Retaining a High Quality Teaching Workforce: The Effects of Pension Design

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1. Introduction

Over the next decade, more than half of all public school teachers will become eligible for retirement (National Commission on Teaching and America's Future, 2009). Attrition of these experienced persons could have negative consequences on student learning and further exacerbate the disproportionate demand for high quality teachers in disadvantaged schools. This potential crisis is driven by the aging Baby Boom Generation that makes up a large portion of the teaching workforce, but, it is amplified by the public pension systems that provide incentives for teachers as young as 50 years old to retire. My research concerns how these incentives affect the retention of effective teachers who have large impacts on student learning, and the retention of teachers in hard-to-staff schools.

Teacher retirement funds fall short of their liabilities by an estimated $1 trillion, causing many states to consider cost-saving changes including restructuring their pension plans (Pew Center on the States, 2010). Public school teachers in almost every state are eligible for defined-benefit pension plans, which are quite different from the defined-contribution plans (e.g., a 401(k)) offered in most private sector jobs. Defined-benefit plans provide teachers with a fixed annuity paid regularly over their retirement, and teachers must reach certain age-experience thresholds to begin receiving payments. In contrast, a defined-contribution plan entails money put aside in an account that can be accessed by the individual at a later age. The present structure of defined-benefit plans provides incentives to “pull” mid-career individuals toward continuing teaching, while “pushing” later-career teachers out of the profession. These incentives may affect the behavior of teachers differentially, possibly impacting schools and student outcomes. Therefore, I ask:

- How responsive are teachers to the "pull" and "push" of pension incentives?
- Do teachers with different characteristics (qualifications, effectiveness) have different responses to pension incentives?
- Do teachers in different school environments (student racial/ethnic composition, student poverty, grade level, urbanicity) have different responses to pension incentives?

The answers to these questions inform the debate on pension reform. For example, if teachers are quite responsive to these incentives, then schools may benefit from the “pull” to keep them teaching in mid-career, but suffer from “pushing” them out later when students may still gain from their expertise.

I exploit variation driven by pension rules to explore my research questions. In North Carolina, pension eligibility occurs at set age-experience combinations: age 60 with 25 years experience, age 65 with 5 years, or any age with 30 years. Consider two individuals with 25 years of experience, but one is age 59 and the other is 60. The older teacher crosses the age#60-exp#25 threshold earlier and can exit this year and receive benefits immediately, while the younger teacher has to wait an additional year. Assuming the exit behavior of 59- and 60-year-old individuals is comparable in the absence of pensions, the difference in the exit behavior of these two individuals is driven by the pension system.[1] All of my specifications include controls for current pension wealth, age and earnings, and are identified off of differences in an individual's behavior from those with similar characteristics due to sharp changes in pension receipt eligibility.

To empirically explore my research questions, I use a unique set of detailed data on every North Carolina teacher and student over 14 years, as described in Section 3. These data allow me to follow teachers over time and explore their responses to the North Carolina retirement plan. I link teachers to their schools to learn if exit behavior differs by school characteristics, such as student demographics. These data have teacher quality measures that I use to study how exit behavior varies with teacher effectiveness. I associate 4th and 5th teachers with their students who took End-Of-Grade (EOG) achievement tests. This allows me to evaluate a teacher’s quality in terms of her prior teaching performance, measured using teacher value-added.

My results show that teachers are quite responsive to pension incentives: when the average teacher reaches eligibility for her benefits, the probability she exits is around 17 percentage points higher than the probability of exit just two years earlier. High and low quality teachers have a higher probability

[1] More precisely, in order to determine that differences in their exit behavior are driven by pensions, I assume that the natural differences in the propensity of 59- and 60-year-olds are accounted for assuming a smooth function of age.

of exit than those of medium quality upon reaching eligibility. These differences by quality could be driven by the exhausting effort that an individual has to put forth to be a high quality teacher, or a low-quality teacher having fewer non-pecuniary benefits from teaching. It is important to note that these results by quality may not be applicable to the workforce for whom I cannot measure value-added, as non-value-added teachers have a higher propensity to leave than value-added teachers regardless of pension eligibility. Teachers respond differently to pension incentives based on some attributes of their school. Teachers in urban schools and schools with a high percentage of black students are less responsive than those in other schools. This may be due to the comparatively strenuous nature of their working conditions, causing them to receive less non-pecuniary utility from teaching. However, there are no differences in pension responses by percentage of free/reduced price lunch students in one's school. It is important to note that my results are conditional on those who persist in teaching long enough to reach 40-years-old and be a member of my sample. Furthermore, even for those in my sample, the effect of becoming eligible for retirement benefits is only identified by those who chose to stay in teaching until that point. However, prior to eligibility for one's pension the average attrition rate for teachers in my sample is around five percent, so selective attrition is limited.

In Section 2 I describe the literature on modeling pension incentives, and provide evidence that, despite receiving similar salaries, other research has found that teachers with different quality or working conditions vary in terms of their persistence in the workforce. This evidence suggests that teachers may also respond differently to pensions. To understand why these differences exist, I develop a model of teacher behavior in Section 4 where individuals have different values for teaching and exiting. Teachers' values differ because they have different non-pecuniary benefits from teaching, such as a helpful principal or simply enjoy the profession. My inclusion of individuals' characteristics is a significant innovation in modeling retirement behavior, and especially important when studying teachers because they are paid according to a rigid salary schedule.

In Section 5 I present my estimation strategy to examine variation in teacher exit behavior in response to the pension eligibility rules. These rules, as well as growth in pension wealth create the "pull" and “push” described earlier, allowing me to estimate the causal effect of pension incentives on teacher retention. In Section 6 I describe my results. In Section 7 I explain some policy implications of this research.

2. My Contributions and a Review of the Literature

A few studies examine teacher pensions (Costrell and Podgurksy, 2009; Friedberg and Turner, 2010), with five focusing on differential responses among teachers (Furguson, Strauss, and Vogt, 2006; Friedberg and Turner, 2011; Costrell and McGee, 2010; Koedel, Podgursky, and Shi, working paper; McGee, working paper). In the most closely related study, McGee (working paper) analyzes teacher responses by quality level in Arkansas. I use a different methodology that isolates an additional source of the variation in retirement incentives within the North Carolina pension plan: years until eligible for immediate pension benefit receipt. McGee (working paper) is hampered by potentially important data limitations due to measuring teaching quality at the grade-level (grouping several teachers together). I have measures of teacher quality at the teacher-level, which substantially reduces the measurement error associated with grade-level data. I also have a 14-year panel of data, which allows me to observe an individual's work history and separate the effects of pension incentives from the effects of an increase in the value of leisure over an individual's lifetime.

My study lies more broadly at the intersection of two areas of research: behavioral responses to retirement incentives and teacher retention. Economists have established a number of ways to assess the value of future retirement income to an individual today (e.g., Stock and Wise, 1990; Samwick, 1998). I study a single pension system where individuals are paid using a salary schedule based on years of experience and education. I exploit variation driven by the pension rules that affect one’s eligibility for pension receipt and the magnitude of her pension wealth over time.

There is a large body of literature on teacher retention, often studying teachers early in their careers. Many papers study the effect of current compensation on teacher turnover using variation in pay scales across districts, which may be endogenous, or salaries in alternative occupations, which are difficult to accurately measure (e.g. Podgursky et al., 2008; Hanushek et al. 2004). I use variation in more precise measures, benefit eligibility thresholds and pension accruals, which are primarily driven by exogenous factors such as a teacher's age and years of experience.

Another branch of literature focuses specifically on the quality of retained teachers. These studies show that teacher retention varies by teachers' general knowledge test scores and the competitiveness of the college attended, finding that those with better credentials are more likely to exit (Boyd et al., 2005; Lankford et al., 2002). Researchers have also developed the value-added measure of quality, which is the average growth in achievement that a teacher’s students experience during the school year (Rivkin et al., 2005). Many studies compare the value-added measures of exiting early-career teachers to those who stay, finding that those with higher value-added are more likely to stay (e.g. Boyd et al., 2007; Goldhaber, Gross, and Player, 2007). I study the behavior of mid- and later-career teachers with respect to their qualifications, as well as their value-added as measured over multiple years.[2]

Researchers have additionally studied the sorting of different types of teachers across schools, concluding that schools with more disadvantaged students are likely to have high teacher turnover and generally less effective teachers (Clotfelter et al., 2006; Boyd et al., 2007). I study whether teachers in hard-to-staff schools are also more responsive to pension incentives.

3. North Carolina Pension Plan and Data

North Carolina teacher pension plan. Teachers in North Carolina, and most other states, are eligible for a defined-benefit pension plan that provides an annuity paid regularly after they retire from teaching. This annuity equals 1.82% of the average salary of their last four years, multiplied by the years they have taught in North Carolina public schools. This annuity comprises a large portion of a teacher’s total compensation; for instance, a 30-year teacher receives over half of her highest salary each year upon retirement. Teachers are entitled to full pension benefits when they reach certain age-experience thresholds: full benefit eligibility at age 60 with experience 25, age 65 with experience 5, or any age with

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[2] Rothstein (2008) notes the bias introduced in value-added measures due to the non-random assignment of students and teachers. Koedel and Betts (2011) show that measuring value-added with many years of data, as I do, reduces this bias.

experience 30.[3] I explore exit behavior as a function of distance from these thresholds as a measure of pension incentives. If exit behavior if the same regardless of how close or far away one is from eligibility, then the incentive to wait for eligibility is not strong. On the other hand, if the probability of exit decreases as one approaches eligibility (relative to what it would be in the absence of pensions) then pension incentives were likely "pulling" individuals to stay. Once one has passed eligibility, they might exit more rapidly than they would in the absence of pensions due to a pension “push” and the possibility of her total retirement income actually decreasing if she waits too long to retire.

Any retirement plan is likely to affect teacher exit behavior. In order to isolate the effect of defined-benefit pensions I control for one’s pension wealth in all of my specifications. I calculate pension wealth by collapsing the stream of annuity payments one will receive into one number: the pension’s present discounted value. The pension wealth of individual i who exits teaching in year t and receives annuity $annuity_{it}$ is:

$$(1) \quad PensionWealth_{it} = \sum_{s=t}^{T} \beta^{s-t} \pi_{s|t} annuity_{it}.$$

This calculation discounts payments received later (because they are less valuable than those received sooner) by multiplying by a discount rate β, which I assume to be 0.95. Pension wealth is also a function how long one lives, so each annuity is multiplied by the probability $\pi_{s|t}$ that one is alive in the later period (s) to receive that payment (conditional on being alive in period t). I calculate $\pi_{s|t}$ using life tables by gender and race (white, black, Hispanic, and other) from the National Center for Health Statistics for the year 2006 (Arias 2010a, 2010b).

Figure 1 shows pension wealth as a function of exit age for a hypothetical North Carolina teacher. Figure 2 shows how much pension wealth accrues for each additional year of teaching. This defined-benefit plan provides incentives to continue teaching in the middle of her career (up to age 52), when an additional year of work and increased salary significantly raise the annuity amount. During this time,

[3] Teachers can retire short of these thresholds and receive a reduced benefit. Reduced benefit eligibility: age 50/60 with 25/5 years of teaching. Benefits are reduced by 3-5 % per year short of full retirement threshold, depending on age at retirement. Note, a teacher may retire before reaching an age-threshold, but not receive benefits until her age and experience are past the threshold. E.g., a 58-year-old could retire after her 25th year and receive reduced benefits immediately and thereafter, or wait two years and get full benefits upon turning 60.

pension wealth also increases because she is closer to receiving her benefits – one more year of work implies (at least) one fewer year she has to wait to get her annuity. The accrual rate is at its highest when she is 49 years old, at which point she would receive an additional $56K worth of pension wealth for teaching just one more year. Once she reaches age 52 she is able to receive her annuity immediately upon exiting teaching, after which the accrual rate drops from $38K to $14K. These incentives may "pull" her to continue teaching. Later in her career, the annuity amount would still increase if she continued teaching, but her total pension wealth nonetheless declines because each additional year of teaching imposes an implicit cost – it is one fewer year that she could be receiving benefits. After age 65, this cost exceeds the additional annuity amount, possibly "pushing" her out of teaching. I measure the effects of pensions by exploring the relationship between exit behavior and the years until or since one is eligible for pension receipt.

Data. I address my research question using data from administrative records of all North Carolina public school students and teachers over the 1994-95 through 2008-09 school years, maintained by the North Carolina Education Research Data Center. These records follow individuals over time and link students and teachers in classrooms of schools. I observe students' 3rd- through 8th-End-of-Grade (EOG) math and reading test scores, race, sex, exceptionality status, limited English proficiency status, and free/reduced price lunch eligibility. I observe employees' undergraduate and graduate degree institutions, graduation date, salary, race, sex, teaching assignment, and years of experience.[4] I do not observe the teacher's age, but assume they are 21 when they graduate from college. This attenuates the effect of becoming eligible for pension benefits, as teachers who graduate when they are older are eligible for benefits before I label them as such.

[4] Other variables that influence retirement (marital status, health status, household assets) are not available in these data. I do not expect that these variables are correlated with pension accrual or pension wealth.

In light of pension eligibility and data requirements, I exclude some individuals from the sample, as described in Table 1.[5] I exclude individuals who are under 40 years old because teachers younger than 40 generally have a very low accrual rate (but this begins to change around age 40). The resulting sample size is 61,767 individuals. The sample of teachers that I am able to link with EOG math and reading scores is the subset of 5,329 of these teachers who teach 4th- or 5th-grade between the 1998-99 and 2007-08 school years. I choose this subset due to two data limitations. First, student EOG scores are associated with the teacher who proctored the exam. In elementary school grades (3 through 5), the proctor is likely to be the student's instructor for math and reading, because students are generally with one teacher most of the day. In 6th through 8th grades, the proctor may not be the student's instructor of math or reading. In these middle school grades a teacher may instruct multiple classes of students. North Carolina administers EOG tests to all students within the school at the same time, making it impossible for all of a teacher's students to be proctored by her. (It is likely that students are proctored by their "homeroom" teacher.) I follow Xu et al. (2008) and compare the student composition (class size, number of white students, number of male students) of the tested class with that of the class that the proctor instructs (data from a separate source). If the characteristics of tested classroom are similar to the instructor's classroom, then I deem the proctor to also be the instructor. Second, in order to calculate a teacher's value-added I need her students' prior test scores and demographic characteristics. The prior test scores of 3rd-grade students are unavailable (because there is no test prior to 3rd-grade), so I exclude 3rd-grade teachers from my value-added analysis. The available student demographic data varies from year to year, and only the 1998-99 through 2007-08 school years contain the student information that I include in my value-added specification. Table 2 shows descriptive statistics for teachers in the beginning, middle and end of the time period I study for the full sample as well as the sample for whom I have value-added.

I define a teacher as exiting if they are not observed as a full-time employee in the North Carolina data for two consecutive years. Figures 3 and 4 show the proportion of individuals who exit by age and

[5] I include those who are ever full-time teachers with greater than five years of experience (making them eligible for the defined-benefit pension plan) if their date of college graduation and other demographic variables are given, and work in a single school with non-zero salary during each year in the data.

years of experience. Many of the discrete jumps in the exit rate coincide with teachers becoming eligible for retirement benefits. The most pronounced is the jump at 30 years of experience, when all teachers (regardless of age) are eligible for full benefits immediately upon exiting teaching.

I classify schools as elementary (PK-1 through 1-8), middle (4-7 through 5-9), and high (7-12 through 12) according to the lowest and highest grade levels of the school in the Common Core Data each year. Schools are split into quartiles (over all schools within that year) of percent free/reduced price lunch and percent black students according to the Common Core Data. If the data on student characteristics are missing, I impute the quartile from the closest non-missing year for that school. I associate teachers with the competitiveness of the institution from which they received their undergraduate degree, where competitiveness is measured according to the Barron's rankings from the year closest to their graduation date (1984, 1986, 1988, 1990, or 1992). "Less competitive" is a Barron's rating of noncompetitive, less competitive; "competitive" is a rating of competitive; and "more competitive" is a rating of very competitive, or more competitive.

4. Theoretical Model

My theoretical model differs from the canonical models that have been used to study retirement because I include non-pecuniary benefits from work. Teachers are paid according to a rigid salary schedule, so these non-monetary factors are an important extension to explain differences in retirement behavior. These non-pecuniary factors may be utility received from enjoying the teaching profession or school characteristics. I outline the following model to guide my estimation strategy.

Model. Each period a teacher makes the choice to exit (d_{it}=1) and never return to teaching, or to continue teaching (d_{it}=0) and face the same decision the following period. As shown in (2), her per-period consumption depends on both her choice to leave or exit, and her eligibility for pension benefit receipt. In every period that she teaches, she receives income w_{it}^{τ}. Her income upon exiting depends on her eligibility for pension benefit receipt $Elig(\cdot)$, which depends on her current age age_{it} and teaching experience exp_{it}. All income is used for consumption c_{it} each period.[6]

She makes the decision to teach or exit this year in order to maximize the discounted sum of expected lifetime utility (3) subject to the budget constraint (2), where d_{is}^{*} is the optimal teaching/exit decision in period $s > t$, and z_{it} are state variables related to consumption z_{it}^{c} (teaching income w_{it}^{τ}, pension $annuity_{it}$, age age_{it}, experience exp_{it}), leisure z_{it}^{l} (age age_{it}), and teaching z_{it}^{τ} (effectiveness e_i, taste for teaching θ_{i0}, and school attributes $School_{it}$). The expectation in (3) is taken with respect to future state values.

(2) $c_{it} = (1 - d_{it}) \cdot w_{it}^{\tau} + d_{it} \cdot annuity_{it} \cdot 1\{t \geq Elig(age_{it}, exp_{it})\}$

(3) $V_t(z_{it}) = E\left[\sum_{s=t}^{T} \beta^{s-t} \pi_{s|t} u(d_{is}^{*}, z_{is}) \,|z_{it}\right]$

Individuals receive utility from consumption, leisure, and teaching. Utility is linear in consumption (4). Utility from leisure is only gained if an individual exits, and is quadratic in age (5).[7] Utility from teaching (6) is a linear function of a teacher's taste for teaching θ_{i0}, her exogenously defined quality e_i^{τ},and school characteristics $\boldsymbol{School}_{it}$ (demographics, location, etc.).[8]

(4) $u^{c}(d_{it}, z_{it}^{c}) = \gamma_0 + \gamma_1 c_{it}$

(5) $u^{l}(z_{it}^{l}) = \alpha_0 + \alpha_1 age_{it} - \alpha_2 age_{it}^2$

(6) $u^{\tau}(z_{it}^{\tau}) = \theta_{i0} + \theta_1 e_i^{\tau} + \boldsymbol{School}_{it}\eta$

An individual's utility u in period t (7) is an additive function of utility from consumption u^c, leisure u^l (if she exits), and non-pecuniary utility from teaching u^{τ} (if she teaches). Before making any choices, each individual receives a shock ζ_{it} to this period's value of working and the value of exiting (e.g. a person's health deteriorates or her spouse gets a job in a new city). This will generate some sudden, unplanned retirements.

[6] Given linear utility, individuals have no incentive to smooth consumption.
[7] When utility is linear in consumption, pension wealth is proportional to the individual's value of future pension benefits.
[8] Including a quadratic in experience to allow for the utility of teaching to vary by tenure does not qualitatively change my results.

$$(7)\quad u(d_{it}, z_{it}) = u^c(d_{it}, z_{it}^c) + d_{it} \cdot u^l\left(z_{it}^l\right) + (1 - d_{it}) \cdot u^\tau(z_{it}^\tau) + \zeta_{it}(d_{it})$$

I define the choice-specific conditional value functions (8) and (9) as the current period utility net of the choice-specific shock ζ_{it} plus the discounted expected value of future utility.

$$(8)\quad v_t(d_{it} = 1, z_{it}) = u^c(1, z_{it}^c) + u^l\left(z_{it}^l\right) + \beta E[V_{t+1}(z_{it+1})|d_{it} = 1, z_{it}]$$

$$(9)\quad v_t(d_{it} = 0, z_{it}) = u^c(0, z_{it}^c) + u^\tau(z_{it}^\tau) + \beta E[V_{t+1}(z_{it+1})|d_{it} = 0, z_{it}]$$

Teachers continue to teach if the total value (including ζ_{it}) of teaching exceeds that of exiting. Table 3 summarizes the utility components in period t and future periods conditional on today's decision and whether the individual is eligible for pension receipt.

The value of exiting (8) depends on whether she is eligible to receive her pension benefits. If she exits when she is not eligible, the current period utility includes the value of leisure in this period as well as all future periods until she is eligible for benefits. If she exits when she is eligible, then the current period utility is the value of receiving her annuity and leisure. Regardless of whether one is eligible for benefits when she exits, she has no other decisions to make for the rest of her lifetime. There may be uncertainty with respect to shocks ζ_{it} to her utility, but she knows when she will start receiving her annuity.

There are two important distinctions between utility from exiting and continuing. The first is that the current period utility for someone who continues teaching is the value of teaching income, and an extra term – the utility of non-pecuniary benefits she receives from teaching $u^\tau(z_{it}^\tau)$. The second distinction is the value of utility in future periods. In contrast with someone who exits this period, one who continues to teach has the option to choose between teaching and exiting again next period. Her expected future value of utility is a function of future teaching salaries and school characteristics for the expected remainder of her teaching career; as well as pension income, non-teaching income, and the length of her life once she exits. This value will vary depending on how long she intends to continue teaching, which is related to the relative value of teaching and exiting in all future periods.

Impact of pensions. Pensions affect an individual's retirement decision through the budget constraint. I focus on two ways that pensions affect behavior, creating a wealth effect and an 'eligibility' effect.

A given accrual in pension wealth (or any other retirement wealth) from one year to the next generates a wealth effect for teachers eligible for any type of retirement benefits. There are two ways that cause pension wealth to change from year-to-year. First, the pension annuity amount increases over time for early and mid-career teachers as they add more years of service and their salary increases. Second, as individuals age they move closer to the eligibility dates for annuity payments, which increases the current value of their future retirement income. Pension wealth increases are not specific to defined-benefit plans – defined-contribution plans accrue wealth as more money is added to the retirement account and the money grows due to investment. In both plans, these increases in lifetime wealth may cause a teacher to consume more of all normal goods, including leisure, increasing her likelihood of retirement. In order to accurately measure the response to defined-benefit pension incentives it is important to separately account for the wealth effect, which would be present in any retirement plan.

In the context of my model, the wealth effect is due to changes in the value of exiting this period due to variation in the current value of pension wealth. Equation (10) defines the current value of pension wealth PW_t. Co-variation between exit behavior and PW_tmeasures the wealth effect.

(10) $PW_{it} = \sum_{s=t}^{T} \beta^{s-t} \pi_{s|t} annuity_{it} \cdot 1\{t \geq Elig(age_{is}, exp_{is})\}$.

One key benefit of teaching until eligible for immediate pension receipt is a constant stream of income over her lifetime. I term a teacher's response to this incentive the 'eligibility' effect. The eligibility effect is a substitution effect in that the leisure of retirement is very costly in the years leading up to eligibility (because one has neither teaching nor pension income to consume if she retires). She will receive her pension income eventually, but there are periods when she receives neither. If she teaches until eligibility, retirement is suddenly cheaper – even though she must forgo teaching income, she receives her annuity and goes through no periods with zero income. This effect would not be present in the defined-contribution plan, where pension wealth is always accessible to the individual (although sometimes with a penalty if the individual is too young). Additionally, pension accruals in a defined-benefit pension plan level off (and eventually decline) after one is eligible (see Figure 1 after age 52), but in a defined-contribution plan accruals continue climbing at generally the same rate regardless of one's age or experience. Importantly, in addition to being a marker that distinguishes a time of sharp versus smooth pension accrual, the time of eligibility is a salient feature of defined-benefit pensions, making it a variable that individuals are likely to respond to.

In the context of my model, prior to eligibility, the possibility of having an uninterrupted stream of income over one's life (by teaching until eligibility) makes continuing to teach this period more valuable than it otherwise would. Post eligibility, the relative value between teaching and exiting is diminished because one can exit and does not have to endure any periods of zero income. These shifts in the values of teaching versus exiting over one's lifetime create the eligibility effect. I examine the differences in exit behavior in years prior to, at, and post eligibility to quantify this effect.[9]

Teachers with different characteristics may respond differently to pension incentives. The relative value of continuing to teach depends on how long one intends to continue teaching because the amount of pension wealth one is likely to gain is based on their expected persistence. Put simply, someone who does not intend to stay until eligibility should not be affected by the utility gains from staying until eligibility. My model posits that this intention to stay varies with teachers' attributes, causing individuals with different characteristics to respond differently to retirement incentives. Teachers may have different tastes for their work that give her non-pecuniary benefits from teaching, either through the enjoyment of teaching, satisfaction from being an effective teacher, or having a fondness for a particular school environment. Teachers with high non-pecuniary benefits would be less influenced by the value of pension accruals as it relates to her retirement decision. For example, consider two teachers with the same salary and years until they are eligible to retire, but one has high non-pecuniary benefits because she likes

[9] There are additional substitution effects due to the magnitude of pension accrual that one can gain by continuing to teach, but, given that I only study one pension system, there is not enough variation in these measures to identify meaningful effects separate from the wealth and eligibility effects.

her school environment and the other does not. As they age and the value of teaching approaches the value of exiting, the teacher with high non-pecuniary benefits has a higher value of teaching because she values the non-pecuniary benefits that she can continue to receive over her future career. This makes her less sensitive to both the "pull" and the "push" of pensions than the other teacher. To capture differences in responsiveness to pension incentives, I study the relationship between exit behavior and years until eligibility for teachers with different non-pecuniary benefits.

This model motivates an empirical investigation to describe the magnitude of teachers' responsiveness to pensions, and whether their responses vary with teacher or school characteristics.

5. Estimation Strategy

In this section I describe the specifications and identifying assumptions I use to model teacher exit behavior and teacher quality.

Exit behavior. My model informs the following specification to determine how teachers respond to pension incentives. I model the probability that teacher i in year t exits teaching $(d_{it} = 1)$ as a probit:

$$(11) \quad Prob(d_{it} = 1) = \Phi\big(\delta_0 + \delta_1 w_{it}^{\tau} + \delta_2 age_{it} + \delta_3 age_{it}^2 + \delta_3 PW_{it} + \boldsymbol{YrsElig}_i \boldsymbol{\lambda} + \boldsymbol{X}_{it} \boldsymbol{\beta}\big).$$

I control for the teacher's total compensation w_{it}^{τ} and a quadratic in age (to capture the utility of leisure from retiring). δ_3 represents the wealth effect of pensions, the co-variation between current pension wealth PW_{it} and exit behavior. $\boldsymbol{YrsElig}$ is a vector of indicator variables $YrsElig_{Elig-t}$, which are equal to one if an individual is $Elig - t$ many years away from eligibility. $Elig - t$ is less than zero when she is not yet eligible, equal to zero when eligible, and greater than zero once eligible. The coefficients on these indicator variables $\boldsymbol{\lambda}$ represent the eligibility effect of pensions. In order to determine if individuals vary in their responsiveness to pensions, I interact $\boldsymbol{YrsElig}$ with a teacher's individual or school characteristic, such as her quality (described below) or her school's demographic composition.

The last term, $\boldsymbol{X}_{it}$, contains characteristics about the teacher including the teacher's race, sex, and an indicator for the school year (to capture any system-wide changes in the attractiveness of teaching). I cluster standard errors at the individual level to account for error correlation within an individual over time.

Teacher quality. I measure teacher quality $Quality_i$ as a time-invariant trait characterized by the competitiveness of her college (definition of which is discussed in Section 3) or her value-added.[10] I estimate a value-added for individuals in my analytic sample using the following specification for teachers of grades 4 and 5, for whom I have students' prior year EOG achievement test scores, important student demographics, and am confident that they are accurately matched with their instructor.

$$(12) \quad Achievement_{jit} = Quality_i + Y_{jt}\rho + \nu_{jit}$$

The dependent variable is the normalized (mean zero, standard deviation one) test score $Achievement_{jit}$ of student j of teacher i in year t. I regress this on a vector of student, class, and school attributes Y_{jt}, which includes student j's test score from the previous year, demographic and achievement measures for other students in j's classroom and school, and grade and year fixed effects.[11] I do not include any measure of the teacher's experience in this specification. It is well established by the literature (Rockoff, 2004; Boyd et al., 2008) that teachers' value-added increases as they gain experience, especially in the first few years of teaching. Teachers in my sample are in their fifth or higher year of teaching so it is likely that these teachers have little variation in quality due to increases in experience. Additionally, I want to compare the pension responsiveness of all teachers to one another as opposed to their same-experienced peers, as this is the most policy relevant comparison.

The value-added measure of a teacher's quality $Quality_i$ is the average growth in teacher i's students, compared to the growth of other teachers' students, after netting out the average effects of other observable factors. To address concerns about bias in value-added measures, I follow Koedel and Betts (2011) and estimate a teacher's value-added using the test scores of her students over multiple years. I use empirical Bayes shrinkage (Wisconsin Center for Education Research, 2010) to account for measurement

[10] I can test the assumption that teacher quality is time-invariant by measuring value-added at the teacher-year level and study trends in these measures over time.
[11] I intend to test different specifications to calculate teacher value-added.

error in the value-added estimates. To address the possible endogeneity of an individual's value-added and her exit behavior, I drop the students in the teacher's class during her final year of teaching from the value-added estimation. Because there are separate math and reading tests, I compute three different measures of teacher value-added: math value-added, reading value-added, and average value-added (the average of reading and math). I split teachers into terciles of quality (high, medium, and low) to explore non-linear effects.

6. Results

Table 4 shows my specification for teacher value-added, which I estimate for 4th- and 5th-grade teachers in my sample who teach 10 or more students in a given year. Recall that value-added is measured at the teacher (not the teacher-year) level. On average there are 76 test scores per teacher, but this ranges from 10 to 227. The standard deviation of math and reading value-added is 0.19 and 0.11. The correlation between these two measures is 0.66. I split teachers into terciles based on their math, reading, and the average of their math and reading value-added to study differences in retirement patterns.[12]

Table 5 has coefficients from the probit described in equation (10) as well as the corresponding linear probability model (LPM). The predictions of these two models are qualitatively the same, but the coefficients of the LPM are more readily interpretable.[13] The omitted category for the $\boldsymbol{YrsElig}$ variable is someone who is 10 years away from eligibility. The LPM coefficients on $\boldsymbol{YrsElig}$ display a pattern consistent with the "eligibility" effect of pensions – the coefficients are negative prior to eligibility, with a sharp jump at eligibility, and a consistently higher value after eligibility. Nine years away from eligibility (YrsElig=-9), an individual does not have much more of an incentive to stay than someone who is 10 years away. However, as one approaches eligibility the benefits of continuing to teach are larger because

[12] The results are robust to using average quality quintiles (instead of terciles).

[13] Usually one reports the marginal effects corresponding to the probit model, but neither the average of the marginal effects, nor the marginal effects at the average are appropriate to describe the effect of the YrsElig indicator variables. This is due to fact that many variables (age, salary, and YrsElig) move together over time. For example, in calculating the average of the marginal effects, it would be inappropriate to include the marginal effect of reaching eligibility for a 40-year-old observed individual because this individual would never be eligible. Similarly, this specification cannot be generalized into the marginal effect for someone who is always the average age (49), because some marginal effects (e.g., the effect of being 5 years past eligibility) do not affect 49-year-olds.

one has fewer years to wait for her benefits, as seen by the increasing magnitude of the coefficients on $\boldsymbol{YrsElig}$. By the time one is two years away from eligibility, she has a five percentage point lower probability of exiting than she did when she was 10 years out. As she moves from two years away to being eligible, her probability of exit increases by 17 percentage points. (The slight jump up at one year from eligibility is likely due to measurement error in age.) After eligibility teachers have a five to 10 percentage points higher likelihood of exiting than they do when they are 10 years from eligibility.

Other coefficients in this specification are in line with theoretical predictions. A $100,000 increase in the value of pension wealth today (PW_{it}) leads to a 4.5 percentage point increase in the probability of exiting. This is indicative of the wealth effect described earlier. Higher values of teaching salary increase the value of continuing to teach and, thus, decrease the likelihood of exiting by 7.2 percentage points for every $10,000.

It is difficult to tell the effects of pensions through these coefficients because many variable values are changing at once. An individual is aging, and her pension wealth and salary are changing as $\boldsymbol{YrsElig}$ changes. To visualize the effects of pensions, I use my model to predict the probability to exit for hypothetical teachers. I choose three hypothetical teachers based on the age-experience distribution of teachers in my sample. Approximately half of the teachers in my sample started teaching at 21 or 22. Teacher A represents this group – she started teaching right out of college when she was 21. Approximately one third of the sample started teaching between the ages of 22 and 29, with more starting earlier rather than later. Teachers B and C represent this group. Teacher B started when she was 25, and Teacher C started when she was 29. I assume that these teachers are always paid according to the 2000-01 salary schedule, and that they are white females, representative of the majority of teachers. Due to their different start ages, they have different pension wealth distributions and vary in the year in which they are eligible for pension receipt. Figure 5 shows their pension wealth distributions by age and $\boldsymbol{YrsElig}$. Figure 6 shows the predicted probability of exit (using the probit model in Table 5) by $\boldsymbol{YrsElig}$ for each of these teachers.

$YrsElig$ accounts for a good deal of variation across these three types of teachers. In Figure 5, note how different the pension wealth distributions are when graphed by age, but how similar they look when graphed by $YrsElig$. I am able to identify coefficients on a quadratic function of age in order to isolate exit behavior related to pensions from that related to age because I have teachers of different ages at each value of $YrsElig$. Figure 6 visually displays the pattern of the coefficients described in Table 5, with a low exit probability when far from eligibility, rising sharply around eligibility, and staying markedly higher afterward. Note that Teacher C (the oldest one) always has a higher probability of exiting, and Teacher A (the youngest) has the lowest. These differences are especially strong after eligibility, showing that the oldest teacher may feel more of a "push" than the younger ones.

Given the absence of an obvious counterfactual retirement plan, the clearest way to determine whether teachers respond differently to pension incentives is to simply compare responses to this pension plan for teachers with different attributes. To do this I predict exit probabilities for Teacher A (who started teaching right out of college, similar to about half of all teachers in my sample) assuming she has different attributes and then look to see if these predicted probabilities are statistically different from one another. I predict these probabilities using the probit specification in equation (11) with an additional interaction between the variable of interest (effectiveness, school urbanicity, etc.) and $YrsElig$.

Figures 7 through 9 show how exit probabilities differ based on teacher quality and qualifications. Figure 7 shows that, for the sample that I can calculate value-added, there are few differences in their exit behaviors. The only meaningful and statistically significant different occurs right at eligibility – teachers of medium quality have less of a jump in the exit probability than those of high or low quality. It could be that high quality teachers exert a lot of effort in order to be high quality, and they are quite responsive to the relief that retirement might bring. Low quality teachers, on the other hand, may have less of an attachment to teaching and view retirement eligibility as a good time to leave the profession. It is unclear whether these results by quality can be extrapolated to the workforce in general. Figure 8 shows the exit probability for the 90 percent of teachers for whom I cannot calculate value-added is always significantly higher than the teachers for whom I do have value-added. This could be due to selection into teaching assignments that are under high accountability pressures. Perhaps the teachers who persist in these assignments are also particularly committed to the profession in general.

Figure 9 shows the exit probability for teachers who attended competitive and most competitive colleges. For the sake of visual clarity, those who attended less competitive colleges are not included in this graph, but they behave qualitatively similar to those who attended competitive colleges. Teachers from more competitive colleges have a slightly smaller jump at eligibility (0.26 versus 0.31). About 10 percent of teachers in my sample attended these more competitive institutions. It could be that they gave up more attractive careers in order to stay in teaching, making them more likely to persist in the profession regardless of pension incentives.

Figures 10 through 13 show how exit behavior differs by school characteristics. Figure 10 shows that exit behavior is generally no different among elementary, middle, and high school teachers. Figure 11 shows that teachers in urban settings are slightly more likely to exit the profession when they are far from eligibility, but when they become eligible, they have a slightly lower likelihood of exiting than rural (and town/suburban teachers who behave similarly to rural teachers but are not shown). There is a similar effect for teachers in schools with the highest percentage of black students (Figure 12), but no difference between the highest and lowest quartile of percent free lunch students (Figure 13). Thus, there is some evidence that teachers who select into different working conditions have different exit behaviors – in particular, teachers at urban schools and those with a high percentage of black students are actually more likely to persist in the profession conditional on having stayed until eligibility.

7. Summary and Policy Implications

The impending retirement of the Baby Boom Generation has considerable implications for school staffing and student learning. States are concerned with the financial burden that this mass retirement could impose and are considering comprehensive changes to public pension systems. These debates around cost-saving reform overlook the effects that pension incentives have on school staffing. My study investigates these effects to see if teachers with different characteristics or school environments have different responses to pension incentives. I develop a conceptual model of teacher retirement behavior and employ a unique data set to estimate the causal effect of pensions on teachers' exit decisions.

I find that teachers are quite responsive to the eligibility cutoffs – a teacher who is eligible for immediate pension benefits has a 17 percentage point increase in the probability of exiting than one who is two years away from eligibility. Given that the average rate of attrition for those prior to eligibility less than five percent, a 17 percentage point jump is quite sizable (an increase of 300 percent). There is some evidence that teachers respond differently to pension incentives. Those with high and low value-added are five percentage points more likely to exit at eligibility than those with medium value-added. However, these results may not apply to teachers for whom I cannot measure their quality. Teachers who attended competitive and less competitive colleges are also around five percentage points more likely to exit teaching at eligibility than those who attended more competitive colleges. I find that teacher responses to pensions do not vary much by school environment, but that teachers in urban schools and those with a high proportion of black students are slightly less responsive to pension incentives.

This research is a necessary first step in considering the effects of pension reform in order to implement a retirement system that encourages the retention of high quality teachers in all types of schools. It is clear that teachers are generally quite responsive to pension incentives and likely to change their behavior if there are changes to the structure of retirement income. For the set of teachers for whom I can measure effectiveness, both the high and low quality teachers are more responsive to pension incentives. However, whether this means they are highly responsive to the "pull" (which keeps them in teaching until eligibility), or responsive to the "push" (which kicks them out at eligibility) is important for the design of new pension systems. Given that the teachers in my study are all subject to the same pension system, it is difficult to determine what the behavior of these teachers would be in the absence of pensions, but simulations with alternative pension systems could provide clues to how teachers might respond to pension reform.

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Table 1: Sample Selection

	N	Percent
Full-time individuals, age 40 or more, eligible for pension	95,906	100%
Not in sample because:		
Ever not a teacher	20,056	20.9%
Unknown/unreasonable salary or hours worked	2,215	2.3%
Unreasonable/inconsistent values of experience	2,421	2.5%
Unreasonable/unknown value of age	5,723	6.0%
Unknown sex or race/ethnicity	3,724	3.9%
In sample:	61,767	64.4%
In sample with teacher value-added:	5,329	8.6%

Table 2: Descriptive Statistics for Full Sample and Value-Added Sample

		Full sample			Value-Added sample		
Year		1994-95	2000-01	2006-07	1994-95	2000-01	2006-07
N		30,610	32,424	30,711	2,484	3,818	3,283
Age (in fall)	mean	46.91	48.64	49.68	45.30	48.57	50.30
	s.d.	5.15	5.13	6.00	3.98	4.99	5.84
	min	40	40	40	40	40	40
	max	70	70	70	62	65	69
Experience (in fall)	mean	20.60	21.54	21.14	19.20	21.66	21.77
	s.d.	6.21	6.68	7.39	5.26	6.63	7.37
	min	4	4	4	4	4	4
	max	40	40	40	35	40	40
Current Pension Wealth / $100K	mean	1.77	2.20	2.12	1.37	2.22	2.28
	s.d.	1.33	1.47	1.52	1.01	1.48	1.53
	min	0.07	0.07	0.08	0.09	0.08	0.10
	max	6.32	6.73	7.09	5.14	5.86	6.62
Teaching Salary / $10K	mean	4.82	5.39	5.13	4.68	5.38	5.16
	s.d.	0.62	0.65	0.67	0.54	0.62	0.63
	min	2.40	2.50	2.49	2.57	3.10	3.06
	max	7.57	9.24	8.67	6.44	7.57	7.89
% Black students in school	mean	30.33	30.98	27.41	28.64	31.25	26.09
	s.d.	22.10	23.26	22.39	22.53	24.71	22.47
% Free lunch students in school	mean	28.78	31.39	35.57	33.85	37.76	39.03
	s.d.	17.41	19.36	18.36	16.85	20.14	19.70
Rural School		0.24	0.38	0.45	0.29	0.41	0.45
Town/Suburban School		0.41	0.33	0.30	0.41	0.33	0.30
Urban School		0.34	0.28	0.24	0.30	0.26	0.24
Elementary School		0.50	0.49	0.48	0.93	0.94	0.92
Middle School		0.21	0.21	0.21	0.06	0.05	0.07
High School		0.28	0.27	0.28	0.00	0.00	0.00
More Competitive College		0.09	0.09	0.12	0.06	0.07	0.09
Competitive College		0.51	0.52	0.51	0.51	0.50	0.49
Least Competitive College		0.41	0.39	0.38	0.43	0.42	0.41
Female		0.84	0.84	0.82	0.95	0.95	0.94
White		0.83	0.84	0.85	0.83	0.82	0.84
Black		0.16	0.15	0.13	0.16	0.17	0.15

Table 3. Current and Future Utility by Today's Decision

Period t decision	Period t utility	Utility in period $s > t,\ s < Elig_{it}$	Utility in period $s > t, s \geq Elig_{it}$
Exit & $t < Elig_{it}$	$u^l(age_{it})$	$u^l(age_{it})$	$u^c(annuity_{it}) + u^l(age_{it})$
Exit & $t \geq Elig_{it}$	$u^c(annuity_{it}) + u^l(age_{it})$	n/a	$u^c(annuity_{it}) + u^l(age_{it})$
Teach	$u^c(w_{it}^{\tau}) + u^{\tau}(z_{it}^{\tau})$	$V_s(z_{is})$	$V_s(z_{is})$

Table 4. Teacher Value-Added Specification
Dependent variable=standardized (mean 0, s.d. 1 in grade and year) EOG test score

	math	reading
Previous score (standardized by grade and year)	0.741 **	0.690 **
	(0.001)	(0.001)
Female	-0.011 **	0.015 **
	(0.002)	(0.002)
Black	-0.102 **	-0.134 **
	(0.002)	(0.003)
Hispanic	0.015 **	-0.004
	(0.005)	(0.005)
Other race	0.011 **	-0.028 **
	(0.004)	(0.004)
Limited English proficiency status	-0.032 **	-0.109 **
	(0.007)	(0.008)
Eligible for free/reduced price lunch	-0.072 **	-0.090 **
	(0.002)	(0.002)
Student variables (switching schools, repeating a grade, age in 3rd grade)	X	X
Year indicators	X	X
Grade 4 indicator	X	X
Student exceptionality status (gifted, speech or language disability, physical disability, emotional disability, mental disability, learning disability, or other disability indicators)	X	X
Class-level variables (membership, lagged achievement, % non-white, % female, % LEP, % free lunch)	X	X
School-level variables (% black, % Hisp, % free lunch)	X	X
N	409,903	407,377
R-squared	0.76	0.69

Standard errors shown in parentheses. *, ** signify significance at the 5% , 1% level.

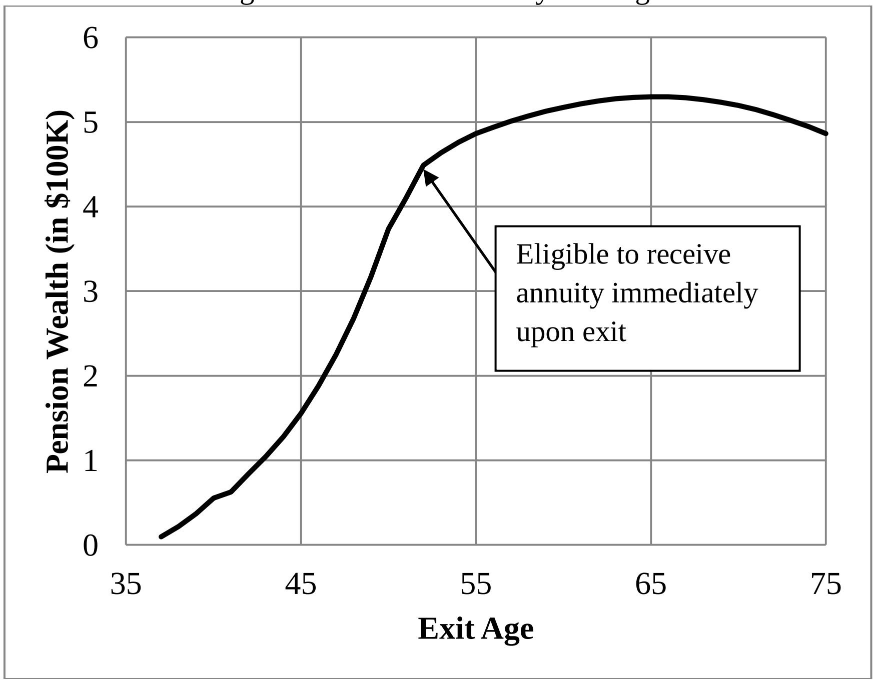
Table 5. Probit and LPM Results for Full Sample using Equation (11)
Dependent variable = 1 if exit, = 0 if continue

	Probit		LPM	
Years Eligible (-10 omitted)				
-9	-0.062 (0.022)	**	-0.004 (0.002)	*
-8	-0.174 (0.023)	**	-0.011 (0.002)	**
-7	-0.276 (0.025)	**	-0.019 (0.002)	**
-6	-0.354 (0.026)	**	-0.027 (0.003)	**
-5	-0.389 (0.029)	**	-0.031 (0.004)	**
-4	-0.510 (0.033)	**	-0.044 (0.005)	**
-3	-0.587 (0.038)	**	-0.052 (0.006)	**
-2	-0.585 (0.044)	**	-0.050 (0.007)	**
-1	-0.274 (0.049)	**	0.020 (0.008)	*
0 (eligible)	-0.032 (0.055)		0.120 (0.009)	**
1	-0.167 (0.059)	**	0.100 (0.010)	**
2	-0.326 (0.063)	**	0.072 (0.011)	**
3	-0.403 (0.066)	**	0.067 (0.012)	**
4	-0.505 (0.070)	**	0.055 (0.013)	**
5	-0.467 (0.074)	**	0.087 (0.014)	**
6	-0.565 (0.079)	**	0.074 (0.015)	**
Pension wealth today / $100,000	0.472 (0.018)	**	0.049 (0.003)	**
Teaching Salary / $10,000	-0.568 (0.013)	**	-0.072 (0.002)	**
Female	-0.166 (0.009)	**	-0.017 (0.001)	**
Black	0.077 (0.009)	**	0.006 (0.001)	**
Other Race	0.056 (0.030)		0.006 (0.004)	
Age	-0.218 (0.014)	**	-0.038 (0.002)	**
Age^2	0.003 (0.000)	**	0.000 (0.000)	**

Constant	5.077 ** (0.375)	1.204 ** (0.055)
Year indicators	Yes	Yes
Observations	414,203	414,203
R-squared	n/a	0.10

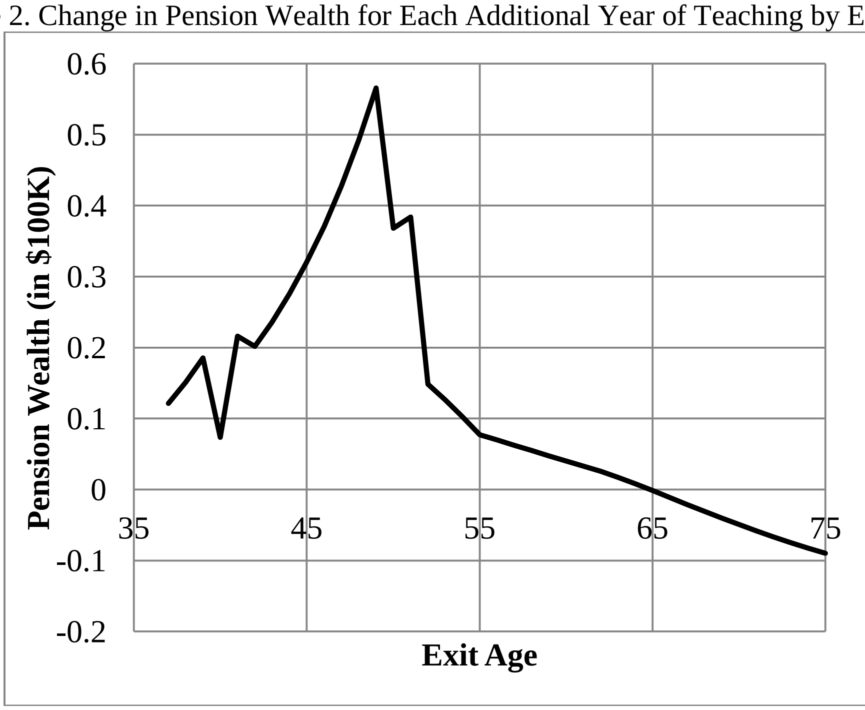
Standard errors shown in parentheses. *, ** signify significance at the 5%, 1% level. Monetary values are in 2009 dollars. Years Eligible are indicator variables showing how many years one has until she is eligible for retirement (if Years Eligible < 0), or how many years one has been eligible (if Years Eligible ≥ 0). The specification include additional values of Years Eligible (-20 through -11, and 6 through 10) but these coefficients are not shown.

Figure 1. Pension Wealth by Exit Age



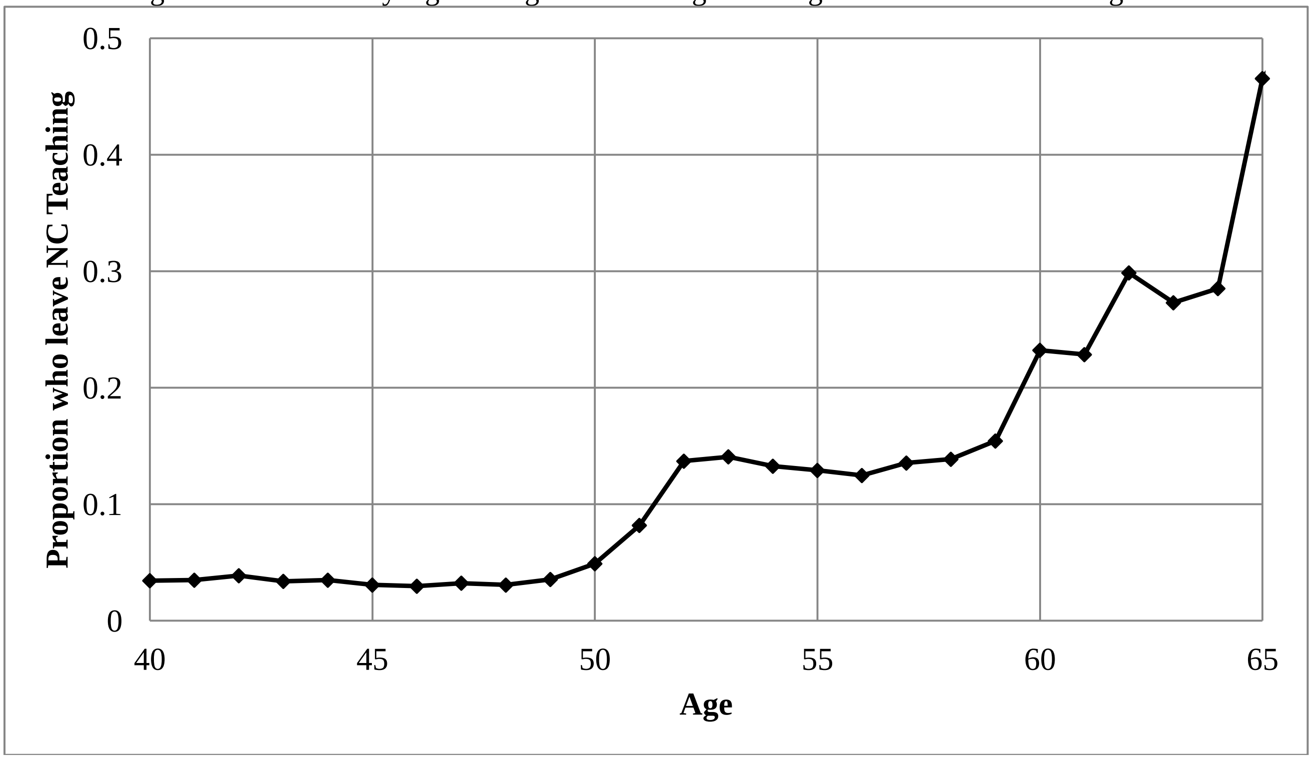
Pension wealth for a hypothetical teacher who starts teaching at age 21 and faces 2000-01 North Carolina salary schedule during entire career.

Figure 2. Change in Pension Wealth for Each Additional Year of Teaching by Exit Age



Same hypothetical teacher as Figure 1.

Figure 3. Exit Rates by Age: Marginal Percentage Leaving North Carolina Teaching

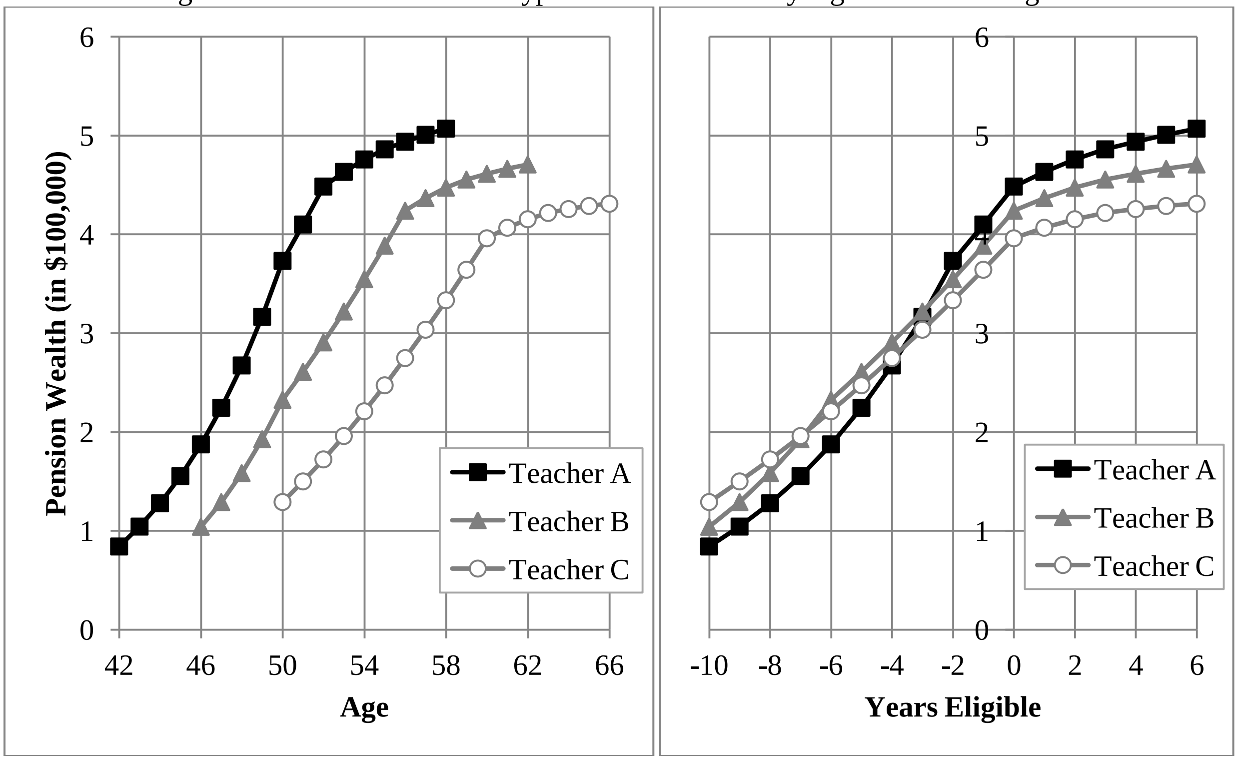


Exit hazard for all individuals in full sample.

Figure 4. Exit Rates by Years of Experience: Marginal Percentage Leaving North Carolina Teaching

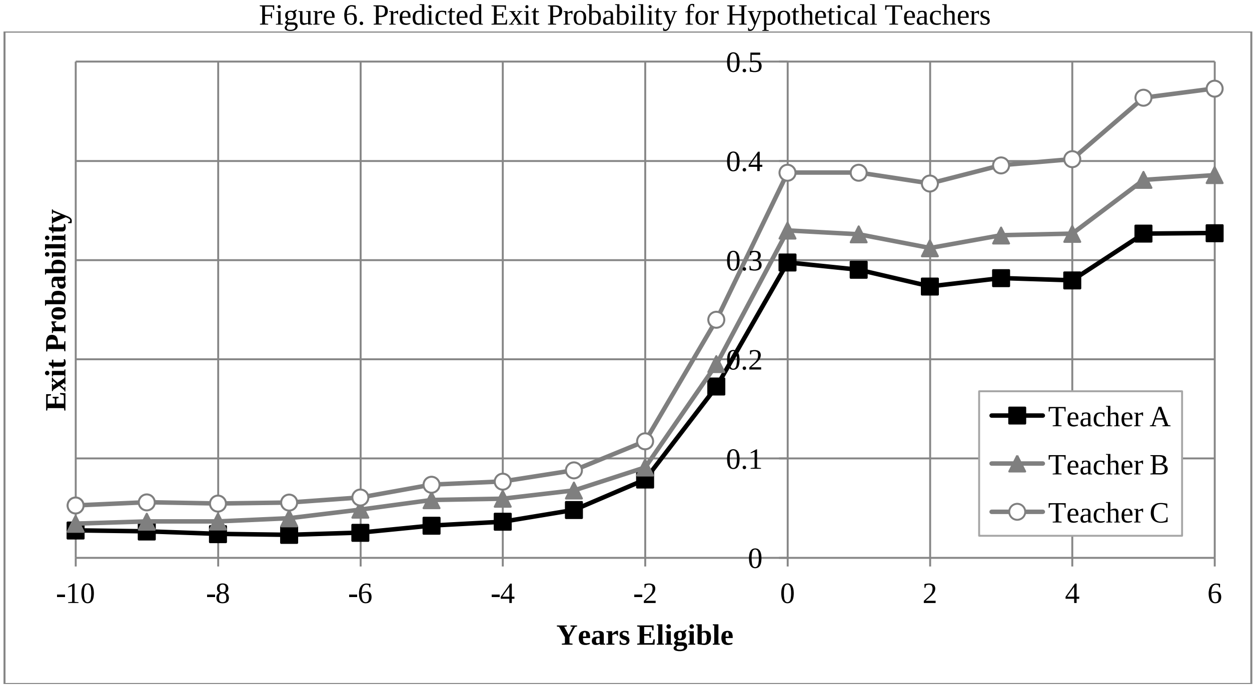
Exit hazard for all individuals in full sample.

Figure 5. Pension Wealth for Hypothetical Teachers by Age and Years Eligible



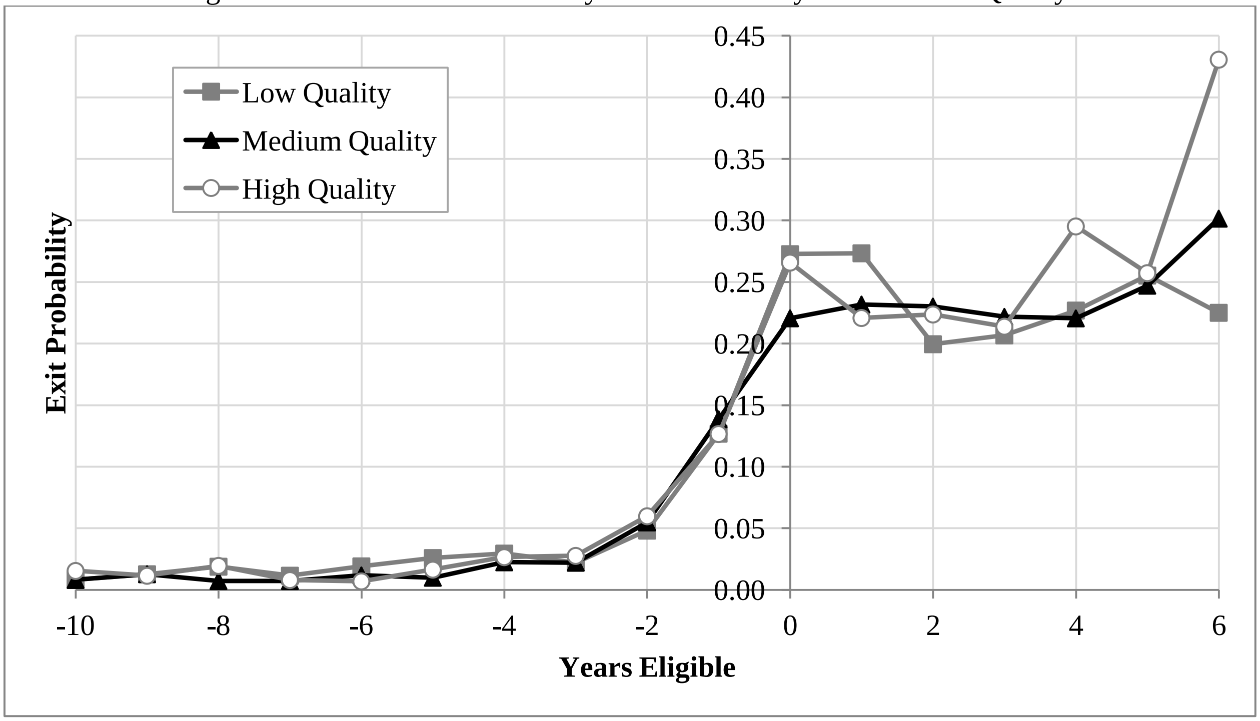
Teachers A, B, and C are hypothetical white females who started teaching at age 21, 25, and 29. I assume they are always paid according to the 2000-01 salary scale. Years Eligible corresponds to how many years an individual has until (if <0) or since (if ≥0) pension receipt eligibility.

Figure 6. Predicted Exit Probability for Hypothetical Teachers



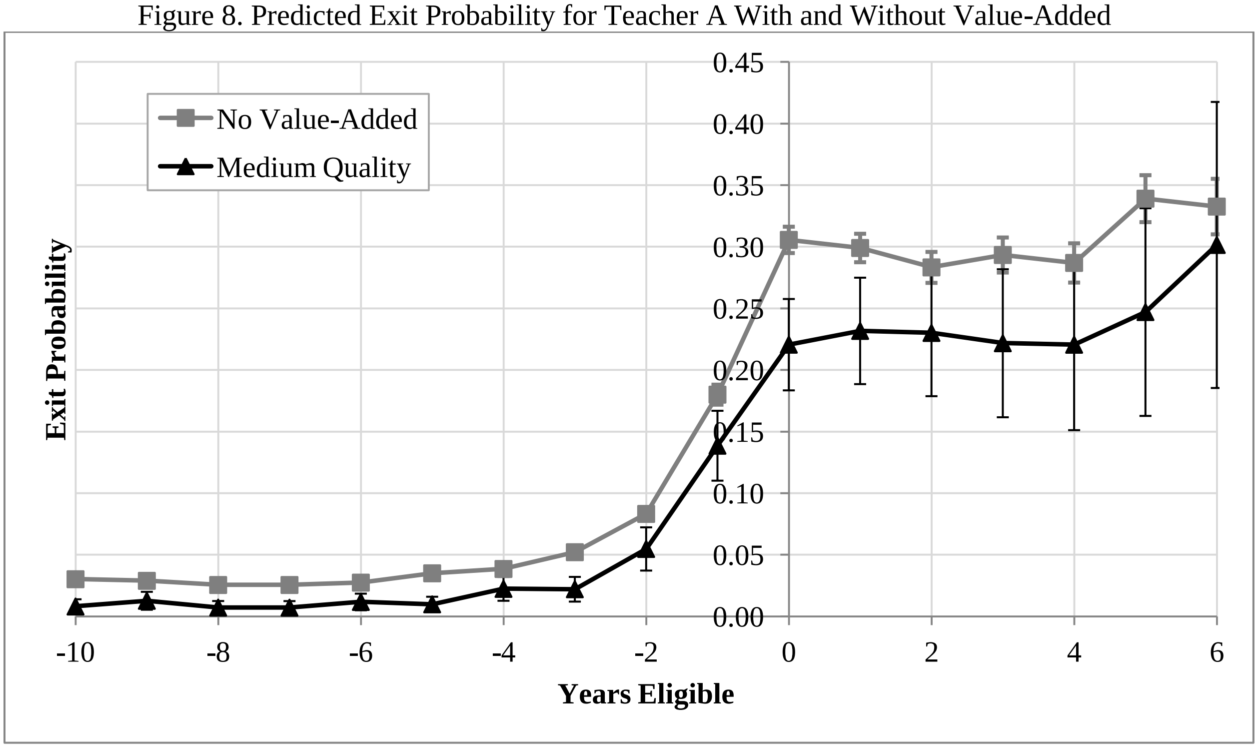
See Figure 5 notes for definition of Teachers. Predicted probabilities calculated using Table 5 probit. For each value of Years Eligible, the exit probabilities across teachers are statistically different at the 1% level.

Figure 7. Predicted Exit Probability for Teacher A by Value-Added Quality



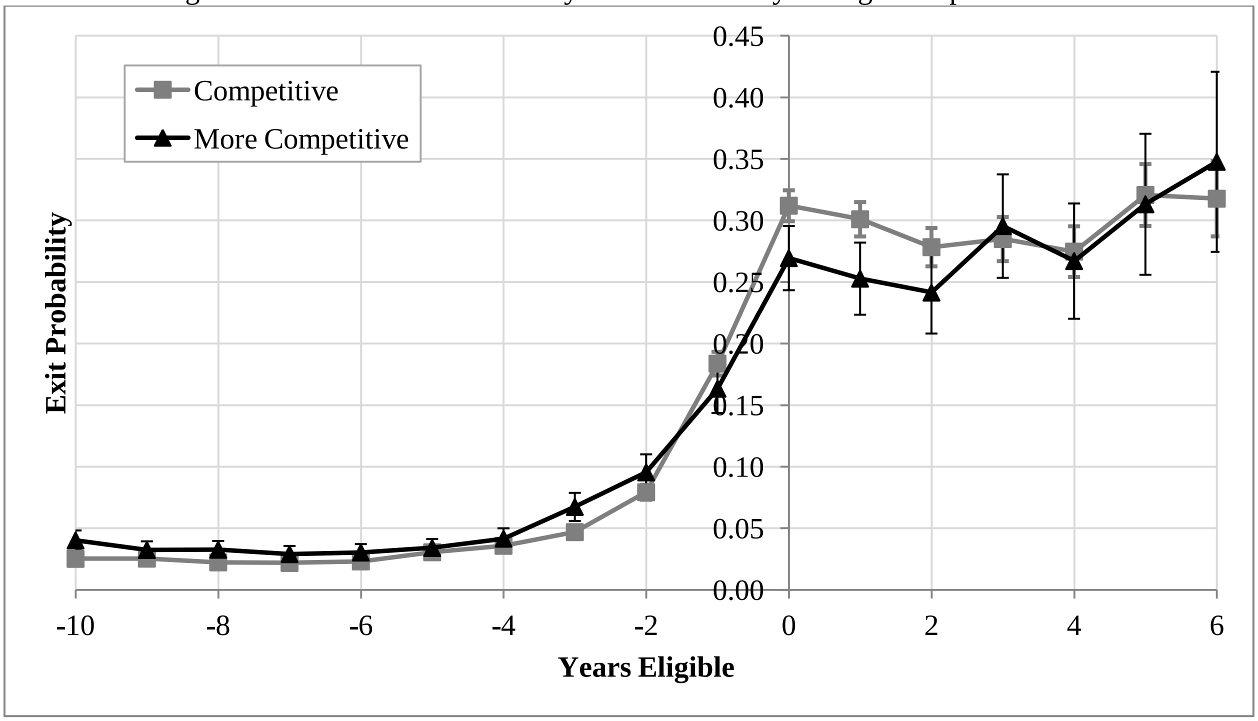
Predicted exit probability for Teacher A (see Figure 5 notes) using specification in equation (11) with interaction between quality and YrsElig. The difference between high/low quality vs. medium quality at YrsElig=0 is statistically significant at the 5% level.

Figure 8. Predicted Exit Probability for Teacher A With and Without Value-Added



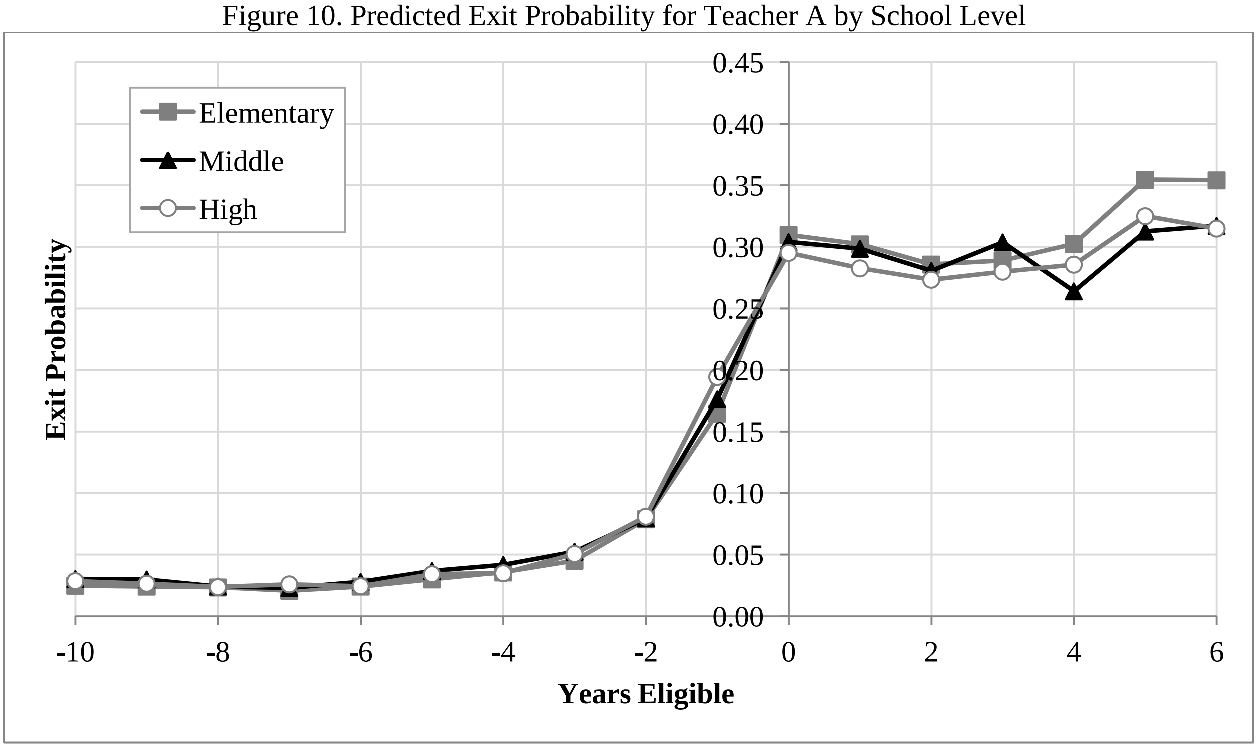
Predicted exit probability for Teacher A (see Figure 5 notes) using specification in equation (11) with interaction between quality and YrsElig. Error bars show 95% confidence regions.

Figure 9. Predicted Exit Probability for Teacher A by College Competitiveness



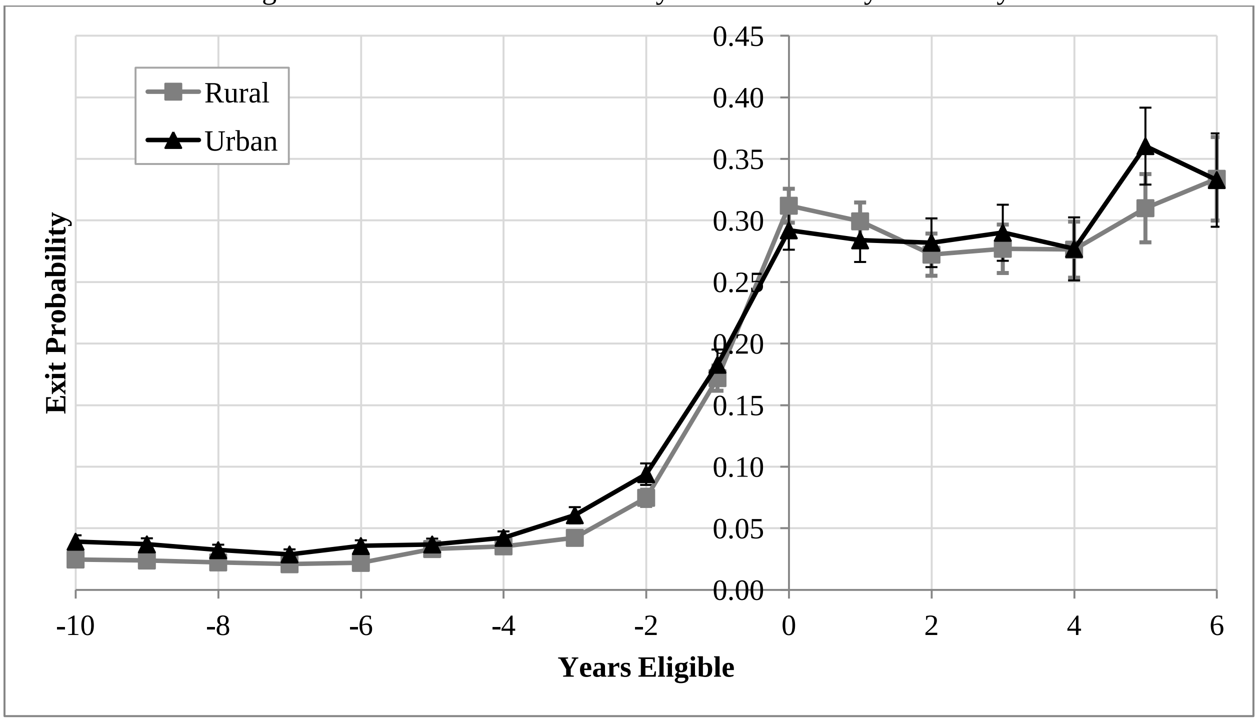
Predicted exit probability for Teacher A (see Figure 5 notes) using specification in equation (11) with interaction between college competitiveness and YrsElig. Teachers who attend less competitive colleges behave similarly to those who attend competitive colleges. Error bars show 95% confidence regions.

Figure 10. Predicted Exit Probability for Teacher A by School Level



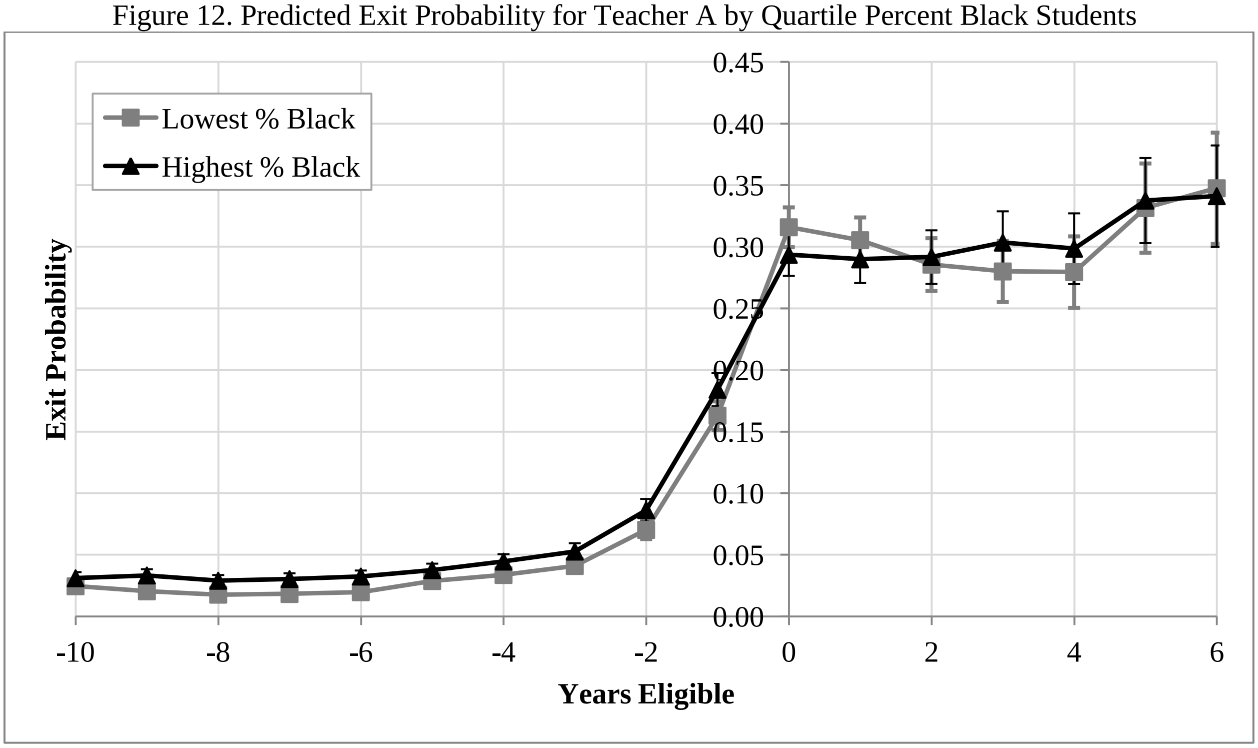
Predicted exit probability for Teacher A (see Figure 5 notes) using specification in equation (11) with interaction between school level and YrsElig. There are no statistically significant differences by school level.

Figure 11. Predicted Exit Probability for Teacher A by Urbanicity



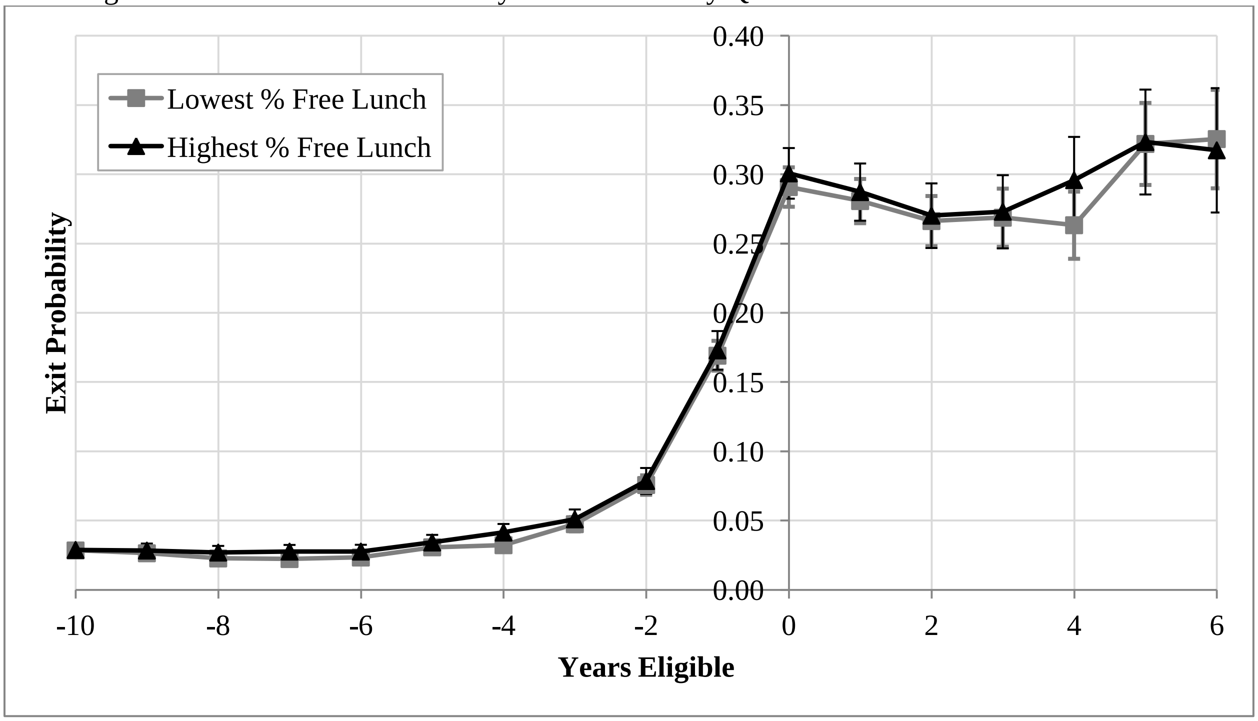
Predicted exit probability for Teacher A (see Figure 5 notes) using specification in equation (11) with interaction between urbanicity and YrsElig. Teachers who work at town/suburban schools behave similarly to those at rural schools. Error bars show 95% confidence regions.

Figure 12. Predicted Exit Probability for Teacher A by Quartile Percent Black Students



Predicted exit probability for Teacher A (see Figure 5 notes) using specification in equation (11) with interaction between % black students quartiles and YrsElig. Error bars show 95% confidence regions.

Figure 13. Predicted Exit Probability for Teacher A by Quartile Percent Free Lunch Students



Predicted exit probability for Teacher A (see Figure 5 notes) using specification in equation (11) with interaction between % free lunch students quartiles and YrsElig. Error bars show 95% confidence regions.