The Determinants of Teacher Attrition in Upstate New York

Jan Ondrich
Emily Pas
John Yinger
Maxwell School, Syracuse University, New York

Policy makers and scholars have long been interested in teacher attrition, particularly in poor, urban schools. We investigate the determinants of teacher attrition in five large metropolitan areas in upstate New York. We focus on a teacher's decision to leave a school district or to leave teaching using the Prentice-Gloeckler-Meyer technique for proportional hazards with unobserved heterogeneity. We find that teachers in districts with higher salaries relative to nonteaching salaries in the same county are less likely to leave teaching and that a teacher is less likely to change districts when he or she teaches in a district near the top of the teacher salary distribution in that county. We also find, however, that the impact of salary on the probability of leaving teaching is small and that very large salary increases would be required to offset the impact of concentrated student disadvantage on the attrition of female teachers.

Keywords: *teachers; wages; labor supply; job mobility*

1. Introduction

Problems recruiting and retaining teachers are of great concern to school officials, policy makers, and researchers. This article contributes to the debate on these issues by examining the determinants of teacher attrition in upstate New York. Using a large sample of teachers over a fourteen-year period and a duration model with unobserved heterogeneity, we find that the more their district pays relative to the salaries of college graduates in the region, the less likely teachers are to leave teaching. We also find that the higher the salary schedule in their district relative to others in the county, the less likely teachers are to transfer to another school district.

Nationally, 11 percent of teachers leave the profession after the first year, and 39 percent leave within five years. In recent years, over 90 percent of new

hires are replacements for recent departures, with departures for retirement accounting for only 12 percent of turnover (Ingersoll 2002). In New York State, 13 percent of elementary school teachers leave their initial school after the first year, and only 48 percent of elementary school teachers are still at their original school after five years.[1] These average numbers mask differences across schools and districts. In particular, high poverty urban districts are more likely to have high turnover rates. Nationally, high poverty public schools have much higher annual turnover rates—16 percent—than low poverty schools—9 percent (Ingersoll 2002).

Evidence that state policy makers are concerned with these facts can be seen in the variety of programs aimed at recruiting and retaining teachers, including education assistance, housing assistance, signing bonuses for new teachers, and retention bonuses for highly qualified or veteran teachers.[2] In most cases, however, these programs are not targeted toward teachers in high need districts. For example, thirty-four states and the District of Columbia offer retention bonuses to veteran or highly qualified teachers, but only five of them target these bonuses at teachers in high need districts.[3]

In New York State, recent policies focus on districts facing the most difficulties recruiting and retaining teachers. The New York State Education Department's Teachers of Tomorrow initiative is designed to help recruit teachers for districts experiencing shortages. It provides annual awards of $3,400 to teachers in subject areas with shortages or in communities without enough qualified teachers, and candidates who complete internships in urban schools in New York City, Buffalo, Rochester, Syracuse, and Yonkers can receive stipends of up to $2,000.[4] Also, in 2002 the state legislature approved funding for a pilot program for New York City and other urban districts that pairs new teachers in internships with experienced teachers.[5]

The high rates of teacher attrition and the resulting teacher turnover have implications for the quality of the education students receive. Teacher turnover costs the school money that could be spent elsewhere. Turnover

costs can include separation costs (e.g., exit interviews), hiring costs, vacancy costs (hiring substitutes), and training costs. One study (Texas Center for Educational Research 2000) used detailed information on Texas school districts to estimate the cost of replacing one teacher and total costs for current turnover rates and found estimated costs per teacher equal to at least 25 percent of salary and benefits.

Teacher turnover also affects the distribution of experienced teachers across schools. New teachers are not as effective as teachers with more experience, suggesting that students in schools with more inexperienced teachers will learn less than students in schools with a greater percentage of experienced teachers, all else being equal.[6] Therefore, high teacher turnover can lower student performance.

Teacher turnover also can affect how teachers with certain skills or qualifications are distributed across schools or school districts. Some studies have found, for example, that turnover has a particularly severe impact on poor, urban districts. Lankford, Loeb, and Wyckoff (2002) found that teacher moves increase inequities in teacher qualifications across schools; teacher qualifications include having passed the teacher certification exam on the first try and quality of undergraduate college. Recent work by Boyd et al. (2005b) finds that teachers who score the highest on the general knowledge certification exam are substantially more likely to leave schools having the lowest achieving students. However, research using other measures of teacher skill has not found that the most skilled teachers are more likely to leave. Hanushek et al. (2005) find that teachers with greater student test score gains are not more likely to leave urban schools, and Murnane (1984) finds that teachers with lower student test score gains and worse supervisor's evaluations are more likely to leave teaching after one or two years.[7] The relative quality of teachers who are leaving a school may also vary across schools. An "optimal" turnover rate for a particular school depends on the skills of those leaving, the skills of those being hired, and the costs of turnover, none of which are easy to quantify.

Overall, high rates of teacher turnover have direct monetary costs and alter the distribution of teacher experience and skill across districts. These findings suggest that a better understanding of teacher attrition may lead to policies that improve the quality of education and students' outcomes in later life. As a result, reducing teacher attrition could pay large dividends, particularly in poor school districts. In this context, we believe it is important to estimate the extent to which teacher attrition is affected by salary and other job characteristics.

2. Data

We investigated the impact of teacher and job characteristics on teacher attrition in upstate New York using two data sets collected by the New York State Education Department, the Personnel Master File (PMF) and the Institutional Master File (IMF). Both data sets contain information collected annually from surveys. The PMF is composed of information on most public school teachers in New York State based on surveys of teachers that include questions on personal characteristics and working conditions. The IMF is based on surveys sent to school administrators and contains information on school characteristics such as enrollment, student characteristics, and the race and ethnicity of teaching staff.

In the PMF, the data are originally presented at the teacher-class level. For the purposes of this study, however, the data are converted so that each observation corresponds to a teacher in a given year. For variables that vary over classes, including subject taught, information was consolidated across classes. The data contain all first teaching spells for teachers who started teaching between 1985 (1985-1986 school year) and 1998 (inclusive).[8] Academic and nonacademic (such as gym and music) teachers are included.

Our analyses focus on school districts in Albany, Broome, Erie, Monroe, and Onondaga counties, the counties that contain Albany, Binghamton, Buffalo, Rochester, and Syracuse, respectively.[9] These counties all include large, poor city school districts and wealthy suburban school districts, so they allow us to examine teacher attrition across a wide range of school conditions within five large metropolitan areas.

Tables 1, 2, 3, and 4 present summary statistics for the four samples used in the analyses: men transferring districts, men leaving teaching, women transferring districts, and women leaving teaching. Further explanation of these samples is provided in section 3.

2.1. Salary Variables

While many district characteristics, such as the socioeconomic background of students, are outside the control of school officials, districts can set teachers' salaries. Some prior research has investigated the relationship between salary and teacher attrition after accounting for other school characteristics (Mont and Rees 1996; Hanushek, Kain, and Rivkin 2004; Imazeki 2002; Scafidi, Sjoquist, and Stinebrickner forthcoming; Stinebrickner 1998, 1999). In general, these studies find that higher salaries are associated with

Table 1
Summary Statistics: Men Transferring Districts

Variable	First Year of Teaching Spell		All Teacher Spell Years	
	Mean	Standard Deviation	Mean	Standard Deviation
Log relative salary of nearby districts	0.16	0.10	0.17	0.13
Teach math or science in grades 7 to 12	0.19	0.39	0.19	0.39
Teach subject other than math or science in grades 7 to 12	0.47	0.50	0.46	0.50
Advanced degree	0.25	0.43	0.45	0.50
Regular certification	0.86	0.35	0.90	0.30
Nonminority share in school relative to maximum share in district	0.88	0.24	0.87	0.24
	Minimum	Maximum	Minimum	Maximum
Log relative salary of nearby districts	0.00	0.94	0.00	2.15
Teacher spell years	1,138		4,847	

Table 2
Summary Statistics: Men Leaving Teaching

Variable	First Year of Teaching Spell		All Teacher Spell Years	
	Mean	Standard Deviation	Mean	Standard Deviation
Log relative salary of teachers	–0.47	0.12	–0.35	0.21
Log relative salary of teachers with master's degree and 10 years of experience	–0.16	0.13	–0.16	0.16
Teach math or science in grades 7 to 12	0.19	0.39	0.19	0.39
Teach subject other than math or science in grades 7 to 12	0.47	0.50	0.46	0.50
Advanced degree	0.25	0.43	0.48	0.50
Regular certification	0.86	0.35	0.90	0.29
Nonminority share in school relative to maximum share in district	0.88	0.24	0.88	0.24
	Minimum	Maximum	Minimum	Maximum
Log relative teaching salary	–1.23	0.18	–6.40	2.65
Log relative salary of teachers with master's degree and 10 years of experience	–1.11	0.25	–2.19	0.25
Teacher spell years	1,138		5,488	

Table 3
Summary Statistics: Women Transferring Districts

Variable	First Year of Teaching Spell		All Teacher Spell Years	
	Mean	Standard Deviation	Mean	Standard Deviation
Log relative salary of nearby districts	0.17	0.11	0.17	0.15
Teach math or science in grades 7 to 12	0.10	0.30	0.09	0.29
Teach subject other than math or science in grades 7 to 12	0.31	0.46	0.28	0.45
Advanced degree	0.30	0.46	0.54	0.50
Regular certification	0.85	0.35	0.91	0.28
Nonminority share in school relative to maximum share in district	0.87	0.24	0.86	0.24
	Minimum	Maximum	Minimum	Maximum
Log relative salary of nearby districts	0.00	2.15	0.00	2.15
Teacher spell years	3,096		14,732	

Table 4
Summary Statistics: Women Leaving Teaching

Variable	First Year of Teaching Spell		All Teacher Spell Years	
	Mean	Standard Deviation	Mean	Standard Deviation
Log relative salary of teachers	−0.05	0.12	0.06	0.19
Log relative salary of teachers with master's degree and 10 years of experience	0.26	0.12	0.25	0.16
Teach math or science in grades 7 to 12	0.10	0.30	0.09	0.29
Teach subject other than math or science in grades 7 to 12	0.32	0.47	0.29	0.46
Advanced degree	0.30	0.46	0.55	0.50
Regular certification	0.85	0.35	0.92	0.27
Nonminority share in school relative to maximum share in district	0.87	0.24	0.87	0.24
	Minimum	Maximum	Minimum	Maximum
Log relative salary of teachers	−1.73	1.04	−2.95	1.77
Log relative salary of teachers with master's degree and 10 years of experience	−1.79	0.62	−1.79	0.62
Teacher spell years	3,100		15,908	

significantly lower teacher attrition, all else being equal. Other studies find that salary appears to have differential effects on the length of time in an initial teaching job for teachers who transfer districts and those who leave teaching (Hanushek et al. 2005; Imazeki 2002). A series of articles using Washington State data (Theobald 1990; Gritz and Theobald 1996; Theobald and Gritz 1996) also found that the spending priorities of a district appear to affect teacher attrition.

The focus in this article is the impact on teacher attrition of teacher salaries relative to alternative opportunities. We use two variables to measure a teacher's relative salary. The first is the log of predicted individual salary divided by an estimate of nonteaching salary. This variable measures a teacher's salary relative to a nonteaching salary, which is one measure of the opportunity cost of teaching. We expect that the larger the ratio of teaching salary to nonteaching salary, the less likely a teacher would be to leave teaching for nonteaching labor market opportunities.

Our predicted salary variable is based on district pay scales, which usually give pay increases for additional years of experience or additional education, such as a master's degree.[10] We analyze this pay scale for each district year by regressing the log of teachers' salaries (in 2001 dollars) on a spline of teaching experience and indicator variables for degree. Returns to experience may also differ between teachers with bachelor's degrees and those with master's degrees; we account for this possibility by interacting degree and teaching-experience splines.[11] We then predict each teacher's salary based on his or her actual experience and degree. Predicted salaries vary across teachers both because teachers are on different parts of the pay scale for their districts and because different districts have different pay scales.

We use predicted salary instead of actual salary for three reasons. First, actual salary includes payment for coaching and other extracurricular activities that are not relevant to our analysis. Second, the use of a predicted value rules out the possibility of bias from a correlation between a teacher's actual salary and his or her unobserved traits, an issue to which we return below. Third, data on actual salary are missing for a small share of our observations.

Nonteaching salary is estimated using earnings of college graduates in each of the five metropolitan statistical areas corresponding with the five counties. Using decennial Public Use Microdata Samples data, we calculated the median income of college graduates who were not teachers, who were between the ages of twenty-two and fifty-five (inclusive), and who were in the labor force full time. This was done separately for men and women.[12] To translate these results into median annual earnings, we calculated the growth

in median earnings between decades and added one-tenth of that growth for each intermediate year.[13]

Our data do not allow us to determine whether a teacher is married. Presumably, however, many teachers are married, and attrition decisions by a teacher may be affected by the labor-market opportunities of his or her spouse.[14] This effect could work in either direction. Higher nonteaching earnings for men, for example, might make married female teachers less likely to look for higher paying nonteaching jobs, or they might make these teachers more likely to leave teaching and raise a family. As a result, some of our analyses include opposite sex nonteaching earnings as an additional control variable.[15]

Our second salary variable addresses other public school teaching opportunities in the same county. It is the log of the maximum teaching salary in the county for a teacher with ten years' experience in one district and a master's degree divided by the salary in a teacher's district for a teacher with the same qualifications. These salaries are predicted using the regressions we estimated to explain individual teachers' salaries. We expect that teachers who are in districts near the top of the salary distribution for their county will be less likely to transfer districts than teachers in districts closer to the bottom of the teacher salary distribution.

Whether the findings from our analysis (or from previous studies) represent a causal effect of salary on teacher attrition depends on whether unobserved district or teacher characteristics are correlated with both salary and teacher attrition. A poor district might be unable to pay high salaries, for example, and might also have unobserved working conditions that lead to more attrition. In this case, a significant negative coefficient for a salary variable might be biased; that is, it might simply indicate that these unobserved conditions exist, not that higher salaries lead to less attrition. To minimize this type of bias, we include additional teacher and district characteristics in our regressions, and as indicated earlier and discussed below, we define our salary variables based on predicted not actual values.

Because we have a relatively long panel of data (fourteen years), we also can account for unobserved time-invariant district characteristics using district fixed effects.[16] As is well known, this approach makes it more difficult to estimate the impact on teacher attrition of time-varying district characteristics because it removes these characteristics' cross-sectional variation. Our approach is to estimate our main models without district fixed effects but also to present the results of models that include these effects to see if controlling for unobserved district characteristics makes a difference.

Without district fixed effects, another type of bias could arise if teachers are more likely to develop attachments to some regions than to others.[17] Several studies provide evidence that regional attachment plays an important role in teacher placement. Research on New York State teachers by Boyd et al. (2005a) finds that 85 percent of teachers teach within 40 miles of their hometowns, and teachers are likely to teach near where they attended college. Using Pennsylvania data, Strauss et al. (2000) find that, on average, 40 percent of teachers teach in the district where they attended high school. Although a teacher's location reflects both teacher and district choices, we follow Boyd et al. (2005a) by assuming that a teacher can choose the region in which he or she will teach.[18]

The share of locally grown teachers, an indicator of regional attachment, varies by region. Boyd et al. (2005a) show, for example, that 45 percent of teachers in Buffalo are originally from Buffalo, whereas 55 percent of teachers in Rochester are originally from Rochester. This apparent variation in regional attachment could be a source of bias in our models if it is correlated with both teacher attrition and teachers' salaries. A link between regional attachment and teacher attrition, particularly leaving teaching, is plausible because teachers may be more likely to leave teaching positions that are not close to home. Salary also varies systematically across regions; indeed, Lankford, Loeb, and Wyckoff (2002) find that a large share of the salary variation in New York State is across regions, not across districts within a region. This variation in salary might be correlated with regional attachment.

To eliminate this bias, we estimate some models with region indicators. These indicators not only control for variation in a region's ability to generate attachment but also control for other potential unobserved differences across regions, such as differences in the cost of living. This approach represents a compromise between models with and without district fixed effects; regional fixed effects have the advantage that they do not remove as much cross-sectional variation as do district fixed effects, but they also have the disadvantage that they do not account for time-invariant, within-region unobservables.

2.2. Teacher Characteristics

Teacher-specific attributes, including subject specialty and academic ability, may also affect a teacher's alternative employment opportunities. Previous research (Murnane and Olsen 1989, 1990; Murnane, Singer, and Willett 1989) finds that subject specialties, particularly math or science, are related to teacher turnover. We created two variables to capture potential differences in opportunity cost across grade level and subject taught. The first indicates that

a teacher teaches math or science at the high school level; the second indicates that a teacher teaches some high school subject other than math and science. The omitted category is teaching in elementary or middle school.

In addition to subject specialty and grade level, other teacher characteristics may be related to a teacher's propensity to transfer districts or leave teaching. The PMF includes information on each teacher's sex, education, and type of certification.[19] We estimate results separately for men and women, because family obligations or differences in preferences could cause men and women to value certain job characteristics differently.[20] For example, men may value salary differently than women if they are less likely to take time off to raise children. A limitation of this data set is a lack of information on teachers' marital status or number of children. Stinebrickner (1998, 1999, 2001) finds that marriage and fertility variables are important predictors of length of stay in teaching.

Some of our regressions include a measure of certification type, which may reflect commitment to teaching. We include indicator variables for having regular certification (provisional or permanent), and we expect teachers with regular certification to be less likely to leave teaching. In New York State, permanent certification requires a master's degree, but the timing of certification does not necessarily coincide with the timing of education. As a result, we also include a variable to indicate whether a teacher has an advanced degree (a master's or PhD) in some analyses.[21]

We also include analyses without these two variables, because the choices they represent might be correlated with an unobserved propensity to leave teaching. While teachers in New York State are required to obtain advanced degrees to get professional certification, the timing of an advanced degree is the teacher's choice. Thus, conditional on time in teaching (spell duration variables), advanced degree is a choice variable and potentially correlated with a teacher's propensity to remain in teaching. A similar argument applies to a teacher's choice concerning type of certification. When we exclude these two variables from our models of teachers' decisions to leave teaching, we also adjust the relevant salary variable, which is a teacher's predicted salary relative to nonteaching earnings in the county. Specifically, to remove education decisions from the salary variable in these models, all teachers' salaries are predicted assuming that the teacher has a master's degree and ten years of experience.

Some control variables used in previous studies are not available in our data set. Some scholars have hypothesized that teachers with greater academic ability will have better job opportunities outside of teaching, and some studies have found that teachers with higher test scores leave teaching

sooner (Murnane, Singer, and Willett 1989; Murnane and Olsen 1990). Unfortunately, our data do not include any information on teachers' academic ability.[22] Boyd et al. (2005a) find that teachers in New York search for jobs near their hometowns or in districts similar to their hometowns. The value teachers place on being near their hometowns may also affect their quit behavior, but we do not have information on hometowns in our data set.

Our estimation method requires data on each teacher in each year of an observed teaching spell. As a result, missing spell-year information must be completed in some way. In the case of teacher characteristics, the data set contains some gaps, which we fill in based on information in surrounding years. If the degree variable is missing in one year, for example, but the teacher has a master's degree the previous year and a master's degree the following year, we fill in the missing value as a master's degree.[23]

2.3. School Characteristics

Schools with a large concentration of disadvantaged students may have a more challenging working environment than schools with relatively advantaged students, and these differences in working conditions could affect teacher mobility.[24] The IMF contains information on the socioeconomic status and racial and ethnic background of a school's students. We explore the impact on teacher attrition using data on the concentration of minority students (defined as black, Hispanic, or Native American) and the share of students who are "members of families whose primary means of support is a public welfare program."[25]

A teacher's mobility decisions may be affected both by the characteristics of the teacher's current school and by the characteristics of other schools within the district. Teachers may leave a district or leave teaching if they find themselves teaching in a school with many disadvantaged students relative to other schools in the district. Teachers often transfer to another school within the same district, however, and a teacher currently in a school with many disadvantaged students may be less likely to leave if he or she sees an opportunity for a future move to other schools in the district with less concentrated disadvantage.[26] To focus on this intradistrict variation in student disadvantage, we use two ratio variables.[27] The first is defined as the percentage of nonminority students in a teacher's school divided by the percentage of nonminority students in the school with the fewest minority students in the district.[28] The second is defined as the percentage of nonwelfare students in a teacher's school divided by the percentage of nonwelfare students in the school with the fewest welfare students in the district.

Following the above reasoning, these variables could affect teacher attrition in either direction.

3. Estimation Technique

In this study, we focus on the determinants of the quit behavior of teachers in five major metropolitan areas in New York State (excluding New York City) between 1985 and 1998. The term *quit* can be defined in several ways, and we use two definitions and corresponding sets of teaching spells in our study. The first quit definition is "leaving a given school district while remaining a teacher" (in New York State), a behavior referred to as "switching districts." In this case, a teaching spell consists of years in a teacher's first district. The cell is censored if a teacher leaves the district but does not transfer to another district.

The second quit definition is "leaving teaching in New York State." The teaching spell consists of continuous years in any districts in the five metropolitan areas. If a teacher leaves these metropolitan areas but continues teaching in New York State, the spell is censored.

Other studies have found that salary has differential effects on the time in an initial teaching job for teachers who transfer districts and those who leave teaching (Hanushek, Kain, and Rivkin 2004; Imazeki 2002). We hypothesize that quits by the first definition (switching districts) will be influenced by a teacher's salary relative to the salaries for comparable teachers in nearby districts. We also hypothesize that quits by the second definition (leaving teaching) will depend on a teacher's salary relative to nonteaching salaries in the region.

Quit refers here to either of these two types of quits. For each quit definition, we determine durations to the first quit for a sample of male teachers and a sample of female teachers. Spells that do not end with an exit in 1998 are censored.[29] Because our primary focus is on teacher salary, which is a district-level variable, we do not consider transfers within a district to be an exit. The causes of within-district transfers are certainly worth studying, but they are not addressed in this article.

Teachers are defined as leaving teaching if they are absent from the data for at least one year.[30] Unfortunately, we face the same constraint as most other studies, namely, that we are not able to distinguish between teachers who leave teaching to stay at home with their children or to switch careers and those who leave New York to teach in another state. Increases in salary could potentially have quite different effects on the behavior of teachers in these categories.[31]

Our goal is to find the determinants of the conditional quit rate (quit hazard rate). Some care must be taken with the statistical terminology being used. The quit rate might be defined as the quit rate at a point in time within the calendar year or as the quit rate for a given year. Somewhat arbitrarily, we refer to the first possibility as the "quit rate" and the second possibility as the "quit probability."

A given sample in our study is assumed to consist of N independent teaching durations. Let T_i be the duration of the first teaching spell for $i = 1, \ldots, N$. The duration T_i is properly considered to be a continuous variable. The quit hazard rate for teaching spell i takes the proportional hazard form developed by Cox (1972):

$$\lambda_i(t) = \lambda_0(t) \exp(z_i(t)' \beta), \tag{1}$$

where $\lambda_0(t)$ is the unknown baseline hazard at time t, $z_i(t)$ is the vector of time-varying covariates, and β is the coefficient vector.

To estimate the coefficient vector, we use the technique proposed by Prentice and Gloeckler (1978) as well as Meyer's (1990) adaptation that allows controls for unobserved heterogeneity. In the Prentice-Gloeckler technique, the parameters $\lambda(t)$ of the log-integrated baseline hazard are nonparametrically estimated simultaneously with the coefficient vector. The estimation method does not use the continuous quality of the duration variable but rather discretizes this variable into time intervals. The Prentice-Gloeckler technique uses the extreme-value distribution function to estimate the conditional survivor function at age $t + 1$:

$$\Pr[T_i \geq t + 1 | T_i \geq t] = \exp(-\exp(z_i(t)' \beta + \gamma(t))), \tag{2}$$

where the covariate vector $z_i(t)$ is assumed to remain constant over the period from t to $t + 1$. This technique is particularly appropriate for the current study because in the teaching duration samples, quits only occur at yearly intervals. (This type of data is called "grouped" or "interval-censored.") Generally, when the Prentice-Gloeckler technique is used, a γ parameter is estimated for each interval. Parameters for intervals in which no quits occur are not estimated, and all such intervals are dropped from the sample.

The interpretation of parameters is an important component of presenting the results of maximum-likelihood or other nonlinear estimation. The interpretation of the β coefficients is similar to the interpretation of the regression coefficients of a log-linear or semi-log regression model. In a log-linear model, where both the dependent variable and the regressors are logged, a

regression coefficient can be interpreted as an elasticity. Similarly, if a regressor is logged in the Prentice-Gloeckler likelihood, its coefficient can be interpreted as a hazard elasticity. In a semi-log regression, in which the dependent variable is logged but the regressors are not, the elasticity of the dependent variable with respect to a regressor is given by the value of the regressor times the coefficient. Similarly, if a regressor is not logged in a Prentice-Gloeckler likelihood, its hazard elasticity is given by the value of the regressor times the coefficient.

Interpretations of the coefficients of categorical variables remain problematic, but even these can be handled using the hazard-ratio transformation of β. The hazard ratio for component β_j of β is $\exp(\beta_j)$. The hazard ratio is the percentage change in the hazard because of a unit increase in the jth regressor. Using hazard ratios, the effect of the jth regressor on the hazard is significantly positive if the hazard ratio significantly exceeds one and significantly negative if the hazard ratio is significantly less than one. Defining s_j to be the (estimated) standard error of the maximum likelihood estimate $\hat{\beta}_j$ of β_j, the relevant asymptotic t statistic for a test of H_0: $\exp(\beta_j) = 1$ is $(\exp(\hat{\beta}_j) - 1)/(\exp(\hat{\beta}_j) s_j)$. In many packages that estimate the Prentice-Gloeckler likelihood, hazard ratios are an alternative format for the estimation results.

The theoretical contribution of Meyer (1990) is to use random effects to incorporate unobserved heterogeneity into the Prentice-Gloeckler likelihood. The resulting likelihood is called the Prentice-Gloeckler-Meyer likelihood. The random effect summarizes the effects of all (unobserved) excluded regressors that are constant over the teaching spell and orthogonal to included regressors. It is well known that failure to control for such unobserved heterogeneity will result in inconsistent parameter estimates in structural models such as the Prentice-Gloeckler model (Lancaster 1979; Heckman and Singer 1984). Studies that incorporate controls for unobserved heterogeneity in models of teacher retention include Dolton and van der Klaauw (1995, 1999) and Stinebrickner (2001, 2002).

Incorporating the multiplicative random effect θ_i into the hazard results in

$$\lambda_i(t) = \theta_i \, \lambda_0(t) \exp(z_i(t)' \, \beta). \tag{3}$$

Meyer (1990) assumes that the random effects θ_i are independent of the $z_i(t)$ and are i.i.d. gamma variates with mean one and variance σ^2. The variance σ^2 must now be estimated together with the coefficient vector β and the $\gamma(t)$'s. Testing the significance of the estimate of σ^2 is complicated by the fact that zero is on the edge of the parameter space. Chernoff (1954) demonstrated

that under these conditions, the appropriate critical value for a test of size α is the critical value for a test of size 2α under standard conditions.

Note that when θ_i equals one, the value of the hazard is the same as in equation (1). This means that conditional on the random effect assuming its mean value, the regressor coefficients and hazard ratios have the same interpretation in Prentice-Gloeckler-Meyer likelihood as in the Prentice-Gloeckler likelihood. The Prentice-Gloeckler-Meyer technique estimates the survivor function at age $t + 1$ using the following probability:

$$\Pr[T_i \geq t + 1] = \left(1 + \sigma^2 \sum_{k=0}^{t} \exp(z_i(k)' \beta + \gamma(k)) \right)^{-\sigma^{-2}} \tag{4}$$

4. Results

4.1. Descriptive Statistics

Figures 1, 2, 3, and 4 show the hazard rates for the four samples (two exit states and two genders) used in our analyses.[32] In most cases, the hazard rates are highest in the first three years of a teaching spell. For both men and women, the hazard rates for transferring districts (Figures 1 and 3) are quite small (less than 0.02) by year four and continue to decline throughout the spell except for a small increase around year ten. The hazard rates for leaving teaching (Figures 2 and 4) do not decline so rapidly and in fact go up in the fourteenth year for both men and women. After the first year, however, the hazard rate for women always exceeds the hazard rate for men; that is, after the first year, women are more likely to leave teaching than are men.

4.2. Estimation Results

Estimation results are presented in Tables 5, 6, 7, and 8.[33] Results using both estimating methods are presented for the exit state leaving teaching. We were not able to obtain estimates for the Prentice-Gloeckler-Meyer model for the exit state transferring districts because the models did not converge.[34] For transferring districts, therefore, we only present results for the Prentice-Gloeckler model.

Tables 5, 6, 7, and 8 present results in the form of hazard ratios, or $\exp(\beta_j)$, where a number less than one indicates that a variable is negatively related to teachers' quit rate. Hazard elasticity results for the logged salary variables are presented in the text. Years in the teaching spell with no quits in the data are excluded from the analyses, and the spell duration dummy

Figure 1
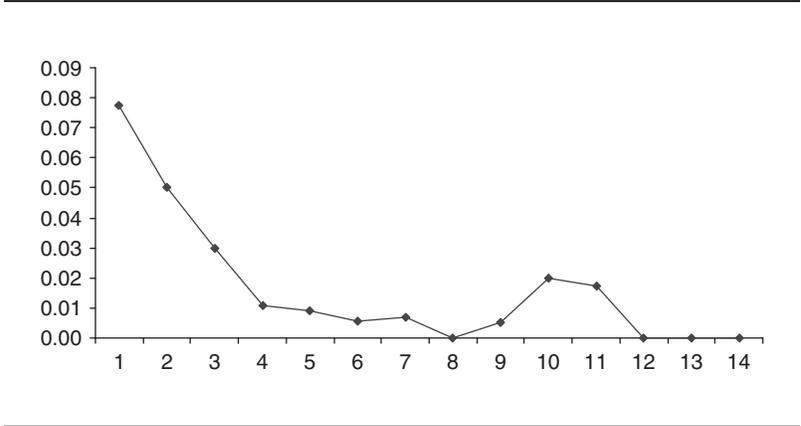**Hazard for Men Transferring Districts**

Figure 2
Hazard for Men Leaving Teaching
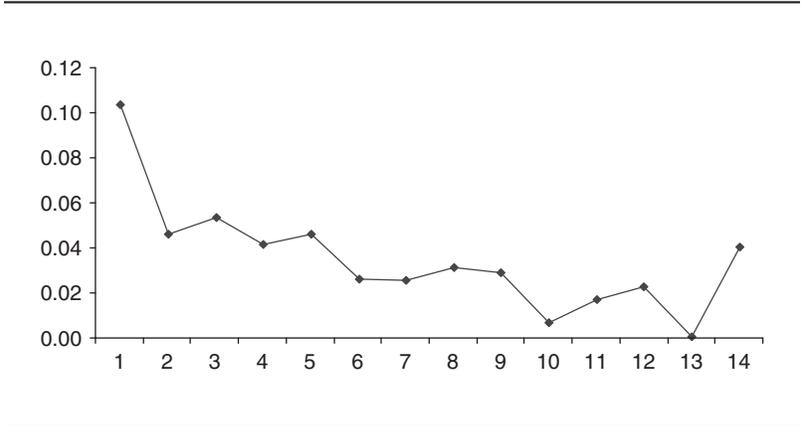
variables for those years are then excluded as well. For men leaving teaching, for example, there were no quits in year thirteen of the teaching spells, so all observations in year thirteen were excluded from the analyses, and the spell duration indicator for that year was dropped.

Figure 3
Hazard for Women Transferring Districts
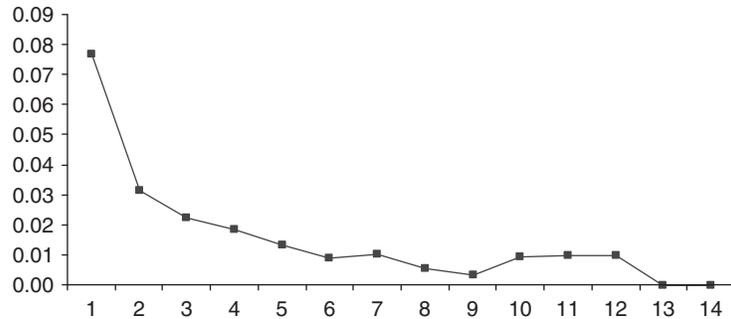
Figure 4
Hazard for Women Leaving Teaching

Table 5 (for men) and Table 7 (for women) present our results for transferring districts. As discussed earlier, we define two salary variables; for conciseness, these two variables are called the "relative salary of teachers" and the "relative salary of nearby districts," respectively. We present results

Table 5
Analysis Results for Men Transferring Districts
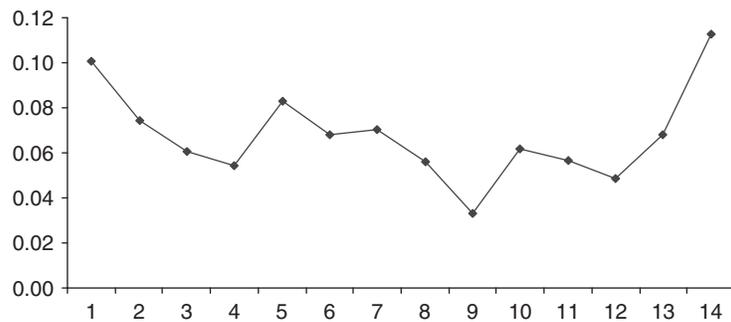
	Prentice-Gloeckler Model (Complementary Log-Log)	
	Hazard Ratio (std. error)	Hazard Ratio (std. error)
	Model 1	Model 2
Relative salary of nearby districts	2.09	2.01
	(0.98)	(0.93)
Teach math or science in grades 7 to 12	1.57	1.58*
	(0.35)	(0.35)
Teach subject other than math or	1.45*	1.45*
science in grades 7 to 12	(0.27)	(0.27)
Advanced degree	1.04	—
	(0.18)	—
Regular certification	1.38	—
	(0.38)	—
Nonminority share in school relative	0.96	1.04
to maximum share in district	(0.34)	(0.37)
$\gamma(0)$	0.04***	0.05***
	(0.02)	(0.02)
$\gamma(1)$	0.03***	0.03***
	(0.01)	(0.01)
$\gamma(2)$	0.02***	0.02***
	(0.01)	(0.01)
$\gamma(3)$	0.01***	0.01***
	(0.00)	(0.00)
$\gamma(4)$	0.00***	0.01***
	(0.00)	(0.00)
$\gamma(5)$	0.00***	0.00***
	(0.00)	(0.00)
$\gamma(6)$	0.00***	0.00***
	(0.00)	(0.00)
$\gamma(8)$	0.00***	0.00***
	(0.00)	(0.00)
$\gamma(9)$	0.01***	0.01***
	(0.01)	(0.01)
$\gamma(10)$	0.01***	0.01***
	(0.01)	(0.01)
Number of teachers	1,138	1,138
Log likelihood	−689.33	−690.11

Note: A * signifies statistical significance at the 10 percent level, ** signifies statistical significance at the 5 percent level, and *** signifies statistical significance at the 1 percent level—all for the null hypothesis that the coefficient equals 1.0.

Table 6
Analysis Results for Men Leaving Teaching

	Prentice-Gloeckler Model (Complementary Log-Log)		Prentice-Gloeckler-Meyer Model (Complementary Log-Log with Gamma Heterogeneity)	
	Hazard Ratio (std. error)	Hazard Ratio (std. error)	Hazard Ratio (std. error)	Hazard Ratio (std. error)
	Model 3	Model 4	Model 5	Model 6
Relative salary of teachers[a]	0.65***	0.56***	0.70	0.52*
	(0.14)	(0.16)	(0.37)	(0.29)
Teach math or science in grades 7 to 12	1.31	1.29	3.47	2.51
	(0.23)	(0.23)	(3.35)	(1.98)
Teach subject other than math or science in grades 7 to 12	1.30*	1.30	1.76	1.68
	(0.18)	(0.18)	(0.75)	(0.60)
Advanced degree	0.56***	—	0.28***	—
	(0.09)	—	(0.21)	—
Regular certification	0.69***	—	0.56**	—
	(0.12)	—	(0.20)	—
Nonminority share in school relative to maximum share in district	0.81	0.69*	1.51	0.91
	(0.21)	(0.17)	(1.27)	(0.65)
$\gamma(0)$	0.14***	0.12***	0.19***	0.12***
	(0.04)	(0.03)	(0.17)	(0.06)
$\gamma(1)$	0.06***	0.05***	0.24*	0.11***
	(0.02)	(0.01)	(0.42)	(0.13)
$\gamma(2)$	0.08***	0.06***	0.59	0.20**
	(0.02)	(0.02)	(1.49)	(0.40)
$\gamma(3)$	0.06***	0.05***	0.94	0.24
	(0.02)	(0.01)	2.99	(0.63)
$\gamma(4)$	0.08***	0.05***	2.08	0.42
	(0.02)	(0.02)	(7.93)	(1.33)
$\gamma(5)$	0.05***	0.03***	2.32	0.32
	(0.02)	(0.01)	(10.29)	(1.18)
$\gamma(6)$	0.05***	0.03***	4.07	0.40
	(0.02)	(0.01)	(20.22)	(1.61)
$\gamma(7)$	0.07***	0.03***	9.32	62
	(0.03)	(0.01)	(51.70)	2.75
$\gamma(8)$	0.06***	0.03***	13.51	0.77
	(0.03)	(0.01)	(81.62)	(3.72)
$\gamma(9)$	0.01***	0.01***	3.99	0.20
	(0.02)	(0.01)	(25.47)	(1.05)

Table 6 (continued)

	Prentice-Gloeckler Model (Complementary Log-Log)		Prentice-Gloeckler-Meyer Model (Complementary Log-Log with Gamma Heterogeneity)	
	Hazard Ratio (std. error)	Hazard Ratio (std. error)	Hazard Ratio (std. error)	Hazard Ratio (std. error)
	Model 3	Model 4	Model 5	Model 6
$\gamma(10)$	0.04***	0.02***	12.55	0.57
	(0.03)	(0.01)	(82.20)	(3.02)
$\gamma(11)$	0.05***	0.02***	22.32	0.96
	(0.04)	(0.02)	(151.52)	(5.35)
$\gamma(13)$	0.09***	0.04***	60.55	2.27
	(0.09)	(0.04)	(433.35)	(13.76)
σ^2	—	—	13.29	9.49
	—	—	(14.53)	(13.85)
Number of teachers	1,138	1,138	1,138	1,138
Log likelihood	−1065.74	−1076.73	−1064.08	−1076.36

Note: A * signifies statistical significance at the 10 percent level, ** signifies statistical significance at the 5 percent level, and *** signifies statistical significance at the 1 percent level—all for the null hypothesis that the coefficient equals 1.0.
a. For models 4 and 6, this variable is the relative salary of teachers with a master's degree and 10 years of experience.

with and without the inclusion of the certification and advanced degree variables. These tables present results with student disadvantage measured by the share of nonminority students. Results for the measure based on the share of nonwelfare students are similar.

The relative salary of nearby districts has the expected impact on the probability of transferring districts but is statistically significant only for women. The estimated coefficients (expressed as hazard ratios) are greater than one; the higher the salary of nearby districts relative to a teacher's salary, the more likely the teacher is to transfer to another district.

When it is not exponentiated, the coefficient of this salary variable can be interpreted as a hazard elasticity. For men transferring districts, the elasticity of this salary variable is 0.74 in the specification that includes certification and advanced degree variables and 0.70 in the specification without those variables, which implies that a 1 percent increase in the relative salary

Table 7
Analysis Results for Women Transferring Districts

	Prentice-Gloeckler Model (Complementary Log-Log)	
	Hazard Ratio (std. error)	Hazard Ratio (std. error)
	Model 7	Model 8
Relative salary of nearby districts	2.29**	2.26**
	(0.53)	(0.52)
Teach math or science in grades 7 to 12	1.63**	1.63**
	(0.26)	(0.26)
Teach subject other than math or	2.02***	2.01***
science in grades 7 to 12	(0.21)	(0.21)
Advanced degree	1.28**	—
	(0.13)	—
Regular certification	1.09	—
	(0.18)	—
Nonminority share in school relative	1.19	1.19
to maximum share in district	(0.2.7)	(0.2.6)
$\gamma(0)$	0.04***	0.04***
	(0.01)	(0.01)
$\gamma(1)$	0.01***	0.02***
	(0.00)	(0.00)
$\gamma(2)$	0.01***	0.01***
	(0.00)	(0.00)
$\gamma(3)$	0.01***	0.01***
	(0.00)	(0.00)
$\gamma(4)$	0.01***	0.01***
	(0.00)	(0.00)
$\gamma(5)$	0.00***	0.01***
	(0.00)	(0.00)
$\gamma(6)$	0.00***	0.01***
	(0.00)	(0.00)
$\gamma(7)$	0.00***	0.00***
	(0.00)	(0.00)
$\gamma(8)$	0.00***	0.00***
	(0.00)	(0.00)
$\gamma(9)$	0.00***	0.01***
	(0.00)	(0.00)
$\gamma(10)$	0.00***	0.01***
	(0.00)	(0.00)
$\gamma(11)$	0.00***	0.01***
	(0.00)	(0.00)
Number of teachers	3,096	3,096
Log likelihood	−1,806.10	−1,806.13

Note: A * signifies statistical significance at the 10 percent level, ** signifies statistical significance at the 5 percent level, and *** signifies statistical significance at the 1 percent level—all for the null hypothesis that the coefficient equals 1.0.

Table 8
Analysis Results for Women Leaving Teaching

	Prentice-Gloeckler Model (Complementary Log-Log)		Prentice-Gloeckler-Meyer Md.(Comp. Log-Log + Heterog.)	
	Hazard Ratio (std. error)		Hazard Ratio (std. error)	
	Model 9	Model 10	Model 11	Model 12
Log relative teaching salary	0.68***	0.66***	0.68***	0.63***
	(0.09)	(0.10)	(0.10)	(0.11)
Teach math or science	1.21*	1.23*	1.26	1.27
in grades 7 to 12	(0.12)	(0.13)	(0.16)	(0.17)
Teach subject other than math	1.29***	1.30***	1.40***	1.42***
or science in grades 7 to 12	(0.08)	(0.08)	(0.13)	(0.15)
Advanced degree	0.98	—	0.94	—
	(0.07)	—	(0.08)	—
Regular certification	0.67***	—	0.63***	—
	(0.06)	—	(0.07)	—
Non-min. share in school rel.	0.72***	0.66***	0.63***	0.55***
to max. share in district	(0.09)	(0.08)	(0.11)	(0.11)
$\gamma(0)$	0.18***	0.15***	0.21***	0.19***
	(0.02)	(0.02)	(0.04)	(0.04)
$\gamma(1)$	0.13***	0.11***	0.18***	0.16***
	(0.02)	(0.01)	(0.05)	(0.05)
$\gamma(2)$	0.11***	0.09***	0.17***	0.14***
	(0.02)	(0.01)	(0.06)	(0.06)
$\gamma(3)$	0.10***	0.08***	0.16***	0.14***
	(0.02)	(0.01)	(0.06)	(0.07)
$\gamma(4)$	0.16***	0.12***	0.28***	0.23***
	(0.02)	(0.02)	(0.12)	(0.14)
$\gamma(5)$	0.13***	0.10***	0.26***	0.22***
	(0.02)	(0.02)	(0.14)	(0.15)
$\gamma(6)$	0.14***	0.11***	0.29***	0.25***
	(0.02)	(0.02)	(0.17)	(0.19)
$\gamma(7)$	0.11***	0.08***	0.26***	0.21***
	(0.02)	(0.02)	(0.17)	(0.19)
$\gamma(8)$	0.07***	0.05***	0.16***	0.13***
	(0.02)	(0.01)	(0.11)	(0.12)
$\gamma(9)$	0.13***	0.09***	0.31***	0.26***
	(0.03)	(0.02)	(0.23)	(0.26)
$\gamma 1(0)$	0.11***	0.08***	0.31***	0.26***
	(0.03)	(0.02)	(0.25)	(0.29)
$\gamma(11)$	0.10***	0.07***	0.28***	0.24***
	(0.03)	(0.02)	(0.25)	(0.28)
$\gamma(12)$	0.14***	0.10***	0.42***	0.37***
	(0.05)	(0.03)	(0.40)	(0.47)

(continued)

Table 8 (Continued)

| | Prentice-Gloeckler Model (Complementary Log-Log) | | Prentice-Gloeckler-Meyer Md.(Comp. Log-Log + Heterog.) | |
| | Hazard Ratio (std. error) | | Hazard Ratio (std. error) | |
	Model 9	Model 10	Model 11	Model 12
γ (13)	0.22***	0.16***	0.77**	0.71
	(0.08)	(0.06)	(0.80)	(1.00)
σ^2	—	—	1.13	1.46
	—	—	(0.90)	(1.34)
Number of teachers	3,100	3,100	3,100	3,100
Log likelihood	–4,049.05	–4,059.47	–4,047.93	–4,058.62

Note: A * signifies statistical significance at the 10 percent level, ** signifies statistical significance at the 5 percent level, and *** signifies statistical significance at the 1 percent level—all for the null hypothesis that the coefficient equals 1.0.

a. For models 10 and 12, this variable is the relative salary of teachers with a master's degree and 10 years of experience.

of nearby districts leads to a 0.74 and 0.70 percent increase in the hazard rates. This elasticity applies to the hazard or quit rate, not the annual quit probability, as defined earlier. (In a later section, we provide simulations for the impact of salary on annual quit probabilities.) The elasticities of the salary ratios for women transferring districts are 0.83 (with certification and advanced degree variables) and 0.82 (without those variables). The similarity of the results for models 1 and 2 in Table 5 for men and models 7 and 8 in Table 7 for women suggests that the inclusion of certification and advanced-degree variables does not lead to biased estimates.

Table 6 (for men) and Table 8 (for women) present our results for leaving teaching. In most cases, we find that the relative salary of teachers has a statistically significant impact on the probabilities that both male and female teachers will leave teaching. In models for men leaving teaching that incorporate unobserved heterogeneity, however, the salary ratio variables are not statistically significant (model 5) or are significant at only the 10 percent level (model 6). The estimated hazard ratios are all less than one, which indicates that relatively higher teachers' salaries or, alternatively, relatively lower nonteaching salaries lead to lower quit rates.

In the Prentice-Gloeckler specification for men (models 3 and 4 in Table 6), the hazard elasticities are –0.44 (with certification and advanced-degree variables) and –0.45 (without those variables and with the alternative salary

variable), which indicate that a 1 percent increase in the relative salary of teachers leads to a decrease of about 0.45 percent in the hazard rate for leaving teaching. The hazard elasticity in the Prentice-Gloeckler-Meyer models for men (models 5 and 6 in Table 6) are –0.35 and –0.66. The first of these estimates is not statistically significant, however, and the second is significant at only the 10 percent level. The hazard elasticities for women are –0.36 and –0.42 in the Prentice-Gloeckler models (models 9 and 10 in Table 8) and –0.38 and –0.47 in the Prentice-Gloeckler-Meyer model (models 11 and 12 in Table 8).

As with the models for changing districts, these results suggest that our two methods for addressing certification and advanced degrees do not lead to substantially different results. Moreover, accounting for unobserved heterogeneity also has a relatively small impact on the estimated hazard elasticities for the salary variable, but it does result in estimates for men that are not statistically significant at conventional levels.

Tables 5 to 8 also present estimated hazard ratios for the categorical variables, teaching math or science in high school, teaching a subject other than math or science in high school, having an advanced degree, and having regular certification. We find that male high school teachers of math or science and male high school teachers of other subjects are not significantly more likely to leave teaching or transfer districts than elementary teachers. In contrast, women teachers of math or science and women teachers of other high school subjects are more likely than elementary teachers to transfer districts and to leave teaching.[35] It appears that women trained to teach high school subjects have more career options than women trained to teach elementary and middle school.

Male teachers with an advanced degree are less likely to leave teaching, but women teachers with an advanced degree are more likely to change districts. These results suggest that a teacher's advanced degree is more closely associated with advancement within teaching than with a broadening of employment opportunities outside teaching. Certification does not have a significant impact on transfers between districts, but both men and women teachers with regular certification are less likely to leave teaching than are teachers with temporary or no certification. These results suggest that certification or advanced degrees contribute to advancement within the teaching profession.

These tables also indicate that relative concentrated disadvantage in a teacher's school does not have an impact on a teacher's decision to transfer districts, but teachers in schools with less concentrated disadvantage are less likely to leave teaching.[36] This result is highly significant in all four models for women in Table 8 but is only significant in model 4 for men in

Table 6 and then at only the 10 percent level. We obtain similar results (not presented) for our alternative measure of student disadvantage based on families receiving welfare.[37] These results suggest that teachers assigned to the schools in their district with the most disadvantaged students are the most likely to leave teaching.[38] This effect is quite large relative to the effect of salary; the result for model 12 in Table 8, for example, implies that for female teachers, a 1 percent decline in the nonminority ratio requires a 1.26 percent increase in salaries to generate the same exit probabilities.[39] As noted earlier, we do not have information on an individual teachers' race or ethnicity, so we cannot determine whether a concentration of disadvantaged students has a larger impact on attrition for teachers in some racial or ethnic groups.

We also estimated several variations on the models in Tables 5, 6, 7, and 8.[40] First, we investigated the possibility whether spousal earnings may affect teacher attrition by including opposite sex nonteaching salaries as an additional variable in the estimation. The opposite sex nonteaching variable was not statistically significant in any specifications, and inclusion of it changed the results for the salary ratio variables only slightly.

Second, to control for unobserved region level information, such as cost of living or the share of teachers who grew up relatively far away from their current schools, we estimated the models with region indicator variables. The inclusion of these indicators does not substantially change the results. The magnitudes of the coefficient estimates on the salary ratio variables are similar, and our conclusions about the statistical significance of these variables do not change. Results for the measure of concentrated student disadvantage are also similar. For women leaving teaching, the coefficient of the concentrated disadvantage variable has a magnitude similar to the one in Table 8 and it is still statistically significant. These findings indicate that our results are not driven by salary variation across regions, teacher labor markets differences, or other unobservable regional-level factors.

Third, to address unobservable time-invariant district characteristics, we included district fixed effects. In these specifications, the salary variable essentially measures within-district, over-time variation in teaching salary ratios. Coefficient estimates of the salary ratio variables in specifications with district fixed effects are generally similar to specifications without district fixed effects, but, as expected, the estimates are less precise. Coefficient estimates of the salary ratio variables continue to be statistically significant, however, for men leaving teaching (without advanced degree and certification variables), women transferring districts, and women leaving teaching. The results for men leaving teaching with the advanced degree and certification

variables included are no longer statistically significant. In addition, inclusion of district fixed effects leads to an insignificant coefficient estimate for the concentrated disadvantage variable in the models of women leaving teaching. Overall, our salary results are not very sensitive to the inclusion of district fixed effects, mitigating concern over the existence of time-invariant district characteristics correlated with salary.

4.3. Simulation

For additional perspective on the extent to which salaries affect teacher's quit behavior, we conducted a simulation based on our estimates. More specifically, we use the results from model 12 in Table 8, which incorporates unobserved heterogeneity and does not include the certification or advanced-degree variables, to determine the effects of changes in the salary of a teacher with a master's degree on the cumulative retention rate of female teachers for the first five years of teaching.[41]

Our procedure consists of two steps. First, we find a representative female teacher and calculate her predicted cumulative retention rates, that is, the probabilities that she has not left teaching at each of the first five years of her teaching career, for values of the majority-ratio variable equal to unity and to 0.1. These values represent extremes. The majority-ratio variable takes on a value of 1.0 for a teacher in a school with the highest share of nonminority students in a district, whereas it takes on a value of 0.1 for a teacher in a school with a nonminority share that is only one-tenth the share in the school with the highest majority concentration. Second, for the case of the very low majority ratio, we calculate the impact on these retention rates of a 20 percent increase in the master's level salary.

The representative teacher taught at the elementary school level in a school district in Erie County, which includes Buffalo. She did not leave teaching for at least five years. The actual values of the master's level salary for these first five years were used to construct the salary ratios; in other words, the simulations use the same values for the salary ratios that were used in the estimation. We calculated predicted cumulative retention rates for the first five years of teaching for each of the two values of the majority ratio—the first step in our simulation procedure. We recalculated the retention rates for the very low value of the majority ratio after increasing the master's level salary by 20 percent.

The simulation, which is summarized in Figure 5, shows that the effect of the level of the majority ratio on teacher retention is relatively large, while the compensating effect of the salary increase is quite small. The conclusion

Figure 5
Survival Rate for Women in Teaching
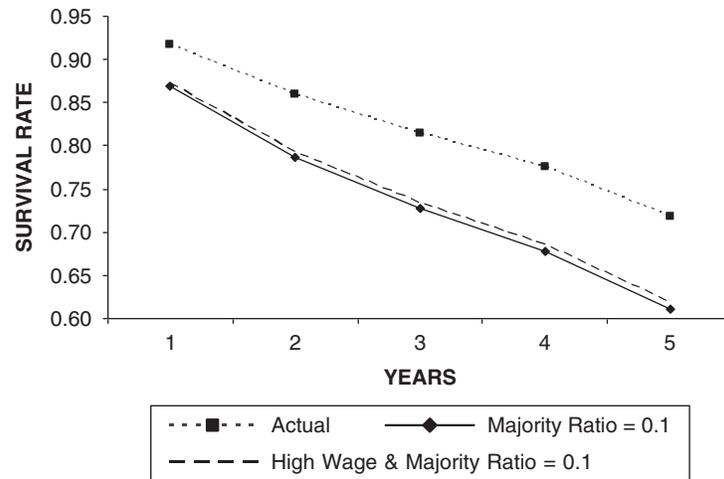
to be drawn is that salary increases well in excess of 20 percent would be needed to increase the retention rates of teachers teaching in schools where 10 percent of the students are nonminority to the retention levels of teachers teaching in schools where all the students are nonminority. At actual salary levels, the five-year predicted retention rate for female teachers teaching in a school with a majority ratio of unity is 71.8 percent, but only 61.0 percent for teachers teaching in a school with a majority ratio of 0.1. A salary increase of 20 percent increases the second percentage to 61.8.

5. Conclusions

This research contributes to the literature by showing that teacher attrition is affected by different salary comparisons under different circumstances. We find that teachers in districts with higher salaries relative to nonteaching salaries are less likely to leave teaching. We also find that a teacher is less likely to transfer to another district if the district in which he or she teaches has high salaries relative to other districts in the same county.

These results are obtained using a proportional hazard model that, unlike most of the previous studies, controls for unobserved heterogeneity. Compared to previous studies, our data set observes a relatively large number of teachers over a relatively long time period and contains most of the important control variables identified by the literature. Nevertheless, this data set does not contain several potentially important control variables, such as a teacher's marital status, race, and ethnicity, and some caution should be exercised in interpreting our results.

We also find that other teacher characteristics, including education level, grade level, subject taught and certification, are related to teachers' transfer and quit decisions in some cases. In addition, we find that women teachers are less likely to leave teaching when they teach in a school with a low concentration of disadvantaged students relative to other schools in the district. Measures of student disadvantage were not significant in other models, however, and more research on this topic clearly is warranted.

Our results indicate that the level of teaching salaries relative to regional nonteaching salaries for college graduates has a significant impact on the probability that teachers will quit teaching. In addition, the teaching salary in one district relative to the teaching salary in surrounding districts has a significant impact on the probability that teachers will transfer out of that district. If other districts respond to one district's salary increases by increasing salaries themselves, however, it may be difficult for a district to move up the teacher salary distribution. Moreover, our simulations indicate that moderately large salary increases will not dramatically alter the rate at which either male or female teachers leave teaching. Because concentrated student disadvantage strongly affects women teachers' decisions to quit teaching, even substantial salary increases would be insufficient to raise retention rates in schools with a high share of disadvantaged students up to the level observed in other schools in the same district. These findings suggest that poor urban districts are unlikely to be able to raise teacher retention in schools with the highest concentrations of disadvantaged students up to the levels in their other schools, let alone raise teacher retention across the board, without additional resources from the state.

Notes

1. This is an average from our data (described below) of teachers of academic subjects who started teaching from 1993 to 1999. Numbers are similar for recent years.

2. Although policy makers believe turnover rates in some districts are too high, research suggests that among recent college graduates, teachers stay in the same occupation longer than individuals in other occupations (Henke and Zahn 2001).

3. See "Quality Counts 2003: To Close the Gap, Quality Counts," *Education Week*, January 9, 2003, http://www.edweek.com/sreports/qc03/templates/article.cfm?slug=17exec.h22.

4. The program was first put in place during the 2000-2001 school year.

5. See "Quality Counts 2003: The Teacher Gap: New York," *Education Week*, January 9, 2003, http://www.edweek.com/sreports/qc03/templates/state.cfm?slug=17qcny.h22. Some mentoring programs seem effective in reducing teacher attrition (National Governors Association Center for Best Practices 2002). Clotfelter et al. (2005) find no impact on teacher retention from a (poorly administered) bonus program in North Carolina.

6. Most studies estimating the effect of teacher experience do not account for possible nonrandom attrition of teachers. If more (or less) effective teachers are more likely to leave teaching, average teacher quality changes by experience level. Rivkin, Hanushek, and Kain (2005) address the possibility of nonrandom teacher attrition and find that first-year teachers perform significantly worse than teachers with more experience, probably because of on-the-job learning.

7. In addition, Rivkin, Hanushek, and Kain (2005) find that the average quality of teachers who quit after one year is similar to that of those who remain.

8. The year 1999 was used to calculate exit states for teachers teaching in 1998 but was otherwise not included.

9. Some districts overlap county lines. In those cases, we use the county that is listed for the district on the New York State Education Department Web site.

10. These pay scales are set by contracts with a teachers' union, so school districts cannot use pay increases to reward effective teachers or teachers in subject areas experiencing shortages unless specific reward policies are negotiated.

11. Specifically, we used three teaching experience variables: total teaching experience, experience in the district, and experience in other public schools. Districts may reward teaching experience in other schools, and teaching experience in other schools may not be equivalent to teaching in the district. Total teaching experience could include teaching in private schools, which may also be rewarded by districts.

12. Our measure of nonteaching wages is similar to the approach used in Loeb and Page (2000). However, they use change in teacher wages and change in nonteacher wages, while we use wage levels. In addition, since we are considering individual teachers' exit decisions, we use individual predicted teacher salaries instead of average teacher salaries. An alternative approach would be to use wages for occupations that are believed to be similar to teaching. Allegretto, Corcoran, and Mishel (2004) identify some occupations that use skills similar to teaching. We prefer aggregate information on college graduates to occupation information since we are focusing on relatively small geographic areas.

13. It would have been ideal to have county earnings data for college graduates on an annual basis. These data do exist in the Outgoing Rotations Groups from the Current Population Survey, but the geographic areas we focus on had extremely small sample sizes, and the data did not appear reliable for our purposes.

14. Stinebrickner (1998, 1999, 2001) finds that marriage and fertility variables are important predictors of length of stay in teaching, and Scafidi, Sjoquist, and Stinebrickner (2003) show that few teachers in Georgia leave for nonteaching jobs.

15. The nonteaching earnings of men and women are highly correlated. It may therefore be difficult to untangle the impacts of same-sex and opposite-sex nonteaching opportunities.

16. Hanushek, Kain, and Rivkin (2004) use this approach in some specifications.

17. In principle, other unobserved teacher characteristics, such as the propensity to stay home with children, could also be a source of bias. To the best of our knowledge, however, no existing research has found a correlation between family characteristics and teacher salaries.

18. In surveys of Pennsylvania and New York State school districts (Strauss et al. 2000; Balter and Duncombe forthcoming), districts report advertising locally, which could reflect either where districts expect to find teachers or the preferences of districts.

19. Some studies have found that attrition patterns differ by teacher's race or ethnicity or that teacher's race/ethnicity is important when interacted with the race/ethnicity of the students in a school (Murnane and Olsen 1989; Hanushek, Kain, and Rivkin 2004). Unfortunately, the PMF does not have information on a teacher's race. We do know the percentage of teachers in different racial and ethnic groups in each school, but the share of minority teachers is highly correlated (correlation = 0.8) with the share of minority students, so we did not include this variable in our analysis.

20. A likelihood ratio test indicates that men and women should be analyzed separately.

21. The PMF also contains information on the number of pupils in each teacher's class. We are not including any measure of class size because of missing data.

22. A method for estimating individual opportunity costs, which our data also do not allow, was used by Dolton and van der Klaauw (1995, 1999), who estimated individual level measures of opportunity cost based on the wages of those who left teaching and teacher characteristics.

23. Details of the data imputation method are available on request. We do not consider these values to be estimated with error, as would be the case for other imputation methods, since we base imputed information not on a model, but on information provided in other years for the same individual. Therefore, we do not adjust coefficient estimates or standard errors.

24. A number of previous studies have found that the racial or ethnic composition of the district or school is related to teacher mobility. See Gritz and Theobald (1996), Hanushek, Kain, and Rivkin (2004), Imazeki (2002), Mont and Rees (1996), Murnane and Olsen (1989, 1990), and Scafidi, Sjoquist, and Stinebrickner (forthcoming).

25. The IMF also has data on the percentage of students eligible for free or reduced price lunches, but those data are only available from 1993 on.

26. This analysis suggests that the impact of student disadvantage may be different for new and experienced teachers. We estimated some models interacting our measures of student disadvantage with duration in teaching spell and found no evidence to support this possibility.

27. Of course, concentrated student disadvantage also varies across schools. A large share of across district variation is captured by school district fixed effects, which are included in some of our estimations. As discussed in note 37, we also estimated several models with alternative measures of student disadvantage.

28. We used nonminority and nonwelfare measures instead of minority and welfare variables, because we did not want to have zeros in the denominator (i.e., often the schools with the fewest minority or welfare students would have zero percent minority or welfare students). As in the case of teacher characteristics, we impute missing student characteristic data for a school year based on observed values of the data in other years for the same school.

29. Transfers to administrative positions are also censored.

30. In other analyses with this data, we also created exit state variables that allowed for one or more year absences from the data. Alternative definitions of the exit state variable did not substantively change the results.

31. Dolton and van der Klaauw (1999) show that salary and other factors affect exits from teaching differently for teachers who exit to the nonteaching sector and teachers who exit to the nonworking state. Stinebrickner (2002) finds that the presence of a newborn child is an important determinant of exit decisions, and Scafidi, Sjoquist, and Stinebrickner (forthcoming) find that the effect of salary varies depending on whether teachers leave the workforce or switch to a nonteaching job.

32. Hazard graphs were created using the hazards calculated with the "ltable, hazard noadjust" command in Stata 9.2. See Stata Corporation (2005).

33. The Prentice-Gloeckler and the Prentice-Gloeckler-Meyer results are estimated using the "pgmhaz8" command developed by Stephen Jenkins. The Prentice-Gloeckler estimates using pgmhaz8 without the "eform" option are equivalent to estimates using the "cloglog" command. See Stata Corporation (2005).

34. We tried many starting values for the log of the gamma variance in pgmhaz8. We also programmed the log-likelihoods in GQopt, where we could use analytic partial derivatives to attempt to maximize the log-likelihood. However, these models still did not converge.

35. The result for women math and science teachers leaving teaching is significant at the 10 percent level in models 9 and 10 but is not significant in models 11 and 12.

36. This result is consistent with Hanushek, Kain, and Rivkin (2004) and Scafidi, Sjoquist, and Stinebrickner (forthcoming), who find that student characteristics are significant predictors of teacher mobility. However, not all studies or all specifications have found these variables significantly related to teacher exit decisions.

37. We also obtain similar results using the percentage of majority or percentage of non-welfare students at the teacher's current school. Specifically, these variables are not statistically significant for men transferring districts or leaving teaching or for women transferring districts, but women are more likely to leave teaching if they teach in schools with more disadvantaged students by either measure. These two measures are highly correlated and we do not obtain sensible results when both are included.

38. An alternative, even more discouraging interpretation is that the teachers least likely to leave teaching select or are assigned to the schools with the least concentrated disadvantage.

39. Our results are roughly consistent with the findings in Hanushek, Kain, and Rivkin (2004), in that a school with 10 percent more black students would have to have 10 percent higher salaries to have the same teacher exit probabilities.

40. The results from these alternative regressions are available from the authors on request.

41. Given the incorrect signs and/or high marginal significance levels of the coefficient estimate for the majority percentage ratio in the male estimations, we did not perform similar simulations for male teachers.

References

Allegretto, Sylvia A., Sean P. Corcoran, and Lawrence Mishel. 2004. *How Does Teacher Pay Compare? Methodological Challenges and Answers*. Washington, D.C.: Economic Policy Institute.

Balter, Dana, and William Duncombe. 2007. Recruiting highly qualified teachers: Do district recruitment practices matter?" *Public Finance Review 36*, 33-62.

Boyd, Donald, Hamilton Lankford, Susanna Loeb, and James Wyckoff. 2005a. The draw of home: How teachers' preferences for proximity disadvantage urban schools. *Journal of Policy Analysis and Management* 24(1): 113-32.

———. 2005b. Explaining the short careers of high achieving teachers in schools with low performing students. *American Economic Review, Articles and Proceedings* 95 (2): 166-71.

Chernoff, Herman. 1954. On the distribution of the likelihood ratio. *Annals of Mathematical Statistics* 25:573-8.

Clotfelter, Charles T., Elizabeth J. Glennie, Helen F. Ladd, and Jacob L. Vigdor. 2007. Teacher bonuses and teacher retention in low-performing schools: Evidence from the North Carolina $1,800 teacher bonus program. *Public Finance Review 36*, 63-87.

Cox, D. R. 1972. Regression models and life-tables. *Journal of the Royal Statistical Society*. Series B (*Methodologica*l) 34 (2): 187-220.

Dolton, Peter, and Wilbert van der Klaauw. 1995. Leaving teaching in the UK: A duration analysis. *The Economic Journal* 105 (429): 431-44.

———. 1999. The turnover of teachers: A competing risks explanation. *The Review of Economics and Statistics* 81 (3): 543-52.

Gritz, R. Mark, and Neil D. Theobald. 1996. The effects of school district spending priorities on length of stay in teaching. *The Journal of Human Resources* 31 (3): 477-512.

Hanushek, Eric A., John F. Kain, and Steven G. Rivkin. 2004. Why public schools lose teachers. *Journal of Human Resources* 39 (2): 326-54.

Hanushek, Eric A., John F. Kain, Daniel M. O'Brian, and Steven G. Rivkin. 2005. The market for teacher quality. National Bureau of Economic Research. Working paper 11154 (February), Cambridge, MA.

Heckman, James, and Burton Singer. 1984. A method for minimizing the impact of distributional assumptions in econometric models for duration data. *Econometrica* 52 (2): 271-320.

Henke, Robin R., and Lisa Zahn. 2001. Attrition of new teachers among recent college graduates: Comparing occupational stability among 1992-93 graduates who taught and those who worked in other occupations. National Center for Education Statistics Report 2001-189. U.S. Department of Education, Washington, D.C.

Ingersoll, Richard. 2002. The teacher shortage: A case of wrong diagnosis and wrong prescription. *National Association of Secondary School Principals Bulletin* 86 (631): 16-31.

Imazeki, Jennifer. 2002. Teacher salaries and teacher attrition: How much is enough?" Unpublished manuscript. San Diego State University, CA.

Lancaster, Tony. 1979. Econometric methods for the duration of unemployment. *Econometrica* 7 (4): 939-56.

Lankford, Hamilton, Susanna Loeb, and James Wyckoff. 2002. Teacher sorting and the plight of urban schools. *Educational Evaluation and Policy Analysis* 24 (1): 37-62.

Loeb, Susanna, and Marianne E. Page. 2000. Examining the link between teacher wages and student outcomes: The importance of alternative labor market opportunities and non-pecuniary variation. *Review of Economics and Statistics* 82 (3): 393-408.

Meyer, Bruce. 1990. Unemployment insurance and unemployment spells. *Econometrica* 58 (4): 757-82.

Mont, Daniel, and Daniel I. Rees. 1996. The influence of classroom characteristics on teacher turnover. *Economic Inquiry* 34 (1): 152-67.

Murnane, Richard J. 1984. Selection and survival in the teacher labor market. *The Review of Economics and Statistics* 66 (3): 513-8.

Murnane, Richard J., and Randall J. Olsen. 1989. The effects of salaries and opportunity costs on duration in teaching: Evidence from Michigan. *The Review of Economics and Statistics* 71 (2): 347-52.

———. 1990. The effects of salaries and opportunity costs on length of stay in teaching: Evidence from North Carolina. *The Journal of Human Resources* 25(1): 106-24.

Murnane, Richard J., Judith D. Singer, and John B. Willett. 1989. The influences of salaries and "opportunity costs" on teachers' career choices: Evidence from North Carolina. *Harvard Educational Review* 59 (3): 325-46.

National Governors Association Center for Best Practices. 2002. Issue Brief: Mentoring and Supporting New Teachers, January 9. Available at http://www.nga.org/Files/pdf/010902NEWTEACH.pdf (accessed on November 13, 2006).

Prentice, Ross L., and Lynn A. Gloeckler. 1978. Regression analysis of grouped survival data with application to breast cancer data. *Biometrics* 34 (1): 57-67.

Rivkin, Steven G., Eric A. Hanushek, and John F. Kain. 2005. Teachers, schools, and academic achievement. *Econometrica* 73 (2): 417-58.

Scafidi, Benjamin, David L. Sjoquist, and Todd R. Stinebrickner. 2003. Do teachers really leave for higher paying jobs in alternative occupations? Working paper. Georgia State University, Atlanta.

Scafidi, Benjamin, David L. Sjoquist, and Todd R. Stinebrickner. Forthcoming. The impact of wages and school characteristics on teacher mobility and retention. *Economics of Education Review*.

Stata Corporation. 2005. *Stata user's guide*, release 9. College Station, TX: Stata Press.

Stinebrickner, Todd R. 1998. An empirical investigation of teacher attrition. *Economics of Education Review* 17 (2): 127-36.

———. 1999. Estimation of a duration model in the presence of missing data. *The Review of Economics and Statistics* 81 (3): 529-42.

———. 2001. Compensation policies and teacher decisions. *International Economic Review* 42(3): 751-79.

———. 2002. An analysis of occupational change and departure from the labor force. *The Journal of Human Resources* 37 (1): 192-216.

Strauss, Robert P., Lori Bowes, Mindy Marks, and Mark Plesko. 2000. Improving teacher preparation and selection: Lessons from the Pennsylvania experience. *Economics of Education Review* 19 (July): 387-415.

Texas Center for Educational Research. 2000. The cost of teacher turnover. Report prepared for the Texas State Board for Educator Certification.

Theobald, Neil D. 1990. An examination of the influence of personal, professional, and school district characteristics on public school teacher retention. *Economics of Education Review* 9 (3): 241-250.

Theobald, Neil D., and R. Mark Gritz. 1996. The effects of school district spending priorities on the exit paths of beginning teachers leaving the district. *Economics of Education Review* 15 (1): 11-22.

Jan Ondrich is a professor of economics at the Maxwell School of Citizenship and Public Affairs, Syracuse University, New York.

Emily Pas is a graduate assistant in economics at the Maxwell School of Citizenship and Public Affairs, Syracuse University, New York.

John Yinger is a professor of economics and public administration at the Maxwell School of Citizenship and Public Affairs, Syracuse University, New York.