(IPR) 11022/March 2004
Final Version

Relative Pay and Teacher Retention: An Empirical Analysis in a Large Urban District

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Approved for distribution: March 2004

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This document was prepared under Grant Number REC-0107014 for the National Science Foundation. This document represents the best opinion of The CNA Corporation at the time of issue. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the National Science Foundation or the district that provided data for this study.

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Summary

Evidence suggests that compensation affects teacher retention. In general, studies have concluded that higher teacher pay increases the likelihood that a person will continue to teach. Similarly, attractive earnings opportunities outside teaching encourage people to leave the teaching profession. While these findings are intuitive, researchers have used a variety of approaches when measuring compensation, and only a few include measures of expected future earnings.

In this paper, we make use of the Annualized Cost of Leaving (ACOL) model, a framework developed by military manpower analysts, to estimate the effect of current and future relative earnings on teacher retention. While the ACOL model is used and widely accepted by all branches of the military to analyze manpower issues, it has been used in only a few applications outside the military. To our knowledge, this paper is the first to apply it to an analysis of teacher retention, and the first to model the effect of teachers' future earnings opportunities in a theoretically defensible fashion.

Data

For each school year from 1990-91 to 2000-01, we have complete personnel records for everyone employed by a large urban public school district. We combine these records with data from state and federal sources to construct measures of expected earnings and working conditions faced by teachers in the district. For teachers' earnings, we use pay tables contained in contracts between the district and the teachers union. For estimates of expected earnings in competing professions, we use the National Science Foundation's 1993 College Grads Survey and the March Current Population Surveys for 1990 through 2001. Finally, to account for the role of working conditions on teachers' decisions to stay or leave teaching, we include information on the condition of schools in which teachers work contained in the

Common Core of Data (CCD) and, for a subset of years, a data set of school attributes maintained by the state. Our analysis focuses on secondary school teachers at salary steps 10 and below; the sample includes 24,682 observations on 6,429 teachers who taught in the district over the period.

Findings

A simple regression of teacher's relative earnings on turnover would verify the strong correlation between these two factors over the timeframe of our study. But multivariate analysis reveals that much of the change in turnover can be explained by changes in the characteristics of teachers over the period. Controlling for these other factors, we find that teachers do respond to changes in pay, but the effect is small. For school years (SYs) 1991-2001, a 1-percent increase in pay is associated with a 0.7-percent decline in turnover. To give an example, turnover averaged 9.3 percent in SY 2001. If the district were to raise the *entire pay table* by 10 percent, turnover would be predicted to decline by 7 percent, or about 6-tenths of a point, to 8.7-percent. Disaggregating the data by teaching area suggests that math teachers, and possibly science teachers, are more sensitive to changes in pay than other secondary school teachers.

All else equal, teachers who have an undergraduate major in an education-related field have turnover rates that are a full point lower than those of other teachers; turnover is higher for teachers with Master's degrees; turnover is 1 to 3 points lower for teachers who earned their undergraduate degree from 3 universities within the state. Finally, working conditions had no impact on retention rates. This finding is counter to those of other researchers who report that working conditions are more important than pay in the stay-leave decisions made by teachers (Hanushek, Kain, and Rivkin, 1999), and may be explained by personnel policies that allow teachers to move among schools in this large and diverse district.

After controlling for observable school and teacher characteristics, there are still statistically significant differences in turnover from one year to the next that we cannot explain with our data. Factors that may help account for these differences include fluctuations in unemployment rates, making it easier in some years to obtain alternative employment, and possibly, changes in work environment associated with across-the-board policy changes that affect teachers.

Conclusions

Detailed records for personnel and students, like those examined here, provide an opportunity to carefully examine various aspects of school systems. Such examinations can give visibility to problems, and can point the way to possible solutions.

Our analysis of teacher retention reveals that turnover in this district has increased substantially over the last decade, and has been consistently higher for science teachers than for others. Turnover for the least experienced teachers is also substantially higher than that of their more experienced counterparts.

The increase in turnover in recent years has been accompanied by a decline in average years of teaching experience, and a decline in the share of teachers with Master's degrees. These findings raise questions about the impact of the rise in turnover on the quality of the instructional workforce.

Our empirical analysis shows that, while pay matters, the effect of changes in compensation on teacher retention is small. With retention rates over 90 percent, an across-the-board increase in compensation is an inefficient way to raise retention even further, since much of the additional compensation would go to teachers who would stay in the school district even without the pay raise. A more cost-effective approach would be to target a pay increase to teachers most likely to be "at risk" of leaving the school district. If compensation is targeted to a smaller group of people, the same increase in retention could be achieved at substantially lower cost.

In addition to pay adjustments, our analysis suggests that other factors could be leveraged to influence turnover. Candidates worthy of further analysis include programs to attract students from selected colleges into teaching, induction and mentoring programs, and opportunities for policy changes that could improve job satisfaction. Finally, the impact on student outcomes of teacher attributes, which have changed markedly over the period, should be examined.

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Introduction[1]

School districts often report difficulties retaining teachers in several critical fields, including science and mathematics. Such shortages are expected to become more severe due to retirements by an aging workforce and public pressure to reduce class sizes. These problems are typically more acute for urban school districts, since teachers in these schools are more likely to leave the teaching profession.

While a large body of literature demonstrates that job attributes and working conditions affect teacher turnover, these conditions are probably not responsible for disproportionate attrition in science and mathematics. Within a school district, these teachers typically face a work environment similar to other secondary school teachers. A more plausible explanation, then, is that math and science teachers have higher earnings opportunities outside the teaching profession than their colleagues do.

Many researchers have estimated the effect of relative earnings opportunities on teacher retention. However, these studies use several disparate measures of compensation, and only a few include measures of expected future earnings. Consequently, most of these models are limited in the number of alternative compensation options that can be examined.

1. We are grateful to the National Science Foundation for providing funding for this research under grant number REC-0107014. We thank the district Director of Personnel Wages and Salaries for preparation of personnel data. We also thank Dan Burke and Matt Goldberg for their comments, insights, and suggestions and Marc Laitin, Robert Shuford, and Katrine Wills for their efforts in preparing the data for our analysis. The views expressed herein are solely those of the authors. Any remaining errors are our own.

This paper uses data from a large urban school district to examine the determinants of teacher retention and to assess whether differences in earnings opportunities can explain attrition of math and science teachers. Furthermore, we make use of the Annualized Cost of Leaving (ACOL) model, a framework developed by military manpower analysts, to estimate the effect of both current and future relative earnings on teacher retention. To our knowledge, this paper is the first to model the effect of teachers' future earnings opportunities in a theoretically defensible fashion.

Compensation, working conditions, and teacher retention

Evidence suggests that compensation affects teacher retention. In general, several studies have concluded that higher teacher pay increases the likelihood that a person will continue to teach, while higher opportunities outside teaching cause people to leave the teaching profession.[2] Although these findings are intuitive, researchers have used a variety of approaches when measuring compensation.

Most of the literature uses a person's current salary as a measure of teacher compensation; however, researchers have used the earnings of a number of different populations to estimate alternative earnings opportunities. Examples include women with at least a college degree working full time (Loeb and Page, 2000), all college graduates (Flyer and Rosen, 1994), and earnings of those who have actually left the teaching profession (Rickman and Parker, 1990). In addition, Murnane and Olsen (1989) use the average starting salary paid by field, while Hanushek and Rivkin (1997) simply include the proportion of non-teachers that earn less than teachers. Most of these measures have a statistically significant effect (of varying magnitude) on teacher's retention.

Only a few researchers have attempted to include measures of expected future earnings in measures of relative compensation. Specifically, Brewer (1996) models the probability that a teacher will eventually become an administrator; Hosken (1996) and Imazeki (2002) model expected wage growth based on current pay tables.[3]

2. For example, see Murnane and Olsen (1989), Rickman and Parker (1990), Gill and Southwick (1992), Gritz and Theobold (1996), Hanushek, Kain and Rivkin (1999), and Loeb and Page (2000).

3. However, the authors only include contemporaneous wages and unemployment rates as proxies for non-teaching earnings opportunities.

Each of these studies finds that expected future compensation affects teacher retention.

There is also a great deal of evidence that working conditions have a large effect on teachers' retention. Several disparate measures of school or community characteristics have been used as proxies for teachers' working conditions. Examples include growth in enrollment, spending on special and vocational education, average student achievement scores, percentage of students from low-income families or who are racial or ethnic minorities, average property values, unemployment rates, median incomes, and the percentage of residents who are immigrants.[4] In general, these factors have a significant effect on teacher retention.

Rather than measure specific characteristics and estimate each factor's effect on retention, others have used school-level fixed effects models to control for working conditions. In general, this increases the degree to which researchers are able to explain differences in teacher salaries. This finding is consistent with the importance of working conditions and suggests that, to some extent, schools offer higher wages as a "compensating differential" to make up for unpleasant working conditions (see Murnane and Olsen, 1989 and Loeb and Page, 2000).

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4. See, for example, Hosken (1996), Hanushek, Kain and Rivkin (1999), and Gritz and Theobold (1996).

Annualized Cost of Leaving (ACOL) framework

For the majority of our analysis, we use the Annualized Cost of Leaving (ACOL) model.[5] This framework was originally developed by Warner (1978) for the President's Commission on Military Compensation as a tool to help analyze reforms to the military retirement system. More recently, the ACOL model has been used to quantify the relationship between changes in enlisted compensation and changes in the reenlistment behavior of enlisted personnel.[6] Today, the ACOL model is used and widely accepted by all branches of the military to analyze manpower issues.

The earliest studies of the relationship between compensation and reenlistment typically used *ad hoc* models to quantify the importance of compensation in a person's decision-making process. These specifications were generally not rigorously linked to a utility-maximizing framework. Furthermore, while researchers suspected that future compensation affected reenlistment decisions, there was little guidance on how expectations of future earnings should be modeled.

The advent of the ACOL model solved several of these problems. ACOL possesses two advantages over previous models used to study compensation and retention behavior. First, the ACOL model is built on the assumption that a person combines all elements of compensation into a single measure of remuneration and compares it to alternative earnings opportunities when making retention decisions. Thus, the model can be used to examine the effect of any policy that can be expressed in financial terms (e.g., across-the-board pay raises, salary increases at specific career milestones, bonuses, adjustments to

5. See Goldberg (2001) for an extensive discussion of the ACOL model.

6. Seminal papers demonstrating the usefulness of the ACOL model include Enns, Nelson and Warner (1984) and Warner and Goldberg (1984).

the retirement system). Second, in comparing the value of relative compensation over time, the ACOL framework reveals the time horizon over which these relative earnings should be evaluated. The ACOL model has proved to be a reliable forecasting tool and is both more flexible and more appealing than simpler, *ad hoc* specifications (Hansen and Wenger, 2002).

Though the ACOL framework was designed to examine retention of enlisted personnel, its application to the analysis of teacher retention is straightforward. Furthermore, the literature on retention decisions of teachers relies on several of the *ad hoc* models that the ACOL model was designed to improve.[7] In the next section, then, we formally describe this theoretical framework and discuss its application to the labor market for teachers.

Theory

Formally, the ACOL model presumes that someone with t years of teaching experience has two choices: remain as a teacher for an additional y years or separate from the teaching profession immediately. The person will remain as a teacher as long as

$$\sum_{i=t+1}^{t+y} T_i * (1+r)^{t-i} > \sum_{i=t+1}^{t+y} (N_i + \tau) * (1+r)^{t-i}, \qquad (1)$$

where T_i is expected teacher compensation at i years of experience, N_i is expected non-teaching compensation for the same year, r is the real discount rate, and τ represents the person's relative "taste" for non-teaching versus teaching employment. Equation (1) can be rewritten to define the ACOL variable at y years of experience:

$$ACOL_y \equiv \frac{\sum_{i=t+1}^{t+y} (T_i - N_i) * (1+r)^{t-i}}{\sum_{i=t+1}^{t+y} (1+r)^{t-i}} > \tau . \qquad (2)$$

7. The use of the ACOL methodology in a non-military context is not without precedent (e.g., Stock and Wise, 1990).

Finally, the ACOL framework suggests that a person will remain as a teacher if there is at least one time horizon over which equation 2 is satisfied. In other words, a person will choose to remain as a teacher if the cost of leaving the teaching profession is greater than the relative taste for non-teaching, or if

$$\max_{y}\{ACOL_y\} > \tau . \quad (3)$$

This result is powerful, since it implies that earnings streams beyond the horizon that maximizes equation 3 need not be considered in a model of teacher retention.[8]

Estimation

While the theory is straightforward, several empirical decisions are necessary to estimate an ACOL model. In this section, we focus on two major categories that are particularly relevant to a model of teacher retention: modeling compensation and modeling relative preference for the teaching profession.

Modeling teacher pay

Calculating expected teacher compensation is relatively straightforward. Teacher salaries follow a well-defined progression according to a pay schedule negotiated by the school district and the teachers' union. These salaries are delineated by "steps," corresponding to a year of teaching experience within the school district. For every year a teacher remains with the district, his or her salary increases to the next step. For all of its disadvantages, the pay table does offer teachers an objective benchmark by which to measure expected future compensation.

8. The ACOL model is conceptually equivalent to a stay-leave decision model that compares the present value of relative earnings in teaching with a person's next best alternative. In traditional models, the time horizon over which this present value is calculated is fixed for everyone at some assumed endpoint (e.g., 30 years of service). In contrast, ACOL models yield the time horizon over which the present value is calculated; the length of this time horizon is teacher-specific.

Of course, annual salary increases for teachers are not identical to the increase mandated by the pay schedule. New contracts (and, with them, new pay tables) are negotiated every year by the district and the union. Given the frequent negotiations of new pay tables, teachers likely anticipate that future compensation will differ from that implied by the existing pay table. Without an objective methodology with which to model individual expectations, however, we use the pay table at the time of the retention decision to construct expected future compensation.

There are three additional sources of compensation for teachers. First, pay increases with educational attainment. In the present school district this amount does not vary by step or years of teaching experience, but merely by educational degree.[9] To calculate expected future teacher compensation, we must estimate the probability that a teacher eventually acquires a Master's or degree or Ph.D. Second, teachers receive additional compensation for performing duties in addition to their teaching schedule (e.g., basketball coach, driver's training instructor). Since these additional duties are voluntary, reflect a person's relative preference for teaching, and, in principle, are opportunities available to all teachers, we do *not* include this additional compensation in our measure of expected future teacher pay.

Finally, teachers who have passed certain career milestones qualify for retirement benefits. For the time period over which we have data, all teachers were covered under the state's retirement system. After 10 years of service, teachers are vested and eligible to draw full retirement benefits after 30 years of service, or at age 62 if they leave teaching before 30 years of service. Teachers are not required to make contributions to fund their accounts; upon retirement, a teacher's benefit is defined by a function of years of service and an average of one's five highest years of compensation. When calculating the value of future compensation (both as a teacher and outside the teaching profession) at the time of the retention decision, we use a discount

9. Furthermore, these amounts have not changed over the time period on which we focus. Over this time period, then, inflation-adjusted pay differentials by educational attainment have fallen.

rate of 10 percent. This is consistent with the discount rate estimated by Gilman (1976), whose estimates are based on employees' participation in employer-sponsored retirement plans. Note that the size of the discount rate does not matter when examining the effect of across-the-board increases in compensation; it is only a relevant parameter when evaluating targeted increases in pay.

Modeling non-teacher pay

Alternatives to teaching

For teachers who leave the school district, expected compensation is much more complicated and uncertain. Teachers who leave the school district in which they are currently employed fall into one of four categories: employment in another school district, employment in a non-teaching occupation, retirement, or departure from the labor force. In general, it is not possible to know which options teachers are considering when making retention decisions.[10]

Ingersoll (2000) examines teacher turnover and reports that a substantial number of teachers who leave their current positions pursue each of these various options. Using data from the Teacher Follow-up Survey (TFS) of the Schools and Staffing Survey (SASS), a nationally representative data set, he finds that 7 percent of all teachers take a position in another school district, and an additional 7 percent leave the teaching profession entirely. Of those who leave teaching, approximately 25 percent retire and more than 40 percent report leaving for "family or personal reasons."

Our model of teacher retention assumes that the only alternative to teaching is employment in a non-teaching occupation.[11] In other

10. In principle, one could identify what teachers do if they leave the school district. However, this does not imply that this outcome was the only one under consideration for that particular person. There is no way to identify the options being evaluated by teachers who choose not to leave.

11. Technically, we consider retirement as an option. However, we model this as pursuing non-teaching employment for zero years; in other words, retirement is a special case of employment in a non-teaching occupation.

words, we assume that everyone who leaves the district leaves the teaching profession altogether. Furthermore, despite the well-documented prevalence of separations due to family or personal reasons, we do *not* separately model the probability of leaving the labor force and the probability of pursuing alternative employment.

Since we are interested in the extent to which alternative earnings opportunities affect teacher retention, this directly affects our conclusions. If teachers who consider leaving the labor force are less responsive to changes in compensation than other teachers, including these people in our sample will bias our estimate of the relationship between relative pay and retention downward.[12] Our assumption that teachers who leave the district do not do so to take another teaching job may be more innocuous, because pay scales exceed those of surrounding districts.

Employment opportunities outside teaching

We also require data on the types of occupations in which teachers expect to find employment if they leave the teaching profession. Ideally, we would like data on people who actually leave the teaching profession. It seems reasonable to assume that the occupations teachers enter are roughly comparable to the types of occupations that teachers consider when making their retention decisions.

The National Center for Education Statistics collects data on teachers who leave the profession through the Teacher Followup Surveys. Unfortunately, the sample sizes are too small to measure these occupation distributions with any precision. Only 300 to 400 respondents indicate the occupation in which they work after leaving the teaching profession; disaggregating by subject taught, gender, or type of school reduces sample sizes further. Consequently, we are forced to pursue an alternative way of calculating these distributions.

We make use of the 1993 College Grads Survey, a public database of the National Science Foundation.[13] These data contain employment

12. Intuitively, our estimate can be thought of as a weighted average of the effect of pay for teachers considering non-teaching jobs and for teachers considering leaving the labor force.

and demographic characteristics of a sample of people who reported holding a Bachelor's degree during the 1990 Census. Using these data, we are able to calculate the distribution of graduates across occupations; we estimate these separately by college major (math and related areas, science and related areas, and other majors), gender, and by age.[14] This approach allows us to assess the degree to which math and science majors follow different career paths than other graduates.[15]

To calculate these distributions, we focus on all non-teaching occupations (but including postsecondary education) and aggregate the remaining careers into similar groups of occupations. For each college major/gender/age combination, we can estimate the proportion of each group that is in each occupational category. In estimating non-teaching pay, we assume that those who leave teaching enter each occupational category with a probability equal to the proportion of people (of similar gender/age/college major) currently in these occupations. Although this assumption is tenuous, it allows us to estimate separate earnings profiles by subject taught, and is likely to be a fairly accurate representation of the earnings differentials of math, science, and other teachers.

Finally, we combine these data with the March Current Population Surveys (CPS) to estimate non-teaching earnings opportunities for current teachers. Using these data, we estimate log earnings regressions separately for men and women, controlling for race, ethnicity, region, educational attainment, occupational category, and experi-

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13. These data are part of the Scientists and Engineers Statistical Data System, and can be accessed via the internet at *http://srsstats.sbe.nsf.gov/*.

14. These data are available for age groups (25- to 29-year-olds, 30- to 34-year-olds, etc.).

15. We classify all science and life science majors as "science," as well as those fields of engineering that relate to a field of science (i.e., biomedical engineering, environmental engineering). We classify theoretical and applied math majors, as well as computer science/programming, data processing, actuarial science, and most non-science fields of engineering as "math." All other fields are classified as "other."

ence.[16] The estimated coefficients allow us to predict expected current and future non-teaching earnings for each person.

Modeling relative preference for teaching

Finally, selecting appropriate proxies for "taste for teaching" is critical to the estimation of an ACOL model. In our model, we include several variables that reflect both a relative preference for teaching and different earnings opportunities in non-teaching labor markets (e.g., race/ethnicity). We also identify a few variables that are reasonable proxies of taste for teaching and do not substantively affect outside earnings opportunities. These include having a Bachelor's degree in an education-specific field, performance of additional non-teaching responsibilities within the school, and, when possible, characteristics of the school where a person is employed.

16. We estimate these regressions separately for each year and for men and women. The relationships between our explanatory variables and earnings are consistent with well-known patterns in U.S. labor markets. Complete regression results are available upon request.

Data

Most of our data come from the Office of Wage and Salary Administration in the school district. For each school year from 1990-91 to 2000-01, we have complete personnel records for everyone employed by this district. For teachers, these data include demographic information (e.g., gender, race/ethnicity, age), educational attainment (e.g., degrees earned, major/specialty, college/university), teacher certification, pay step, and detailed information about the teaching environment (e.g., name of school, subject taught, paid supplemental duties).

Using these data, we are able to measure teacher retention from one year to the next. Specifically, a teacher separates from the district in school year t if he or she is not teaching in the district in school year $t+1$. Note that this is a measure of district and not school retention; if a person moves from one school to another within the district, he or she does not separate from the school district. Similarly, this is a measure of teacher and not individual retention; if a teacher moves into a non-teaching position (e.g., administrative position), we consider this person to have "left teaching in this district."

For 1996-97 to 2000-01, we also have information from a database of school attributes maintained by the state. These data contain several indicators of school performance and environment, such as school size, average class size, per-pupil expenditures, test scores, absences, and crime rates. This information provides a more complete picture of the environment in which a person teaches and the extent to which this environment affects one's decision to remain a teacher in the school district. As an extension of our analysis, then, we estimate our model of teacher retention with these additional data for the subset of years for which we have this information.

Finally, we make use of the National Center for Education Statistics' Common Core of Data (CCD) to provide additional evidence on the relationship between the teaching environment and retention. The CCD is a national database that contains information on all public schools and school districts each year. Specifically, these data provide school level information on student enrollments by race and ethnicity, eligibility for free or reduced-price lunch and Title 1 programs, counts of full-time equivalent faculty, and indicators for charter and alternative schools.

Although the CCD are not as complete as the state's database, they are available for the full time horizon of our study. Therefore, we use these data to obtain information on the ethnic and racial mix of students within a teacher's school, as well as free lunch program eligibility rates. As an extension of our analysis, we include these school characteristics as determinants of teacher retention.

Teacher turnover

To better understand the relationship between experience and retention, figure 1 displays turnover rates of secondary school teachers by salary step in 1999-00.[17] While 5.8 percent of all teachers left the district before the next school year, figure 1 reveals significant variation in turnover by salary step. Turnover is relatively high for inexperienced teachers (e.g., those at salary step 5 or less); after salary step 10, turnover is relatively low until the point at which teachers begin to consider retirement.

Although estimates vary widely, the turnover rate for the school district is similar to overall turnover rates within the profession. For example, Ingersoll (2000) reports average turnover rates of about 13 to 15 percent per year, but notes that about half of this is due to teachers changing schools. Furthermore, the highest turnover rates are associated with the most inexperienced teachers; for example, Darling-Hammond (1999) indicates that nearly one-third of all new teachers leave the profession within 5 years.

17. Differences in turnover rates by salary step are similar in other school years.

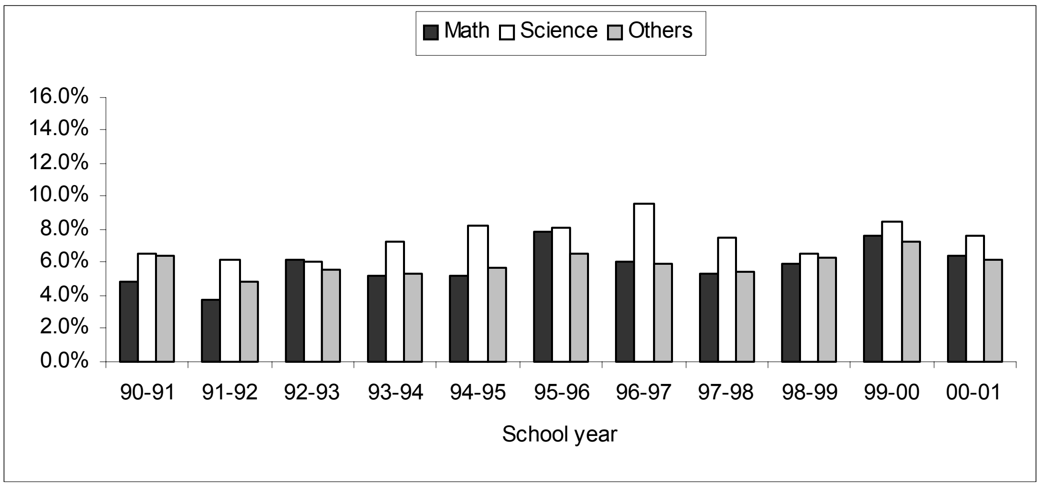
Figure 1. Turnover rates of secondary school teachers by salary step--1999-00

Figure 2 displays turnover rates of secondary school teachers from 1990-91 to 2000-01, calculated separately for math, science, and all other teachers. For each year, we measure average teacher turnover, without disaggregating by salary step. As figure 2 demonstrates, science teachers are more likely to leave the district than math teachers and other secondary school teachers in most years for which we have data. Science teacher turnover ranged from a low of 6.1 percent in 1992-93 to a high of 9.5 percent in 1996-97. In contrast, turnover for math and other secondary school teachers *averaged* 6 percent over the time period for which we have data.

Figure 2 does not provide strong evidence that math teacher turnover is appreciably higher than that of other secondary school teachers. With the exception of the 1995-96 school year, math teacher retention was only slightly different from that of other teachers. Over the last two years, however, math teacher turnover was above that of other secondary school teachers.

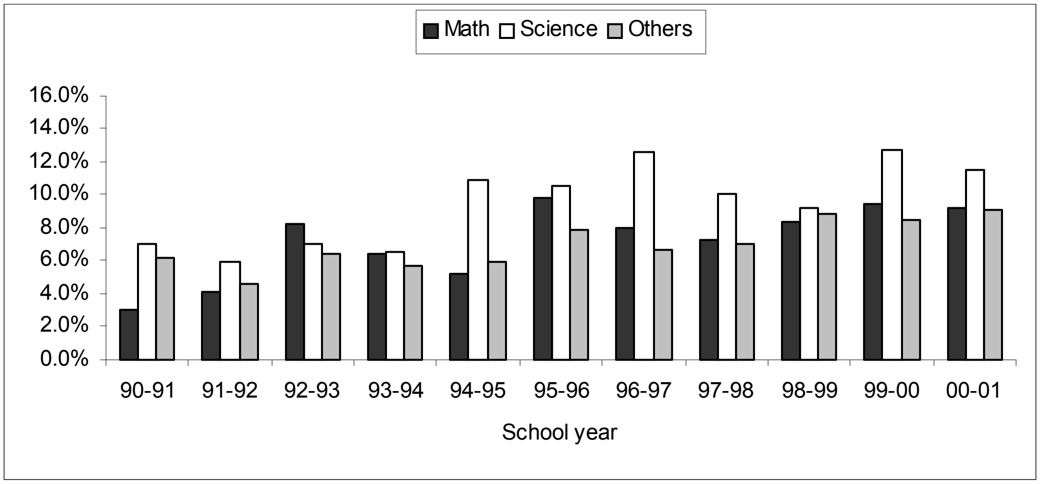
The data in figure 2 include all separations from the district, including those who leave teaching to retire. It is possible that differences in retirement rates are masking differences in the proportion of teachers who leave for non-teaching professions. Figure 3, then, displays turnover rates of secondary school teachers at salary steps 10 or below.

Figure 2. Turnover rates of secondary school teachers, 1990-91 to 2000-01



Focusing on teachers in salary steps 10 and below reveals an upward trend in turnover. In 1990-1991, for example, turnover rates averaged about 6.1 percent. Rates hovered around 6 percent through 1994-1995. Over the next 3 years, the average rate exceeded 7 percent. In the last 3 years, turnover rates were closer to 9 percent. As figure 3 shows, the differences in turnover rates for math, science, and all other secondary school teachers at these salary steps are similar to those in figure 2. Science teachers still have relatively high attrition, whereas math teachers appear more similar to other secondary school teachers. Therefore, it appears that differences in retirement rates are not responsible for the different turnover rates by subject taught.

Figure 3. Turnover rates of secondary school teachers at salary step 10 or below, 1990-91 to 2000-01



Teacher mobility within the school district

School-to-school transitions

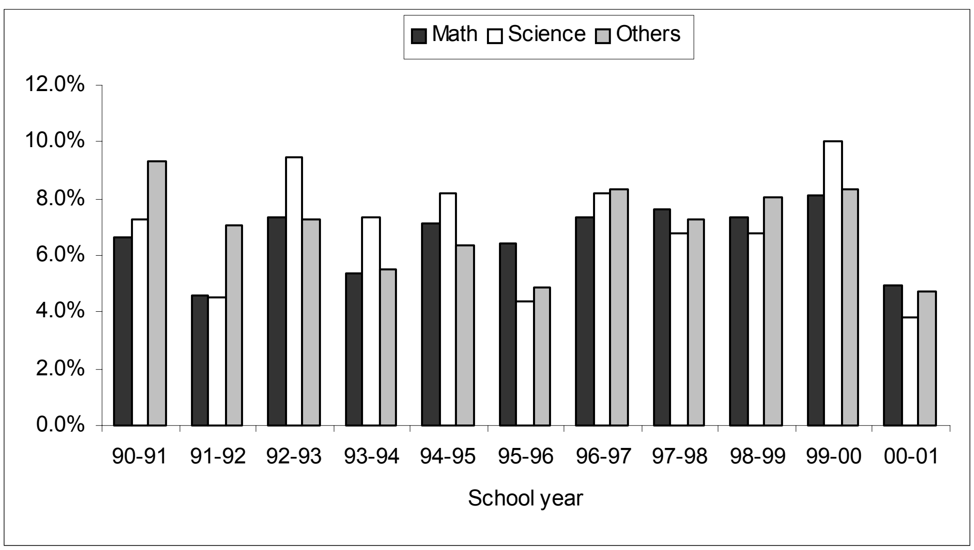
Teacher attrition from schools within the district is actually higher than figures 1 through 3 indicate. Many teachers remain with the school district, but move from one school within the district to another. From the school's perspective, these teachers must be replaced and therefore represent a "loss" to the school. To the extent that teachers systematically leave one group of schools for another, the data in figures 1 through 3 do not accurately represent the attrition problems that may exist within the school district.[18] Furthermore, the policy implications differ depending on whether one considers attrition from the perspective of the school or of the school district.

Figure 4 presents, by school year, the proportion of teachers that do not leave the district but do switch schools the following year. Over

18. Conversely, it is difficult to construct a hypothesis as to why math and science teachers might leave certain schools disproportionately.

the 1990-91 to 2000-01 time period, about 7 percent of secondary school teachers switch schools from one year to the next. There does not appear to be any trend in these data or consistent differential between math, science, or other teachers. However, a comparison with figure 2 reveals that, in some school years, the amount of turnover *within* the school district exceeds the amount of turnover *from* the district. This relatively high turnover presents staffing challenges for individual schools, even when turnover from the district is relatively low. Although these intra-district moves are clearly important, we postpone analysis of their causes and impact on student outcomes to subsequent research.

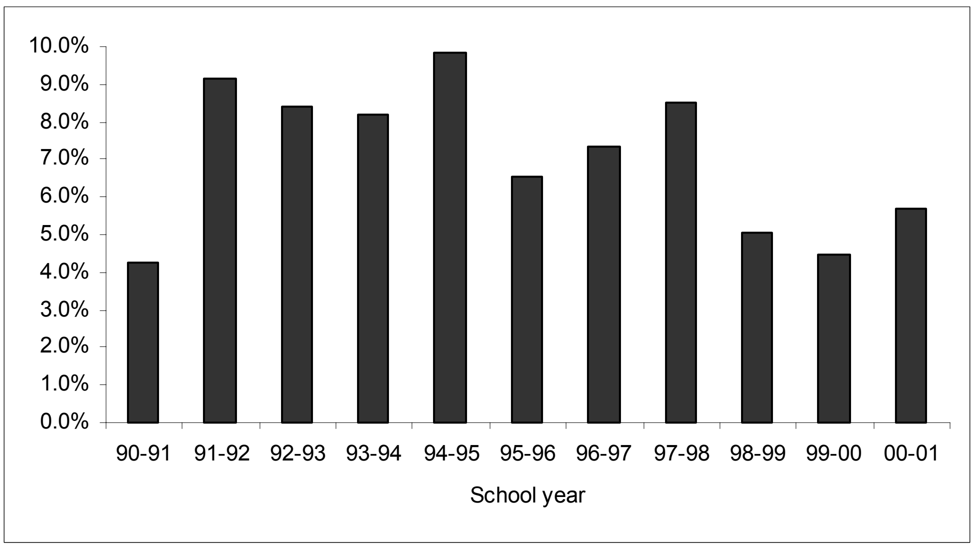
Figure 4. Percentage of remaining secondary school teachers that switch schools, 1990-91 to 2000-01



Teacher-to-administrator transitions

As figure 5 demonstrates, some of the attrition in figures 1 through 3 represents teachers who leave the teaching profession but remain in the school district. Figure 5 shows, of the teachers who no longer teach in the school district, the proportion who move into administrative positions. Given relatively small sample sizes, these data are not presented separately by subject taught. Each year, about 7 percent of all teachers who leave do so for administrative positions within the district. With an average turnover rate of about 6 percent, this corresponds to 0.4 percent of all teachers leaving each year to become administrators in the school district.

Figure 5. Proportion of leavers who become administrators, 1990-91 to 2000-01



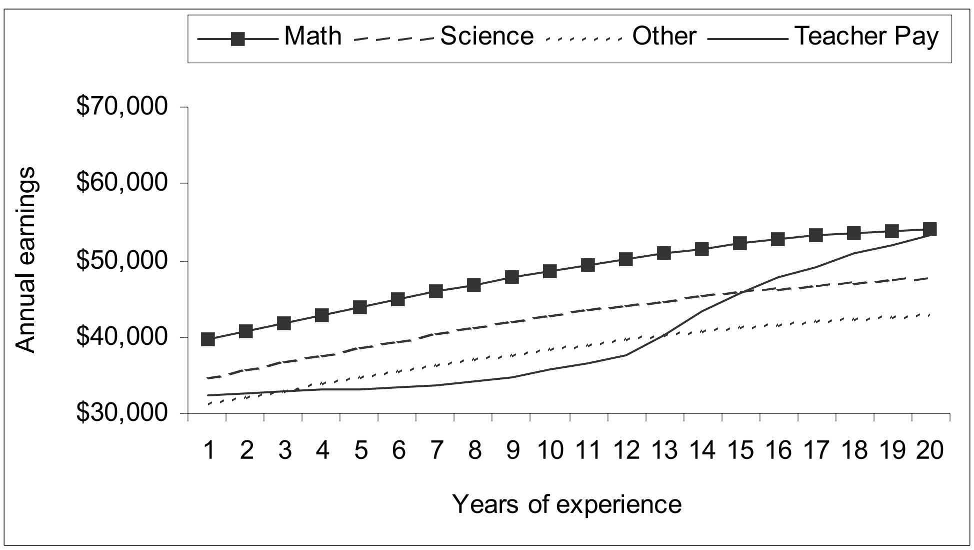
Given the relatively small number of teachers who move into administrative positions, we do not distinguish these types of separations in our model of teacher retention. As Brewer (1996) notes, however, the likelihood of moving into administration is undoubtedly above average for some teachers. Nevertheless, it is unlikely that modeling this facet of the teacher decisionmaking process would substantively affect our results.[19]

19. Brewer (1996) estimates that, in New York State, 1.4 percent of male and 0.7 percent of female teachers moved into administrative positions within the 1978-79 school year.

Teachers' relative compensation

Figure 6 displays our estimates of predicted earnings in 2001 for female teachers. For simplicity, expected earnings in non-teaching professions are calculated for a white (non-Hispanic) woman with a Bachelor's degree who has just begun her teaching career. Expected earnings in non-teaching occupation are calculated separately for math teachers, science teachers, and those teaching all other subjects. For comparison, expected teacher compensation is also displayed (these earnings do not vary by subject taught).

Figure 6. Comparison of earnings of female teachers in 2001 with expected earnings outside the field of teaching



As figure 6 demonstrates, there is a great deal of variation in non-teaching earnings opportunities, depending on one's specialty. Expected earnings of math teachers are about 14 percent higher than those of science teachers, and about 27 percent higher than those of all other teachers.[20] This differential between earnings of female math

20. Our estimates of non-teaching earnings opportunities assume the same returns to additional experience for each type of teacher. Consequently, these differentials remain constant throughout the earnings distribution.

and science teachers outside the teaching profession is consistent with the differences reported by Hecker (1998).

A comparison of these expected earnings outside the teaching profession with teacher compensation reveals several more interesting aspects of these relative pay streams. Initially, earnings for non-math or science teachers exceed slightly estimated earnings in alternative occupations. By year three however, teacher salaries lag behind estimated earnings of non-teachers with equivalent years of experience. Teachers' salaries continue to lag behind our estimate of non-teacher earnings until the 13-year point, at which time teacher salaries begin to increase dramatically.

For female math teachers, expected earnings outside of teaching are always higher than teacher compensation; however, this differential narrows dramatically after about 10 years of service, from 36 percent to less than 2 percent. Expected compensation for science teachers is also higher outside the teaching profession, until 15 years of experience, when teacher salaries surpass estimated earnings of non-teachers. This is due to the dramatic rise in teacher compensation after reaching step 12 in the school system.

Figure 7 presents comparable estimates for male teachers and reveals several differences in expected earnings for men and women. For men, there is virtually no difference between expected earnings outside the field of teaching for math and science teachers. Furthermore, expected earnings growth outside the teaching profession is higher for men than for women. Finally, expected non-teacher earnings for men are always greater than expected teacher earnings.

Figures 6 and 7 reflect expected compensation for only one cohort and do not capture differences in earnings for different ethnic groups or educational attainment.[21] Still, these two figures reflect significant variation in expected earnings. The total variation in expected earnings in our data, then, is even larger and provides us with the ability to make more precise estimates of the relationship between compensation and retention of teachers.

21. These differences are taken into account in our multivariate analyses, however.

Figure 7. Comparison of earnings for male teachers in 2001 with expected earnings outside the field of teaching

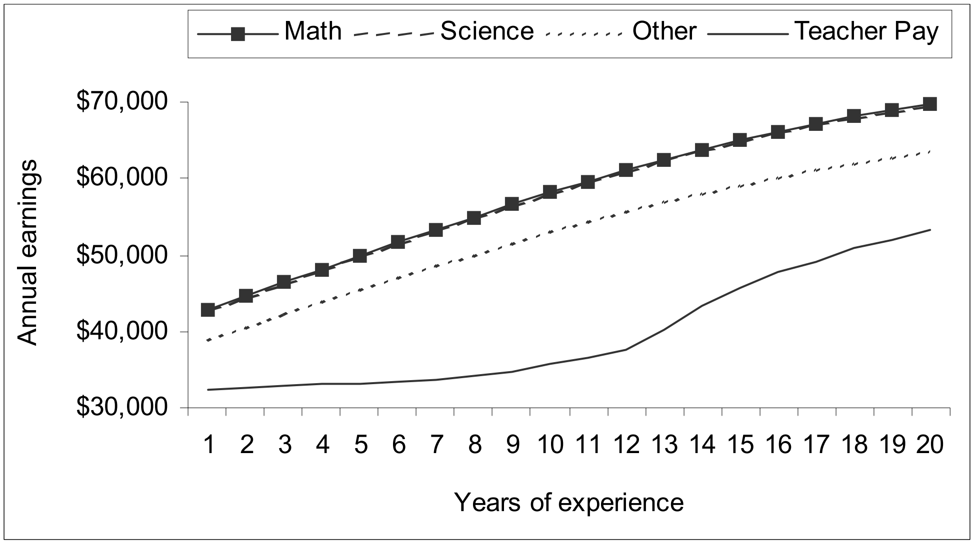


Figure 8 presents expected relative compensation of secondary school teachers for the 1990-91, 1994-95, and 2000-01 school years. For each school year, we display expected teacher earnings divided by expected earnings in non-teaching occupations. A ratio above 1.0 means that teachers can expect to earn more as a teacher in a given year than in another occupation; conversely, a ratio below 1.0 implies that non-teaching opportunities are more favorable. Figure 8 presents these ratios for the entire sample; however, separate calculations for math, science, and all other secondary school teachers generate similar results.

As figure 8 shows, expected relative compensation fell over the time period for which we have data. In other words, non-teaching opportunities became more favorable from 1990-91 to 1994-95, and again from 1994-95 to 2000-01. Furthermore, a comparison of figure 8 with figure 3 reveals that these declines in relative compensation were accompanied by increases in secondary school teacher turnover. This correlation suggests that relative pay does affect teacher retention. In the next section, we estimate the magnitude of this effect, controlling for other observable characteristics that potentially affect teacher retention as well.

Figure 8. Expected relative compensation of secondary school teachers in 1990-91, 1994-95, and 2000-01

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Determinants of teacher turnover

Model specification

To estimate the effect of compensation on turnover, we make use of a standard logit regression model.[22] Because the logit model estimates a nonlinear relationship between the explanatory variables and the probability of leaving the district, the interpretation of the coefficients is not straightforward. Therefore, we calculate and present the percentage-point change in the average turnover rate associated with each explanatory variable.[23]

For variables that indicate a teacher characteristic (e.g., gender), the marginal effect measures the percentage-point difference in the probability of leaving the school system for teachers with this characteristic, relative to a comparison group. For example, a marginal effect for male teachers of -0.7 implies that, for two otherwise identical teachers, the probability of leaving the district is 0.7 percentage point lower for the male teacher than for the female one. Since female teachers have an average turnover rate of 6.9 percent, our results indicate that, holding all other factors constant, male teachers have a turnover rate of 6.2 percent.

Finally, we express the relationship between changes in compensation and changes in turnover by the *pay elasticity*. The pay elasticity of teacher turnover measures the percent change in turnover associated with a 1-percent, across-the-board increase in teacher pay.

Table 1 presents descriptive statistics for the variables we use in our analysis. Consistent with the previous section, we focus on secondary school teachers with 10 years of experience or less in the following sections. In addition, table 1 presents turnover rates for different

22. See [9] for a detailed explanation of the logit model.

23. Complete regression results, however, can be found in appendix A.

types of teachers in our sample. For purposes of comparison, we also display these characteristics for school year 2000-2001, the most recent school year included in our sample.

Table 1. Characteristics and turnover rates of secondary school teachers with less than ten years of experience

Variable	Mean (Median) SY 1990-91 to 2000-01	Mean (Median) SY 2000-01
Gender		
Male	0.42	0.42
Female	0.58	0.58
Race / ethnicity		
Other	0.02	0.03
White	0.43	0.31
Black	0.24	0.27
Hispanic	0.31	0.39
Subject taught		
Other	0.63	0.60
Math	0.19	0.21
Science	0.18	0.20
Baccalaureate degree		
Non-education	0.49	0.75
Education degree	0.51	0.25
Educational attainment		
No Master's degree	0.77	0.85
Master's degree	0.23	0.15
Years of experience		
1	0.06	0.04
2	0.10	0.19
3	0.10	0.10
4	0.11	0.11
5	0.11	0.11
6	0.11	0.10
7	0.11	0.10
8	0.10	0.09
9	0.09	0.06
10	0.09	0.09
Variable	SY 1990-91 to 2000-01	SY 2000-01

Table 1. Characteristics and turnover rates of secondary school teachers with less than ten years of experience (continued)

	Mean (Median)	
Average years of experience		
Years of experience	5.6	5.2
Average age		
Age	35.3	34.9
Baccalaureate institution		
Other	0.68	0.58
University A	0.05	0.05
University B	0.05	0.05
University C	0.23	0.32
School year		
1990-1991	0.11	0.00
1991-1992	0.09	0.00
1992-1993	0.08	0.00
1993-1994	0.07	0.00
1994-1995	0.09	0.00
1995-1996	0.09	0.00
1996-1997	0.09	0.00
1997-1998	0.09	0.00
1998-1999	0.09	0.00
1999-2000	0.09	0.00
2000-2001	0.10	1.00
Turnover rate		
All	6.5%	9.3%
Math	6.4%	8.4%
Science	8.3%	11.1%
Other teachers	6.1%	9.1%
ACOL		
All	70 (953)	-4,750 (-4,089)
Math	-4,803 (-3,693)	-8,517 (-8,162)
Science	-3,566 (-1,026)	-8,083 (-4,077)
Other teachers	2,581 (4,292	-2,371 (758)
Leave district	-1,984 (-1,273)	-6,097 (-5,308)
Stay in district	214 (1,111)	-4,611 (-4,069)
Number of observations	24,682	2,387
Number of teachers	6,429	2,387

For the 10-year period of our analysis, the secondary teacher workforce in this large urban district was, on average, 58 percent female, 43 percent white, 24 percent black, and 31 percent Hispanic. The share of teachers who are female was unchanged in school year 2001, but the share of teachers who are white fell from 55 percent at the beginning of the period to 31 percent. The 2001 workforce ("current teachers") is 39 percent Hispanic, and 27 percent black. These changes are broadly consistent with the changing demographics in the area.

Just over half of teachers in the 10-year sample have a Baccalaureate in an education-related field, and 23 percent have a Master's degree. These teachers have 5.6 years of experience, on average. Only a quarter of current teachers have an undergraduate degree in an education related field; only 15 percent hold a Master's degree, and the average level of experience has fallen slightly to 5.2 years. In contrast, 75 percent of teachers held an education-related degree and 33 percent held a Master's degree at the beginning of the period. In addition, experience has fallen steadily since reaching a peak of 6.2 years in 1992.

The share of teachers who teach math or science has increased from 31 to 41 percent over the period; this probably reflects an increase in mathematics and science requirements for graduation. Another striking change in the workforce can be seen in the undergraduate institutions from which teachers earn degrees. For the full sample, one-third of teachers earned their degree from one of three public in-state universities. In the 2000-01 school year, this had risen to 42 percent, with all of the growth from a single local university.

Table 1 also displays turnover rates for the full sample and for SY 2001. Turnover averaged 6.5 percent over the 10-year period for all secondary teachers. In contrast, turnover in 2001 was 9.3 percent. Turnover rates have been higher for science teachers throughout our period of analysis and averaged 11.1 percent in SY 2001. Turnover of math teachers has been much closer to the average for all other non-math/non-science teachers.

Results

Effect of changes in teacher compensation

Table 2 presents our estimates of the pay elasticity of teacher turnover. Over the 1990-91 to 2000-01 time period, we estimate an elasticity of 0.7; in other words, a 1-percent, across-the-board increase in teacher pay decreases turnover by 0.7 percent. With a turnover rate of 6.54 percent, we predict that this increase in teacher compensation would lower turnover slightly, to about 6.50 percent.[24]

While this effect is statistically significant, it is relatively small. In other words, the data *do* support the notion that increases in compensation decrease turnover. However, the effect is not large. With retention rates over 90 percent, an across-the-board increase in compensation is an inefficient way to raise retention even further. Doing so would raise pay for all teachers, most of whom would stay in the school district even without the pay raise.

A more cost-effective approach would be to target a pay increase to teachers most likely to be "at risk" of leaving the school district. If compensation is targeted to a smaller group of individuals, the same increase in retention could be achieved at substantially lower cost. For example, if retention of math and science teachers is considered a "problem," a retention bonus could be offered to these groups of teachers. Compensation could even be targeted to junior teachers (for example, those with less than 5 years of teaching experience) or to teachers in schools with disproportionately high turnover. The smaller the population to whom this pay is offered, the smaller the "economic rents" of additional retention. Targeting a group with relatively low retention would maximize the return on investment of the increase in compensation.

24. 2000-01 compensation and turnover rates yield an identical estimate of the pay elasticity of teacher turnover. This is true for all pay elasticity estimates throughout this paper.

Table 2. Determinants of teacher turnover

Independent variable	Predicted turnover rate	Marginal effect	Percentage change
Subject taught			
Other[a]	6.3		
Math	6.1	-0.2	-3
Science	7.6	1.3[b]	21
Experience			
1 - 2 years[a]	10.2		
3 - 8 years	6.0	-4.2[b]	-41
9 - 10 years	4.8	-5.4[b]	-53
Baccalaureate degree			
Non-education[a]	7.0		
Education degree	6.0	-1.0[b]	-14
Educational attainment			
No Master's degree[a]	6.2		
Master's degree	7.7	1.5[b]	24
Baccalaureate institution			
Other[a]	7.5		
University A	6.2	-1.3[c]	-17
University B	4.5	-3.0[b]	-40
University C	4.6	-2.9[b]	-39
School year			
1990-91, 1992-93 - 1994-95[a]	5.7		
1991-92	3.9	-1.8[b]	-32
1995-96 - 1997-98	6.6	0.9[d]	16
1998-99 - 2000-01	8.2	2.5[b]	44
Gender			
Female[a]	6.9		
Male	6.2	-0.7	-10
Race / ethnicity			
Other[a]	3.3		
Hispanic	6.0	2.7[b]	82
White (non-Hispanic)	8.0	3.7[b]	142
Black (non-Hispanic)	5.1	1.8[d]	55

a. Italicized variables indicate the reference group with which the effects of other variables are compared.
b. Zero lies outside the 99-percent confidence interval for this estimate.
c. Zero lies outside the 90-percent confidence interval for this estimate.
d. Zero lies outside the 95-percent confidence interval for this estimate.

Math and science teacher turnover

Table 2 presents our estimates of the effects of several other teacher characteristics on turnover. The second column displays the average predicted turnover rate associated with each characteristic. The third column presents the marginal effects, which measure the percentage-point difference in turnover rates for teachers with a given characteristic, relative to a reference group. Finally, the fourth column lists the percentage difference in turnover between teachers with a given characteristic and those of the reference group. These estimates come from a parsimonious model of the determinants of turnover; richer specifications do no better at explaining teacher turnover.

Of particular interest are the differences in predicted turnover rates for math, science, and all other secondary school teachers. As table 1 shows, turnover rates of math and science teachers are 5 and 36 percent higher, respectively, than those of all other teachers. Holding all else constant, however, table 2 suggests that there is no significant difference between turnover of math teachers and all non-math, non-science teachers.[25] That is, once we account for other characteristics of these teachers (including different non-teaching earnings opportunities), there is no longer an appreciable difference in turnover rates. The implication is that, if all other characteristics were identical, math teachers and non-math, non-science teachers would have identical turnover rates.

For science teachers, however, our estimates lead to a different conclusion. Even after controlling for all other observable characteristics, table 2 suggests that science teacher turnover is still significantly higher than that of all other teachers. While the predicted difference between these turnover rates falls from 36 to 21 percent, science teacher turnover is still relatively high. In other words, even after adjusting for the relatively strong non-teaching earnings opportunities of science teachers, this group still has higher turnover.

25. In fact, our model predicts slightly lower turnover for math teachers. However, this difference is not statistically significant.

There are a few potential explanations for this statistically significant difference. First, it is possible that we have not adequately characterized science teachers' non-teaching earnings opportunities. If we have underestimated non-teaching compensation for this group, the science teacher fixed-effect would reflect the average difference between actual earnings opportunities and our estimate. Second, it is possible that other unobservable factors influence retention differently for science teachers than for other types of teachers. Finally, it is possible that science teachers have a lower preference for teaching, holding all else constant.

Our estimates of the pay elasticity imply that it would be expensive to reduce science teacher turnover to the level of all other teachers. Over the 1990-91 to 2000-01 time period, we estimate that science teachers would have had to receive a *51-percent* pay premium per year to reduce their turnover to a level comparable to other teachers. For a teacher at salary step 4 in 2000-01, this would be an increase in annual salary of almost $17,000.

While the differential between science and non-math, non-science teacher turnover is smaller in 2000-01, a 31-percent pay premium would still have been required to eliminate this disparity. For a teacher at salary step 4, this is still an increase in annual salary of over $10,000. Math teacher turnover is closer to that of other teachers; a 6.6-percent premium would lower math teacher turnover to the level of all other teachers.

We are not suggesting that the retention rate of other teachers is "optimal," nor that science/math teacher retention *should* be raised to this level. Rather, our estimates suggest what it might cost for the school system to bring science teacher turnover closer in line with that of other teachers. Despite these pay premia, however, it is important to emphasize that decreasing turnover with salary differentials that target hard-to-fill teaching positions is far more cost-effective than across-the-board increases in compensation.

Effect of other teacher characteristics

Many of the other explanatory variables affect turnover in ways that one might expect. For example, turnover declines with years of teaching experience in the school district. There appear to be three distinct points at which turnover patterns vary over the experience profile. During the first two years in the district, turnover is relatively high (over 10 percent per year). For teachers that stay at least two years, however, turnover rates drop by about 40 percent, to 6 percent per year. Turnover rates are relatively flat until the 9th year of teaching in the district, after which they drop to under 5 percent per year.

Although relatively high turnover rates are normal among new job entrants, the rates for new teachers are more than double those of teachers with 9 to 10 years of experience. We estimate that beginning teachers would require a 36-percent pay increase to reduce their turnover from 10 to 8 percentage points. Although it would be expensive to bring down turnover rates of teachers with one or two years of experience through pay raises, increasing the relative pay rates of more junior teachers would begin to change the pay profile for teachers shown in figures 6 and 7 so that they look more like the pay profiles in competing occupations.

Turning to other teacher attributes, we find that teachers who graduate from the largest university pipelines into the district's schools have lower turnover than other teachers. Specifically, graduates from three public state universities have lower turnover than teachers from other undergraduate institutions. These schools are three of the four largest suppliers of teachers to the school district. Graduates from these schools may be more likely than others to come from the surrounding area, and therefore, may be more likely to stay in the district. This effect would be consistent with Boyd, Lanford, Loeb and Wycoff (2003) who have shown that teacher labor markets are highly localized. In addition, this finding is consistent with the notion that graduates from these schools are more familiar with the teaching environment in the school district, given the close relationship between the school district and the university.

Similarly, teachers whose undergraduate degree was in education, or in a specific subject with a specific focus on being an educator in that subject, are less likely to leave the district than other teachers. This probably reflects a strong commitment to being a teacher; those who have been explicitly planning to teach are probably less likely to leave for non-teaching employment than other people.[26]

We found no evidence that those with math- or science-education degrees had different turnover patterns than other teachers with education degrees. Unfortunately, our data do not differentiate between different non-education degrees, so it is not possible to examine turnover rates of those with Bachelor's degrees in math or science.

Finally, even after controlling for pay and other factors, the data suggest that turnover rates have risen over the past few years. Turnover was generally stable from the 1990-91 to 1994-95 school years, at 5.7 percent per year.[27] During the 1995-96 to 1997-98 school years, turnover rose by about 16 percent, to 6.6 percent per year. More recently, turnover rates hover around 8 percent per year.

Since these rates are calculated holding all observable characteristics of teachers constant, we cannot explain the upward trend in turnover with our data. Rather, these results suggest that other factors have negatively influenced teacher retention in recent years. Possibilities include a broad-based deterioration in working conditions, reductions in spending for school supplies or building maintenance, across-the-board personnel policy changes, or even high-stakes testing. In a later section, we investigate the possibility that changes in working conditions led to this decline in retention.

Math and science teachers' responsiveness to pay

The pay elasticity reported thus far can be thought of as "average" teacher responsiveness to pay. In other words, this elasticity reflects the general response to a change in across-the-board compensation. This general response, however, is an average of the responsiveness of

26. It is possible that these people are more desirable to other school districts, increasing the likelihood that these teachers leave for employment in another district. Their relatively low turnover, however, suggests that this effect is of second-order importance.

27. Turnover dropped during the 1991-92 school year, but returned to its 1990-91 level in the following year.

different groups of teachers. It is possible that some teachers are more responsive to pay than the elasticity suggests, while other teachers do not respond to an increase in compensation at all. In particular, it is possible that math and science teachers react differently than other teachers to an increase in pay.

To investigate this possibility, we re-estimate the model presented in table 2, adding separate relative compensation variables for math, science, and all other secondary school teachers. Resulting elasticities are displayed in table 3.

Table 3. Pay elasticities of teacher turnover

Group	Estimate
Math teachers	1.3[a]
Science teachers	0.6[b]
Other teachers	0.7[c]

a. Zero lies outside the 99-percent confidence interval for this estimate.
b. Zero lies outside the 90-percent confidence interval for this estimate.
c. Zero lies outside the 95-percent confidence interval for this estimate.

As table 3 demonstrates, there is some evidence that math teachers are more responsive to changes in compensation than other teachers. While the pay elasticity for science teachers is similar in magnitude to that of non-math, non-science teachers, the responsiveness of math teachers is twice as large. In other words, given an identical increase in compensation, math turnover declines twice as much as turnover of all other teachers.

The model used to generate the estimates presented in table 3 only allows the effect of pay on turnover to vary by type of teacher. Given that responsiveness to pay varies over this dimension, it is possible that other determinants of turnover do as well. To investigate this model, we re-estimate this model, estimating separate effects of all explanatory variables for math, science, and all other teachers. The pay elasticities from this model are presented in table 4.

Table 4. Pay elasticities of teacher turnover—fully interacted model

Group	Estimate
Math teachers	1.8[a]
Science teachers	1.0[b]
Other teachers	0.3

a. Zero lies outside the 99-percent confidence interval for this estimate.
b. Zero lies outside the 90-percent confidence interval for this estimate.

As table 4 demonstrates, different teachers do have very different responses to the same increase in compensation. Once we allow the effects of all explanatory variables to differ by subject taught, there is no significant relationship between pay and turnover for non-math, non-science teachers. In contrast, a 1-percent increase in across-the-board compensation decreases science teacher turnover by about 1 percent and math teacher turnover by about 1.8 percent.

As we have discussed, science teacher turnover is higher than that of math teachers, despite the fact that expected non-teacher compensation for female math teachers is significantly higher than that of female science teachers. This suggests that, for science teachers, factors other than pay are important considerations in the stay/leave decision. For example, science teachers decision to stay in teaching may be more influenced by the working conditions of their school. While we are unable to capture all non-compensation characteristics of teaching, we now turn to models that include indicators for a teacher's working environment.

Teaching environment and teacher turnover

Common core of data

A number of authors report that teachers are relatively insensitive to pay changes, and that working conditions are more important to the decision to stay in teaching or to leave. Using data from the state of Texas, for example, Hanushek, Kain and Rivkin (1999) are able to track moves within districts, as well as across-district moves within the state. They find that earnings plays a small role in such moves. Instead, teachers tend to move to schools with higher test scores, and to schools with a demographic mix that matches the teacher's background. Similarly, Lankford, Loeb, and Wycoff (2002) find that schools with better test scores attract teachers with better credentials, when those teachers enter the district, and as they move over time within the district.

The National Center for Education Statistics' Common Core Data Base (CCD) allows us to examine the relationship between teacher retention and some school demographic characteristics. For the 1990-91 through 2000-01 school years, CCD includes information on the ethnic and racial characteristics of the student body, and free school lunch programs eligibility rates for all district public schools. [28]

We find that school demographic data from the CCD are weakly correlated with teacher retention when we don't control for individual teacher characteristics. Adjusting for differences in teacher characteristics, however, completely explains these relationships. In other words, we are unable to find a statistical link between these aspects of the working environment and teacher retention. The interpretation of these data is that, although teachers in schools with high-minority/ high-poverty student populations are more likely to leave the district, their decision to leave can be traced to other factors, and not to the demographic mix of the student body.

School Indicators

Finally, we make use of a state data set of school indicators to examine the effect of the teaching environment on retention. The advantage of these data is that they contain several detailed indicators of school performance and environment for each school in the school district. Examples include class sizes, test scores, per-pupil expenditures, and even crime rates within the school. The main disadvantage, however, is that these data are only available for the 1996-97 to 2000-01 school

28. We matched the district data with the CCD schools based on school names. For 17 schools in our personnel records we were unable to find a comparable CCD school listing,and we exclude these schools from our analysis. Without observations from those schools, the data set includes 24,414 observations on 6,409 teachers.

years. Consequently, we can only examine the impact of these conditions on turnover for the subset of years for which we have this information.

These data do not provide strong evidence that school performance and environment affect teacher retention. Most of these data are not correlated with teacher retention, even when we do not attempt to control for teacher characteristics.[29] This includes such data as per-pupil expenditures, student test scores on state exams, tenure and education of other teachers in the school, and dropout rates.

Furthermore, for the few characteristics that do appear to affect retention, the results are difficult to explain. For example, the average size of science classes in a school appears to affect retention of math teachers in the school, but not the retention of science teachers in the school. Similarly, average SAT scores in a school appear to affect the retention of science teachers in the school, but not the retention of other teachers. Given these implausible results, the most likely explanation is that these school characteristics are correlated with some other, unobserved characteristic of the school for which we cannot control but that affects teacher retention. In other words, it is probable that the observed school characteristics do *not* have the effects on retention that we observe but reflect the effects of unobserved characteristics.

Two school characteristics have a statistically significant effect on turnover that is also consistent with our expectations. The first is the number of incidents of crime and violence per student.[30] schools in which crime is more prevalent have higher turnover rates. Second, there is a positive relationship between expenditures on at-risk stu-

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29. Intuitively, controlling for additional factors reduces the correlation between teaching environment characteristics and retention, since these other factors help to explain teacher turnover. For these data, the correlation with retention is weak before controlling for these factors.

30. These include violent acts against individuals, possession of alcohol, tobacco, or other drugs, property crimes, fighting/harassment, weapon possession, disorderly conduct, and other nonviolent offenses. However, crime data are not disaggregated by type of offense until the 1998-99 school year.

dents and turnover. Schools in which these expenditures are high are most likely schools with other, unobserved problems that contribute to higher turnover.

Two important caveats to these findings, however, severely limit their use. First, several of the determinants of turnover described in table 3 cease to have statistically significant effects when we focus on the 1996-97 to 2000-01 school years. This likely reflects the lack of variation in the data over the smaller time frame. Second, it is difficult to reconcile the findings that accord with expectations with those that do not. In conclusion, the data offer *very* limited evidence that working conditions affect teacher turnover in the district.

Taken together, the CCD and data from the state database do *not* provide support for the hypothesis that working conditions affect teachers' decisions to leave the district. It *is* possible, however, that teachers who are particularly sensitive to working conditions are able to improve their work environment through intra-district transfers rather than by leaving the district. If this is the case, one would expect to find a negative relationship between the quality of working conditions and teacher mobility within the district. In subsequent work, we will explore this hypothesis.

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Conclusion

Since the early 1990s, teacher turnover in secondary schools in the district increased, particularly for teachers with low levels of experience. For most of these years, science teachers were more likely to leave the school district than other teachers. This differential is consistent with conventional wisdom that science and mathematics teachers have more favorable employment opportunities than other teachers.

To examine the effect of relative compensation on secondary teacher retention, we make use of the Annualized Cost of Leaving (ACOL) model. Our analysis suggests that relative teacher compensation does have an effect on teachers' retention decisions; increases in pay do lead to increases in retention, even when controlling for other factors. The magnitude of this effect, however, is small. This implies that across-the-board increases in compensation will have only modest effects on turnover rates of secondary teachers.

There is some evidence that mathematics and science teachers are more responsive to changes in pay than other secondary teachers. However, differences in relative earnings do not completely explain differences in turnover between science teachers and other secondary teachers. While science teachers have higher expected earnings outside teaching, the data suggest that science teacher turnover would still be higher than that of other teachers, even if earnings opportunities were identical.

In addition to pay adjustments, our analysis suggests that other factors could be leveraged to influence turnover. Candidates worthy of further analysis include programs to attract students from specific colleges into teaching, induction and mentoring programs, and opportunities for policy changes that could improve job satisfaction. In addition, the relationship between student outcomes and teacher attributes, some of which have changed markedly over the period of analysis, should be explored.

The available data suggest that working conditions in this district do not play a role in teacher retention. Teachers who are unhappy with working conditions in their current school may simply wait to move into a better school within the district. Given the large amount of intra-district mobility within the district, future work will explore the role of working conditions on mobility and how this mobility affects student outcomes.

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