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AIR

Teacher Pension Plan Incentives, Retirement Decisions, and Workforce Quality

Shawn Ni
Michael Podgursky
Xiqian Wang

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Shawn Ni
University of Missouri - Columbia

Michael Podgursky
University of Missouri - Columbia / CALDER

Xiqian Wang
University of Missouri - Columbia

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1000 Thomas Jefferson Street NW, Washington, DC 20007
202-403-5796 • www.caldercenter.org

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Abstract

As states attempt to staff public school classrooms with qualified teachers, primary attention has focused on educator preparation and early career retention. Far less research has examined the staffing consequences of turnover induced by teacher pension plans. This paper makes use of a unique longitudinal data file with performance measures for all public school teachers in Tennessee. Descriptive analysis finds that higher quality teachers are less likely to retire for a given age and experience. To better understand the effects of pension plan incentives on workforce quality, we estimate a structural retirement model that explicitly allows for different work-retirement preferences for high and low quality teachers. We find that high quality teachers have a lower disutility for teaching as compared to retirement. Given that it costs less to keep high as compared to low quality teachers on the job, we use the structural estimates to simulate the effect of retention bonuses targeted to the former. One year retention bonuses produce an additional year of high quality teaching at a cost of roughly $40,000.

Keywords: Teacher Pensions, Teacher Quality, Teacher Retirement

1 Introduction

Teacher pensions have attracted considerable media and policy attention. Pension costs have been rising, often sharply, as states seek to pay down unfunded liabilities of these plans. This has led school districts to make cuts in other areas of school budgets (Burnette and Will, 2018; Krausen and Willis, 2018). In addition, the “pull” and “push” incentives built into these plans tend to lock experienced teachers into plans, and then push them into retirement at relatively early ages (Costrell and Podgursky, 2009). A number of studies have shown that teachers respond to the incentives built into these teacher retirement benefit plans in timing retirement (Brown, 2013; Costrell and McGee, 2010; Fitzpatrick and Lovenheim, 2014; Friedberg and Turner, 2010; Knapp, Brown, Hosek, Mattock, and Asch, 2016; Ni and Podgursky, 2016).

While the effect of teacher pensions on overall school staffing and teacher turnover has been studied, much less attention has focused on their effect on the quality of the teaching workforce. This is important because recent research highlights the role that teacher quality plays not only in raising short-term student achievement, but also consequential long-term outcomes such as high school graduation, college attendance, and labor market earnings (Chetty, Friedman, and Rockoff, 2014). Several studies have examined the effect of teacher attrition on the quality of the teaching workingforce (e.g., Feng and Sass (2017); Goldhaber, Gross, and Player (2010); Kreig (2006)), but the focus is on early career turnover. Fitzpatrick and Lovenheim (2014) find that the district take-up rate of a one-time pension enhancement in Illinois, which encouraged retirement, was associated with student achievement increases at the district level. Koedel, Podgursky, and Shi (2013) explicily compare the value-added of teachers who retire at different points in the late-career cycle and find no significant effect effects on workforce quality.

This paper examines the effect of teacher pensions on teacher quality using a statewide administrative educator database in Tennessee that includes performance measures. In so doing, it makes several contributions. First, as noted, few papers examine the effect of teacher quality on late-career teacher retirement decisions. This study uses both reduced-form and structural estimates to analyze retirement behavior and teacher quality. We use the resulting structural estimates to cost out policies designed to postpone retirement of high quality teachers through the use of retention bonuses.

In the next section, we describe the background of Tennessee pension rules and the teacher evaluation system. We then examine the empirical relationship between performance scores and teacher retirement, estimate a structural retirement model that incorporates teacher quality directly into preferences, and uses these estimates to simulate the effect of various retention bonuses.

2 Institutional Background

2.1 Teacher Pension Rules

Teachers in Tennessee are in a final average salary defined benefit (FAS-DB) pension plan, which is the typical plan for U.S. public school teachers. Tennessee teachers are also covered by Social Security (teachers in some states are not). Tennessee teachers become eligible for a regular pension when they are aged 60 with at least five years of service or when their years of service equals at least 30. Benefits at retirement are determined by the formula:

$$Annual\ Benefit = rf \times S \times FAS$$

where rf stands for replacement factor. S denotes years of teaching experience in the system. FAS is the average of the highest consecutive five years of salary, which are typically the five years prior to retirement. Table 1 summarizes the Tennessee pension rules.

$(Table\ 1)$

One way to assess the retirement incentives arising from these pension plan rules is to compute the pension wealth at different points in a representative teacher's work life. Pension wealth is calculated as the expected present value of pension benefits at retirement year r, which is formulated as follows:

$$PW(r) = \sum_{s \geq r} (1+b)^{r-s} \pi(\,s|r)\, P(\,s|r\,),$$

where $\pi(\,s|r)$ is the conditional probability of survival, and $P(\,s|r\,)$ is the pension benefit at year $s \geq r$ if the teacher retires at year r, and $b > 0$ is the annual discount rate. Pension wealth accumulation can be calculated as follows:

$$pw(r) = \frac{PW(r) - (1+inf) * PW(r-1)}{Salary(r)},$$

where $PW(r)$ is pension wealth if the teacher retires at year r, inf is inflation rate, $Salary(r)$ is salary at year r.

Figure 1 shows life-cycle pension wealth accrual, Social Security wealth, and total retirement wealth for a representative teacher in Tennessee who enters the system at age 25. Figure 2 reports annual pension wealth accrual. Figures 1 and 2 are consistent with previous literature about the incentives underlying FAS-DB plans, which show that the life-cycle pattern of pension wealth accrual is nonlinear and has several spikes (Costrell and Podgursky, 2009). These spikes encourage teachers to retire at local peaks of wealth accumulation.

$(Figures\ 1\text{-}2)$

2.2 Teacher Evaluation System

As a winner in the US Department of Education "Race to the Top" grants competition, Ten-nessee received funding to implement a new statewide teacher evaluation system which began operation in the 2011-2012 school year. Half of a teacher's evaluation score is based on a quali-tative measure (classroom observations) and the remaining half is based on student outcome measures, including student growth represented by a value-added score (35 percent) and student achievement (15 percent). The classroom observations represent process-oriented measures while the student growth and achievement scores are output-based measures (Stein-berg and Sartain, 2015). Thus the teachers are rated by multi-dimensional measures. Every teacher in the new evaluation system is evaluated regardless of teaching experience or tenure status. There are five effectiveness levels for evaluation scores, from Level 1 (Significantly Below Expectations), to Level 5 (Significantly Above Expectations).

3 Data and Descriptive Statistics

In this section, we compare the empirical retirement behavior of female and male teachers. The data include all teachers aged 50-65 in the 2011-2012 school year with at least 5 years of service experience. This cohort is tracked forward to the 2014-15 school year. Table 2 reports descriptive statistics for female and male teachers. Note that the average evaluation levels (based on the five point scale) are the levels reported in the base year (2011-2012). The number of female senior teachers is about four times that of males and the average evaluation score of females is higher than for males.

(*Table* 2)

Figure 3 plots the distribution of teacher evaluation score (1-5) for female and male teachers in the base year (2011-2012). First, there is a considerable spread in the scores – not all teachers receive the highest score. In addition, male teachers are underrepresented in the top performance category, and overrepresented in the bottom two. To make our structural estimation below tractable, we group levels 1-3 and label them low quality teachers, and levels 4-5 are high quality teachers.

(*Figure* 3)

Table 3 reports retirement rates for male and female, high and low quality teachers over the three year panel. For both males and females the retirement rate for low quality teachers is higher than for high quality teachers, with a larger gap for males. It is worth noting that this finding is consistent with recent studies of teacher quality and early career turnover – less effective teachers are more likely to exit the profession (Feng and Sass, 2017; Goldhaber et al., 2010; Kreig, 2006). This pattern seems to hold at the end as well as the beginning of teaching careers.

(*Table* 3)

Figure 4 and Figure 5 plot the age and experience distributions for the 36 percent of teachers who retired during the three year panel. Among teachers who retired, low quality teachers tended to retire with less experience and at a younger age, and the pattern is more pronounced for male teachers. However, it should be kept in mind that 64 percent of our observations are right-censored (i.e., still teaching at the end of the panel), so we do not observe a value of retirement age and completed experience for these teachers.

(*Figures* 4-5)

4 Does Impending Retirement Induce Shirking?

Before undertaking further analysis of teacher retirement by quality, it is worth considering whether the association between baseline teacher quality and retirement may be spurious in that teachers who plan to retire may shirk or exert less effort (and hence get lower

evaluation scores) immediately prior to retirement. Unfortunately, our panel only extends for three years, reflecting the introduction of the statewide performance measures in 2011-12. In Figure 6 we report statistics on the year-to-year changes in the binary quality measure for teachers who retired by 2014. The first thing to note is that for the vast majority of teachers, the binary performance measure does not change from one year to the next. Because the high quality teachers greatly outnumber low quality teachers, there are far more high quality teachers reclassified as low quality teachers than the other way around. Roughly 17-19 percent fell from high to low, and about 9-12 percent rose from low to high. For our purposes it is important to note that there is very little difference in these percentages for teachers who retired in the next year and those who did not. In fact, for both males and female teachers, the probability of decline is slightly lower in the year prior to retirement, as compared to two years prior, which is inconsistent with the shirking hypothesis. Thus, our retirement data seem to suggest real differences in retirement behavior between high and low quality teachers.[1]

(*Figure* 6)

[1]A recent study of the Tennessee teacher evaluation system by Koedel, Li, Springer, and Tan (2017) finds that when otherwise similar teachers are given a lower evaluation (i.e., at a regression discontinuity) job satisfaction drops. Their measure of job satisfaction includes questions about plans to quit teaching and satisfaction with her career choice. Hence a poor evaluation score induces job exit.

5 Teacher Quality and Retirement: Reduced-Form Estimates

To quantify the relationship between teacher quality and retirement behavior, we begin by estimating a linear probability regression. The data we use are teachers aged 50-65 in the baseline 2011-2012 school year, the same cohort of teachers as above. The model is as follows:

$$Retire_i = \beta_0 + \beta_1 Quality_i + \beta_2 Experience_i + \beta_3 Age_i + \epsilon_i.$$

$Retire_i$ is an indicator variable equal to 1 if the teacher i chooses to retire in the next three years. $Quality_i$ is the teacher i's teacher binary quality measure in the baseline 2011-2012 school year. $Experience_i$ and Age_i are the experience and age of teacher i in the 2011-2012 school year. ϵ_i is the error term.

Table 4 reports estimated coefficients for linear probability models for female and male teachers respectively. Regression (3) and (4) include district fixed effects. The coefficients on the teacher quality measure for all regressions are negative and statistically significant indicating that higher quality teachers are less likely to retire than low quality teachers who have the same age and experience. Table 2 shows that the difference between retirement rates in the sample period for high quality and low quality teachers is -0.028 and -0.065 for females and males, respectively.

($Table$ 4)

6 A Dynamic Structural Retirement Model

Stock and Wise (1990) developed a structural model of retirement which was extended by Ni and Podgursky (2016) to an analysis of public school teachers. This study further

modifies

and extends the Stock-Wise model to include Social Security along with the teacher pension and incorporates teacher quality parametrically into the model, so as to permit high and low quality teachers to have different work-retirement preferences.

Consider a teacher who has not retired at the beginning of year t. The present value of expected lifetime utility for the teacher if she retires in year r is:

$$E_t V_t(r) = max_{c_1,c_2} E_t\{\sum_{s=t}^{r-1} \beta^{s-t}\pi(s|t)U_w(Y_s, B_s(c_1)) + \sum_{s=r}^{T} \beta^{s-t}\pi(s|t)U_r(P_s(c_2), B_s(c_1))\} \quad (6.1)$$

where

$$U_w(Y_s,\ B_s(c_1)) = (k_s((1-c)Y_s + I_s^1 B_s(c_1))\,)^{\gamma} + \omega_s, \quad (6.2)$$

$$U_r(P_s(c_2),\ B_s(c_1)) = (I_s^2 P_s(c_2) + I_s^1 B_s(c_1))^{\gamma} + \xi_s. \quad (6.3)$$

$$I_s^1 = \begin{cases} 1 & if\ s \geq c_1 \\ 0 & otherwise \end{cases} \quad (6.4)$$

$$I_s^2 = \begin{cases} 1 & if\ s \geq c_2 \\ 0 & otherwise \end{cases} \quad (6.5)$$

The value function depends on future annual earnings Y_s before retirement, pension benefits $P_s(c_2)$ if the teacher starts collecting a pension benefit at year c_2, Social Security benefits $B_s(c_1)$ if she starts collecting Social Security at year c_1. The collection years are optimally chosen to maximize the expected utility given the retirement year r. The parameter c is the contribution rate for teachers before retirement; and k_s represents the disutility of working, which depends on age. $\pi(\,s|t\,)$ is the conditional survival rate.

We assume that $k_s = k(\frac{60}{age})^{k_1}$ for high quality teachers, and $k_s = k_2 * k(\frac{60}{age})^{k_1}$ for low quality teachers, where k_2 differentiates utility for the two groups. If k_2 is close to 1, it means the low quality teachers value teaching similarly to high quality teachers. However, if k_2 is less than 1, the same salary produces less utility for low quality teachers.

In every year, a nonretired teacher has two choices: continue teaching or retire. The expected gain from postponing retirement can be seen as the "option value" of continuing working, which is the key feature of this model. Retirement occurs if the value of continuing teaching is less than the value of retiring, or in other words, the option value of continued teaching is negative.

The teacher's future salary, pension benefits, and Social Security benefits are assumed to be predictable. In the empirical analysis we replace the expected salary and benefits with forecasts based on historical data. For prediction of the logarithm of salary we fit a cubic function of experience.

The expected gain from retiring in year r (later than t) becomes

$$G_t(r) \;=\; E_tV_t(r) \;-\; E_tV_t(t) = g_t(r) + K_t(r)\nu_t, \tag{6.6}$$

where the first term $g_t(r) = \sum_{s=t}^{r-1} \beta^{s-t}\pi(\,s|t\,)\,((k_s((1-c)Y_s + I_s^1 B_s(c_1))\,)^{\gamma})+$

$\sum_{s=r}^{T} \beta^{s-t}\pi(\,s|t\,)\,((I_s^2 P_s(c_2) + I_s^1 B_s(c_1))^{\gamma} - [\sum_{s=t}^{T} \beta^{s-t}\pi(\,s|t\,)\,(I_s^2 P_s(c_2) + I_s^1 B_s(c_1))^{\gamma}]$. And the second term, $K_t(r) = \sum_{s=t}^{r-1}(\beta\rho)^{s-t}\pi(\,s|t\,)$, depends on parameters we need to estimate. The preference error $\nu_t = \omega_t - \xi_t$. We assume ν_t follows an AR(1) process: $\nu_t = \rho\nu_{t-1} + \epsilon_t$. Moreover, ϵ_t is assumed to be iid $N(0, \sigma^2)$.

Suppose $r^{\dagger}$ solves $max_{r\in\{t+1,t+2,......T\}}\, E_tV_t(r)$. Thus, the teacher will continue working at t if $G_t(r^{\dagger}) \;=\; E_tV_t(r^{\dagger}) - E_tV_t(t) > 0$. The probability of retirement for an employee at time t is $\mathrm{P}[R = t] = \mathrm{P}[G_t(r) \leq 0, \forall r \geq t+1] = \mathrm{P}[G_t(r^{\dagger}) \leq 0]$, which can be represented as

$$\mathrm{P}[g_t(r_t^{\dagger})/K_t(r_t^{\dagger}) \leqslant -\nu_t], \tag{6.7}$$

The above condition implies that a low quality teacher is more likely to retire in current year t than a high quality teacher with the same age and experience and the same distribution of preference errors. This is because with $k_2 < 1$, $g_t(r^{\dagger})$ for the low quality teacher is smaller than that for the high quality teacher for any r, while the denominator $K_t(r^\dagger)$ only depends on the preference parameters other than k_2.

In this model there are seven unknown parameters to be estimated, which are listed in Table 5.

($Table$ 5)

6.1 Issues in Estimation

Since the timing of retirement is the key variable of interest, we would like to focus on a teacher population who are eligible to retire at some point during the sample period. We track Tennessee teachers from the 2011-2012 school year for three years until the 2014-15 school year. Given the short panel, we chose a sample of teachers aged 50-65 and with at least 5 years of experience in the base year 2011-12. Almost all of these teachers are eligible for early or regular retirement. However, teachers who would have been in the sample but chose to retire before the baseline year are excluded, while those who chose to continue teaching remain in the sample. Thus, for the same age and experience, the "stayers" have preference errors that favor teaching over retirement. This produces sample selection bias and results in overprediction of retirement for relatively young teachers (Ni and Podgursky, 2016).

This selection bias also depends on teacher quality. Given age and experience, low quality teachers are more likely to retire, therefore low quality "stayers" in the initial sample year must have preference shocks that more strongly favoring staying. Hence, the selection bias is larger for low quality teachers.

The average experience in the initial sample differs by teacher quality. Table 3 shows that in the initial sample high and low quality teachers have roughly the same average age but low quality teachers have 0.8 (female) and 0.7 (male) fewer years of experience.

If teacher quality did not affect retirement probability, the probability of retirement during the sample period would be higher for a sample with more years of experience, hence the low quality teachers should be less likely to retire during the sample period. We observe the opposite. In Table 3 retirement rates for low quality teachers are 0.028 and 0.065 higher for females and males respectively, than their high quality counterparts. The regression in Table 4 shows that the probability of retirement during the sample period for low quality teachers is higher after controlling for the initial age and experience.

The experience gap between low and high quality teachers in the initial sample is expected from the sample selection prior to 2011, because low quality teachers are less likely to survive until 2011 than their high quality counterparts with the same age and experience. To estimate the parameters we need to take into account the difference in survival bias by quality conditional on the teachers having survived until 2011.

We propose to correct this selection bias by using conditional probability to weight teacher observations in our baseline sample. The probability a teacher was retired in our sample period will be conditioned on the fact that the teacher was not retired at the beginning of sample period.

If a teacher chooses to retire at year n, the conditional probability of retiring is:

$$Prob\,(retiring\ at\ n\ |\, appearing\, in\, sample) = \frac{Prob\,(retiring\ at\ n\ \&\, appearing\, in\, sample)}{Prob\,(appearing\, in\, sample)}.$$

If the teacher chooses to stay until the end of sample period N, the conditional probability is:

$$Prob\,(staying\ at\ N\ |\, appearing\, in\, sample) = \frac{Prob\,(staying\ at\ N\ \&\, appearing\, in\, sample)}{Prob\,(appearing\, in\, sample)}.$$

The probability of a teacher appearing in the sample (the denominator in the conditional probability above) differs by teacher. Suppose at the first year of our sample period, a teacher was eligible for retirement (or early retirement) J years ago. We express this probability that the teacher appears in the sample as a function of the structural parameters based on our option-value retirement model. Given age and experience, this probability is lower for low quality teachers. To see why this is the case, assume the sample period starts in year 1 and the teacher in year $-J$ became retirement eligible for the first time. In every year leading to year 0 the teacher decided to stay because condition (6.7) was not satisfied, i.e., $-g_t(r_t^\dagger)/K_t(r_t^\dagger) < \nu_t$ (which means the relative value of retirement is lower than the preference error.) Suppose the preference error ν_t is positively correlated over time, then each term in the sequence $(\nu_{-J}, .., \nu_0)$ is truncated. For low quality teachers, the relative value of retirement, $-g_t(r_t^\dagger)/K_t(r_t^\dagger)$, is larger; hence the probability that a low quality teacher chooses to stay is lower. Furthermore, the left-side truncation of the preference errors prior to the initial sample period, $(\nu_{-J}, .., \nu_{-1})$, shifts the ν_0 of the low quality teacher further to the right. Estimates based on the assumption that ν_0 has a zero mean will be biased. The sample selection bias exists for all teachers but is more severe for lower quality teachers because they are relatively more inclined to retire.

We use the following features common in pension rules and retirement data to reduce computation cost of the sample likelihood. In a DB system, a teacher's retirement incentive depends on age and experience. In the structural model, the deterministic factors in retirement decision are age, experience, gender, and teacher quality. Senior teachers teach continuously until retirement. Hence tracking the retirement counts of a group of teachers given the age and experience in the initial sample period is equivalent to tracking the retirement data of all teachers in that group. Since there are a limited number of age/experience combinations in the initial sample (e.g., age 50-65, experience 5-45), the group-based counts exhibit a limited number of patterns, which does not depend on the number of teachers in the sample. When the number of teachers is large enough (our data include all teachers in

Tennessee) tracking the counts by group makes evaluation of the likelihood for the sample much less costly. Using the data aggregated by age-experience groups instead of teacher-level data to estimate the likelihood function not only results in a large reduction in computational cost.[2]

6.2 MLE Estimates

MLE estimates of the seven parameters in our structural model are reported in Table 6. All estimates are statistically significant. These estimates are quite similar to those in Ni and Podgursky (2016), in spite of the fact that these are teachers in a different state, covered by a different state pension plan, and differentiated by quality.

$$(Table\ 6)$$

The parameter β implies an annual discount rate of $\frac{1}{\beta} - 1$. The estimated parameter γ for both female and male teachers is less than 1, which means the utility function is concave. The concavity of the utility function implies that teachers are risk-averse and prefer income-smoothing. Parameters σ and ρ pertain to unobserved preference errors. They capture the magnitude and persistence of unobserved heterogeneity, respectively. The estimates of σ indicate that unobserved heterogeneity is quite large relative to the flow of utility generated by salary, and the estimates of ρ indicates that unobserved preference errors are positively correlated over time and persistent.

Of particular interest for this study are the parameters k and k_1, which together measure the utility of working for high quality teachers, while for low quality teachers, the utility of working is $k_2 * k(\frac{60}{age})^{k_1}$. Estimates in Table 6 show that k_2 is significantly less than unity,

[2]Using grouped data also makes it possible to estimate this type of model without access to individual-level data, which are more readily available to researchers. For further discussion of grouped estimation methods see Kong, Ni, Podgursky, and Wu (2018)

meaning that low quality teachers have lower utility from teaching relative to retirement. Table 7, which is based on the estimates of k, k_1 and k_2, illustrates the size of this difference. In this table we report the utility equivalent pension benefit to one dollar of teaching earnings. Note first that the utility equivalent pension declines with age for all groups, indicating a growing preference for leisure (retirement) with age. For example, at age 50 a female high quality teacher would require at least \$0.811 of pension income to replace one dollar of teaching salary. By age 65 this drops to \$0.630.

($Table$ 7)

More important, for our purposes, is the difference in utility of teaching between high and low quality teachers. For example, a 60 year old female high quality teacher is indifferent between earning a salary of \$50,000 and retiring with a benefit of \$33,650 (\$50,000*0.673=\$33,650). A similar calculation for a low quality teacher is \$29,500. In other words, focusing only on the current period and without considering the preference errors a \$30,000 pension would induce a low quality teacher to retire, but not a high quality teacher. This implies that it is relatively cheaper to keep a high quality teacher on the job. We can more precisely quantify the effect of the difference in teacher quality on retirement decision based on the estimate of k_2 and other parameters in Table 6.

In fact, high quality, high performance teachers exhibit greater job satisfaction (Koedel et al., 2017), which presumably means it is cheaper to keep them on the job. Indeed, our finding is consistent with a large occupational psychology literature which finds a positive relationship between job satisfaction and job performance (Judge, Thoreson, Bono, and Patton, 2001).

Figures 7-12 provide information regarding the overall goodness of fit of the model. Figure 7 compares the observed and predicted age distribution of retired and non-retired teachers for female and male subgroups. Figure 8 compares the observed and predicted age distributions of high and low quality teachers at the time of retirement. Figure 9 compares the observed and predicted experience distributions of retiring and non-retired teachers for female and male subgroups. As above, Figure 10 compares the observed and predicted experience distributions at the time of retirement by teacher quality and gender. The in-sample prediction is good for age and experience distributions for both retired and non-retired teachers. Figures 11 and 12 shows that the observed and predicted survival rate for each subgroup are very similar as well.

(*Figures* 7-12)

7 Retaining High Quality Teachers with Retention Bonuses

The fact that high quality teachers exhibit stronger preferences for work versus retirement suggests possible options for increasing workforce quality. One advantage in estimating a structural model such as equation (6.1) is that it allows us to simulate behavior under different pension rules and work-retirement incentives. In this section we use the model to examine the cost effectiveness of retention bonuses for high quality teachers.

The policy we consider is a one-time retention bonus to high quality teachers who satisfy a given longevity condition. In this exercise we consider a bonus paid on completing 32 years of experience. We choose 32 years of experience because it is just beyond the retirement spike that occurs under current rules at 30 years experience. Thus, the goal of the bonus would be to nudge some of the latter teachers to stay on the job for two more years.

In thinking about effects on teacher behavior, there are four mutually exclusive cases, each of which has different implications for incremental years of teaching and financial cost.

In the first case, the teacher would have retired in year $s < 32$ in absence of the bonus. Now she delays retirement and stays in the classroom for at least 32 years and collects the bonus. In the second case, the teacher would have retired in year $s < 32$. She postpones retirement in anticipation of receiving the bonus, but ends up retiring prior to year 32 anyway due to a negative shock to utility (e.g., unanticipated poor health, family matters). Teachers in these first two cases would be considered “marginal”.

A third case is “inframarginal”. This is a teacher a who planned to retire with 32 or more years of experience without a bonus. She now takes the bonus and retires as planned. Her years of teaching are unchanged but she receives the bonus anyway. A final case is a teacher who would have retired with less than 32 years experience prior to the bonus and does not change her retirement plans in response to the bonus.

An incentive that increases teaching years while minimizing the financial cost aims to create marginal teachers and avoid producing infra-marginal teachers. To do so, the bonus should be offered to teachers who are most likely to retire (so there is a bigger chance of producing a marginal teacher) and who are past the peak pension wealth year (so there is a saving in pension costs for the first type of teacher.) A bonus at 32 years of experience satisfies both criteria.

We examine three levels of bonus payments for teachers who reach 32 years experience: $5,000, $10,000 and $20,000. We then simulate retirement for our cohort of senior teachers forward for the next 30 years under 4 cases: a baseline with no retention bonus and the three bonus payments.

Figure 13 reports the experience distribution of retired teachers in the baseline case and with different levels of retention bonuses. In all cases a bonus shifts the probability mass to the right. Not surprisingly, the larger the bonus, the larger the spike at 32 years of experience and greater retention beyond. Table 8 provides more detailed information on retention and costs. A $10,000 bonus would yield an expected 431 years of additional teaching for females and 82 years for males (the latter primarily reflecting the smaller employment share of males). The bonus cost (not including salary) per incremental year is roughly $40,000. Interestingly, the average cost is largely independent of the size of the bonus since doubling the bonus roughly doubles the number of additional years. The net cost of the bonuses is lower since most of the marginal teachers are induced to remain on the job past the peak of pension wealth in Figure 2. These savings to the pension plan range from $700 - $1800, which reduces the net cost per incremental teaching year somewhat.

(*Figure* 13)

Structural-model-based simulations on retention bonus offers insights into the channels by which the bonus policy works. Because the bonus is offered when teachers reach 32 years of experience, the relevant subset for a bonus consists of teachers with experience less than 32 years in 2011. For purposes of this simulation, we will assume that only teachers with less than 32 years of experience would be eligible for the program. The second row of the upper panel of Table 9 shows that the total number of female high quality teachers eligible for the bonus policy is 7735 (out of 10,307 in the sample). We now examine in more detail how a $10,000 bonus generates the 431 additional years in Table 8.

Table 9 provides some insight into the gains from a $10,000 bonus, The number of marginal teachers who switched from retiring before 32 years to at or after 32 years is 1959-1904=55. The number of "inframarginal" teachers, i.e., teachers who collect the bonus without changing their previous plan of retiring with 32 years or more experience, is much larger – 1904. At a first glance it is puzzling how 55 switchers can generate 431 additional years. Moreover, would this not make the plan exorbitantly expensive, with a ratio of inframarginal to marginal teachers of nearly 35:1? But Table 9 shows not all years gained are due to switchers, and that there are more than 55 marginal teachers. In fact, for both females and males roughly 45 percent of the additional years due to the bonus are generated by teachers who never collect the bonus. This arises from the longer average years per teacher for the 5776 female and 1111 male teachers who never collect the bonus (Experience < 32 after the bonus).

($Table$ 9)

For comparison, Chetty et al. (2014) estimate that replacing a classroom teacher at the median level of effectiveness with a teacher at the 95th percentile raises the discounted present value of student earnings by $212,000. This suggests that a retention bonus targeted to the best teachers is likely to be justified by benefit to students.[3]

($Table$ 8)

8 Conclusion

Many states are facing challenges financing teacher existing teacher retirement plans as well as staffing schools with qualified teachers. With regard to staffing, much attention has focused on teacher training and early career retention. Workforce churn induced by teacher retirements has received much less attention. In this paper, we make use of a longitudinal administrative teacher data file for Tennessee teachers, where a statewide teacher evaluation system identifies high and low quality teachers.

Descriptive analysis shows that for both females and males, high quality teachers have a lower retirement rate given age and experience. To better understand the effects of pension incentives on retirement behavior, we estimated a structural retirement model, which provided good in-sample fit. The structural estimates imply that high quality teachers have

[3] Of course, if these high quality teachers had retired they would have been replaced by novice teachers at lower pay, and of indeterminate but likely lower quality. Assuming that all high quality teachers are replaced by novices, this would add roughly $25,000 to the net costs per incremental year in Table 8. Presumably there would be a substantial reduction in teacher quality as well if an experienced high quality teacher is replaced by a random novice.

lower disutility of teaching as compared to retirement. We used the structural estimates to simulate the cost of retention bonuses designed to retain high quality teachers. We find that the cost of an additional high quality year is roughly $40,000 per year, depending on teacher gender and the size of the bonus. Assuming the Tennessee system provides a reliable estimate of teacher quality, and given recent estimates of the lifetime value of a high quality teacher (Chetty et al., 2014), these estimates suggest that retention bonuses can be a cost efficient strategy for workforce improvement. More generally, structural retirement models like the one estimated in this paper, can provide a useful tool for analyzing short and long run staffing effects of changes in pension plan design.

Table 1: Summary of Tennessee Teacher Pension Rules

Normal Pension	$Age \geq 60$ with $Experience \geq 5$
	or $Experience \geq 30$
Early Pension (Age 55)	$Age \geq 55$ with $Experience \geq 5$
Early Pension (Experience 25)	$Experience \geq 25$ with $Age \geq 47$
Replacement Factor	1.50%
Benefit Improvement	1.05

Table 2: Descriptive Statistics

	# of Teachers		Age		Experience		Evaluation Level	
	Female	Male	Female	Male	Female	Male	Female	Male
Teachers in 2011-12	13989	3139	56.67	56.79	24.25	22.82	4.11	3.75
Retire 2012	1345	291	59.31	59.64	28.41	26.85	4.01	3.54
Retire 2013	1941	399	59.89	59.86	28.47	25.72	3.98	3.42
Retire 2014	1700	365	60.15	60.47	28.83	27.22	4.12	3.79
Not Retired 2014-15	9003	2084	57.52	57.70	24.45	23.48	4.15	3.83

Note: Tennessee teachers aged 50-65 and with at least 5 years of experience in the 2011-2012 school year. The evaluation levels in all rows are those reported at the base year (2011-2012 school year). The age and experience columns report the averages for retired teachers in that year or for not retired teachers at the end of the sample period .

Table 3: Retirement Behavior for High and Low Quality Teachers

	Female		Male	
	Low	High	Low	High
Number of Teachers in 2011-12	3682	10307	1245	1894
Average Age 2011-12	56.67	56.67	56.85	56.74
Average Experience 2011-12	23.64	24.47	22.40	23.10
Number of Retired Teachers	1387	3599	467	588
Retirement Rate	0.377	0.349	0.375	0.310
Average Age at Retirement	59.69	59.87	59.83	60.15
Average Experience at Retirement	27.83	28.86	25.48	27.41

Note: Retirement rate is defined as Row 4 divided by Row 1.

Table 4: Regression Results for Linear Probability Models

	Dependent Variable: Retire			
	(1)	(2)	(3)	(4)
	Female Teachers	Male Teachers	Female Teachers	Male Teachers
Teacher Quality	-0.035***	-0.064***	-0.028***	-0.059***
	(0.008)	(0.016)	(0.009)	(0.018)
Experience	0.008***	0.004***	0.008***	0.005***
	(0.0004)	(0.001)	(0.0004)	(0.001)
Age	0.036***	0.036***	0.035***	0.036***
	(0.001)	(0.002)	(0.001)	(0.002)
Constant	-1.845***	-1.781***	-1.825***	-1.986***
	(0.052)	(0.106)	(0.069)	(0.148)
District Fixed Effects	NO	NO	YES	YES
Observations	13989	3139	13989	3139
R^2	0.158	0.140	0.185	0.200
Adjusted R^2	0.158	0.139	0.176	0.165
Residual Std. Error	0.440 (df = 13985)	0.438 (df = 3135)	0.435 (df = 13851)	0.432 (df = 3008)

Note: Linear probability model (Regression (3) and (4) include district fixed effects):

$$Retire_i = \beta_0 + \beta_1 Quality_i + \beta_2 Experience_i + \beta_3 Age_i + \epsilon_i$$

*p<0.1; **p<0.05; ***p<0.01

Table 5: Structural Model Parameters

Parameters	Economic Interpretation
$\beta \in (0,1)$	discount factor
$k \in (0,1)\,\&\, k_1 > 0$	$k_s^{high} = k(\frac{60}{age})^{k_1}$: disutility of working for high quality teachers
$k_2 > 0$	$k_s^{low} = k_2 * k(\frac{60}{age})^{k_1}$: disutility of working for low quality teachers
$\gamma \in (0,1]$	curvature in the utility function ($\gamma < 1$ indicates concavity)
$\sigma > 0$	magnitude of unobserved preference shocks
$\rho \in (-1,1)$	persistence in unobserved preference shocks

Table 6: Estimates of Structural Parameters

	Female	Male
β	0.959	0.955
	(0.007)	(0.020)
k	0.673	0.707
	(0.004)	(0.011)
k_1	1.021	0.835
	(0.006)	(0.019)
k_2	0.876	0.829
	(0.007)	(0.021)
γ	0.731	0.784
	(0.007)	(0.018)
σ	5708.019	7774.064
	(58.183)	(154.624)
ρ	0.619	0.693
	(0.006)	(0.016)
Log-Likelihood	-13798.534	-3050.272
Number of Teachers	13,989	3,139

Note: The standard errors in parentheses.

Table 7: Disutility of Working versus Retirement for High and Low Quality Teachers

Age	Female High	Female Low	Male High	Male Low
50	0.811	0.710	0.823	0.682
51	0.794	0.696	0.810	0.671
52	0.779	0.682	0.797	0.660
53	0.764	0.669	0.784	0.650
54	0.749	0.657	0.772	0.640
55	0.736	0.644	0.760	0.630
56	0.722	0.633	0.749	0.621
57	0.709	0.621	0.738	0.612
58	0.697	0.610	0.727	0.603
59	0.685	0.600	0.717	0.594
60	0.673	0.590	0.707	0.586
61	0.662	0.580	0.697	0.578
62	0.651	0.570	0.688	0.570
63	0.640	0.561	0.679	0.563
64	0.630	0.552	0.670	0.555
65	0.620	0.543	0.661	0.548
66	0.611	0.535	0.653	0.541
67	0.601	0.527	0.645	0.535
68	0.592	0.519	0.637	0.528
69	0.584	0.511	0.629	0.522
70	0.575	0.504	0.622	0.515

Note: The table shows the retirement benefit utility equivalent of one dollar of earnings for teachers aged 50 to 70 based on the estimates of k, k_1 and k_2 in Table 6. For example, At age 60, one dollar of teaching earnings is worth \$0.673 for a high quality female teacher.

Table 8: Effects of Retention Bonuses for High Quality Teachers

	Female High Quality, Retention Bonus at Experience 32		
	Bonus $5K	Bonus $10K	Bonus $20K
Additional Teaching Years	210	431	901
Bonus Costs per Additional Teaching Year (2012 $)	$45696	$45265	$44567
Pension Savings per Additional Teaching Year (2012 $)	$763	$795	$957
Net Costs per Additional Teaching Year (2012 $)	$44932	$44470	$43610
	Male High Quality, Retention Bonus at Experience 32		
	Bonus $5K	Bonus $10K	Bonus $20K
Additional Teaching Years	38	82	174
Bonus Costs per Additional Teaching Year (2012 $)	$43901	$41662	$40611
Pension Savings per Additional Teaching Year (2012 $)	$1476	$1583	$1866
Net Costs per Additional Teaching Year (2012 $)	$42425	$40079	$38744

Note: Simulation tracks high quality teachers for 30 years under 4 cases: without retention bonus and with three bonuses – $5K, $10K and $20K – paid in their 32nd year of teaching.

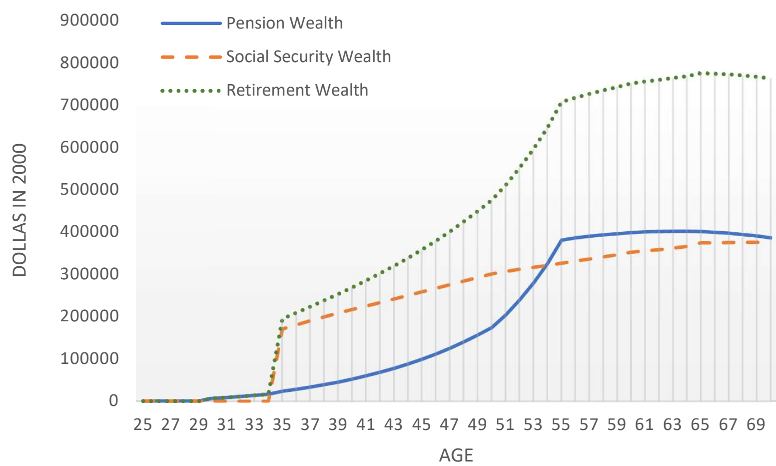
Table 9: Effects of a $10,000 Retention Bonus: Marginal and Infra-Marginal

	Female High Quality					
	Without Bonus			With Bonus ($10K)		
	Retired before 32	Retired ≥32	Total	Retired Before 32	Retired ≥32	Total
Teaching Years	29721	15819	45540	29635	16336	45971
Teachers Retired	5831	1904	7735	5776	1959	7735
Average Years Per Teacher	5.10	8.31	5.89	5.13	8.34	5.94

	Male High Quality					
	Without Bonus			With Bonus ($10K)		
	Retired Before 32	Retired ≥32	Total	Retired Before 32	Retired ≥32	Total
Teaching Years	6018	3058	9076	5996	3162	9158
Teachers Retired	1122	334	1456	1111	345	1456
Average Years Per Teacher	5.30	9.16	6.23	5.40	9.17	6.29

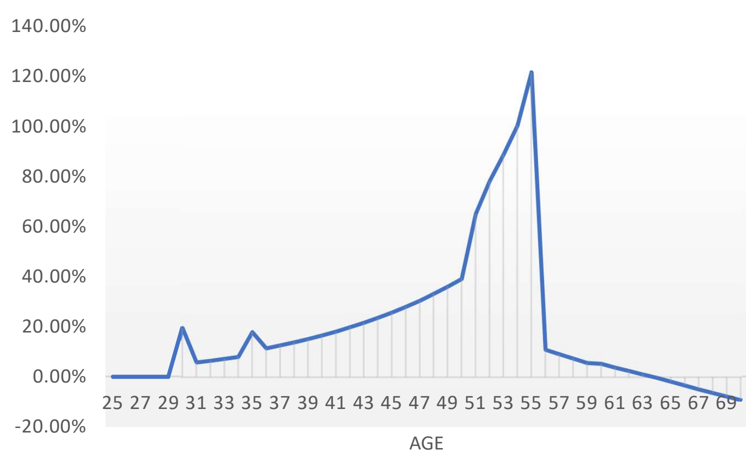
Note: Simulation tracks high quality teachers (only teachers with initial teaching experience under 32 years) for 30 years without retention bonus and with $10K bonus paid in their 32nd year of teaching.

Figure 1: Pension Wealth, Social Security Wealth and Retirement Wealth



Note: This figure illustrates the life pattern of pension wealth, social security wealth and retirement wealth for a representative teacher who enters the system at age 25.

Figure 2: Pension Wealth Accumulation



Note: This figure illustrates the life pattern of pension wealth accumulation for a representative teacher who enters the system at age 25.

Figure 3: Distribution of Teacher Quality (1-5) for Female and Male Teachers in the base year (2011-2012)

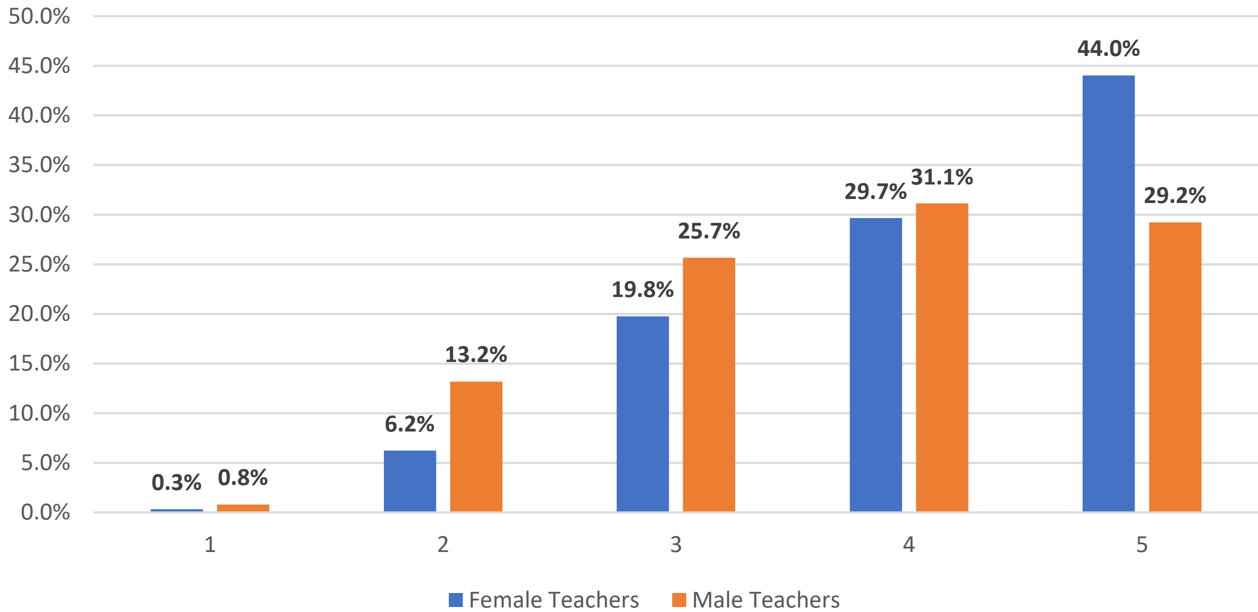
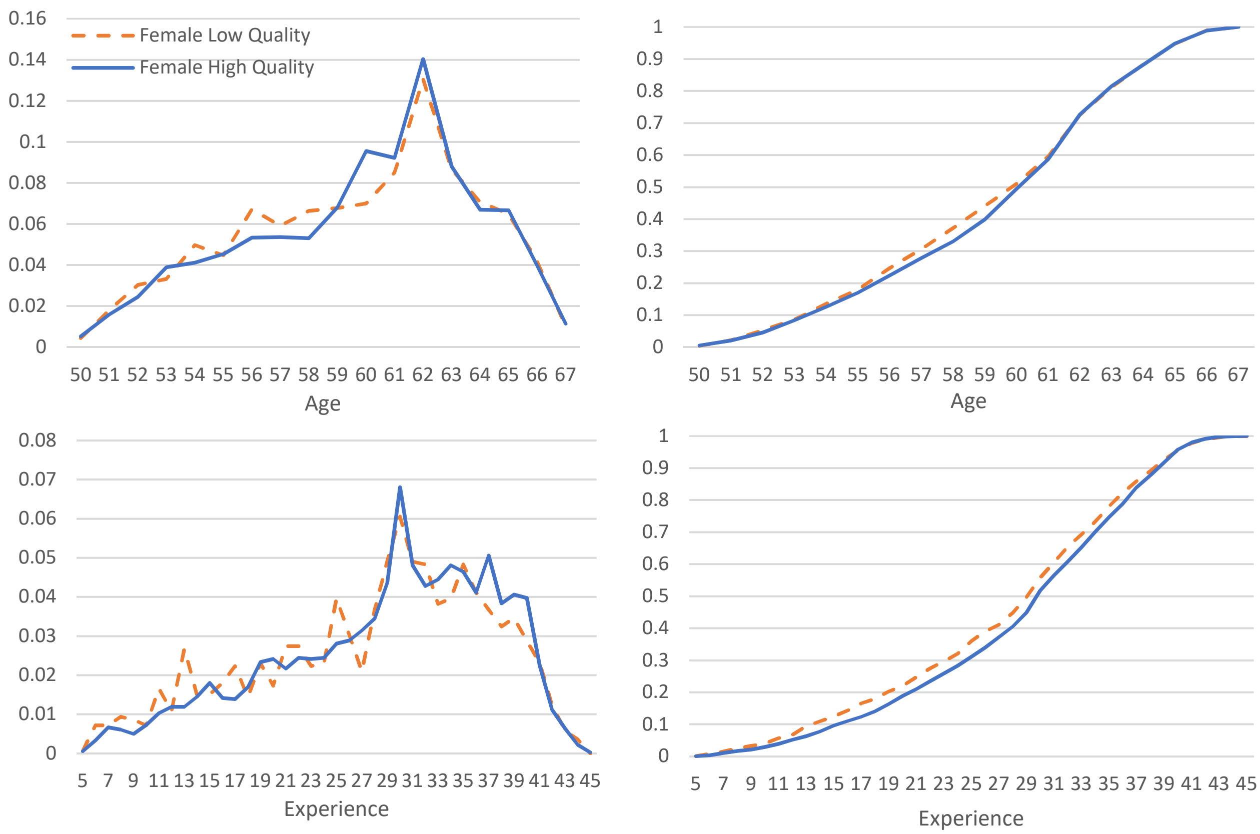
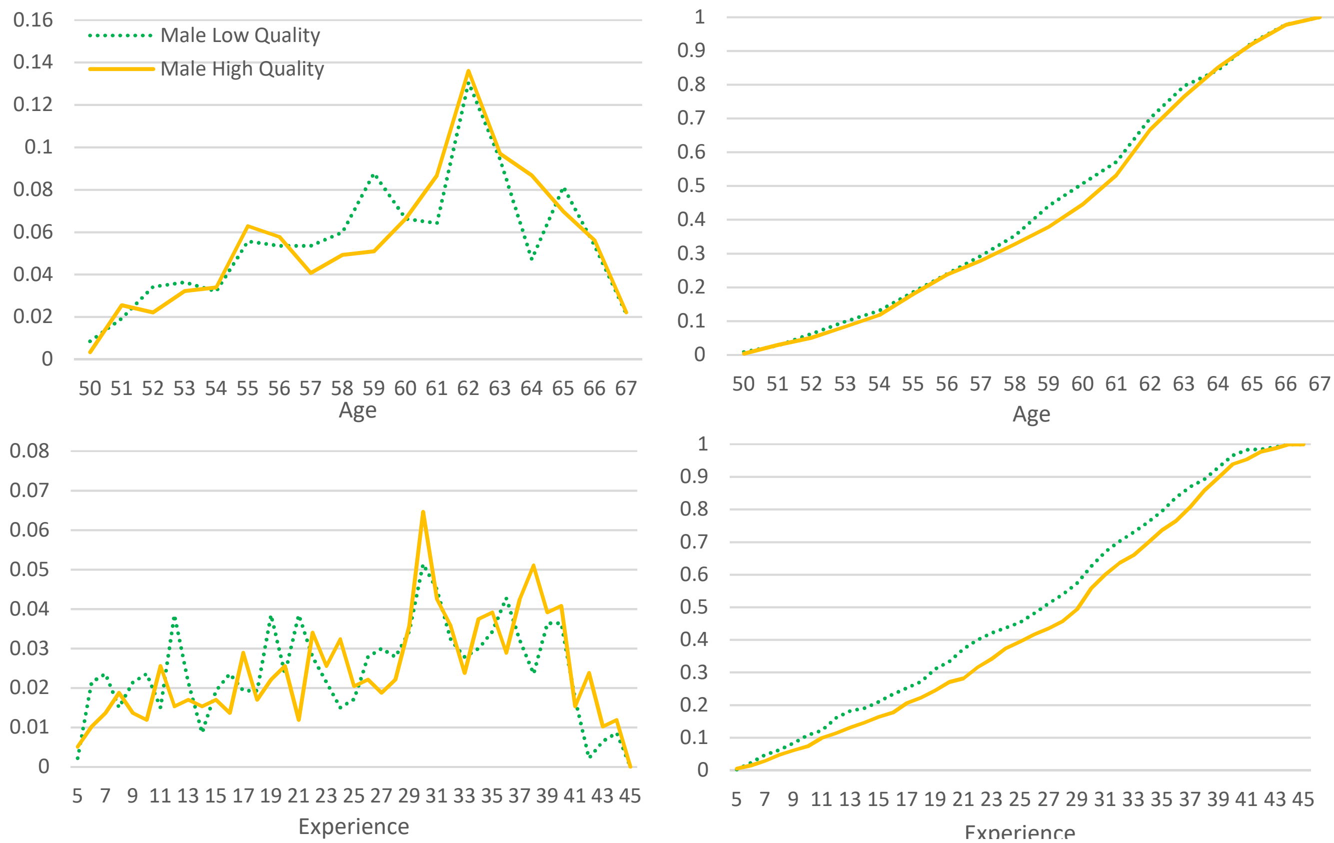


Figure 4: Distribution of Female Retired Teachers by Quality



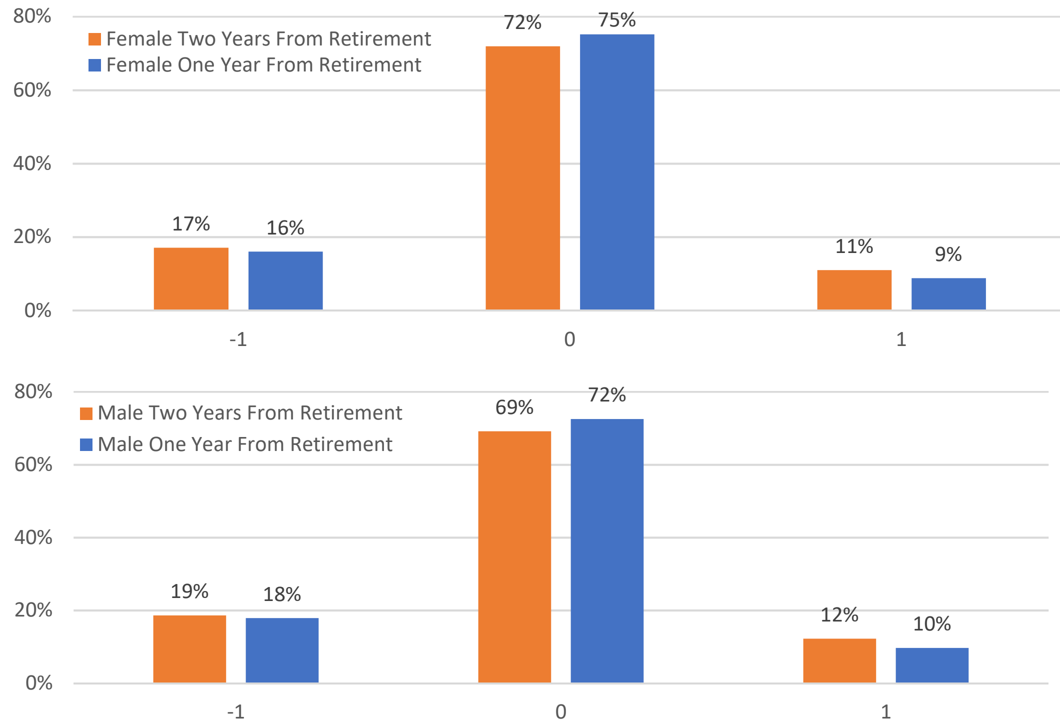
Note: The graphs plot the age and experience distribution of female retired teachers. The two graphs on the left are probability density functions while the two graphs on the right are cumulative density functions.

Figure 5: Distribution of Male Retired Teachers by Quality



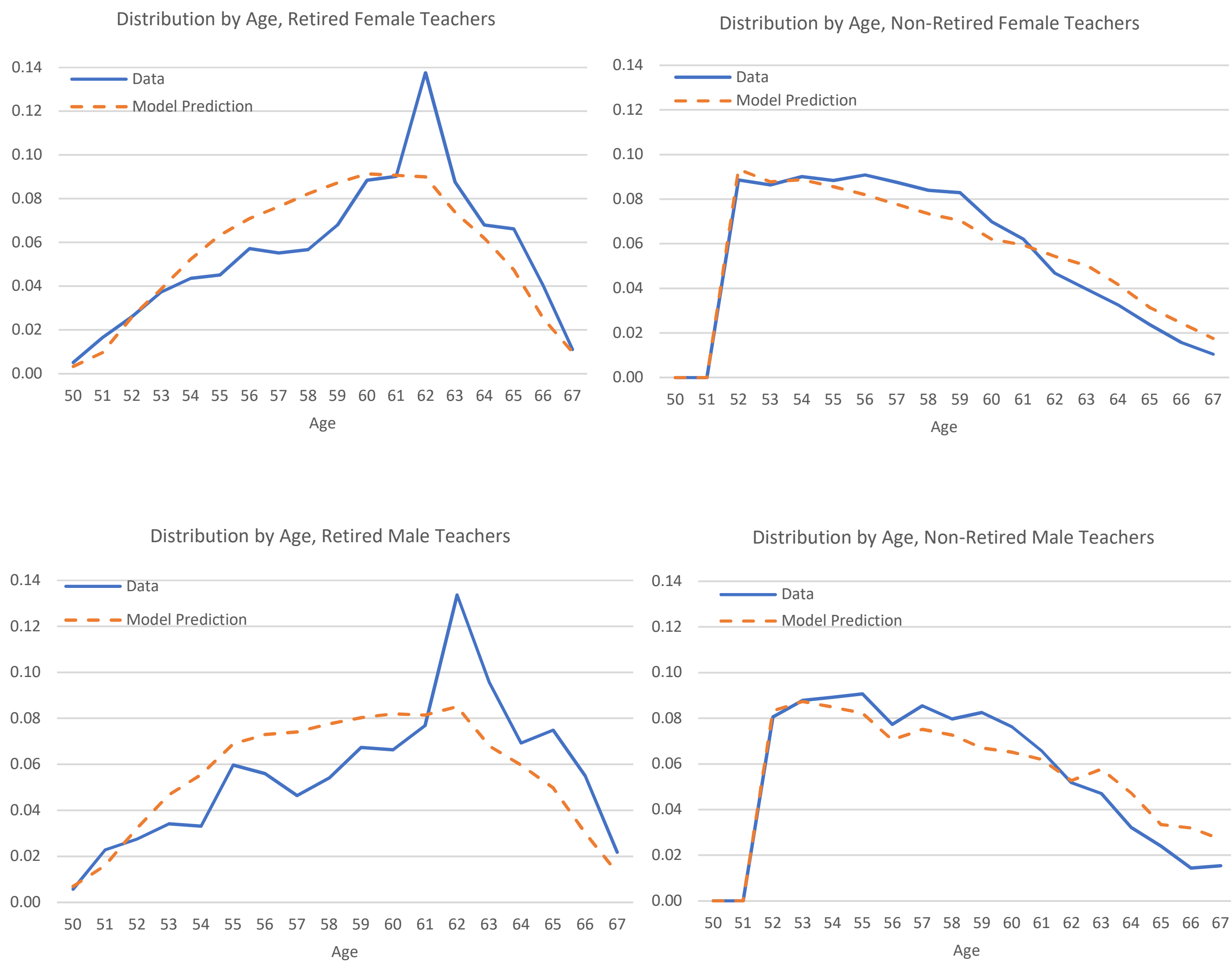
Note: The graphs plot the age and experience distribution of male retired teachers. The two graphs on the left are probability density functions while the two graphs on the right are cumulative density functions.

Figure 6: Year-to-Year Change in Quality Measure for Teachers Who Retired by 2014



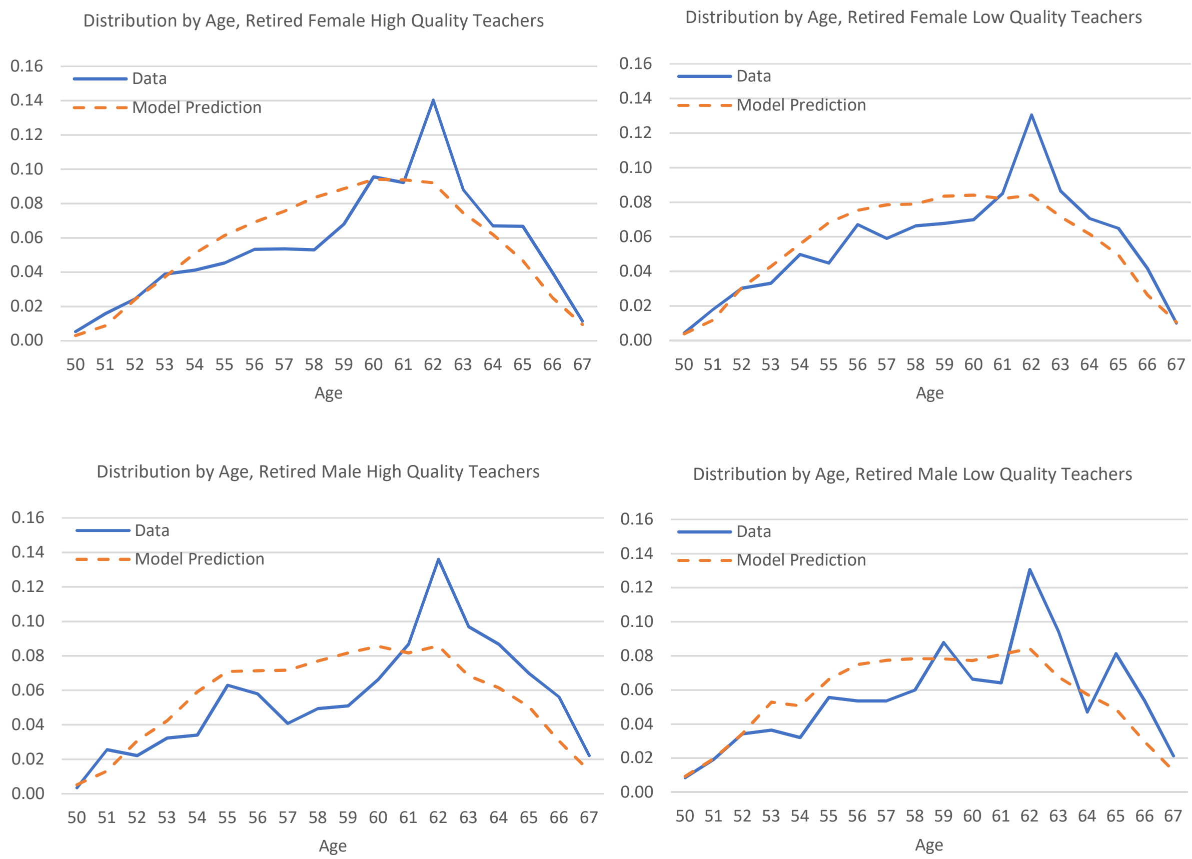
Note: The histograms show the change in quality measure for the same teacher in the two years prior to retirement. If the teacher retired in year t, the left bar indicates the change in score from t-2 to t-1, while the right bar reports the change from t-3 to t-2. The vast majority of teachers have no change in classification. -1 illustrates a fall in classification and +1 indicates a rise.

Figure 7: Observed and Predicted Age Distribution



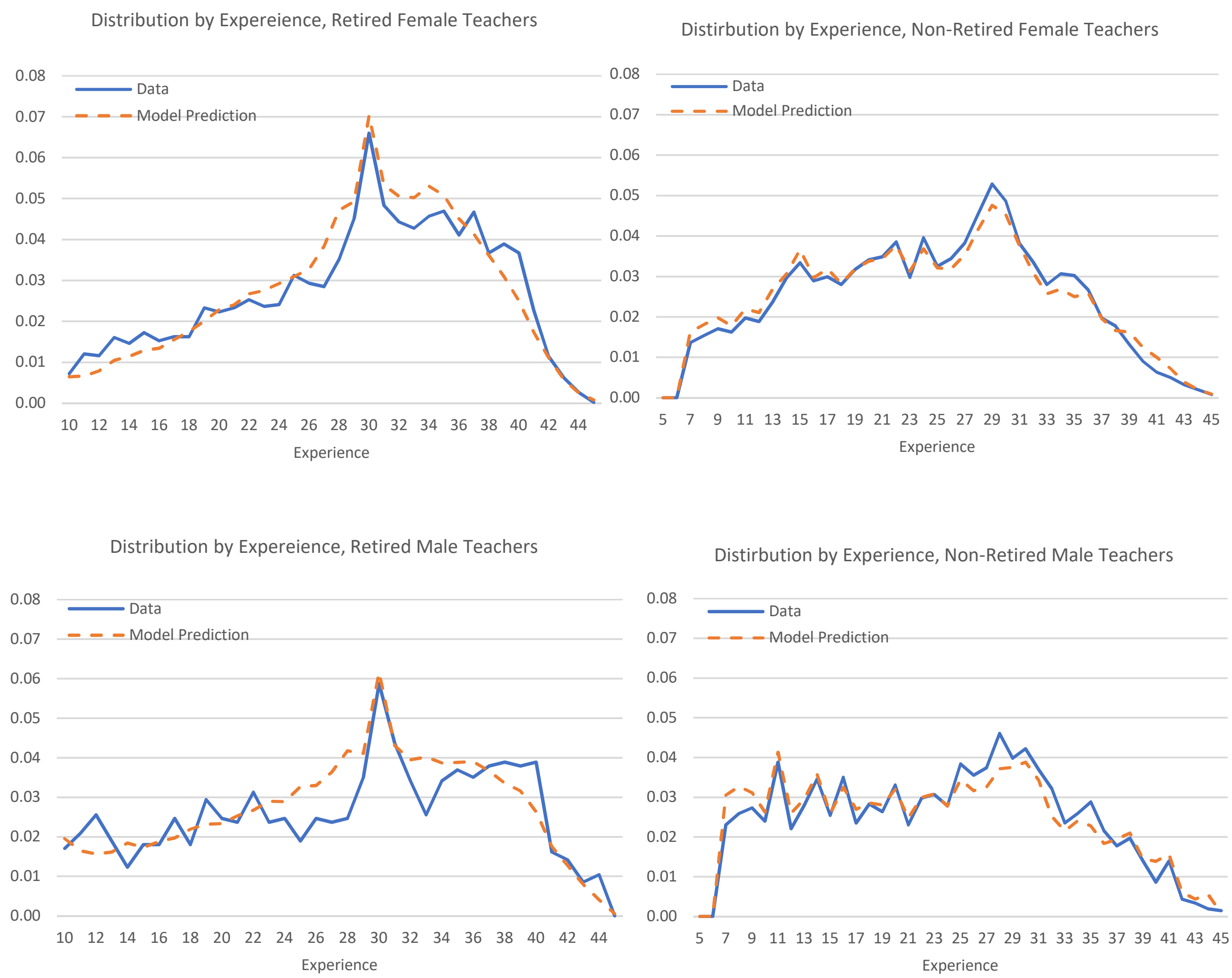
Note: The figure compares observed and predicted age distribution of female and male teachers. The model prediction is the in-sample prediction based on the estimates in Table 6. The left panels represent the distributions for retired teachers and the right panels are distributions for non-retired teachers.

Figure 8: Observed and Predicted Age Distribution for Teachers by Quality



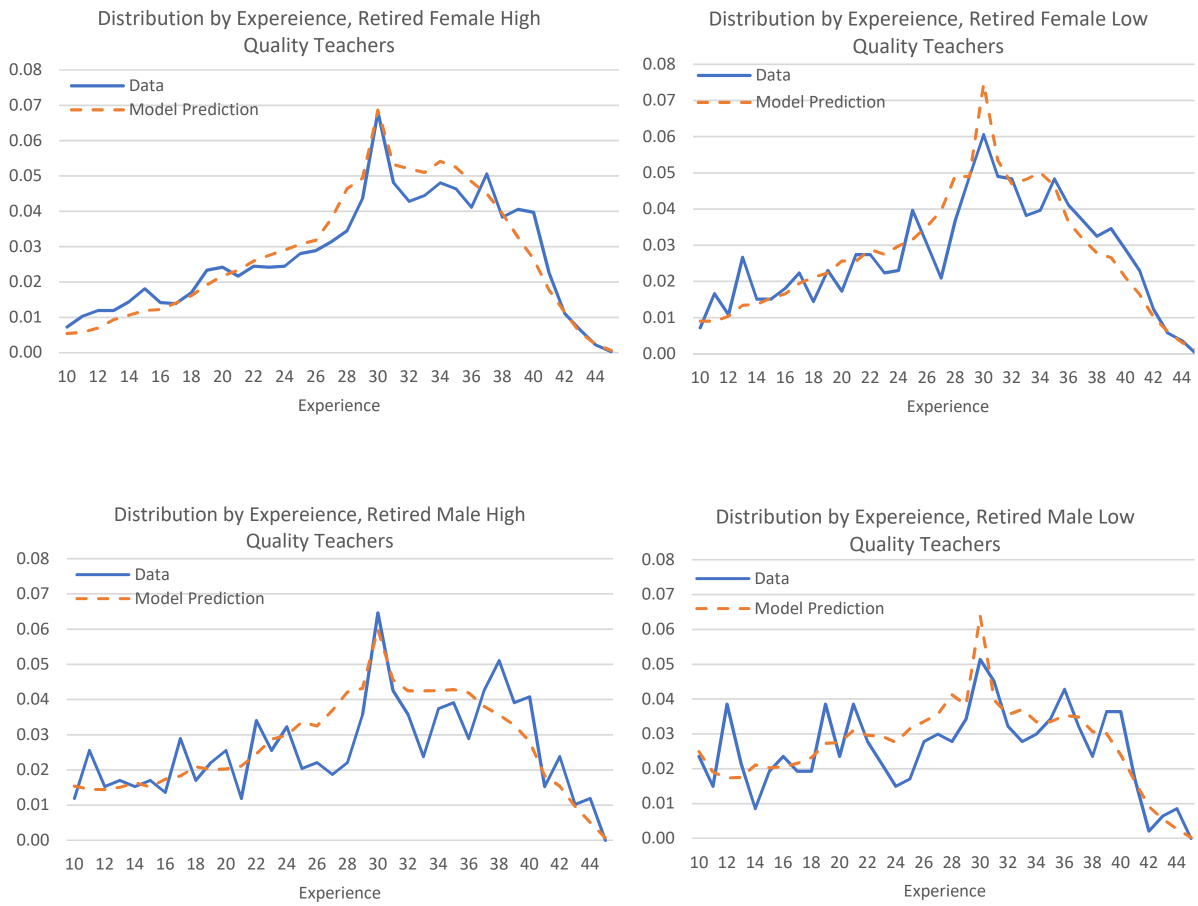
Note: The figure compares observed and predicted age distribution of female and male teachers with high and low performance. The model prediction is the in-sample prediction based on the estimates in Table 6.The left panels are female and male teachers with high score while the right panels are female and male teachers with low score.

Figure 9: Observed and Predicted Experience Distribution



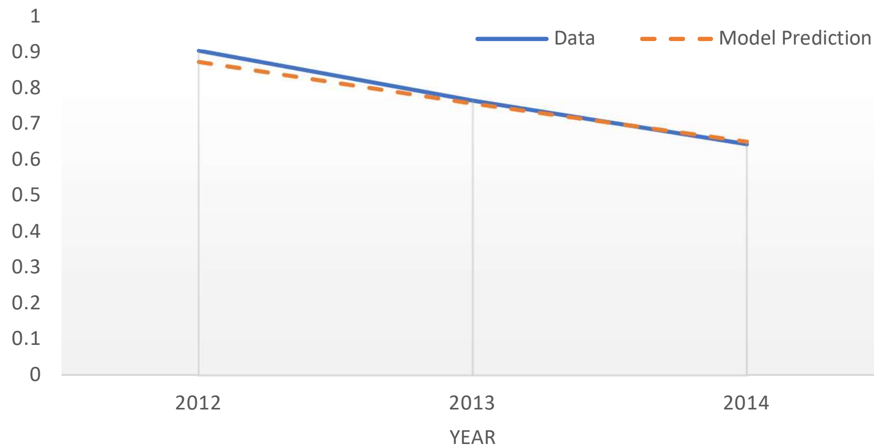
Note: The figure compares observed and predicted experience distribution of female and male teachers. The model prediction is the in-sample prediction based on the estimates in Table 6. The left panels represent the distributions for retired teachers and the right panels are distributions for non-retired teachers.

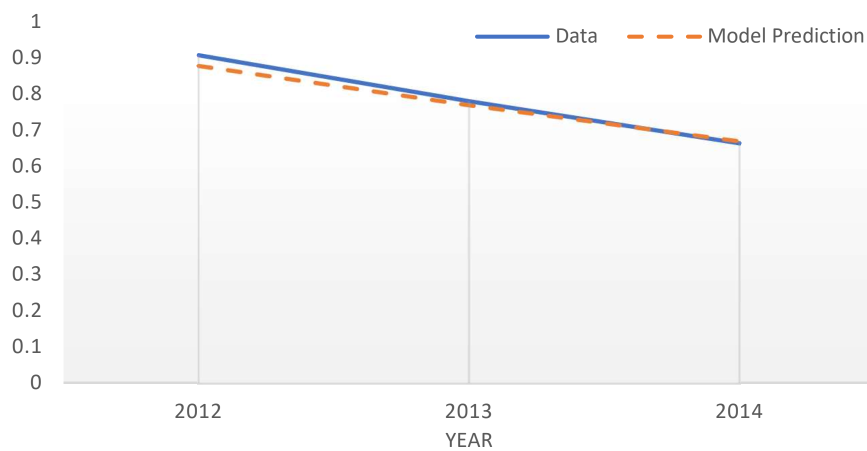
Figure 10: Observed and Predicted Experience Distribution by Quality



Note: The figure compares observed and predicted experience distribution of female and male teachers with high and low score. The model prediction is the in-sample prediction based on the estimates in Table 6. The left panels are female and male teachers with high scores while the right panels are female and male teachers with low scores.

Figure 11: Observed and Predicted Survival Rate



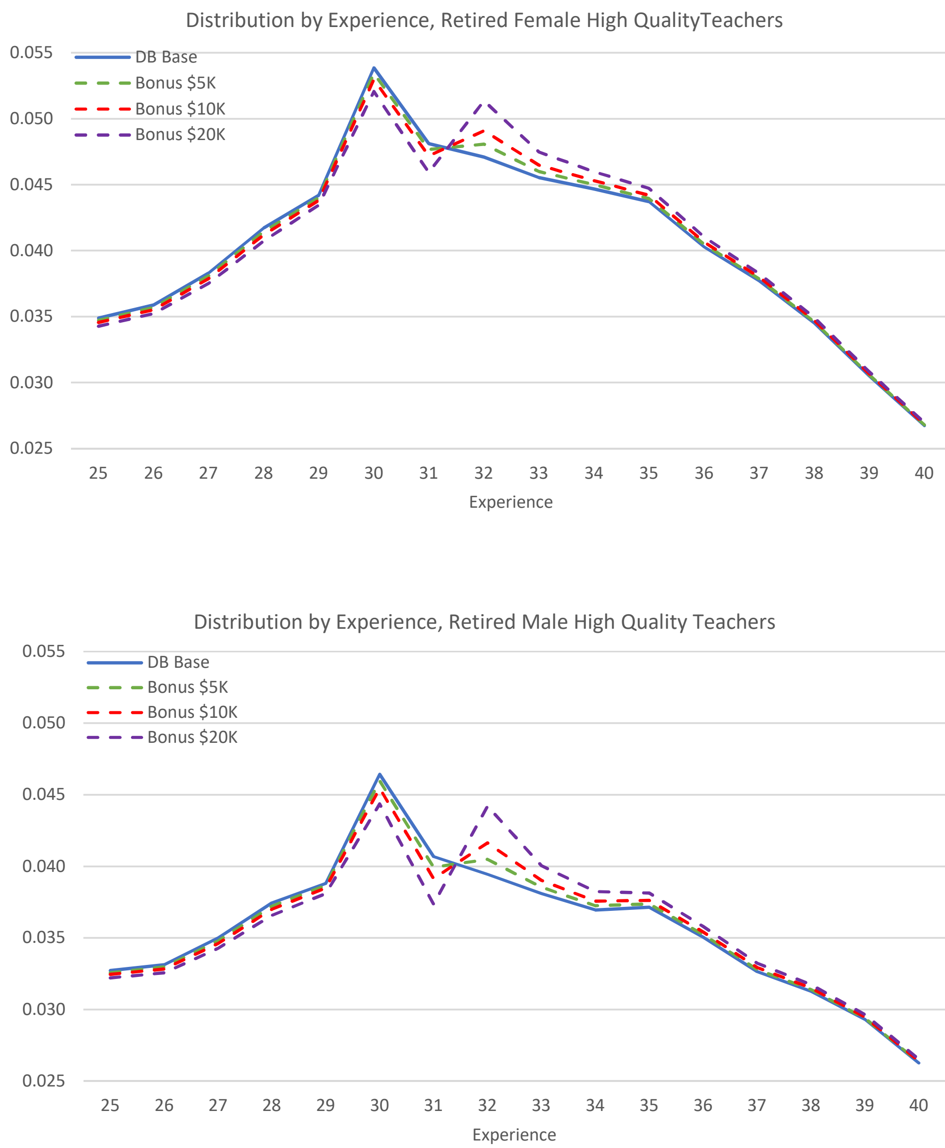


Note: The figure compares observed and predicted survival rate of female and male teachers. The model prediction is the in-sample prediction based on the estimates in Table 6.

Figure 12: Observed and Predicted Survival Rate for Teachers by Quality

Note: The figure compares observed and predicted survival rate of female and male teachers with high and low score. The model prediction is the in-sample prediction based on the estimates in Table 6. The left panels are female and male teachers with high scores while the right panels are female and male teachers with low scores.

Figure 13: Experience Distribution of Retired High Quality Teachers with Retention Bonus



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