportion of a given adult population of non-teachers (for example, recent college graduates, college-educated adults of certain age) that enters teaching between one year and the next. Applying this transition proportion to the individual provides an estimate of the probability that any person chosen at random from the given population will enter the teaching profession. Again, this probabilistic assessment can be improved upon with information on the relationship between individual characteristics, employment conditions, and the likelihood of entering teaching.

Attempts to model attrition and entry rates are usually based on the analysis of microdata for either teachers (in studies of teacher mobility) or adult college graduates (in entry studies). In particular, research in this area seeks to estimate relationships of the form

$$\text{Prob}(\text{attrition}=1) = F(\text{Age, Subject Area, Gender } \dots )$$

where in this example,  $\text{Prob}(\text{attrition}=1)$  is the probability that a teacher leaves the job,<sup>10</sup>  $F(\cdot)$  signifies that this probability is a function of a number of factors or variables, and the characteristics listed within the function  $F(\cdot)$  are the argument of the function – i.e., the variables that influence the attrition probability. For modeling purposes, we are particularly interested in the effect of a change in one of the explanatory variables on the given probability – in other words, how responsive the attrition rate is to changes in age, wages, and so on. In many empirical applications, responsiveness is often summarized by empirical estimates of elasticities. Elasticity is defined as the percentage change in a response variable caused by a percentage change in a key explanatory variable. For example, one might be interested in the elasticity of the attrition probability with respect to teacher salaries, or the percentage change in the attrition probability caused by a percent change in salaries. Responsiveness, however, can be measured more generally as the level change in the dependent variable caused by a small change in the explanatory variable.<sup>11</sup>

It's not too hard to see how knowledge of such functional relationships would greatly enhance the nimbleness of teacher supply-demand models and their utility for planning purposes. If we knew a priori the likely effects of a salary change, a change in retirement rules, or a change in workplace conditions on the attrition probabilities of existing teachers, one could manipulate these variables before the fact with the aim of insuring adequate supplies of teachers in the coming years. As another example, precise information on the relationship between teacher induction opportunities, alternative certification availability, or the use of signing bonuses to

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<sup>10</sup> The event of leaving a job would be measured in the microdata by constructing binary variable “attrition,” which would take on the value of one for those who leave and zero otherwise.

<sup>11</sup> Mathematically, the change in the base probability caused by a small change in one of the explanatory variables holding all else constant is measured by the partial derivative of the function  $F(\cdot)$  with respect to whatever variable we are interested in. For binary variables, one might characterize responsiveness as the average difference in this probability between different levels of the variable (such as the male-female difference). To convert this into an elasticity, one would need to multiply the partial derivative by the ratio of the average value for the explanatory variable to the overall attrition rate.

attract those who are not teaching into the profession would permit adjusting these factors when supply-demand projections indicate substantial increases in new hiring needs in the coming years. Ideally, sufficient knowledge of these empirical relationships would permit a priori estimates of the resources needed to fill all available positions with suitably qualified candidates.

The typical tool used to study these transition probabilities is multiple regression analysis<sup>12</sup> where, for example, the dependent variable might be an indicator that a specific teacher leaves his job over the coming year and the explanatory variables may include characteristics of the teacher's school, personal characteristics in terms of age, race, undergraduate institution, scores on standardized exams, and perhaps some characterization of the "opportunity cost" of the teacher's time. Opportunity costs refer to the characteristics, remunerative and otherwise, of the teacher's next best employment opportunity. Candidate gauges of opportunity cost include the average salary of college graduates or the relative difference in pay between teachers and similarly educated non-teachers.

Multivariate analysis is intended to isolate the impact of specific factors on the outcome of interest holding all other factors constant. For example, suppose for the sake of argument that mathematics teachers are younger on average than other teachers and that the next best salary offers outside of teaching are higher for mathematics teachers than other teachers. If we were interested in studying the effect of outside salary opportunities on the differential propensity for mathematics teachers to leave teaching, we would want to account for the fact that outside salary opportunities is negatively correlated with the age of existing teachers (since the younger mathematics teachers have the best outside opportunities). Since both age and outside salaries influence the attrition decision, one would want to ensure that the influence of each is measured

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<sup>12</sup> Actual estimators used vary across studies, though the most common estimators used are linear probability models, logit regressions, and probit regressions.

independently of any coincident correlation between these two determining factors. Most importantly, if policy makers wish to influence attrition by altering the relative pay of teachers, it is crucial to avoid confounding information on the impact of relative pay by other factors.

To be sure, multivariate analysis has its limitations. For one, in specifying the model to be estimated, researchers may impose incorrect functional relationships between the dependent variable of interest to policy makers and the key explanatory variables of interest, a mistake that may lead to incorrect or biased inferences. Alternatively, there may be some factors that are unobservable to the empirical researcher yet may be correlated with a key explanatory variable and thus lead to erroneous inferences. For example, one might find that schools with lower test scores have higher teacher attrition rates. This can be interpreted causally suggesting that an increase in student scores will lower attrition rates. An alternative interpretation would be that schools with relatively poor test scores have a hard time retaining teachers due to poor working conditions (for example, sub-standard facilities) that are correlated with low test scores, or that high teacher turnover is causing the low test scores (that is to say our explanatory variable is really the dependent variable and vice versa). As this example illustrates, interpreting the results from multivariate analysis is a bit of an art form that requires a somewhat critical eye.

#### *A. Empirical Research on Attrition*

There is fair amount of multivariate analysis of teacher attrition rates. Much of this research is reviewed by Allen (2005). In terms of general patterns that surface in teacher-supply demand analyses across the country, relatively new teachers and teachers with 20 years of experience or more have the highest attrition rates. Attrition is generally higher in high schools and middle schools than in elementary schools. Women are often likely to leave teaching to start

and raise families. In addition, while the research on teacher induction programs and working conditions are somewhat mixed, there does indeed appear to be evidence that working conditions (whether measured by relative pay or autonomy on the job) are important determinants of teacher attrition rates. In this section, I discuss a number of specific studies on these transition probabilities.

Two recent excellent studies that make use of state-level administrative data for teachers are Hanushek et al. (2004) and Lankford et al. (2002). Hanushek and his co-authors use administrative data from Texas that permits longitudinal linking of teacher personnel files with the characteristics of the schools in which they teach. The study analyzes the determinants of within-district and between-district teacher mobility and the likelihood that teachers leave the Texas public school system altogether. The principal aim is to analyze the extent to which compensation characteristics, both in terms of salary as well as non-salary workplace condition, impact teacher mobility decisions. The authors also explore heterogeneity in the responsiveness of these choices by teacher experience level and gender.

The authors find overall mobility rates for Texas that are quite close to those observed for teachers nationally in the SASS and TFS data sets. The study also shows a generally higher level of sensitivity of male teachers and teachers with lower tenure levels to salary differentials. This makes sense theoretically, as new teachers have little invested in their teaching careers in terms of skills that are specific to the teaching profession and that accumulate with teaching experience. As we will soon see, the salary differentials between teaching and non-teaching occupations for men are particularly large, perhaps making them more responsive on the margin to variation in teaching salaries. The authors find that teachers are more likely to leave schools with low test scores and higher proportions of students that are minority. However, minority

teachers exhibit less sensitivity to the latter variables, with black teachers tending to move towards schools with larger black student populations.

Lankford et al. (2002) use detailed administrative data for the state of New York to analyze teacher mobility patterns. Specifically, the authors describe the characteristics of schools that lose teachers and schools that gain teachers, the distribution of teachers across schools by teacher quality, and the degree to which salary either compensates teachers in schools with higher attrition rates or exacerbates the perceived disparities in compensation. In comparing schools that lose teachers to schools that gain teachers, the study shows that origin schools have a higher proportion of students that are minority, lower test scores, and lower pay relative to receiving schools. The paper also documents considerable inequality across schools in terms of the quality of the teaching staff.

Teacher attrition using national level data has been studied extensively by Richard Ingersoll. In addition to documenting relative teacher attrition rates by subject area, gender, and age (Ingersoll 2006), the author has also estimated the effect of workplace characteristics (Ingersoll 2001), the effect of teacher induction programs on attrition among novice teachers (Smith and Ingersoll 2004), and the particular reasons why mathematics and science teachers leave the teaching profession (Ingersoll and Perda 2009).

Ingersoll (2001) uses data from the SASS and TFS to perform a multivariate analysis of teacher turnover as a function of workplace conditions. The author first presents a series of logistic regression models that show the relationship between turnover and teacher characteristics (age, minority status, primary assignment) and basic school descriptors (size, private/public etc.). The author then adds four measures of job quality constructed from the SASS data: average salaries for advanced teachers, the degree of administrative support provided

for the teaching faculty, the degree of severity of student disciplinary problems, and the degree to which faculty exert influence over their workdays. The results show that each measure of job quality has the expected impact on turnover rates, with the exception of wages.

Smith and Ingersoll (2004) analyzed the determinants of turnover after the first year of teaching for new teachers. The paper begins by presenting estimates of overall turnover rates, attrition rates, and migration rates for new teachers in public and private schools. The authors then perform a multivariate analysis of turnover after the first year to assess whether teacher induction activities (assigning a mentor, allowing for common preparation time with other teachers, reducing initial workload, providing additional resources) significantly lowered first year turnover. Having a mentor in one's field reduced the risk that a new teacher leaves after the first year by 30 percent. Being able to collaborate with other teachers (common planning time) also reduced first year turnover rates.

Ingersoll (2000) presents descriptive statistics from the TFS for mathematics and science teachers and for other teachers. The results indicate that mathematics and science teachers do not leave at an appreciably higher rate than other teachers. Roughly one quarter of those who leave are leaving to retire. As a fraction of total turnover (inclusive of interschool moves), however, retirements account for roughly 12 percent. Mathematics teachers who leave due to dissatisfaction with their jobs are more likely to indicate student disciplinary problems and poor student motivation as reasons for job dissatisfaction.

There is some evidence that teacher attrition in hard-to-staff fields is sensitive to small financial incentives. Clotfelter et al. (2006) investigate the effect of the North Carolina bonus program on teacher retention. The program began in 2001 and provided an annual salary supplement of \$1,800 to teachers certified in mathematics, science, and special education who

taught in middle or high schools where either 80 percent of students were eligible for free lunch, or 50 percent or more of its students were performing below grade level in both Algebra I and Biology. They compare attrition rates before and after the implementation of the program for eligible and ineligible teachers in the same schools, as well as in schools that narrowly missed the eligibility criteria. They find that receipt of this bonus reduces teacher turnover rates among those targeted by roughly 12 percent. The impacts of the intervention appear to be particularly large for more experienced teachers relative to novice teachers.

This body of research illustrates several aspects of teacher attrition that bear directly on education policy and planning. First, teacher attrition is a complex process with multiple determinants. In part, attrition reflects rational economic calculations on the part of teachers, but also reflects life-cycle patterns, the importance of non-monetary workplace conditions, and unanticipated random life-course shocks that impact labor supply behavior. Standard supply-demand analyses take these probabilities as fixed and unalterable, creating the impression that future staffing shortages need to be met by expanded hiring. However, this growing body of research suggests that some of the many factors impacting attrition rates are under the control of policy makers, and thus, these factors might rightfully be considered viable policy instruments.

A second theme in this body of research concerns the great deal of heterogeneity in the responsiveness of attrition to variation in determinants. We have already noted that male teachers exhibit greater responsiveness than women to changes in relative incentives. Younger teachers appear quite sensitive to the presence of teacher induction programs. White teachers tend to move from relatively high to relatively low minority schools, while mobility patterns among African-American teachers exhibit the opposite tendency. Cognizance of this heterogeneity and the knowledge gleaned from existing research should aid in tailoring efforts to

reduce teacher attrition and should alleviate pressures to greatly expand hiring beyond the pool of certified teachers.

Ideally, one would want explicit information on the impact of various attrition determinants on attrition rates. One could then simulate the impact of an increase in teacher salaries, a decrease in non-teacher salaries, or the effect of instituting retention incentives or any other measure on continuing supply operating through the impact on attrition rates.

In practice, the state of knowledge is perhaps insufficient to perform such counterfactual simulations. However, one might think along the following lines. In the face of projected shortages, one might first use existing forecast models to identify the teacher attrition rates needed to reduce future new hiring needs to a manageable level. The extant research on the determinants of attrition might then offer guidance on which factors might yield the largest declines in attrition and indicate the plausibility of meeting a school's , district's, or state's labor needs through increased retention of incumbent teachers.

### *B. Empirical Research on The Entry of New Teachers*

As was already mentioned, the lion's share of teacher labor supply in any given year comes from teachers who are continuing their careers into subsequent years. Nonetheless, new hires represent an important source of teachers (slightly under 10 percent of positions in any given year) and clearly are an important source of future supply, as these teachers tend to be relatively young.

The study of teacher entry is less developed than the study of teacher attrition for a number of reasons. For one, studying attrition is much facilitated by the fact that there is a well-defined base population at risk of attriting – i.e., the existing teacher workforce in a given year.

The base population “at risk” of becoming a teacher is a bit more nebulous and depends on the qualification requirements imposed by policy makers. For example, one might study the propensity of recent college graduates to enter teaching, the propensity among recent graduate from education program, the propensity of older mid-career professionals with no teaching experience, the propensity among former teachers, or the propensity to enter teaching among certified individuals who have never taught. In essence, the “reserve pool” of potential teachers (the base from which we would study the transition into teaching) depends on which qualifications we deem absolutely necessary. Further complicating matters, this reserved pool is largely unobservable, unless defined in broad terms such as all college graduates.

A further hindrance to the study of teacher entry is the lack of detailed information on subject area specialties contained in the large U.S. household surveys. The study of teacher entry is essentially the study of the occupational choices made by individual who are qualified to teach yet face a range of options beyond teaching. Empirically studying this choice requires information on otherwise comparable people who choose both to teach and to work in other professions. The standard households surveys used to perform such analyses (such as the Current Population Survey series, the Public Use Microdata Samples from the U.S. Census of Population and Housing, or the new American Community Survey) include information on formal level of educational attainment but not on major or minor areas of emphasis. Moreover, occupational coding permits identification of public elementary and secondary school teachers but not teaching specialty. Hence, one cannot conduct detailed analysis of the occupational choices of mathematics and science majors (or minors) post graduation with the standard U.S. labor force data sets.

Despite these limitations, there are several excellent studies documenting the factors that either pull the qualified into teaching or push them towards other occupational choices. Many recent studies take a long-term view, analyzing relative compensation over many decades and studying explicitly the link between relative compensation and the relative “quality” of those who choose to teach. Regarding compensation, a pair of monographs by Allegretto, Corcoran and Mishel (2004, 2008) present several detailed comparisons of the relative pay of teachers in the U.S. using basically all available large scale surveys. Using census data, data from the outgoing rotation groups from the Current Population Survey, as well as data from the March Current Population Series, the authors document the long term erosion of the relative pay of public school teachers.<sup>13</sup>

Figure 8 documents age-adjusted annual salary differentials between teachers and non-teachers from Allegretto, Corcoran, and Mishel (2008).<sup>14</sup> For teachers overall, teacher pay was on par with pay in other occupations held by college graduates in 1960, dropped slightly below the pay of other graduate in 1970, and fell to nearly 20 percent below the pay of comparable college graduates in non-teaching occupations by 2000. Among female teachers, the differential shifts from a positive 14.7 percent in 1960 to a negative 13.2 percent differential by 2000. Among men, teachers have always made less than non-teachers, with the disparity growing from -20.5 percent in 1960 to -31.2 percent in 2000. In further analysis of Current Population Survey data, the authors show that these disparities have widened even further since 2000. Similar patterns are documented by several other researchers including Hanushek and Rivkin (2007),

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<sup>13</sup> The authors also discuss several other sources including the National Compensation Survey and their suitability for studying relative pay.

<sup>14</sup> The figures depicted are the regression-adjusted annual salary disparities holding constant age and level of educational attainment using data from the PUMS files of the census.

who document that the fraction of the college-educated workforce earning less than teachers has declined steadily, and Temin (2002), who documents declining relative earnings.

Allegretto et al. also assess the degree to which the shorter work year and non-wage fringe benefits compensate for the growing relative disparities in pay. The shorter year (while somewhat of a controversial measurement issue in this literature) does not seem to impact estimates of these trends inasmuch as weekly earnings disparities follow similar paths. Fringe benefits narrow the disparities somewhat, but by no more than 2 percent, thus leaving the majority of the teacher earnings penalty relative to non-teaching occupations.

These large declines in relative pay have led many to speculate that the relative abilities of those who choose teaching must be declining. The reasoning here is straightforward. The labor market clearly values cognitive ability, and the premium placed on such abilities has grown considerably since 1980 (Card 1999, Katz and Autor 1999). The falling relative pay of teachers renders teaching less attractive to the most able as the opportunity cost of this choice has increased. Thus, the internal composition of those who remain in teaching must be shifting towards those among the college-educated with less ability, however that ability is defined.

Several recent studies have directly addressed this question, though they have focused largely on the market for female college graduates. The focus on women is driven largely by the fact that the majority of public school teachers are female (in 2000, 74.5 percent of teachers age 25 to 34 were female). However, the focus on women also emanates from the drastic changes in the labor market prospects of women and the consequences for the supply of teachers.

In tabulations of U.S. census data, Corcoran, Evans, and Schwab (2004) show that in 1964 roughly half of all working women were public school teachers. By 2000, this figure declines to 14.5 percent. This decline reflects greater opportunities for female college graduates

in other professions, and absent other changes would have translated into large declines in the supply of new teachers. However, over the same period female labor force participation rates among relatively young women (25 to 34) increased from 37.2 to 80 percent, while the percentages that are college graduates increased from 8.9 to 27.8 percent. Thus, despite a large decline in the propensity of college educated women to enter the teaching profession, the impact on the supply of teachers was largely offset by the huge shifts in labor force participation and college completion rates.

Nonetheless, the greater opportunities available to women may have increased the propensity of the most able among them to choose other professions. To the extent that academic or cognitive ability impacts student outcomes (a proposition that appears to be supported by empirical research), it may be the case that students today are receiving poorer instruction than students in the past as a result of the relative pay trends documented in Figure 8. Corcoran, Evans, and Schwab (2004) present evidence suggesting that higher ability women are increasingly more likely to choose occupations other than teaching. Their results are reproduced in Figures 8 and 9. Using a number of longitudinal data sets, the authors ranked female high school graduates for a number of cohorts according to their performance on a standardized test. For each cohort, they construct two measures of quality: a centile measure, which for a given young woman measures the percent of her cohort who performed worse than her on the exam; and a raw test score that is standardized to have a mean of zero and a standard deviation of one. Each cohort was interviewed around the age of 25/26. The authors present comparisons of the mean of the ability measures for those who choose teaching and the proportion of women in each skill group (defined by the deciles of the test outcome) that choose to become teachers.

Figure 9 shows that the average centile of teachers appears to decline across cohorts. In other words, among those women who graduate from high school the relative ability ranking of those choosing to become teachers declines between 1971-1972 and 2000. The declines are even more observable when one analyzes the mean standardized test score. Of course, if average ability is increasing overtime, average teacher ability may increase as well since the skill comparisons made by Corcoran, Evans, and Schwab are relative comparisons within cohorts. However, the results clearly show that coincident with the declining relative pay of teachers, the most able women are choosing non-teaching occupations.

This point is driven home in Figure 10. The figure splits women from the cohort interviewed in 1964 as well as women interviewed in 2000 into 10 percent slices (or deciles) of the respective ability distributions for that year. For each year, the figure then shows the proportion of women who at 25/26 are public school teachers. There are notable declines in this proportion in the 10<sup>th</sup> and the 8<sup>th</sup> deciles. There are notable increases in the 7<sup>th</sup>, 4<sup>th</sup>, and 3<sup>rd</sup> deciles.

In addition to an impact of declining relative average salary, Hoxby and Leigh (2004) argue that the compression of teacher salaries has also driven away the most able college graduates. In terms of the parameters in our supply-demand framework, the authors are essentially arguing that the inability to reward the brightest college graduates lowers the entry probabilities from this particular sub-segment of the population. Hoxby and Leigh analyze various years of the surveys of Recent College Graduates and document trends in pay and pay dispersion among female teachers with the aim of assessing whether occupational choices are changing differentially for more and less-able college graduates. The authors use the average combined SAT score at each graduate's undergraduate institution to split students into six ability

groups ranked from lowest to highest. They then analyze how teacher pay changes between 1963 and 2000 within each ability group and relative to non-teaching occupations.

Table 8 reproduces their main results. The first row of figures shows the degree to which the growth rate for average teacher salaries for female graduates in each student group departed from the comparable growth rate for all teachers. Salary growth for teachers from the lowest performing undergraduate institutions was 38 percent greater than salary growth for teachers overall, while salary growth for teachers from the highest performing schools was 36 percent smaller than average salary growth. The clear inverse relationship between salary growth relative to the average and Hoxby and Leigh's ability ranking suggests the strong movement towards salary compression in the market for teachers. Another way of interpreting these figures is that at the same time that the returns to ability are increasing in the wider labor market (Katz and Autor 1999), the returns to ability are declining among teachers. Given the lower average pay among teachers overall, this suggests that there is little (in fact, negative) monetary incentive for the highest ability students to pursue public school teaching.

The second row of the table shows the relative growth in female salaries compared to male salaries outside of teaching within each skill group. While women in the bottom two groups experience slight declines in relative wages, higher ability women experience wage growth that exceeds comparable growth for college educated men in non-teaching professions. The next row of figures presented the authors' estimates of real salary growth among men in non-teaching occupations. These range from 36 percent for the lowest ability group to 52 percent for the highest ability groups. As male-female pay disparities either widened slightly or narrowed over this time period, these are also roughly equal to salary growth experienced by women outside of teaching. Note that Hoxby and Leigh estimate that real salary growth among

recent college graduates in teaching over this time period was a mere 8 percent, far less than that observed in occupations outside of teaching.

The final two lines connect relative salary and salary compressions to changes in who chooses to teach. Among all groups there are large declines in the proportion that choose teaching just out of college. Alternatively stated, the entry probability is declining for all skill groups. However, the proportional declines are greatest among students from undergraduate institutions with the highest SAT scores. Consequently, the internal composition of new teachers as measured in these surveys shifts markedly towards students from lesser ranked institutions.

Thus, while research on the entry probability is somewhat sparse, there is quite strong evidence that the choice to enter teaching is quite sensitive to the relative compensation of teachers. Moreover, the empirical work discussed thus far demonstrates a decline in average ability as measured by standardized tests among those who choose teaching, and also suggests that the salary compressions common in teaching pay structures may be driving away the most able teachers.

In terms of usefulness for planning, it's not immediately obvious how these research findings can be employed to improve upon existing supply-demand studies. The study of teachers overall is insufficiently disaggregated to provide meaningful guidance to a policy maker wishing to incentivize young college graduates to pursue a career in mathematics and science teaching. However, the findings do indicate that new recruits are sensitive to such incentives, and that in the absence of sufficient incentive to pursue teaching, the pool of applicants will be negatively selected from the distribution of college graduate ability.

These studies do, however, provide a how-to guide for a more disaggregated analysis by subject area. For example, the survey of recent college graduates can be used to identify which

college majors supply mathematics and science teachers and to estimate the opportunity cost for these particular teachers and how they have changed over time. Such basic information would be quite useful in laying out the economics fundamentals that may be driving a shortage of mathematics and science teachers. Such information may also be useful in thinking through alternative compensation policies.

## **7. Conclusion**

This paper has provided a review of national-level and state-level supply demand analyses and their potential uses for planning and policy discussion. The review has highlighted the general structure of existing supply-demand studies, their potential for identifying specific staffing shortages, and their potential for performing policy simulations. The review has also identified several limitations of these studies, emanating primarily from their inability to gauge the likely resultant changes in teacher quality associated with alternative hiring levels as well as their inability to simulate policy changes that alter the behavioral incentives faced by teachers and potential teachers.

In the course of the review, I have made several recommendations that I believe would aid in the use of these analyses and perhaps increase their flexibility in applications to counterfactual simulations. To start, some of the most valuable information presented in state level studies is found in the descriptive analysis of trends in the characteristics of the teacher workforce. I recommend that states identify a set of fixed indicators of teacher quality and potential shortage that can be measured consistently over time and across districts and schools, with the aim of being able to monitor the development of potential supply shortages. Since schools tend to fill nearly all vacant positions, movements in measures of teacher quality are likely to provide a stronger gauge of supply problems than movements in vacancies. To this end,

consistent measurement, by school and subject area, of the proportion of teachers that are novices, the proportion of teachers that are under-prepared, and perhaps some measure of academic aptitude such as college GPA or performance on college entry exams would provide a useful barometer of the labor market conditions faces by the state, by specific districts, and by schools.

I have also suggested that the usefulness of existing supply-demand forecasting studies can be greatly enhanced by incorporating the likely behavioral responses of teachers and potential teachers to changing incentives and workplace conditions. I noted that research on teacher attrition is considerably more developed than research on new teacher entry. In fact, the research in the former area is of sufficient density to perhaps formulate some empirical rules of thumb regarding the impact of various factors (such as assigning mentors or increasing pay) that can be incorporated into policy simulations of future supply and future hiring needs.

Research on new teacher entry is somewhat less developed. Nonetheless, there is considerably evidence suggesting that the entry rate of new college graduates has declined in lockstep with the declining relative pay of teachers. There is also strong evidence that graduates with the strongest academic aptitudes are less likely now than in the past to choose teaching and that the compression of pay among teachers is a likely contributing factor. Existing research does provide a blueprint for a more disaggregated study of those qualified to teach mathematics and science. For example, it would be quite useful for someone to reproduce the analysis in Hoxby and Leigh (2004) with an explicit focus on mathematics and science teachers relative to all other sub-specialties. This would provide information regarding whether the relative declines in teacher salaries are worse for mathematics and science teachers and the compositional effects of such developments on those who choose to teach. Such basic information is sorely needed

and would greatly help in assessing the state of the workforce teaching mathematics and science in the nation's public schools.

## **Appendix: Supply Demand Analysis in Other Occupations**

Projections of labor market conditions are used quite extensively in other fields. The most extensive national-level projections are presented by the Bureau of Labor Statistics (BLS) in their *Occupational Outlook Handbook*. In addition to providing information on skill and training requirements, typical work hours, and tasks, the *Handbook* provides projections of future occupational growth for quite detailed occupational categories.

The methodology behind these projections is quite similar in spirit to the demand projections for teachers documented in the main text of this manuscript, although the details are somewhat different.<sup>15</sup> Occupational projections are based on a series of six steps. These six steps involve projecting the size and composition of the labor force, the growth path of the aggregate economy, gross domestic product (GDP), the relationships between productive inputs and outputs, industry output and employment, and finally occupational employment.

The BLS uses a macroeconomic model combined with population projections to forecast GDP into the future. The BLS then forecasts the demand for goods and services based on these projections of aggregate economic activity. Demand projections provide the basis for estimating output by industry. Finally, estimates of the amount of labor of various types used to produce a dollar of industry output are used to estimate future employment by industry and occupation. The sum of these figures across industries but within occupation provides an estimate of total occupational employment for a given year.

Using annual attrition estimates, the BLS also produces estimates of replacement demand. Combined with estimates of overall employment growth, these figures can be used to estimate overall needed new hiring levels. Because the *Occupational Outlook Handbook* is

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<sup>15</sup> The following discussion draws heavily on the information page *Assumptions and Methods Used in Preparing Employment Projections* in the Bureau of Labor Statistics' *Occupational Outlook Handbook* (2006).

designed for use by those trying to choose future employment paths, projection results are described in straightforward language, such as “Growth much faster than average,” or “Decline slowly or moderately.” The outlooks also characterize occupations by whether they offer “very good to excellent opportunities,” “good or favorable opportunities,” or “May face, or can expect, keen competition.”

While the inputs to the demand projections for the Occupational Outlook series are considerably more complex than those used to forecast teacher demand, the general methods and ideas are similar. GDP or aggregate income drives demand for goods and services, which then drive demand for employment. With information on the relationship between income, product demand, and labor demand, one can forecast employment by occupation. Similarly, population growth among those under 18 generates “demand” for public schools, which of course is a function of population totals by age and public school enrolment rates. In the case of forecasting teacher demand, specified pupil-teacher ratios serve the same role as the unit labor requirements in an input-output matrix that would be used to convert industry product demand into industry labor demand.

Supply-demand analyses are also used quite extensively in analysis of labor needs in specific health fields. For example, much has been made in the popular press about the pending shortage of nurses in the United States. Biviano et al. (2004) provide a set of national level and state level supply and demand projections for registered nurses. The supply model makes use of a survey of those with existing nurse licenses and presents estimates by state and specialty of the inflows and outflows of nurses from a base year 2000 stock. The elements of the supply projections include the following:

- **Projection of new graduates from nursing programs:** The report notes the decline in nursing school graduates but assumes that the graduation rate relative to the base population of potential nurses (defined as women between 20 and 44 years old) remains constant.
- **Estimates of the base stock of nurses in 2000 and of the age distribution of the existing nursing workforce:** The nursing workforce has aged in recent years and is projected to age further in the future.
- **Estimates of labor force participation rates relative to the base of all licensed nurses:** Variation in these labor force participation rates takes the place of attrition estimates. Given the difficulty of identifying the base population of teachers against which to apply a labor force participation rate, this particular method for tracking age-and time related attrition is not particularly useful in the education domain.
- **Estimates of cross-state migration patterns for the purposes of generating state-level supply projections:** This is based on a probit model of the likelihood that a licensed nurse migrates across state lines. Estimates are computed separately by age and education level.
- **Estimates of separation rates due to mortality, disability, and retirement.**

What is most interesting about this paper is that the supply projections are performed under three alternative scenarios. First, the authors produce a series of projections assuming all else holds constant. This is similar to the projections performed in most teachers supply demand analyses. Next, they calculate a series of projections assuming that the number of nursing graduates increases. They use this projection to tabulate the amount that nursing school graduate levels

would have to increase in order to meet the pending nursing shortage. Finally, they present a series of supply projections that make varying assumptions regarding changes in the relative wages of nurses. The authors distinguish between the short-run wage elasticity of nurses (increased participation among licensed nurses in all age groups along both the extensive and intensive margin) and the long run wage elasticity of supply (increased participation among licensed nurses as well as a response in terms of those enrolling in nursing programs). The authors admit that there is little consensus regarding nursing behavioral labor supply elasticities. Nonetheless, they assume different specific values in the middle of the range of existing estimates and simulate how the resultant supply projections would also differ.

To estimate demand, the authors perform a number of projections for about a dozen different specialties. For about half of these specialties, they simply use the number of nurses per 100,000 and combine it with population projections to simulate demand. For the other half, they first estimate health care services utilization levels using data on age-gender utilization rates combined with census population projections. They then estimate demand based on the amount of nursing needed to deliver a unit of each type of healthcare.

An example of a state-level analysis of the labor market for nurses is provided by Spetz (2007). In this study, future demand and supply of registered nurses are forecast for the state of California. The author presents a detailed description of the methodology for forecasting the various inflows and outflows into supply and the methodology behind the demand forecast. To estimate supply, the author begins by estimating the stock of nurses in various age groups of individuals residing in California with active nursing licenses. She then estimates the inflow into the nursing pool from new graduates, international migrants, and migrants from other states, as well as the outflows due to inter-state migration. Using age-group specific employment rates

implicitly accounts for differences in labor force participation by allowing nurses to age-up across groups. To forecast demand, Spetz uses two methods. In one method, she applies the national average number of nurses per 100,000 residents in the U.S. to California population projections (a method quite similar to the standard practice in teacher supply-demand analyses). In the second method, she uses information on mandated nursing staffing ratios and estimates of health care utilization per 100,000 and the nursing inputs needed to meet the implied utilization levels (based on California population forecasts).

Supply-demand analysis is also used in the market for physicians. Deal et al. (2007) present an analysis of the future supply and demand conditions for rheumatologists. This study is quite similar in methodology to the study of nurses discussed above. There are relatively few rheumatologists in the U.S. and good centralized licensure data. Hence, the authors are able to enumerate all rheumatologists through an AMA database and other centralized professional association databases. The projections make use of a simple Markov model (similar in spirit to the model implied by the transition probability matrix described in Table 1) based on assumed retirement rates and physician losses due to mortality and projected growth in newly minted doctors.

Finally, the American Association of Medical Colleges (March 2007) has produced a detailed analysis of the market conditions surrounding the provision of oncological services. This is a very descriptive analysis of the oncology workforce (age distribution, workload by workplace setting and gender) and includes some quite standard supply projections. The authors also generate estimates of demand for oncological services based on population projections by age and estimated cancer incidence and implied visitation levels. The methods employed here are no more sophisticated than what is observed in the teacher supply-demand literature.

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**Table 1**  
**Transition Probability Matrix By Age and Occupational Status**

Origin age and occupation group	Destination age and occupation group					
	Younger teachers	Middle-aged teachers	Older teachers	Younger non-teachers	Middle-aged non-teachers	Older non-teachers
Younger teacher	$TT_{yy}$	$TT_{ym}$	0	$TN_{yy}$	$TN_{ym}$	0
Middle-aged teachers	0	$TT_{mm}$	$TT_{mo}$	0	$TN_{mm}$	$TN_{mo}$
Older teachers	0	0	$TT_{oo}$	0	0	$TN_{oo}$
Younger non-teachers	$NT_{yy}$	$NT_{ym}$	0	$NN_{yy}$	$NN_{ym}$	0
Middle-aged non-teachers	0	$NT_{mm}$	$NT_{mo}$	0	$NN_{mm}$	$NN_{mo}$
Older non-teachers	0	0	$NT_{oo}$	0	0	$NN_{oo}$

Note: each entry in the table labels the probability of transitioning from the origin occupation-age group to the destination occupation age-group. The sum of probabilities within a given row must equal one. The table places zeros where the transitions are logically impossible (for example, transitioning up two age groups or down age groups).

**Table 2****Sources of Teacher Supply Within Teacher Age Groups in Year t+1**

	Retentions from within age group	New entrants from within age group	Retentions aging up from younger group	New entrants aging up from younger group
Supply <sup>t+1</sup> <sub>y</sub> =	TT <sub>yy</sub> x Pop <sup>t</sup> <sub>yT</sub>	+ NT <sub>yy</sub> x Pop <sup>t</sup> <sub>yN</sub>		
Supply <sup>t+1</sup> <sub>m</sub> =	TT <sub>mm</sub> x Pop <sup>t</sup> <sub>mT</sub>	+ NT <sub>mm</sub> x Pop <sup>t</sup> <sub>mN</sub>	+ TT <sub>ym</sub> x Pop <sup>t</sup> <sub>yT</sub>	+ NT <sub>ym</sub> x Pop <sup>t</sup> <sub>yN</sub>
Supply <sup>t+1</sup> <sub>o</sub> =	TT <sub>oo</sub> x Pop <sup>t</sup> <sub>oT</sub>	+ NT <sub>oo</sub> x Pop <sup>t</sup> <sub>oN</sub>	+ TT <sub>mo</sub> x Pop <sup>t</sup> <sub>mT</sub>	+ NT <sub>mo</sub> x Pop <sup>t</sup> <sub>mN</sub>

**Table 3**  
**Selected Percentage Distributions of All Public School Teachers, Mathematics and Science**  
**Public School Teachers and All Other Public School Teachers from the 2003-2004 SASS**

	All Teachers	Math and Science	All Other
<b>Age</b>			
Less than 35 years	32.0	33.1	31.9
35-49 years	36.6	39.5	36.1
50 years +	31.4	27.4	32.0
<b>Base Salary</b>			
Less than \$30k	12.1	12.8	12.0
\$30K to \$39,999	34.8	37.2	34.4
\$40K +	53.1	50.0	53.6
<b>Certification type</b>			
Regular state cert.	87.6	89.1	91.5
Other certification	7.3	8.2	7.0
None of the above	1.5	1.7	1.5
<b>School Level Taught</b>			
Elementary	64.4	39.6	68.4
Secondary	30.4	53.3	26.7
Combined	5.2	7.1	4.9

Source: National Center for Education Statistics (2008), "Attrition of Public School Mathematics and Science Teachers," IES Issue Brief, NCES 2008-077

**Table 4**  
**Incidence of Vacancies and Degree of Difficulty in Filling Vacancies in Secondary Public Schools by Subject Area**

Subject Area	Proportion of Public Secondary Schools				
	No Vacancies	Vacancies, easy to fill	Vacancies, somewhat difficult to fill	Vacancies, very difficult to fill	Vacancies, could not fill
Mathematics	0.39	0.13	0.21	0.24	0.02
Special education	0.42	0.14	0.21	0.19	0.04
Foreign languages	0.54	0.09	0.16	0.18	0.02
Physical Sciences	0.56	0.10	0.16	0.16	0.01
Vocational education	0.61	0.10	0.13	0.14	0.02
Biology	0.48	0.16	0.21	0.14	0.01
Music, Art	0.57	0.16	0.16	0.10	0.01
Computer science	0.67	0.09	0.12	0.10	0.01
ESL	0.73	0.07	0.09	0.10	0.02
English	0.39	0.34	0.22	0.05	0.01
Social Studies	0.44	0.39	0.14	0.02	0.01

Author tabulations from the 1999-2000 SASS.

**Table 5**  
**Incidence of Vacancies that Are Either Very Difficult to Fill or Could Not be Filled by Subject Area and the Proportion of Minority Students, Public Secondary Schools**

Subject Area	Proportion of students who are minority				P-value from F-test of difference in means <sup>a</sup>
	Less than 5 percent	5 to 19 percent	20 to 49 percent	50 percent or more	
Mathematics	0.18	0.26	0.28	0.34	0.001
Special education	0.20	0.23	0.23	0.25	0.0023
Foreign languages	0.20	0.24	0.20	0.18	0.2930
Physical Sciences	0.14	0.18	0.20	0.19	0.0259
Vocational education	0.15	0.21	0.16	0.13	0.0062
Biology	0.10	0.16	0.16	0.19	0.0006
Music, Art	0.10	0.14	0.09	0.13	0.0148
Computer science	0.09	0.14	0.11	0.13	0.0136
ESL	0.03	0.14	0.16	0.13	0.0001
English	0.05	0.05	0.05	0.07	0.0435
Social Studies	0.02	0.03	0.02	0.04	0.2887

Author tabulations from the 1999-2000 SASS.

a. P-value provides the likelihood of observing the disparities across school types due to random variation alone. Values less than 0.05 are conventionally interpreted as signifying statistically significant difference across school types.

**Table 6**  
**The Incidence of Specific Staffing Compromises Made to Manage Difficulties Filling Vacancies by the Number of Subject Areas at the School With Vacant Positions**

Staffing compromise	1 to 5 subject areas with vacancies	6 to 11 subject areas with vacancies	Difference
Cancelled planned course offerings	0.05	0.09	0.04 <sup>a</sup>
Expanded class size	0.15	0.22	0.07 <sup>a</sup>
Hired unqualified teachers	0.17	0.25	0.08 <sup>a</sup>
Added to other teachers' workload	0.13	0.22	0.09 <sup>a</sup>
Assign teachers to other subjects/grade levels	0.12	0.17	0.05 <sup>a</sup>
Assigned administrators to teach classes	0.04	0.04	0.00
Used short and long-term substitutes	0.26	0.38	0.12 <sup>a</sup>

Author tabulations from the 1999-2000 SASS. The figures in the first two columns provide the proportion of schools with the given level of subject area vacancies that made the noted staffing compromise.

a. Difference statistically significant at the one percent level of confidence.

**Table 7**  
**AAEE Relative Demand Scores for the All Teacher Composite Index and for Mathematics and Science Teachers, 2002 through 2007**

	Composite	Math	Science Teachers				
			Biology	Chemistry	Earth-physical	Physics	General
2002	3.45	4.28	3.89	4.20	3.96	4.26	3.81
2003	3.27	4.20	3.79	4.08	3.76	4.19	3.71
2004	3.35	4.21	3.88	4.16	3.88	4.31	3.85
2005	3.41	4.21	3.78	4.05	3.79	4.13	3.74
2006	3.46	4.36	3.98	4.26	3.87	4.27	3.91
2007	3.56	4.48	4.11	4.39	4.08	4.40	4.05
Correlation with composite	1	0.88	0.83	0.82	0.84	0.61	0.83

Figures culled from various years of *Educator Demand and Supply*, American Association for Employment in Education.

**Table 8**  
**Analysis of Salary Trends and the Composition of the Female Teaching Workforce for 1963 through 2000 Presented in Hoxby and Leigh (2004)**

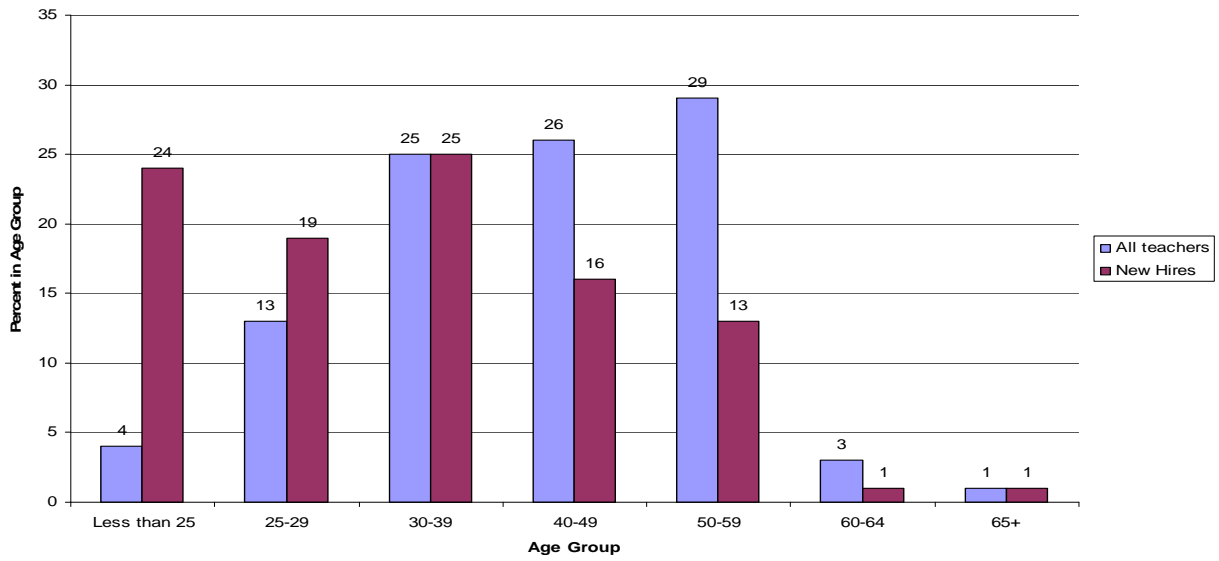
	Students Grouped by Average Combined SAT Scores of Their Undergraduate Institutions					
	Lowest	2nd	3 <sup>rd</sup>	4th	5th	Highest
Proportional growth in teacher earnings within group above and beyond earnings growth for all teachers <sup>a</sup>	0.38	0.34	0.08	-0.13	-0.27	-0.36
Proportional growth in female earnings above and beyond earnings growth for males for non-teaching occupations <sup>a</sup>	-0.04	-0.01	0.01	0.11	0.08	0.09
Real proportional earnings growth for men in non-teaching occupations <sup>a</sup>	0.36	0.35	0.36	0.34	0.39	0.52
Share who were teachers in 1963	0.48	0.41	0.41	0.34	0.30	0.20
Share who were teachers in 2000	0.16	0.18	0.13	0.12	0.10	0.04
Share of all teachers in 1963	0.16	0.26	0.26	0.15	0.12	0.05
Share of all teachers in 2000	0.36	0.31	0.17	0.11	0.04	0.01

Source: Hoxby and Leigh (2004).

a. These figures are tabulated in the following manner. Hoxby and Leigh (2004) report the change in the log-wage relative log-wage differentials (relative to the average teacher in the first row, male-female in the second row) or the change in log wages (male earnings in the third row). Taking the exponent of these relative changes and subtracting one gives the extent to which the proportional change in wages for one group exceeds the proportional change in wages for the other. When applied to the change in the log wages, this transformation gives the proportional change in wages over time.

**Figure 1**

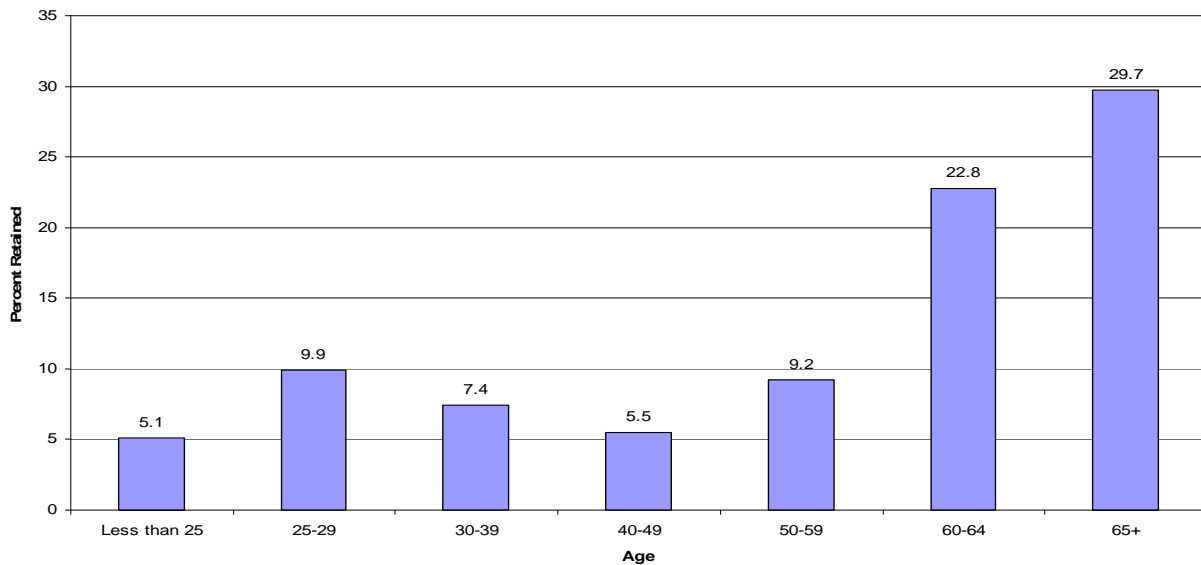
**Age Distributions of All Public School Teachers and Newly Hired Public School Teachers, 2003-2004**



**Source: NCES (2008a)**

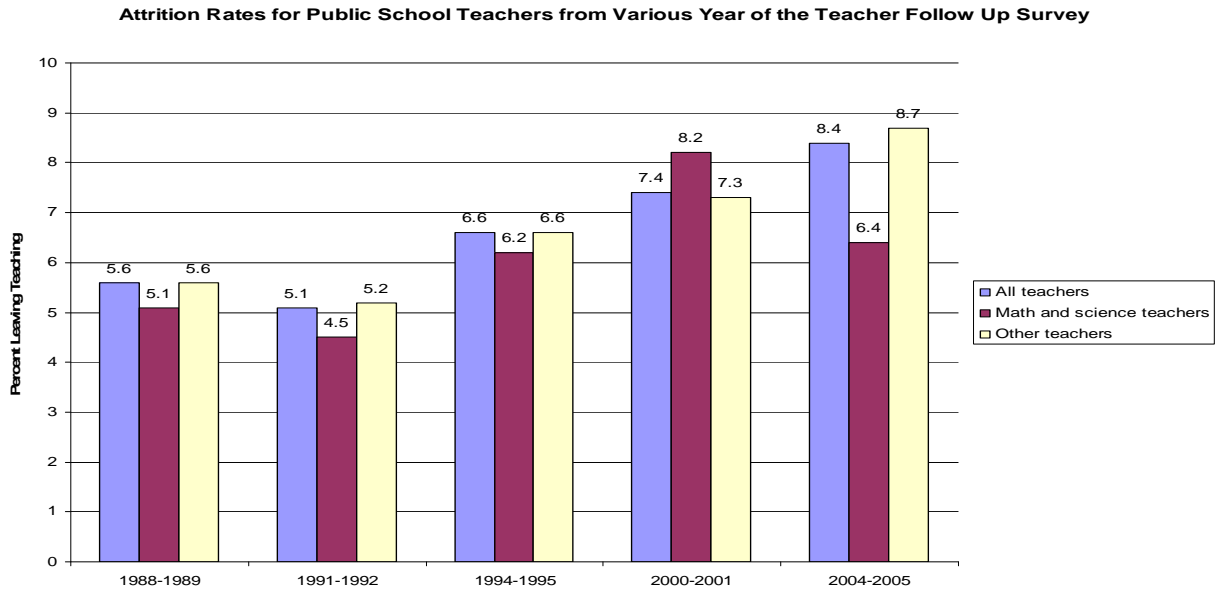
**Figure 2**

**Year-to-Year National Attrition Rates for Public School Teachers by Age School Year 2003-2004 to School Year 2004-2005**



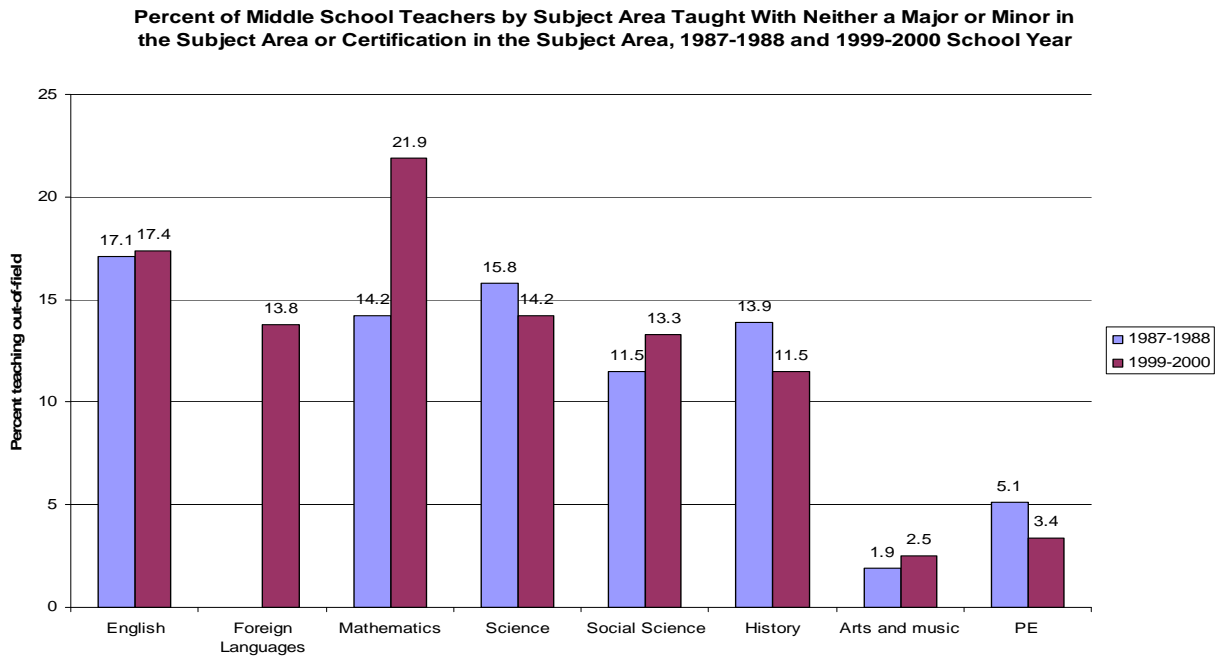
**Source: NCES (2007)**

**Figure 3**



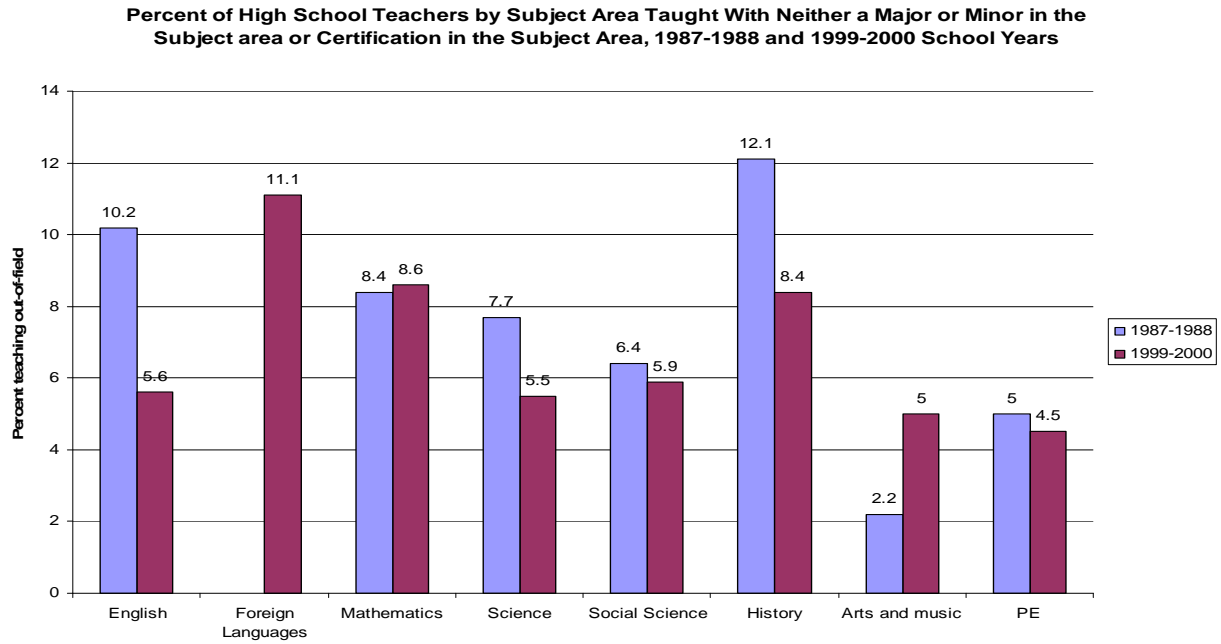
**Source: NCES (2007, 2008b)**

**Figure 4**



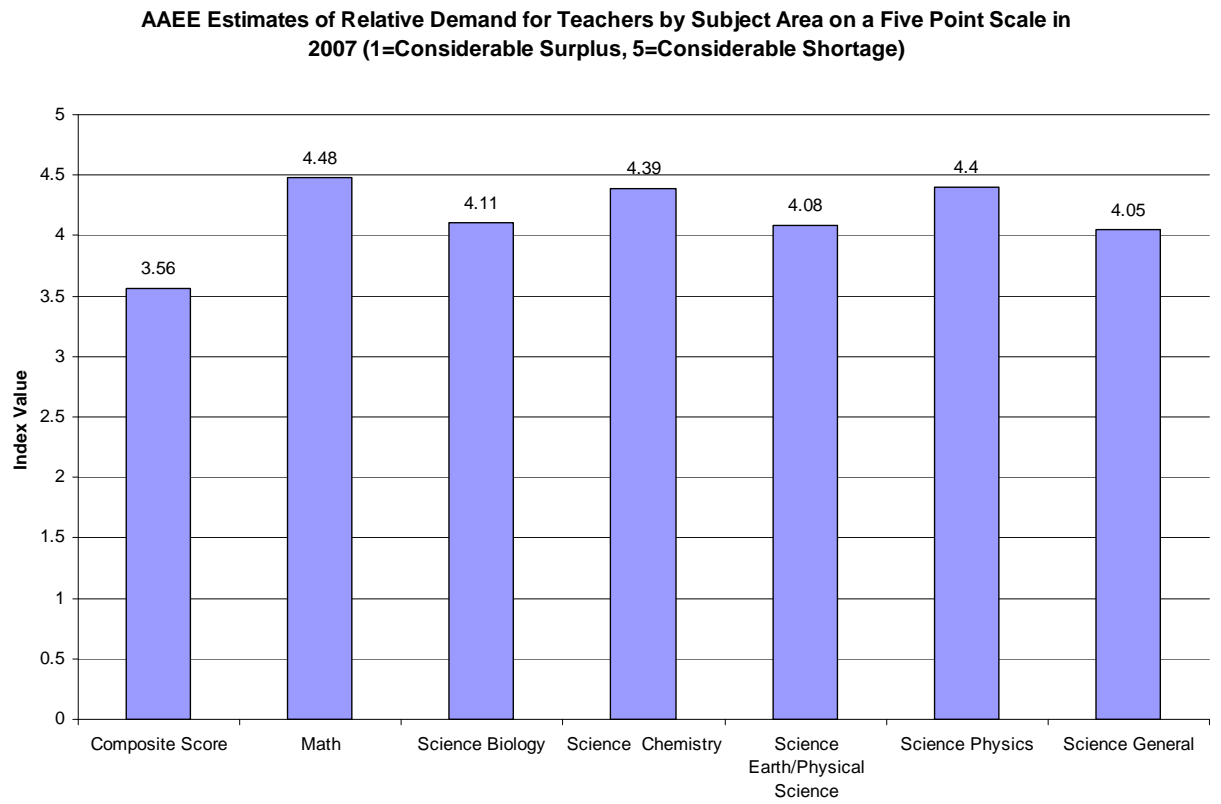
**Source: Seastrom et al. (2004)**

**Figure 5**



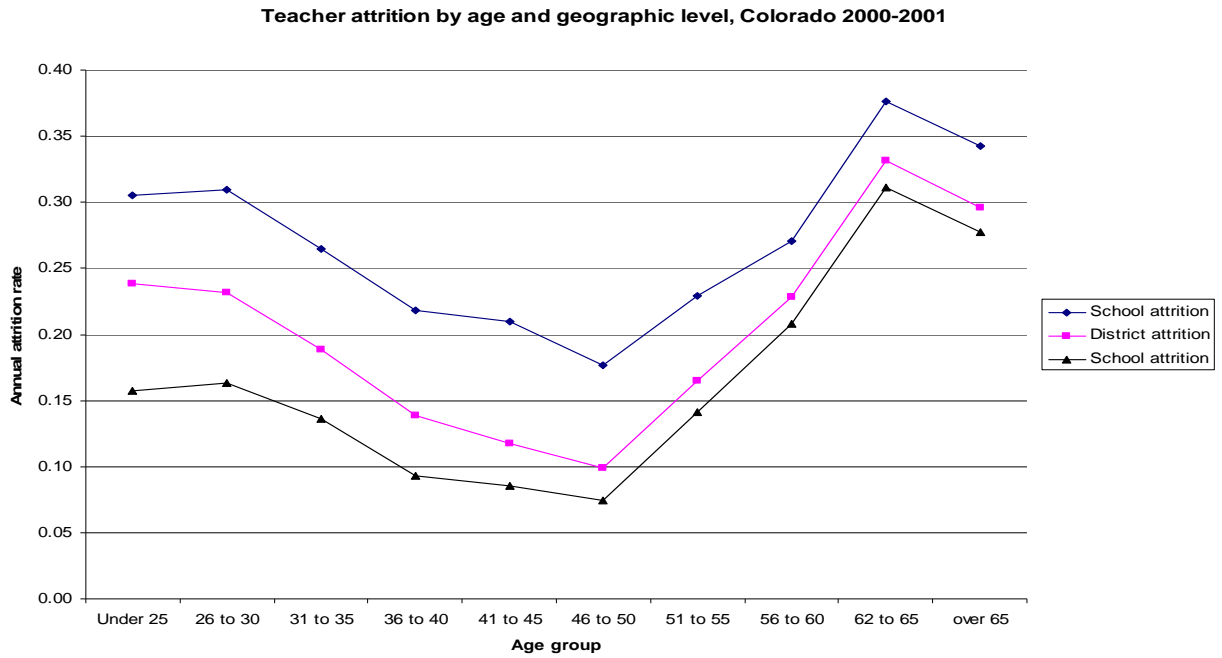
**Source: Seastrom et. al. (2004)**

**Figure 6**



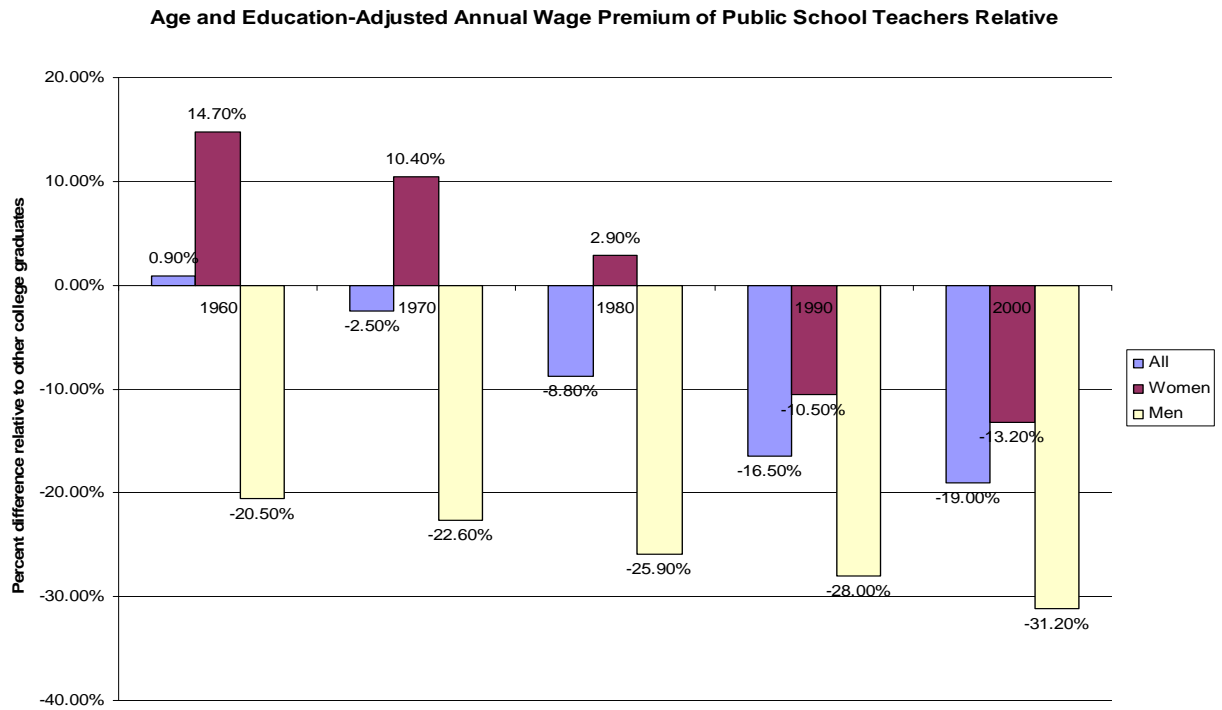
**Source: AAEE (2007), *Educator Supply and Demand in the United States***

**Figure 7**



*Source: Reichardt et. al. (2003) appendix table G-1*

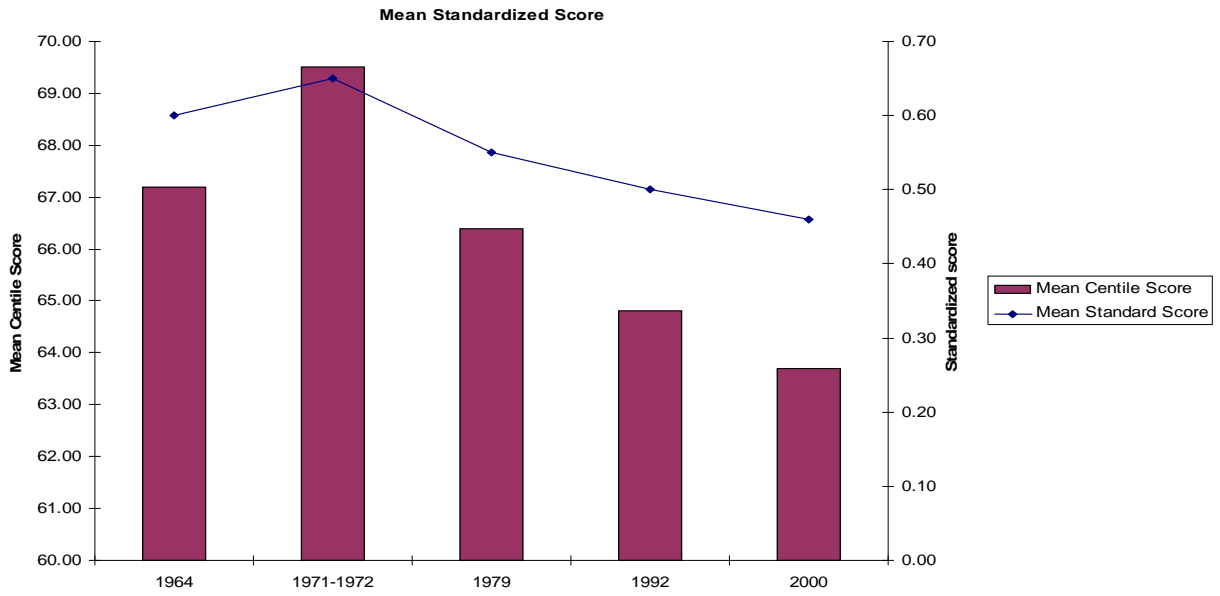
**Figure 8**



*Source: Allegretto, Corcoran, and Mishel (2008)*

**Figure 9**

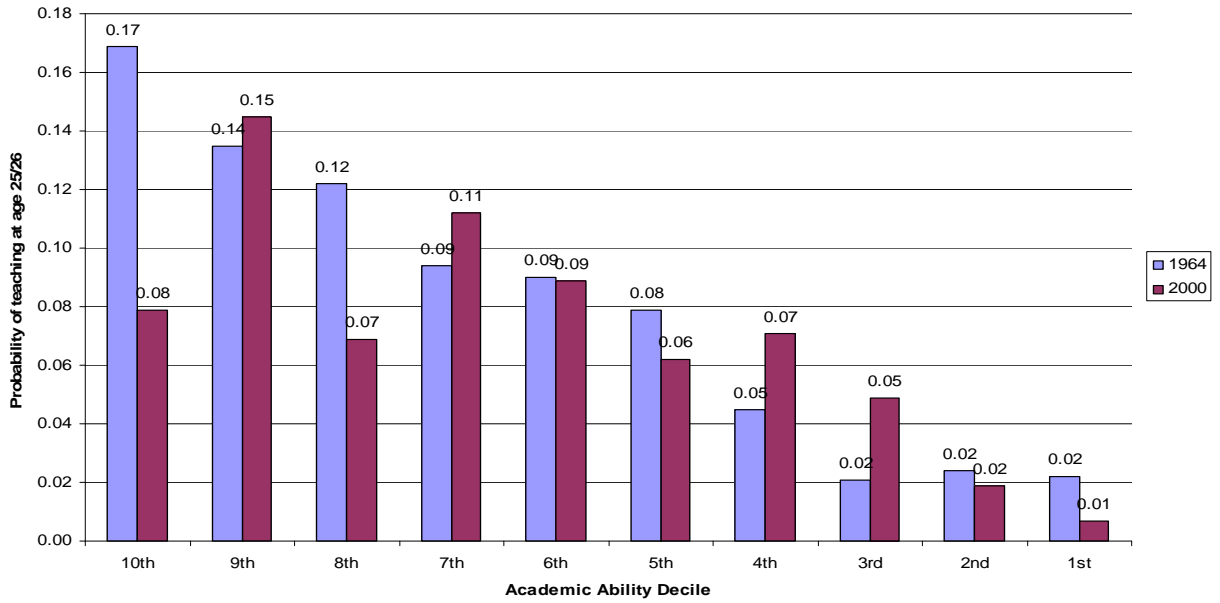
**Average ACademic Aptitude of Women Age 25/26 Who Teach, Centile Relative to High School Graduation Cohort and Average Standardized Scores**



*Source: Corcoran, Evans, and Schwab (2004)*

**Figure 10**

**Predicted Probability That Women Are Teachers at Age 25/26 by Deciles of the Distribution Academic Aptitude Among One's Birth Cohort of High School Graduates**



*Source: Corcoran, Evans, and Schwab (2004)*

## **Acknowledgments**

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