Do Pensions Enhance Worker Effort and Selection? Evidence from Public Schools

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Abstract

Why do employers offer pensions? We empirically examine two theoretical rationales, namely that pensions improve worker *effort* and worker *selection*. We test these hypotheses using rich administrative measures on effort and output for teachers around the pension-eligibility notch. When workers cross the notch, their effective compensation falls by roughly 50 percent of salary, but we observe no reduction in worker effort or output. This implies that pension payments do not increase effort. As for selection, we find that pensions retain low-value-added and high-value-added workers at the same rate, implying similar preferences across teacher quality and no influence on selection.

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1 Introduction

Why do employers provide pensions? We empirically investigate two rationales proposed in the theoretical literature. Both stem from the notion that pensions may enhance productivity by influencing the decisions of workers.

First, pensions may increase worker *effort*, as predicted by several models. The gift exchange model proposes that pension accruals shape reciprocity, with workers returning exceptional effort when accruals are generous, and shirking in response to pay cuts (Akerlof, 1982). Morale models predict a similar dynamic, where morale and effort rise and fall proportionally with pay (Akerlof and Yellen, 1990). Separately, deferred compensation models posit that pensions increase effort by raising the stakes of dismissal, a classic rationale for pensions (Yellen, 1984; Gustman et al., 1994). This rationale is challenged, however, by the scarcity of dismissals where pensions are common. We introduce a new model of deferred compensation wherein pensions improve effort without dismissals. Notably, these various models all predict pensions improve effort before retirement eligibility, but not after.

Second, pensions may improve productivity by enhancing worker *selection*. The underlying model posits that higher quality workers have a stronger preference for pensions than lower quality ones. Workers who are diligent, conscientious, or patient may value pensions more highly than others, so establishments that offer pensions will endogenously attract and retain better workers (Gustman et al., 1994; Morrissey, 2017; Weller, 2017). If true, the model predicts that high-quality workers will exhibit especially high attrition when pension incentives cease at retirement eligibility.

In this paper, we test these two hypotheses—namely that pensions increase worker *effort* and improve worker *selection*.[1] Understanding the effects of pensions can help employers design effective compensation policies, both in government and private enterprise.

The rationales we examine are common in public discourse about whether employers

[1] A thorough cataloging of rationales can be found in Gustman et al. (1994). These include that pensions may improve retention by young workers and encourage retirement by older ones. The retirement rationale is especially important in physically taxing professions like military service and firefighting. Historically, pensions began as a way for the Roman Empire to ease aging soldiers out of battle and into retirement. Glaeser and Ponzetto (2014) proposes a political economy rationale for modern pensions, suggesting that politicians use pensions to win support from public workers, a politically powerful group, with benefits whose costs are less visible to taxpayers.

should offer pensions. A consulting firm advises its clients that "pension plans can increase staff productivity," implicitly invoking the "effort" hypothesis (BP Consulting, 2022). Citing the "selection" hypothesis, Economist Monique Morrissey writes that "pensions are the single most important tool for recruiting and retaining" excellent workers (Morrissey, 2017).[2] These claims are echoed by policymakers. Rick Cost, a public school manager, states that pensions are a "valuable tool in attracting and retaining outstanding teachers" (Badertscher, 2013). We assess these claims with new data and designs.

While intuitive, the effort and selection rationales for pensions have received little empirical testing. Assessing the impact of pensions on effort and selection is key to understanding the benefits they confer on organizations and society more broadly. Measuring the causal effect, however, is quite challenging. Pension enrollment is not random, and there are few natural experiments to shed light. Data on pension eligibility and worker productivity, moreover, are not readily available.

We address these obstacles using administrative data from public schools, which offer distinct advantages. First, the notch provides a discontinuous decline in pension payments while other aspects of the work setting evolve smoothly. Second, since public schools employ over half of government workers, the setting provides large samples and therefore statistical clarity (Blumerman, 2012). Third, while output is unobservable in most work settings, schools collect annual achievement records, offering psychometrically validated measures of output. Together, these features provide an exceptional setting for understanding both the selection and effort effects of pensions.

We exploit these advantages by assembling administrative staffing records and constructing an array of effort and output measures for teachers in North Carolina. We estimate each teacher's yearly effect on students' math and reading skills, as well as on important "non-cognitive" behavioral skills.[3] We estimate yearly effects which we use to construct forecast-unbiased measures of worker productivity, following (Chetty et al., 2014b). These

[2] Similarly, researcher Christian Weller argues that employers offer pensions "to achieve labor management goals, such as recruiting and retaining the best people for the job" (Weller, 2017). BP consulting argues that offering a pension will "helps you recruit the finest personnel" and "retain your high-performers" (BP Consulting, 2022).

[3] All skills are mediated by cognition, making "non-cognitive" skills a useful but inaccurate handle for the concept.

measures allow us to examine "effort" (the potentially *transient* component of productivity) and "quality" (the *predictable* component).

Public school teachers in North Carolina are automatically enrolled in the state's pension plan. Teachers become eligible to receive a pension annuity when they meet certain age and years-of-service requirements. These requirements create a notch that provides empirical leverage into the questions at hand.

First, we examine the "effort" hypothesis. Before reaching the notch, teachers effectively earn an additional 70 percent of their salary through pension accruals each year. When they cross the eligibility notch, however, accruals fall substantially, cutting their pay by 56 percent of their salary. The models we discussed before—reciprocity, morale, and deferred compensation—all predict effort will decline as workers cross this threshold.

Contrary to these predictions, however, we find no such decline in output or effort at retirement eligibility. Using event-study figures and difference-in-difference regressions, we compare individual workers' productivity before and after crossing the eligibility threshold. Productivity evolves smoothly across the threshold, despite the sharp drop in pension compensation. Moreover, work attendance (another marker of effort) slightly *increases* post-threshold, contrary to the prediction of the effort hypothesis. These findings suggest that pension incentives do not increase effort by enhancing morale, fostering reciprocity, or by deferring compensation.

Next, we turn to the "selection" hypothesis of pension provision. This hypothesis posits that worker quality correlates with preferences for pensions. If true, it would have two key implications: (1) before the notch, pensions would differentially retain high-performing workers; (2) at the notch, when pension incentives cease, highly productive workers would have excess retirements because they had been differentially retained by the incentive. To test this hypothesis, we measure retention *changes* at the eligibility notch for teachers with high and low value-added (VA) scores. This approach allows us to identify the fraction of workers retained by the pension incentive across different quality categories. The approach provides a powerful test because the pension's influence on workers is strongest at the notch, where payment changes are large, and pension compensation is most salient to workers.

Consequently, if pensions affect worker selection at any point in a career, it would be most evident here.

We find similar retention probabilities around the notch for high and low-performing teachers, and their retention odds change in the same way at the notch. This pattern implies that pensions exert the same retentive effect, regardless of worker productivity. This in turn implies that highly productive and less productive workers have the same preference for pension income. If preferences for pensions are uncorrelated with productivity, as implied here, they likely have no selective influence on teachers' labor supply decisions throughout the life cycle.

This paper advances the literature on human resources management and improves our understanding of how pensions affect worker selection and productivity (Lazear and Oyer, 2007; Hoffman and Tadelis, 2021). Much like De Ree et al. (2018), we find that large unconditional payments do not improve worker effort or output. By contrast, several authors show that conditional payments (performance pay) can improve worker selection and effort (Mbiti et al., 2019; Brown and Andrabi, 2020; Biasi, 2021; Leaver et al., 2021; Johnston, 2024). Past work on pensions has focused on the role they play in shaping labor supply (Brown, 2013; Manoli and Weber, 2016; Ni et al., 2021; Johnston and Rockoff, 2022). Closest to our work are studies examining the effect of pensions on worker selection. Koedel et al. (2013) compares the value-added of workers who retire at different points in their careers; Goldhaber and Grout (2016) finds that higher-output workers are significantly less likely to select defined-benefit pension plans. Mahler (2018) finds that highly productive workers have lower turnover than less productive workers late in their careers. Ni et al. (2022) estimate a structural model and find that defined benefits plans lower workforce quality while defined contributions plans raise it. And Fitzpatrick and Lovenheim (2014) examine the effect of an early retirement program, and find that it encourages less effective teachers to retire.

Our paper contributes to this line by transparently showing how pensions shape effort and selection. Our paper provides the first direct tests of the effort hypothesis, which we do using detailed administrative data and quasi-experimental designs that identify the effect of pension incentives on effort. Our effort and selection measures are especially comprehensive, leveraging an array of measures including absences and state-of-the-art value-added scores in both cognitive and behavioral skills.

Though past theoretical work has posited that pensions likely improve worker effort and selection, we find no evidence supporting these claims. Because modern pensions are increasingly concentrated in the public sector, moreover, the results are likely representative of the settings in which pensions are now most common.

2 Theoretical Framework and Application

This section outlines the key models underlying the effort and selection hypotheses of pension provision. We examine how these theories apply to our setting of public school teachers and demonstrate how they predict changes in teacher effort and selection at the retirement eligibility notch.

2.1 Models Supporting the Effort Hypothesis

Here we present several theoretical models that predict pensions will enhance worker effort before the notch, but not after. These models lay a foundation for our investigation into the relationship between pension programs and teacher productivity.

2.1.1 Models of Deferred Compensation

Models of deferred compensation are the most frequently cited class of models positing that pensions improve effort by increasing the cost of departure for workers. This classic rationale for pension provision argues that pensions create large, backloaded payments to workers, incentivizing them to maintain employment by avoiding shirking (Lazear, 1979; Gustman et al., 1994). However, once a worker crosses the retirement threshold, this incentive disappears as the backloaded payments have already been secured and pension accruals stop.

Notably, pensions are now most common in settings where dismissal is relatively rare, potentially weakening this rationale. We document this fact by comparing dismissal rates in the private and public sectors using the Current Population Survey.[4] We find that among workers aged 50 and older, the layoff rate is 2.3 percent for the private sector, and 1.0 percent for both public school teachers and the public sector more generally. The lower dismissal risk for public employees suggests the deferred compensation channel may be less potent than in private employment. However, the similar dismissal rates among teachers and other public employees suggest our findings likely generalize to other public settings where pensions are common (Zook, 2023).

In our empirical analysis, we examine how effort and productivity change at the retirement notch, where the pension incentive to remain with the employer stops. According to the deferred compensation model, we expect a decrease in effort at the notch, since teachers no longer risk losing substantial pension wealth through early exit. Given the lower dismissal rates in public schools, however, this effect may be less pronounced than it would be in private employment. Our analysis will help determine whether the deferred compensation mechanism remains relevant in a setting with relatively strong job security.

2.1.2 A Model of Deferred Compensation without Dismissals

While dismissal has been a core component of traditional deferred compensation models, we show that dismissals are not necessary for pensions to increase worker effort, even in this class of models. Pensions can effectively elicit worker effort in environments without dismissals by offering delayed compensation.

Our model proposes that a worker's performance affects the welfare she derives from her job. Intuitively, when a worker exerts effort, she enjoys good relationships with her colleagues and managers. Conversely, when she shirks, she faces a tense work environment with disapproving colleagues. Thus, shirking reduces the utility a worker derives from her current job.

Ordinarily, workers are tempted to shirk, knowing they can find a new job once the

[4] Using CPS data from 2010–2024, we calculated the share of labor-market participants who report being unemployed due to layoff. We identified teachers using the occupation variable and government employment from the "class of worker" question. The sample was limited to those in the labor force between ages 50 and 70, resulting in 22,237 observations of public school teachers.

work environment sours from low effort. But pensions fundamentally alter the calculus. By making job changes more costly, pensions encourage workers to maintain a pleasant work environment through greater effort. The model has similarities to relational contracting models in which non-contractible actions are enforced through repeated play (MacLeod and Malcomson, 1989). Intuitively, pensions make a repeated game with the employer more likely, which elicits more effort in cooperation (Kreps et al., 1982).

In short, our model demonstrates that pensions can encourage effort, even without the threat of dismissal, by lengthening the employment relationship over time. This magnifies the benefits of effort that return to the worker in the form of a more supportive work environment.

This theory extends the traditional efficiency wage model to settings with strong job protections, offering a potential explanation for why employers might offer pensions even when dismissal is rare in the contexts where they are often offered. It also provides an additional theoretical foundation for examining effort effects of pensions in public sector settings, like our study of teachers.

We present a formal mathematical model of this theory in online Appendix C. In our empirical analysis, we examine how effort and productivity change at the retirement eligibility notch, where the incentive to maintain long-term employment greatly diminishes. According to our model of deferred compensation without dismissals, we would expect to observe a decrease in effort at this point, as teachers no longer have a strong motivation to maintain a positive work environment by exerting costly effort.

2.1.3 Models of Morale and Reciprocity

A broader class of efficiency wage models predict effort responds to the generosity of-compensation (Katz, 1986). The canonical model by (Akerlof, 1982) proposes that the labor market can be understood as a system of gift exchange between employers and employees. Whether by deeply ingrained reciprocity motives or notions of fairness, workers respond to generous payments by providing more effort than the minimum required, with workers "gifting back" exceptional effort for generous pay.

Morale models predict the same pattern. Namely, generous payments improve worker morale which elicits greater effort and dedication. The inverse is that, when compensation falls, workers scale back their effort and commitment accordingly (Akerlof and Yellen, 1990; Fehr et al., 1993; Mas, 2006). Indeed, fear of lowering morale and thus effort is among the most cited rationales for nominal wage rigidity (Campbell III and Kamlani, 1997; Bewley, 1998).

A key consideration in applying these models is how teachers perceive their pensions, whether as lump sum payments or yearly accruals. A core economic principle is that people make decisions on the margin, comparing the cost and benefit of incremental actions, rather than making all-or-nothing choices. This classic economic principle, pioneered by Marshall (1890), has been extended to labor supply decisions by scholars like Edgeworth (1881), Robbins (1930), and Hicks (1932).

In the context of pensions, this suggests that teachers rationally respond to year-to-year pension accruals rather than viewing their pension as a fixed-and-unchangeable lump sum received at career's end. Indeed, pensions are designed to shape teachers' decisions using marginal incentives, encouraging retention up to the eligibility notch and encouraging retirement thereafter (Gustman et al., 1994; Koedel and Podgursky, 2016). Our empirical analysis supports this view: we observe a sharp increase in teacher attrition once pension incentives to remain employed disappear, indicating that teachers are attuned to these marginal payments. This understanding of how teachers perceive pension accruals forms the foundation for our subsequent empirical analysis.

In our empirical analysis, we examine how effort and productivity change at the retirement eligibility notch, where generous pension accruals cease. Specifically, before teachers reach the threshold, they accrue 71 percent of their final salary in future pension wealth per year. After reaching the notch, that accrual falls to 15 percent of final salary. The result is that teacher compensation falls by 56 percent of salary at the retirement notch. According to reciprocity and morale models, we would expect a sharp decrease in effort and productivity at this point, as teachers experience a significant effective pay cut.

In summary, each of these models—morale and reciprocity, deferred compensation, and efficiency wages without dismissals—converge on the same prediction: namely, worker effort will decline at the retirement eligibility notch when pension accruals stop.

2.2 Models Supporting the Selection Hypothesis

2.2.1 Models of Distinct Preference

The primary model supporting the selection hypothesis proposes that preferences for pension compensation are positively correlated with worker productivity. This theory suggests that pensions can serve as a mechanism for differentially attracting and retaining more productive workers by appealing to their distinct sensibilities (Gustman et al., 1994; Morrissey, 2017; Weller, 2017).

The core idea is that certain worker characteristics associated with higher productivity—such as diligence, conscientiousness, and patience—may also predispose individuals to value pension benefits more highly. For instance, more conscientious individuals might view pensions as a responsible way to prepare for the future, consistent with their general tendency to be thorough and mindful of long-term consequences.

As a result, organizations offering pension plans may naturally attract a pool of applicants with these desirable traits. Moreover, once employed, these highly productivity workers are more likely to remain with the organization to fully realize their pension benefits.

Typically, employers can only manage a workforce using observed characteristics. The hope of this theory is that unobservably better workers endogenously select into and remain with the organization. If true, a pension would achieve automatically what attentive workforce management could not.

Applying this theory to our study context, the selection hypothesis predicts a specific pattern of teacher retention around the pension eligibility notch. If teacher quality is indeed correlated with a preference for pensions, we would expect two outcomes: First, pensions would have an especially strong retentive effect on more productive teachers approaching the notch. Second, at the notch, teachers retained by a stronger preference for pensions would be more likely to retire than other teachers. This would result in excess retirements of talented workers at the eligibility threshold.

To test this prediction, we measure the change in retention rates that occurs at the pension notch for teachers of different value-added. The model suggests that highly effective teachers will exhibit a larger change in retention rates at the notch, reflecting the fact that high-quality teachers were more likely to be retained by pension incentives.

3 Retirement System for Teachers in North Carolina

North Carolina's teacher pension follows a pattern shared by defined-benefit pension systems across the country. In broad strokes, employees accrue service credits that increase their pension annuity as they remain with the employer. Teachers become eligible to draw their pension annuity when they reach age and years-of-service requirements. These requirements form the notches that serve as an empirical instrument for identification. Teachers in North Carolina become eligible to draw their annuity when

(1) they have 30 years of experience at any age,

(2) they are 60 years old and have at least 25 years of experience, or

(3) they are 65 years old with at least 5 years of experience.

The relevant threshold for 76 percent of teachers is 30 years of experience. The relevant threshold for another 16 percent of teachers is age 60 and 25 years of experience. The notches have not changed over the observation window, which we confirm by examining biennial pension records published by the national teachers' union and stored at the Library of Congress. At least since 1982 through the end of our observation period, the eligibility notches have remained the same

Teachers also have notches for early retirement eligibility. Under early retirement, a teacher can claim a pension annuity early, but her annuity is penalized. In North Carolina, a teacher can claim early at age 60 with at least 5 years of service or at age 50 with at least 20 years of service. This, again, has been constant since at least 1982. If a teacher takes early retirement before age 60, her yearly pension annuity is usually penalized by 5 percent per year that she is shy of 30 years of service credit.[5] If a teacher claims early retirement in her 60s, she faces a 3 percent penalty for each year she is short of 65. We do not observe a measurable retention effect for the early-retirement notch so we focus the analysis on the normal-retirement notch.

Once a teacher is eligible to retire and claims her retirement benefit, she receives a yearly payment of an amount:

$$P_{js} = FAS_j \times (1.82\% \times s_j) \tag{1}$$

That is, an eligible teacher j with years of service s, receives a pension annuity P that is the product of her final average salary calculated at retirement (FAS_j), her years of service (s_j), and a multiplier parameter determined by the state (1.82%). At retirement, her replacement rate will be ($1.82\% \times s$) and she will receive that share of her final average salary each year for the rest of her life. States and programs calculate the final average salary by slightly different formulas. In North Carolina, "final average salary" (FAS_j) is calculated as the average of a teacher's highest consecutive four years of salary prior to retirement. As an example, if a teacher retires with 30 years of experience, and her final average salary is \$80,000, her replacement rate would be $30 \times 1.82\% = 54.6\%$ and she would therefore receive $54.6\% \times \$80{,}000 = \$43{,}680$ per year in retirement.[6]

We consider how pension rules shape a worker's incentive to maintain employment. We first compute the claiming age that maximizes the present value (PV) of benefits for retirees at each level of experience. We calculate the present value of pension wealth accrued over time for an archetypal worker who begins employment at age 24 (the modal start age in our data), works continuously, and uses the optimal claiming age.[7] The optimal claiming age may differ depending on a teacher's discount rate, with impatient workers maximizing their

[5]The penalties are determined by a table that lacks a straightforward formula (North Carolina Department of State Treasurer, 2023).

[6]That amount is normally adjusted each year for cost of living based on the consumer price index and whether investment returns of the fund would cover the expense increase calculated by the state's actuaries.

[7]When calculating the present value of pension wealth, we assume a life expectancy of 85 (the relevant life expectancy for college-educated women). Varying life expectancy produces similar results—teachers who expect to live longer behave like those who have smaller discount rates.

present value by claiming earlier but reducing their total benefits in retirement. We show the returns at two plausible discount rates, 3 and 5 percent.[8] We calculate the marginal pension incentives for retention each year, presented in Figure 1. We express incentives as the percent of a teacher's final average salary (FAS) that she earns in present-value pension wealth by working one additional year. As an example, we find that in the year a teacher vests, her pension incentive is "25," meaning that the teacher accrues 25 percent of her FAS in present-value pension wealth by working in the year she vests.

As seen in Figure 1, pension wealth spikes at five years of service, when workers vest, and again at twenty years when workers become eligible for early retirement.[9] Marginal returns are especially high between 21 years and 25 years of experience as the penalties for early retirement phase out. Workers can claim full retirement at age 60 when they complete 25 years of experience. This reduces the marginal incentive somewhat because workers do not need to work 30 years of service or wait until age 65 to claim. After teachers reach 30 years of experience, they experience a "pension cliff" in which the effective compensation from pensions falls by 56 percent of final salary.[10]

The key takeaway for our purposes is that teachers receive significant pension wealth in the years before workers reach the retirement eligibility notch and their effective compensation falls precipitously when they reach the notch.

North Carolina allows workers to cash in unused sick and personal days to increase their years-of-service credits by up to two years. Teachers can exchange 20 unused sick days for a month-of-service credit. Because teachers in North Carolina receive up to 40 days of leave each year and only use 22.5, the modal retirement is two years before the posted service requirement. We confirm this prediction with the timing of departures which jumps at 28 years of experience, two years before the posted 30-year requirement. We incorporate data on absences to predict which teachers are eligible to claim early, which we describe in

[8]See Giglio et al. (2015) , Best et al. (2018), Ericson and Laibson (2018), and Johnston (2024) for evidence on discount rates. Authors tend to find discount rates of 5 percent per annum with Giglio et al. (2015) finding long-run discount rates closer to 3 percent per annum.

[9]If a teacher has 20 years of experience, she can claim early retirement at age 50.

[10]In the last year before a teacher becomes retirement eligible, they earn 69.7 percent of their final average salary in pension wealth. The next year, they earn just 13.8 percent of their final salary, constituting an effective decline in their compensation of 56 percent of salary.

greater detail shortly.

4 Data and Sample Construction

4.1 Data

We use administrative records from the North Carolina Education Research Data Center (NCERDC), covering staffing and students in North Carolina from 2000 through 2018. The dataset includes several key components. Staffing records include yearly employment of teachers in public schools, allowing us to identify when a teachers leaves the public school system. Our analysis focuses on teachers in grades 4 through 8 who teach tested subjects.[11] We also have information on teacher characteristics, including age and experience (based on pay codes). These enable us to determine each teacher's placement around the pension eligibility notch each year. We have information on teacher absences for sickness, vacation, and the like for the years 2000 through 2008. We use these as a measure of effort and to calculate how many days of unused sick leave each teacher has, which can be transformed into experience credit when teachers retire. Finally, we examine output using detailed achievement and behavior records for students. We link student outcomes to teacher assignments using class assignments for each. These allow us to connect students' outcomes to their relevant teachers, even in higher grades.

4.2 Constructing Value-Added Measures

Student i is assigned to classroom $c = c(i,t)$ in school $k = k(i,t)$ in year t. Each classroom has a single teacher $j = j(c(i,t))$, though teachers may have multiple classrooms. We model student achievement as depending on observed student characteristics, X_{it}, his teacher's value-added VA_{jt}, school effects, μ_k, time effects, μ_t, classroom effects, θ_{ct}, and a

[11] This implies that we use math and reading test score data for students from grades 3 through 8. Because classroom identifiers appear in the data late, we use years 2007-2018 to construct teacher value-added.

randomly distributed error term, $\tilde{\epsilon}_{it}$.[12] Formally:

$$
\begin{aligned}
A^*_{it} &= \beta_s X_{it} + \nu_{it}, \\
\nu_{it} &= f(Z_{jt};\alpha) + \mu_{jt} + \mu_k + \mu_t + \theta_{ct} + \tilde{\epsilon}_{it}.
\end{aligned}
\tag{2}
$$

We model teachers' value added as a flexible function, $f(\cdot)$, of teacher experience, Z_{jt}, and μ_{jt} is teacher j's value-added in year t, excluding the return to experience.[13] We follow Chetty et al. (2014a) in allowing a teacher's effectiveness to "drift" over time. We use math and English test scores (standardized at the state-level to have a mean of 0 and standard deviation of 1 in each grade-by-year) to measure academic achievement in each subject. Teachers may also affect students' behavioral outcomes like truancy and disciplinary infractions, markers of important so-called non-cognitive skills (Jackson, 2018; Petek and Pope, 2023).[14] We measure teachers' impact on the first principal component of a behavioral index including students' log absence rate, an indicator for in-school suspensions, and an indicator for out-of-school suspensions. As teachers may have direct control over current discipline enforcement, we follow Gilraine and Pope (2021) and also use the lead of this behavioral principal component when the focal teacher no longer mediates discipline enforcement. To avoid the possibility of the future teacher impacting our measure we net out the students' subsequent class' current average of the same measure.

We estimate our model in three steps. In the first, we estimate the coefficients on student characteristics by regressing academic achievement or behavioral skills on a set of student characteristics and classroom fixed effects. In the second, we project the residuals ($\hat{\nu}_{it}$) onto teacher fixed-effects, school fixed-effects, year fixed-effects, and the teacher experience return function. In the final step, we form our estimate of teacher j's value-added in

[12] Specifically, we include ethnicity, gender, gifted designation, disability designation, whether the student is a migrant, whether the student is learning English, whether the student is economically disadvantaged, test accommodations, age, and grade-specific cubic polynomials in lagged math and lagged reading scores.

[13] We model the experience return function as a vector of experience indicators for each of the first 6 years of teaching and an indicator for years of experience beyond that.

[14] "Non-cognitive" skills are called such in an attempt to distinguish them from traditional academic skills like reading and mathematics. The term is somewhat imprecise since all human skills are mediated by cognition, whether they be intellectual, behavioral, social, attitudinal, or physical. In this paper, we tend to use "behavioral" skills to draw the contrast with traditional measures of achievement, sometimes lapsing into the well-understood lexicon of cognitive and non-cognitive.

year t (VA_{jt}) as the best linear predictor based on prior data in our sample (the prediction includes the experience function). When examining effort, we use yearly student residuals associated with each teacher to capture the part of productivity that, like effort, can potentially change from year to year. When examining quality selection, we use forecast-unbiased predicted teacher VA to capture durable teacher quality.

4.3 Unused Absences

Teachers in North Carolina need 30 years of service to be eligible for full retirement at any age. In practice, however, they can exchange unused leave for up to two years of credit towards their years-of-experience requirement.

Each year, teachers in North Carolina receive up to 26 days of vacation leave, 12 days of sick leave, and 2 personal days. In total, young teachers are credited 28 full-day absences, and those with at least 20 years of experience are credited 40 full-day absences. We predict each teacher's full retirement eligibility date using her years of service and absence history which we observe from 2000 to 2008. We sum absences each year and calculate the mean number of absences teachers have over the years we observe them. On average, teachers take 22.4 full days off per year (where the school year has 185 days), which means that the average teacher accrues 360 unused absences by their 28th year.

It takes 20 unused absences to earn one month of credit towards their years-of-experience requirement, so the average teacher has enough saved absences to retire 18 months before they have accrued 30 years of experience by classroom teaching. We cannot make a precise mapping from absences over the nine years we observe to total credit since the work histories of teachers near retirement are mostly unobserved. We find that teachers with no more than 25 absences per year are most likely to leave the workforce with 28 years of work experience and those with more than 25 absences are most likely to leave the workforce with 29 years of experience. Even when we look at teachers with absences above the 90th percentile, they are most likely to retire with 29 years of service. We use our measures of absences for each teacher to impute her expected retirement eligibility date. The results are robust to alternative imputations.

5 Design and Results

5.1 Effort Effects of Pensions

Remember that one of the theoretical rationales for provision is that pensions elicit additional effort from employees by improving morale, fostering reciprocity, and magnifying the downside of departure (Lazear, 1979; Gustman et al., 1994; Ruhm, 1994; Akerlof, 1982; Akerlof and Yellen, 1990; Katz, 1986; Fehr et al., 1993; Mas, 2006). The panel dimension of our data allows us to observe yearly measures of effort and output for public school teachers in North Carolina. If effort slackens when a worker reaches retirement eligibility, it implies that large pension payments have successfully elicited additional effort before the notch.

Using the age and experience of each worker, we calculate her distance to the relevant retirement-eligibility notch. To do so, we calculate three values: (1) the employee's distance beyond the 30-years-experience cutoff, (2) the employee's distance beyond the age-60-and-25-years-experience cutoff, and (3) the employee's distance beyond the age-65-and-5-years-experience cutoff. The worker need only meet one notch to be eligible for retirement, so a worker's effective distance to retirement eligibility is the most positive distance to any notch. Those with a distance greater or equal to zero are retirement eligible and those with negative values are not yet eligible to retire.

We model the outcome variable E_{jt} (measures of effort for teacher j in year t) as a function of the teacher's distance to the retirement eligibility notch while accounting for teacher fixed-effects:

$$E_{jt} = \alpha_j + \tau_t + \sum_{m \in PRE} \lambda_m \times \mathbf{1}(t - t_i^* = m) + \sum_{m \in POST} \pi_m \times \mathbf{1}(t - t_j^* = m) + \varepsilon_{jt} \quad (3)$$

Here, the indicators $\mathbf{1}(t - t_i^* = m)$ refer to event-time dummies that equal one if a teacher is exactly m years from retirement eligibility, and zero otherwise. The variable t_i^* represents the time at which a teacher becomes eligible for retirement. The first sum includes pre-eligible event years so that the

$lambda_m$ coefficients capture pre-eligible trends in effort. The second sum includes post-eligible event time. We exclude a dummy for the period $m = -1$ so that period is the omitted category and the implicit reference for comparison.

If pensions elicit greater effort by workers, we expect that the π_m coefficients would be *negative* when the outcome is positively related to effort (like yearly value-add) and *positive* when the outcome is negatively related to effort (like worker absences). We use the average of teacher j's student achievement residuals from equation (2) in year t to measure her productivity that year in our primary analysis, as they do not directly depend upon the teacher's past effort.[15] We demean E_{jt} by year to accommodate possible year effects.

To show how effort and productivity evolve as workers cross the retirement threshold, we present estimates from equation (3) in Figure 2. Specifically, we show how teachers' math value-add, reading value-add, behavioral value-add, and absences evolve around the retirement eligibility notch. In each of the value-added measures, we see teacher output evolving smoothly as they gain experience. At the threshold, we do not observe any significant deviation in the trend, suggesting that effort does not fall at retirement eligibility. We find that teachers have, likewise, a smooth evolution of yearly absences as they approach the eligibility notch, and we do not find an increase in absences as teachers cross the retirement threshold. In total, this suggests pensions do not elicit additional effort, as predicted by theory, through enhanced morale, reciprocity motives, or by deferring compensation.

We pool the estimates to summarize the results with a difference-in-differences specification of the form:

$$E_{jt} = \alpha_j + \tau_t + \pi \times POST_{jt} + \varepsilon_{jt}, \tag{4}$$

Again, α_j denotes teacher fixed-effects and τ_t denotes year fixed-effects. In essence, we measure how worker effort and productivity change on average with retirement eligibility. The estimates make careful comparisons using individual fixed effects, essentially measuring how an individual's effort changes on average at the threshold. Because the values evolve smoothly over time, we also include a time-trend control in one robustness specification and

[15]In table A1 we show the results from a similar exercise using teachers' estimated value-added using only past years of data.

a teacher-specific pre-eligibility trend in a third specification. In each, we find no statistically significant change in measures of effort and productivity at the notch. Crossing the threshold is associated with a 0.0021 (0.0067) effect on math value-add, a -0.0048 (0.0057) effect on reading value-add, a 0.0003 (0.0091) effect on contemporaneous behavioral value-add, and a 0.0048 (0.0136) effect on persistent behavioral value-added. We find a -1.04 (0.323) day effect on teacher absences which does not correspond to value-add increases and runs counter to the effort hypothesis of pension provision. This is especially surprising because workers have an incentive to take fewer vacation days before they are pension-eligible since saved vacation days act as credits toward retirement eligibility. This same pattern is visible in each notch, with reductions in absences ranging from 0.7 to 1.0 days across the different notches.

Three personnel theories predict that effort will fall at the notch: the theory of worker morale from compensation, the theory of reciprocity and gift exchange, and the theory of deferred compensation. The fact that we observe no decrease in effort or productivity at the notch implies that, in this context, these channels do not operate to increase worker effort through these mechanisms.[16]

5.1.1 Robustness

We explore several variations to test the robustness of our conclusions. In Appendix Figure A1, we present event studies of teacher effort as measured by student residuals, this time excluding pre-trend controls. The results align with our baseline findings. While we observe a slight declining trend in residualized math scores leading up to the notch, this trend continues unaltered at the threshold. Trends in reading VA, behavioral VA, and teacher absences remain flat, consistent with our main analysis.

[16] We might not expect the deferred compensation mechanism to operate if job loss is not a risk. Data from the Current Population Survey (2010–2024) shows job-loss rates of 2.3 percent in the private sector, 1.0 percent for public school teachers, and 1.0 percent for the public sector more broadly. This context implies a few things for how what we learn about the deferred-compensation channel generalizes to other relevant settings. First, because public school teachers do face dismissal risk, the deferred compensation channel affecting effort is theoretically live. Second, because teachers have the same dismissal risk as other government employers, the results in this study likely generalize to other government employment, where pensions are relatively common (Zook, 2023). Third, while the private and public sectors have different average dismissal rates, they are of the same order of magnitude, suggesting similar motivational dynamics may be at play.

To further validate our findings, we conduct event studies controlling for teacher-specific pre-trends, as shown in Appendix Figure A2. These results mirror our baseline findings, with the primary difference being reduced precision in the post-eligibility period due to fewer degrees of freedom. We also present event studies using teacher value-added rather than student residuals in Online Appendix Figure A3. These analyses corroborate our main conclusions, providing additional support for the robustness of our results across different measures of teacher effectiveness.

In Appendix Figure A3 we replicate our finding of no productivity effects from crossing the retirement notch using yearly value-added measures of productivity rather than student residuals. This exercise reveals only more precise null effects on productivity.

In light of the recent literature uncovering shortcomings of standard fixed effects estimators, we implement Callaway and Sant'Anna (2021) difference-in-differences estimator which addresses these potential concerns. Appendix Figure A4 shows the estimates from this exercise, which again reveal no decline in effort or output.

Our main DID estimates pool observations from three notches to improve precision. To ensure that this pooling does not mask heterogeneous effects across different retirement eligibility thresholds, we present disaggregated estimates in Appendix Table A2. Here, we compare the estimates for the 30-year notch with those for the two less densely populated notches (requiring five and 25 years of experience). The results are consistent across notches, with none showing increases in effort or productivity at the retirement threshold. This consistency further supports our main findings.

Finally, our DID estimates in Table 2 show a range of specifications, including the baseline specification, one controlling for general pre-trends, and another controlling for individual pre-trends. Each tells the same story.

Collectively, these robustness checks reinforce our primary conclusion, that generous pension payments do not increase teacher effort or productivity

5.2 Selection Effects of Pensions

The second rationale for pensions is to foster positive selection in the workplace. The logic is that pensions may be more attractive to conscientious and committed employees and differentially attract and retain them (Gustman et al., 1994). The pension eligibility notch provides an opportunity to empirically observe whether pensions have a positive effect on selection. If pension incentives differentially retain high-caliber teachers, we would expect to see a larger spike in their attrition at the notch when these incentives cease.

Pensions are structured to provide workers incentives to remain with an employer until the worker is eligible for retirement. Recalling Figure 1, pensions reward those who stay, with especially large accruals in the years leading up to retirement eligibility. Consequently, attrition odds are relatively low before workers reach the notch and especially high after. If pensions do indeed foster positive selection, we would expect to see a more pronounced spike in departures among high-performing teachers at the notch.

To see whether pensions foster positive selection, we test whether high-value-added teachers are more likely to be retained through the pension incentive than low-value-added ones. To operationalize this approach, we separate teachers into three bins based on the predictable part of teacher value-added, calculated as described above. We use yearly VA up to the year prior to eligibility to predict the teacher's durable value-added and use that measure to categorize teachers into three bins: a high-performing bin (the top third), a middle-performing bin (the middle third), and a low-performing bin (the bottom third). Within each of those groups, we plot the departure hazard over time around the retirement eligibility notch.

For a typical teacher, attrition rates are steady at 2 percent per year in the decade leading up to retirement eligibility with attrition rising somewhat just before full eligibility. At the notch, attrition rates vault by an order of magnitude to almost 20 percent, where the change in retention at eligibility describes the retentive effect of the pension. What is important for our purposes is that the attrition patterns of the three groups are very similar around the notch. This is true regardless of which measure of value-added we employ (value-added for math, for reading, or for behavioral skills). This similarity implies that the retentive effect of the pension is similar for low-value-added and high-value-added teachers. If pensions were differentially retaining high-value-added teachers, their attrition would increase by more when those incentives cease. The similarity of the retention patterns for the three groups suggests that they have similar preferences for pensions. Therefore, pensions engender no selection advantage, with similar effects on their labor supply decisions across teacher quality levels.

We gauge the retentive effect of pensions to compare the attrition rate pre- and post-retirement eligibility in a specification to test statistically what we observe visually. We estimate the following equation:

$$Ret_{jt} = \alpha_k + \tau_t + eligible_{jt}\beta + \mathbf{1}[\mathbf{K} = \mathbf{k}] \times eligible_{jt}\boldsymbol{\delta}_k + f(TTE_{jt}) + \epsilon_{jt}, \tag{5}$$

Here, $K = k$ indicates teacher type, α_k is a fixed effect for being a high- or low-value-added teacher and τ_t is a year fixed-effect. The term $f(TTE_{jt})$ represents a local-linear function of time-to-eligibility for retirement. We allow this relationship to differ by teacher type. The coefficient β is the discontinuous effect of becoming retirement eligible for average-quality teachers, and $\boldsymbol{\delta}_k$ reflects the differential magnitude of the discontinuities for low- and high-value-added teachers. We estimate this specification at bandwidths of 5 and 10 years around the retirement eligibility notch to assess robustness.

Like the figures, we find large impacts of the retirement notches on attrition. When teachers reach their retirement eligibility, they become about 17 (2.26) percentage points more likely to retire.[17] We find statistically identical retentive effects for the three groups, regardless of how value-added is constructed. This suggests that pension preferences do not differ by worker quality and therefore pensions do not shape selection. Though our analysis does not directly test early career selection, the implied similarity of preferences makes this possibility unlikely. In a converging literature, Johnston (2024) similarly finds no difference in pension preferences by teacher quality.

Some models suggest that financial incentives of pensions may be second order. Gold-

[17]Consistent with Mahler (2018) in some specifications we find that highly effective teachers have lower attrition rates

haber et al. (2024), for instance, find that retention patterns are similar across pension plans with different retention incentives in Washington state. This suggests that eligibility notches form what amounts to a behavioral anchor or social norm that guides workers selecting their retirement date.[18] The basic results of our paper have a similar takeaway under this model of behavior. If the incentive effects are social or psychological rather than financial, what matters to the employer is whether those intangible incentives operate more powerfully on high-quality workers than low-quality ones, and we find they do not.

5.2.1 Robustness

We conduct several variations to test the robustness of our conclusions regarding the selection effects of pensions. In Appendix Figure A5, we present an alternative version of our graphical attrition-rate analysis that uses counts rather than rates. This approach yields results consistent with our baseline findings: highly effective workers do not exhibit a larger attrition increase at the notch, suggesting they have similar preferences and therefore no positive selection. This pattern holds true across various measures of teacher quality, including math value-added (VA), reading VA, and different versions of behavioral VA.

To ensure our results are not sensitive to the choice of analytic sample, we vary the bandwidth around the notch in our regression analyses (Table 3). We find no significant differences in the results when using narrower or broader bandwidths, further supporting the robustness of our main findings.

We also examine whether our results are sensitive to the specific measure of teacher effectiveness. Our analyses employ various value-added measures (math, reading, and behavioral skills), and the consistency of results across these strengthens confidence in the findings.

Lastly, while our primary regression estimates pool observations from three notches to improve precision, we recognize the potential for this approach to obscure heterogeneous effects across different retirement eligibility thresholds. We present disaggregated estimates in Appendix Tables A3 and A4, separately analyzing the 30-year notch and the two less

[18] This may be particularly powerful if most individual workers don't carefully optimize their retirement date but instead rely on what others tend to do.

densely populated notches (requiring five and 25 years of experience). The results again remain consistent across these different notches, with none showing enhanced retention for more effective workers.

Collectively, these robustness checks reinforce our primary conclusion that generous pension payments do not significantly alter the composition of the teacher workforce through differential retention of more effective teachers. The consistency of our results across various specifications, measures of teacher effectiveness, and retirement eligibility thresholds provides strong support for the validity of our findings.

6 Conclusion

In the theoretical literature around personnel management, the rationales for pension provision include the role pensions might play in spurring worker effort and in fostering positive selection among workers. In this paper, we examine these theoretical claims with rich records on worker output, effort, and retention in a setting that is important in its own right—the institution charged with forming human capital in the next generation.

Despite a sharp and significant drop in pension compensation as workers cross the retirement-eligibility notch, we find no discernible drop in teacher productivity or attendance. This implies that pension compensation does not elicit additional effort from workers. Our analysis also does not find support for the selection hypothesis—the idea that pensions selectively retain more productive workers. Instead, pensions exert similar retentive pull on teachers regardless of their quality or performance. This finding contrasts with claims by advocates that pensions are instrumental in retaining a higher proportion of high-performing workers.

Future research could examine whether pension programs influence selection at the point of entry into the profession. One could imagine measuring preferences for pensions in a choice experiment among college students and testing whether willingness-to-pay for pensions is correlated with skills and attributes that predict productivity (e.g., cognitive ability, conscientiousness, social skills, etc.). Such studies would provide valuable insight into the role of pensions in shaping selection on entry.

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Table 1: Summary statistics

	Full Sample	Within 10 years	Within 5 years
Math VA (mean)	0.00	0.01	0.01
Math VA (sd)	0.147	0.156	0.157
Math VA (N)	22,028	6,705	3,808
Reading VA (mean)	0.00	0.01	0.01
Reading VA (sd)	0.070	0.074	0.075
Reading VA (N)	23,181	7,143	4,068
Behavioral VA (mean)	0.00	0.00	0.00
Behavioral VA (sd)	0.070	0.078	0.080
Behavioral VA (N)	21,975	6,693	3,800
Behavioral VA (t+1) (mean)	-0.00	0.00	0.00
Behavioral VA (t+1) (sd)	0.108	0.119	0.121
Behavioral VA (t+1) (N)	21,994	6,690	3,797
Math student resid. (mean)	-0.04	-0.04	-0.04
Math student resid. (sd)	0.253	0.252	0.252
Math student resid. (N)	22,028	6,705	3,808
Reading student resid. (mean)	-0.00	0.00	0.00
Reading student resid. (sd)	0.190	0.193	0.192
Reading student resid. (N)	23,181	7,143	4,068
Behavioral student resid. (mean)	0.01	-0.00	-0.01
Behavioral student resid. (sd)	0.290	0.288	0.291
Behavioral student resid. (N)	21,975	6,693	3,800
Behavioral student resid. (t+1) (mean)	-0.00	-0.01	-0.01
Behavioral student resid. (t+1) (sd)	0.526	0.525	0.522
Behavioral student resid. (t+1) (N)	21,994	6,690	3,797
Days absent (mean)	23.12	22.86	22.43
Days absent (sd)	12.027	10.228	9.834
Days absent (N)	17,016	3,866	2,199
Notch at experience=28 (mean)	0.44	0.43	0.48
Notch at experience=29 (mean)	0.32	0.23	0.22
Notch at experience=25 (mean)	0.09	0.12	0.11
Notch at age=60 (mean)	0.07	0.09	0.09
Notch at age=65 (mean)	0.08	0.13	0.10
Attrition(mean)	0.03	0.05	0.08
Number of teachers	25,798	9,010	5,591

Notes: This table presents summary statistics for various samples including the full sample of teachers as well as analytic samples of teachers observed within five or ten years of the retirement notch. Math VA is the forecast-unbiased predicted VA based on yearly residuals for each teacher. Current behavioral VA is calculated by principal component analysis using student truancy and disciplinary actions (in-school suspensions and out-of-school suspensions) using the outcomes in the year the student is assigned the teacher of measurement. Persistent behavioral VA is the same but uses as the outcome the behavior of the students in the future, specifically in the year after they have left the teacher of measurement. We show which notch is relevant for the sample with an indicator for being at the notch at different experience and age profiles. Finally, we show the average attrition rate for each sample. Number of teachers is provided several times to explain the sample available for different measures.

Table 2: Teacher effort across the retirement notch

	(1) Math VA	(2) Reading VA	(3) Behavioral VA	(4) Behavioral (t+1) VA	(5) Teacher Absences
Eligible	0.00206	-0.00475	-0.000336	0.00476	-1.044***
	(0.00672)	(0.00566)	(0.00910)	(0.0136)	(0.323)
Control for pre-trends	No	No	No	No	No
Teacher pre-trends	No	No	No	No	No

(a) Baseline specification

	(1) Math VA	(2) Reading VA	(3) Behavioral VA	(4) Behavioral (t+1) VA	(5) Teacher Absences
Eligible	0.00611	-0.00351	0.000831	0.00465	-0.753**
	(0.00683)	(0.00583)	(0.00955)	(0.0142)	(0.344)
Control for pre-trends	Yes	Yes	Yes	Yes	Yes
Teacher pre-trends	No	No	No	No	No

(b) Controlling for pre-trends

	(1) Math VA	(2) Reading VA	(3) Behavioral VA	(4) Behavioral (t+1) VA	(5) Teacher Absences
Eligible	0.00561	-0.00848	0.0145	0.00864	-1.491*
	(0.0135)	(0.0111)	(0.0205)	(0.0293)	(0.787)
Control for pre-trends	No	No	No	No	No
Teacher pre-trends	Yes	Yes	Yes	Yes	Yes
Depvar sd	0.167	0.142	0.242	0.302	9.826
N	41476	43203	41339	37055	33806

(c) Including teacher-specific pre-trends

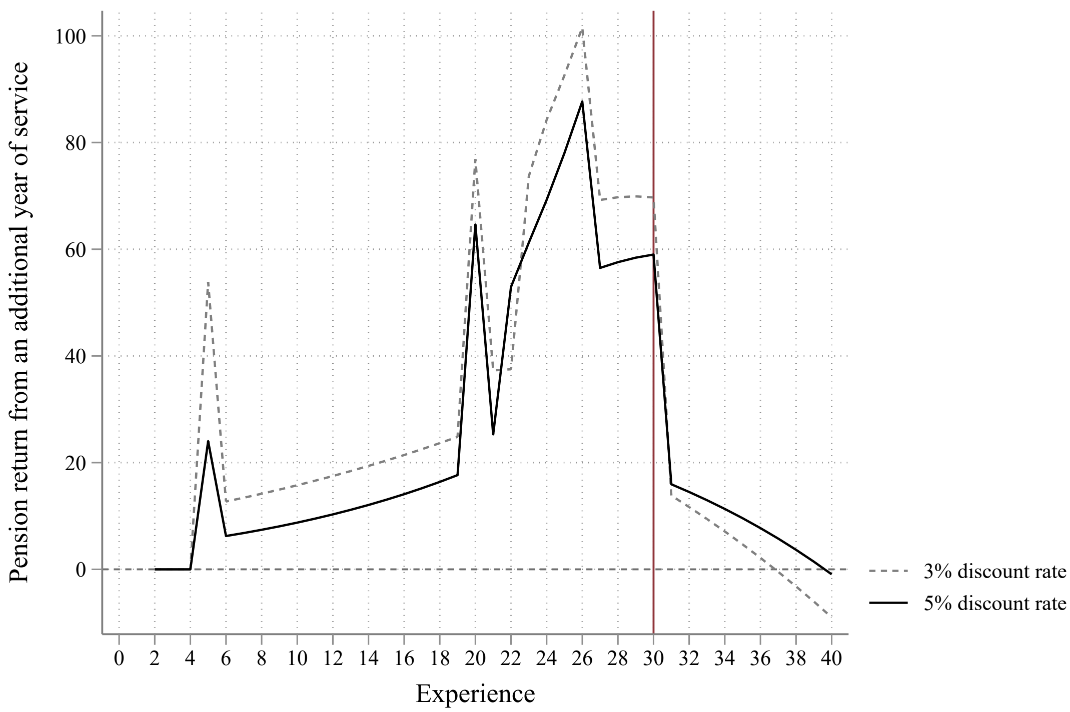
Notes: In this table, we present estimates of how much the pension eligibility notch corresponds to changes in teacher productivity and effort, using equation 4. In short, we regress measures of teacher output on an indicator for pension eligibility with controls for teacher fixed-effects and time fixed-effects. The design compares the effort of retirement-eligible teachers to their own effort before they were eligible. In general, we find that eligibility has little to no impact on productivity. While theory predicts teachers will exert less effort after the notch, we find that teacher attendance increases without a corresponding increase in productivity. All regressions include teacher and year fixed-effects. Standard errors are clustered at the teacher level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Differential attrition by teacher value-add at retirement notch

	Quality by Math VA		Quality by Reading VA		Quality by Behavioral VA		Quality by Behavioral VA (t+1)	
	Attrition	Attrition	Attrition	Attrition	Attrition	Attrition	Attrition	Attrition
Eligible	0.163***	0.171***	0.145***	0.141***	0.148***	0.120***	0.126***	0.151***
	(0.0183)	(0.0226)	(0.0183)	(0.0233)	(0.0181)	(0.0229)	(0.0196)	(0.0238)
Low-quality	0.0135	0.0224	-0.00607	-0.0114	0.000566	-0.0147	-0.00489	0.00995
	(0.0101)	(0.0188)	(0.00994)	(0.0188)	(0.00968)	(0.0182)	(0.0117)	(0.0199)
Low × eligible	-0.0249	-0.0286	0.00807	0.0123	-0.0126	0.0280	-0.00107	-0.0119
	(0.0266)	(0.0331)	(0.0260)	(0.0326)	(0.0258)	(0.0321)	(0.0272)	(0.0334)
High-quality	-0.00716	0.0159	-0.0203**	-0.0168	-0.00988	-0.0194	-0.0217**	-0.0147
	(0.00891)	(0.0168)	(0.00901)	(0.0173)	(0.00941)	(0.0179)	(0.0110)	(0.0187)
High × eligible	-0.00103	-0.0434	0.0160	0.000752	0.0272	0.0465	0.0337	0.0197
	(0.0246)	(0.0306)	(0.0241)	(0.0304)	(0.0250)	(0.0315)	(0.0264)	(0.0325)
Bandwidth	10	5	10	5	10	5	10	5
Depvar mean	0.0515	0.0948	0.0513	0.0940	0.0515	0.0947	0.0743	0.109
N	26444	11548	27917	12183	26330	11491	18252	10036

Notes: This table presents estimates of how much pension eligibility corresponds to increases in attrition for teachers of different output, using equation 5. Intuitively, we measure whether the change in retention at the notch differs for highly productive workers when compared to less productive workers. If attrition increases more for highly productive workers, it implies that the pension incentives for retention acted more powerfully on high value-add workers and improved *selection*. We do not find that pensions are more likely to retain high-performing teachers, suggesting that pensions do not promote positive selection. Robust standard error are in parentheses with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

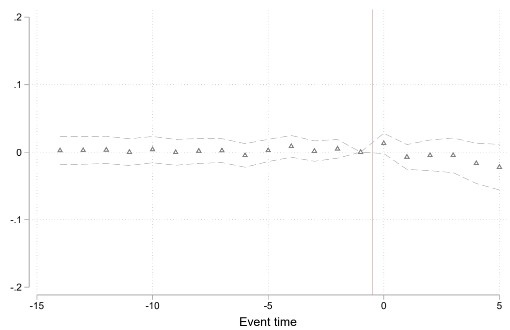
Figure 1: Pension Returns from Experience as Teachers Approach a Retirement Notch



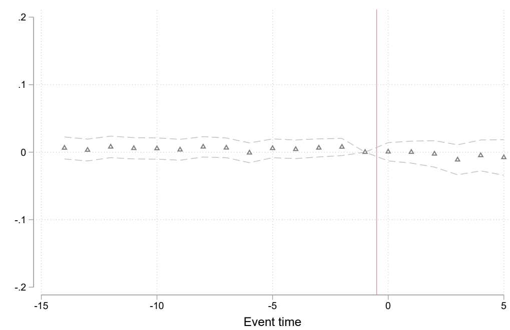
Notes: The figure shows the pension-wealth returns to experience for an archetypal teacher. The archetypal teacher begins her career at age 24 and is therefore not eligible for retirement until she reaches 30 years of service credit. The vertical scale measures how large the return is for an additional year of experience, where the y-axis is a measure of what percent of her final average salary (FAS) she accrues by an additional year of experience in terms of the present-discounted value of her lifetime pension income. In years 22–30, she receives a large present-discounted return, up to 100 percent of her FAS, from each additional year of service. This return falls precipitously when she crosses the retirement eligibility notch at 30 years of experience.

Figure 2: Effort and output across the retirement notch

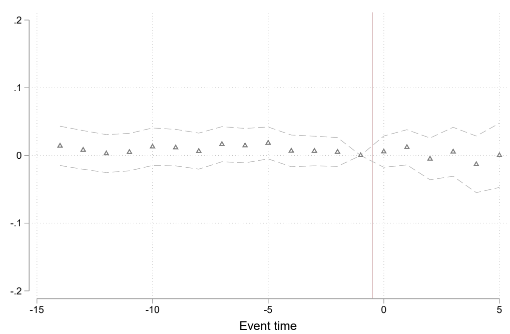
(a) Math



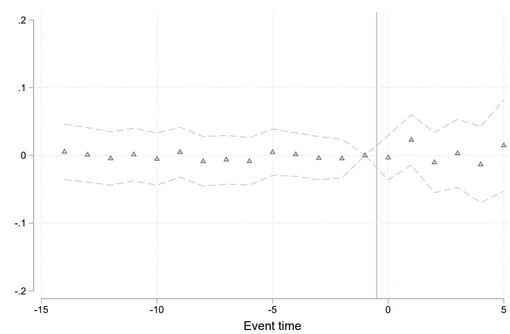
(b) Reading



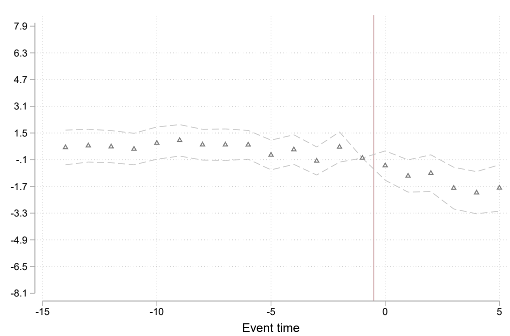
(c) Behavioral



(d) Behavioral (t+1)



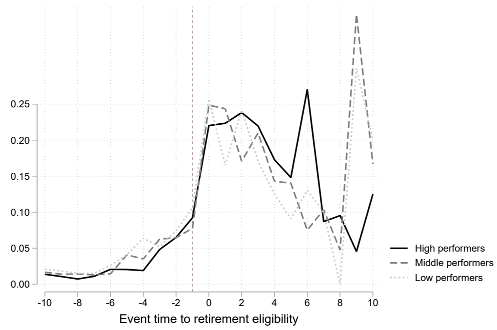
(e) Teachers' days absent



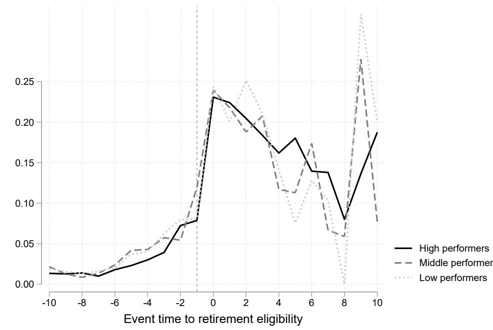
Notes: The figures are plots of the coefficients from equation 3, showing teachers-associated student achievement gains (residuals) and teachers' absences as they cross the retirement-eligibility notch. Because the estimates are conditioned on teacher fixed-effects, the estimates compare a teacher's output to her own output in other years. We calculate student residuals in each year so that they can change from one year to the next as incentives change. We plot the coefficients on event-study dummies here to show transparently how teacher performance changes in the run-up to eligibility, as teachers become eligible, and their dynamics while teachers are eligible to retire but remain working. The y-axis is scaled to approximately reflect 1 SD of the mean student residuals.

Figure 3: Attrition rates around pension notch, by teacher quality

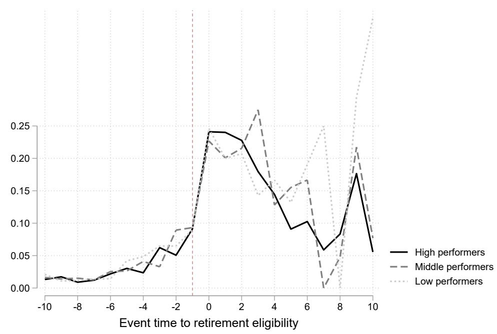
(a) Math



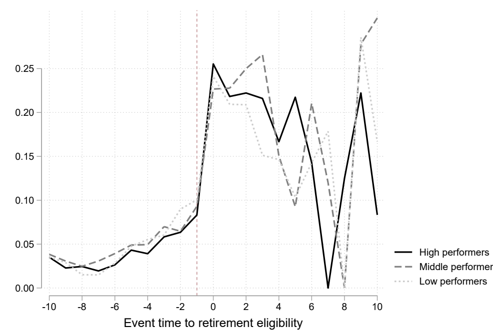
(b) Reading



(c) Behavioral



(d) Behavioral (t+1)

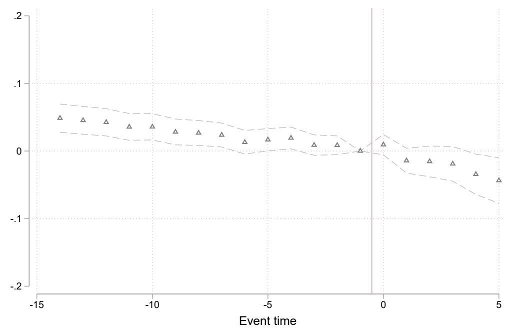


Notes: This figure presents how attrition evolves around the notch for different VA groups (the top third, the middle third, and the bottom third of value-added). We find that attrition increases significantly at the notch. We find no meaningful differences in attrition rates by teacher-effectiveness, meaning that high-VA teachers were not more likely to be retained by the pension than low-VA teachers. This suggests that pensions do not promote positive selection.

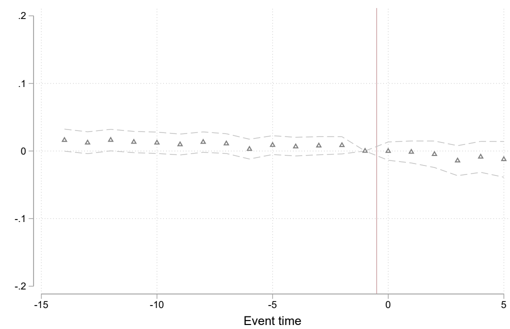
A Appendix: Supporting Figures

Figure A1: Effort and output across the retirement notch, excluding pre-trend controls

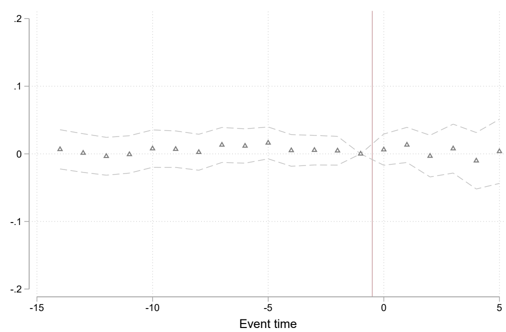
(a) Math



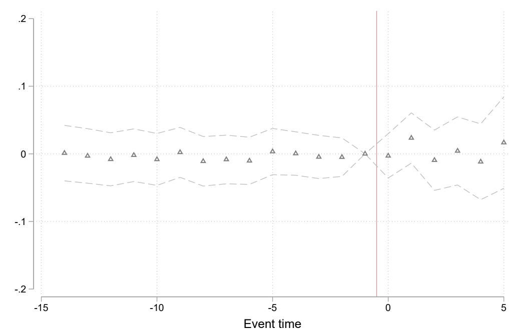
(b) Reading



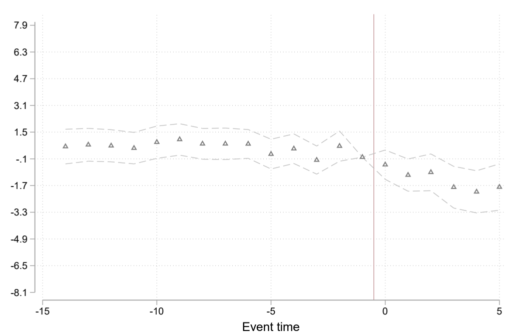
(c) Behavioral



(d) Behavioral (t+1)



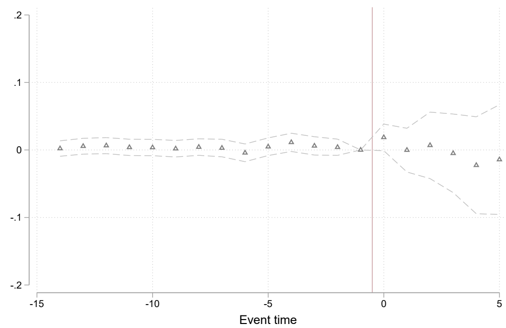
(e) Days absent



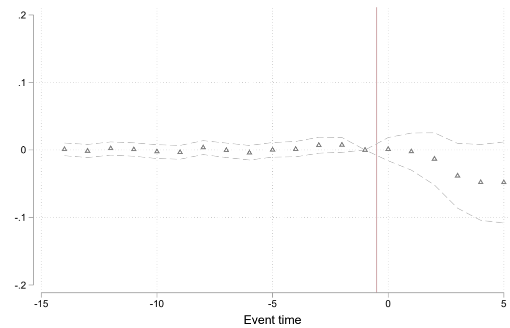
Notes: These figures show teachers' average student residuals as teachers cross the retirement-eligibility notch excluding controls for pre-notch trends. We calculate average student residuals in each year we observe her. We plot the coefficients on event-study dummies here to show transparently how teacher value-added changes in the run-up to eligibility, as teachers become eligible, and their dynamics while teachers are eligible to retire but remain working. The y-axis is scaled to approximately reflect 1 SD of the outcome measure.

Figure A2: Effort and output across the retirement notch, controlling for teacher-specific pre-trends

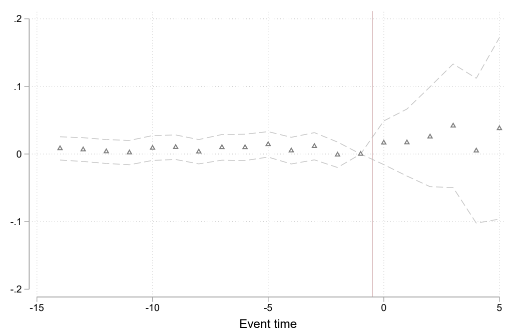
(a) Math



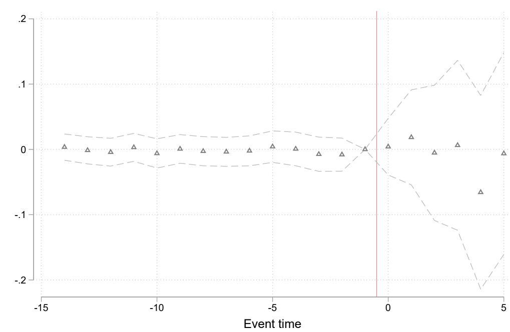
(b) Reading



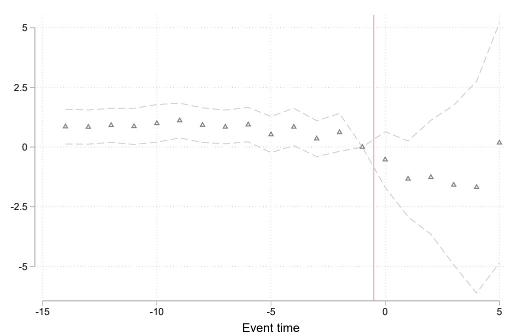
(c) Behavioral



(d) Behavioral (t+1)



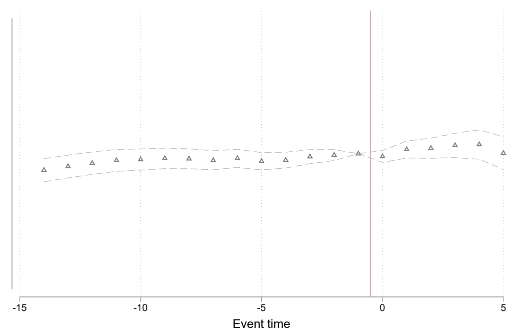
(e) Days absent



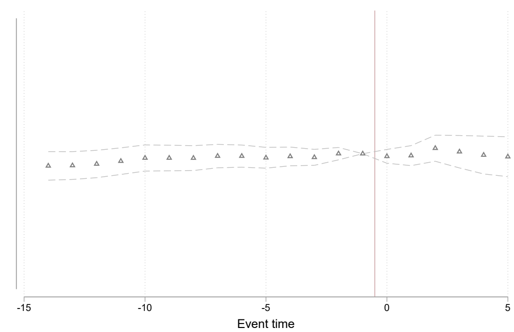
Notes: These figures show teachers' average student residuals as teachers cross the retirement-eligibility notch with teacher-specific detrended data. While the estimates in the post-period are noisier, they still do not show a drop in teacher productivity following the notch. The y-axis is scaled to approximately reflect 1 SD of the outcome measure.

Figure A3: Productivity across the retirement notch, as measured by teachers' VA

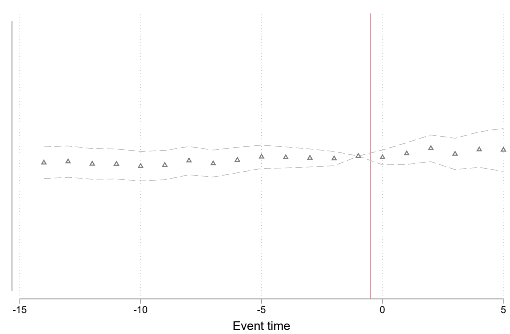
(a) Math



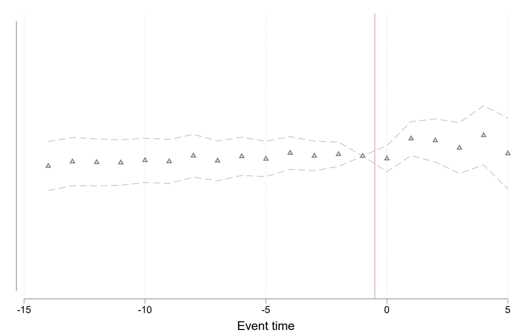
(b) Reading



(c) Behavioral



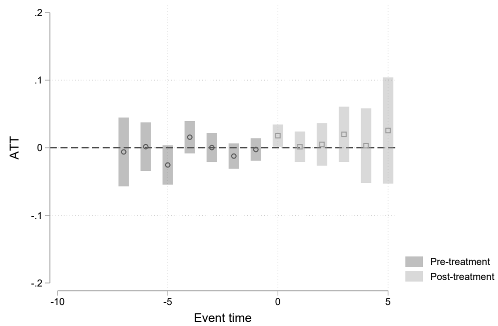
(d) Behavioral (t+1)



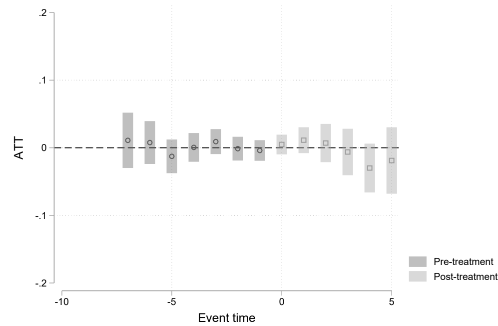
Notes: These figures show teachers' value-added as teachers cross the retirement-eligibility notch. We calculate teacher value-added in each year we observe her. We plot the coefficients on event-study dummies here to show transparently how teacher value-added changes in the run-up to eligibility, as teachers become eligible, and their dynamics while teachers are eligible to retire but remain working. The y-axis is scaled to approximately reflect 1 SD of the value-added measure.

Figure A4: Productivity and effort across the retirement notch using Callaway and Sant'Anna (2021)

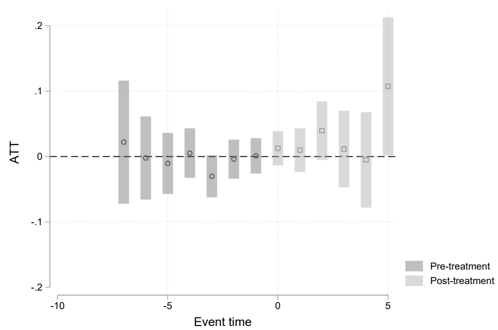
(a) Math



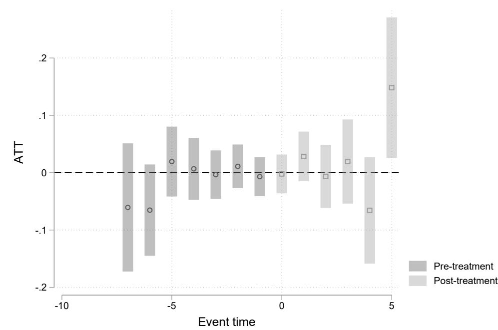
(b) Reading



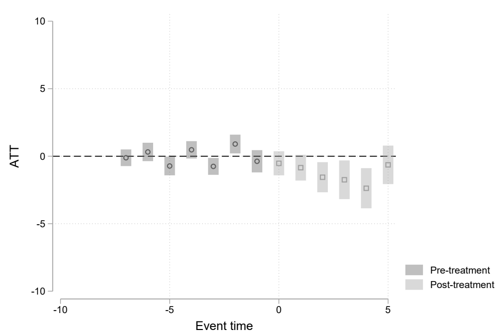
(c) Behavioral



(d) Behavioral (t+1)



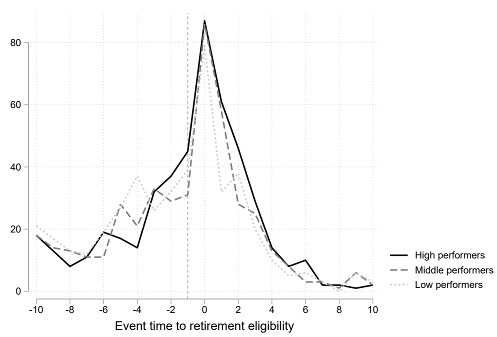
(e) Days absent



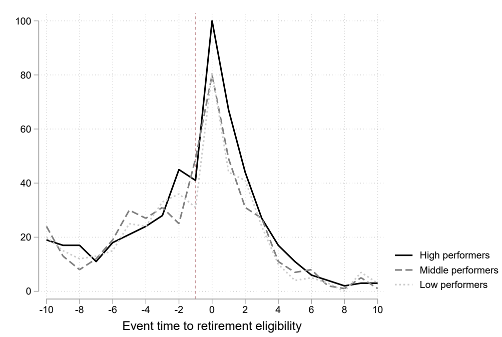
Notes: These figures show teachers' value-added and days absent as teachers cross the retirement-eligibility notch. We calculate teacher value-added in each year we observe her. We plot the coefficients on event-study dummies here from Callaway and Sant'Anna (2021) estimation to show transparently how teacher value-added changes in the run-up to eligibility, as teachers become eligible, and their dynamics while teachers are eligible to retire but remain working. The pretend is abridged with this estimator because unlike with the TWFE estimator, teachers who do not teach past the year of eligibility are designated as never treated and do not inform the magnitude of pre-eligibility coefficients.

Figure A5: Attrition counts around pension notch, by teacher quality

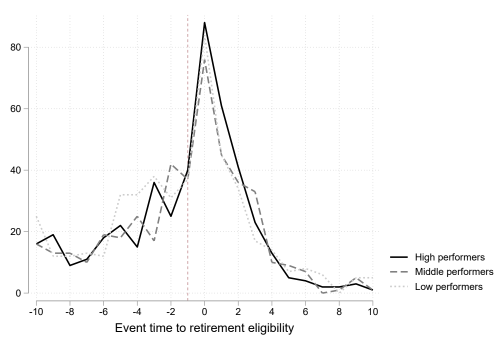
(a) Math



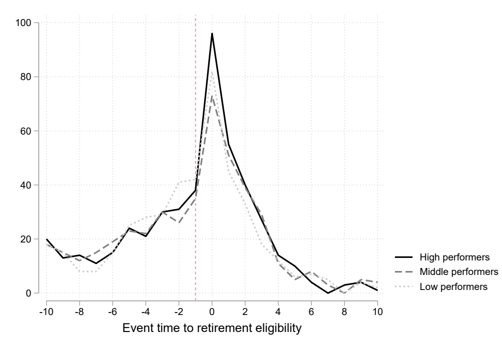
(b) Reading



(c) Behavioral



(d) Behavioral (t+1)



Notes: This figure shows how much pension eligibility corresponds to increases in attrition separately for teachers in the lowest, middle, and highest tertile of teacher effectiveness. In general, we find that eligibility increases attrition significantly. Of interest in this study is whether low-performing workers are less likely to be retained by pension incentives, but we find no meaningful differences by teacher quality in the number of teachers who leave once eligible for retirement. This suggests that pensions do not promote positive selection.

B Appendix: Supporting Tables

Table A1: Teacher effort across retirement notch, measuring productivity by teachers' VA

	(1) Math VA	(2) Reading VA	(3) Behavioral VA	(4) Persistent Behav. VA	(5) Teacher Absences
eligible	0.000525	-0.000747	0.000781	0.000979	-1.044***
	(0.00263)	(0.00168)	(0.00176)	(0.00266)	(0.323)
Fixed effects	Teacher, year	Teacher, year	Teacher, year	Teacher, year	Teacher, year
Depvar mean	0.00707	0.00592	0.000121	0.000744	23.17
Depvar sd	0.154	0.0728	0.0762	0.116	10.33
N	42930	44674	42898	38372	33806

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table presents estimates of how much pension eligibility corresponds to productivity and effort. In general, we find that effort remains strikingly constant across the threshold. As measures of effort here, we include teacher value-added on math tests, reading tests, current student behavior, future student behavior, and teacher attendance. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A2: Teacher effort across the retirement notch, separating notches

	(1) Math VA	(2) Reading VA	(3) Behavioral VA	(4) Behavioral (t+1) VA	(5) Teacher Absences
Eligible	0.000308	-0.00741	-0.0000552	0.0136	-0.748**
	(0.00562)	(0.00511)	(0.00973)	(0.0139)	(0.352)
Observations	42553	43934	33257	30353	22713

(a) 30-year notch

	(1) Math VA	(2) Reading VA	(3) Behavioral VA	(4) Behavioral (t+1) VA	(5) Teacher Absences
Eligible	-0.0104	-0.0140*	0.00680	0.00335	-1.013
	(0.0104)	(0.00849)	(0.0147)	(0.0214)	(1.001)
Observations	22111	23027	18026	16618	10975

(b) lower-experience notches

Notes: This table presents estimates of how much pension eligibility corresponds to changes in teacher productivity and effort. In general, we find that eligibility has little impact on productivity. While the incentive structure might induce teachers to exert less effort after the retirement notch, we find that teacher attendance increases after the notch without a corresponding increase in productivity. All regressions include teacher and year fixed-effects. Standard errors in parentheses are clustered at the teacher level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A3: Differential attrition by teacher value-add at 30-year retirement notch

	Quality by Math VA		Quality by Reading VA		Quality by Behavioral VA		Quality by Behavioral VA (t+1)	
	Attrition	Attrition	Attrition	Attrition	Attrition	Attrition	Attrition	Attrition
Eligible	0.149***	0.163***	0.145***	0.145***	0.137***	0.120***	0.128***	0.148***
	(0.0198)	(0.0252)	(0.0196)	(0.0258)	(0.0189)	(0.0244)	(0.0214)	(0.0264)
Low-quality	0.0128	0.0181	-0.0123	-0.0187	-0.0131	-0.0218	-0.0119	0.00000280
	(0.0107)	(0.0206)	(0.0100)	(0.0193)	(0.00960)	(0.0182)	(0.0123)	(0.0206)
Low × eligible	-0.0100	-0.0176	-0.00450	-0.00191	-0.00620	0.0212	0.0110	-0.00682
	(0.0289)	(0.0370)	(0.0270)	(0.0347)	(0.0264)	(0.0333)	(0.0284)	(0.0354)
High-quality	-0.0108	-0.00724	-0.0150	-0.0173	-0.00540	-0.0177	-0.0200*	-0.0241
	(0.00886)	(0.0171)	(0.00917)	(0.0182)	(0.00972)	(0.0189)	(0.0117)	(0.0197)
High × eligible	0.0122	-0.0204	0.0123	0.00425	0.0448*	0.0634*	0.0403	0.0297
	(0.0254)	(0.0323)	(0.0254)	(0.0329)	(0.0264)	(0.0340)	(0.0282)	(0.0352)
Bandwidth	10	5	10	5	10	5	10	5
Depvar mean	0.0402	0.0725	0.0397	0.0718	0.0402	0.0726	0.0587	0.0832
N	17558	7875	18507	8329	17543	7869	12016	6867

Notes: This table presents estimates of how much pension eligibility at 30 years of experience corresponds to increases in attrition using equation 5. The logic is that we measure whether the change in retention at the notch differs for highly productive workers when compared to less productive workers. If attrition increases more for highly productive workers than less productive workers, it implies that the pension incentives acted more powerfully on high value-add workers and pensions improve *selection*. In general, we find little evidence of differential selection at the 30-year pension eligibility, though teachers with few behavioral infractions and good student attendance are marginally statistically significantly more likely to attrit when looking only at this threshold. We note that this finding may be an artifact of the number of hypotheses that are tested here. Robust standard error are in parentheses with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A4: Differential attrition by teacher value-add, at lower experience notches

	Quality by Math VA		Quality by Reading VA		Quality by Behavioral VA		Quality by Behavioral VA (t+1)	
	Attrition	Attrition	Attrition	Attrition	Attrition	Attrition	Attrition	Attrition
Eligible	0.182***	0.165***	0.150***	0.129***	0.172***	0.120***	0.135***	0.162***
	(0.0336)	(0.0412)	(0.0327)	(0.0413)	(0.0363)	(0.0461)	(0.0355)	(0.0432)
Low-quality	0.0104	0.0211	0.0132	0.00442	0.00308	-0.0232	0.0117	0.0303
	(0.0186)	(0.0348)	(0.0193)	(0.0367)	(0.0191)	(0.0368)	(0.0223)	(0.0389)
Low × eligible	-0.0365	-0.0173	0.0432	0.0632	0.000287	0.0476	-0.0118	-0.0222
	(0.0496)	(0.0604)	(0.0507)	(0.0628)	(0.0506)	(0.0629)	(0.0530)	(0.0644)
High-quality	0.0162	0.0635*	-0.0122	0.00329	-0.0196	-0.0383	-0.00581	0.0175
	(0.0181)	(0.0349)	(0.0174)	(0.0333)	(0.0188)	(0.0362)	(0.0208)	(0.0364)
High × eligible	-0.0127	-0.0531	-0.00373	-0.0163	-0.0171	0.0160	0.000892	-0.0128
	(0.0486)	(0.0607)	(0.0466)	(0.0567)	(0.0503)	(0.0617)	(0.0498)	(0.0613)
Bandwidth	10	5	10	5	10	5	10	5
Depvar mean	0.0690	0.129	0.0681	0.128	0.0690	0.129	0.0970	0.148
N	10331	4321	10897	4533	10331	4321	7322	3754

Notes: This table presents estimates of how much pension eligibility at 25 and 5 years of experience at ages above 60 and 65 corresponds to increases in attrition. In general, we find that eligibility increases attrition significantly, but does not appear to do so differentially by tertiles of teacher quality. Robust standard error are in parentheses with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

C A Model of Deferred Compensation without Dismissals

In this section, we show that pensions can increase effort by deferring compensation, even in the absence of a dismissal threat. In this framework, reputation throughout the length of a worker's career offers an incentive to induce effort, and career longevity may be manipulated through pension generosity. This basic result is clear when comparing pension schemes to none as is common in deferred compensation models. More nuance is required to tailor the model to our environment where there may be incremental changes to pension generosity. We take this latter approach. To formalize the hypothesis, we present a simple model of worker behavior.

Consider a worker who makes two key decisions: the level of his effort in each period and the duration of his employment with his current firm. That is the worker chooses an effort level in each period, E_t, and also chooses the total number of periods he will work for the firm, T.

Let W_t represent the real wage in period t, which grows at the rate of γ.[19] At the end of his career, the worker will be eligible to draw a pension benefit of $\delta T \cdot W_T$ each period, where a policy parameter δ and his terminal tenure determine the share of his final salary the worker receives for the rest of his life, L.

Workers face a trade-off when deciding how much effort to exert at work. The trade-off is central to our model and can be understood through two key components: the cost of effort and its benefits to the worker.

On one hand, exertion is costly for workers. It reduces their immediate utility by αE_t^{β} with $\beta > 2$ and $\alpha > 1$ such that the cost to workers is convex. This cost function reflects the increasing marginal disutility of effort.

On the other hand, greater effort yields important benefits by improving the worker's reputation within the firm. Enhanced reputation, in turn, improves the worker's own subjective utility derived from employment at the firm. "Reputation" can be understood broadly. It captures all the ways that effort improves the worker's subjective utility arising from his own effort. In addition to actual reputation, it includes fostering better relationships with managers and colleagues, contributing to a more pleasant work environment, and increasing overall job satisfaction.

Conversely, shirking carries its own cost. When workers exert less effort, it reduces the worker's reputation and degrades the work setting for the shirking worker. This degraded work environment can manifest in strained relationships with colleagues or weaker standing when requesting assignments, all of which decrease the worker's utility.

To capture these dynamics in our model, we introduce function E(t). This represents

[19] These real wages may be thought of as net of workers discounting.

the cumulative reputation benefit as a share of the base wage, measuring the utility a worker receives in period t based on his history of effort up to that point.

The worker's objective is to choose a duration, T, and an effort sequence E_t that maximizes his lifetime utility. Total lifetime utility is given by:

$$\begin{aligned} U(T,u) \equiv \int_0^T W(1+\gamma t)dt + \int_T^L \delta T W(1+\gamma T)dt \\ + \int_0^T \int_0^t E(s)dsdt - \alpha \int_0^T E^{\beta}(t)dt. \end{aligned} \tag{C.1}$$

The first term, the integral over $W(1+\gamma t)$, captures lifetime utility coming from the sequence of yearly real wages. The second term describes the utility arising from pension accruals. The third represents utility from reputation derived from the worker's own effort in current and past periods. The final term describes the cost of effort from exertion.

To find the optimal effort path, E_t, effort must be that which sets the derivative equal to zero. The optimal effort must satisfy:

$$\lim_{u\to 0} \frac{U(T, E+u\phi) - U(T,E)}{u} = 0 \text{ for all test functions } \phi. \tag{C.2}$$

Using (C.1), this is

$$\int_0^T \int_0^t \phi(s)dsdt - \beta\alpha \int_0^T E(t)\phi(t)dt = 0 \text{ for all test functions } \phi. \tag{C.3}$$

To simplify this expression, we integrate the first term by parts. This technique allows us to reduce the double integral to a single integral:

$$t\int_0^t \phi(s)ds|_0^T - \int_0^T t\phi(t)dt - \beta\alpha \int_0^T E(t)\phi(t)dt = 0$$

Rearranging terms, we obtain:

$$\int_0^T [(T-t) - \beta\alpha E(t)]\phi(t)dt = 0 \text{ for all test functions } \phi.$$

This expression implies that the bracketed factor must integrate to zero on the interval $[0,T]$, yielding the Euler-Lagrange equation

$$(T-t) - \beta\alpha E(t)^{\beta-1} = 0 \tag{C.4}$$

Solving this equation, we can express the optimal effort at time t as:

$$E^*(t) \equiv \Big(\frac{T-t}{\beta\alpha}\Big)^{\frac{1}{\beta-1}}. \tag{C.5}$$

The result shows that the optimal effort choice increases with terminal tenure T. This implies that workers who anticipate longer careers with the firm will exert more effort at work. Therefore, if pensions effectively extend a worker's expected tenure, they also increase his optimal effort. This provides a mechanism by which pensions can motivate higher effort levels even in the absence of dismissal threats.

The solution also shows that effort decreases as the worker approaches his expected departure date. This suggests that worker productivity may naturally decline toward the end of a career, not because of physical or mental deterioration, but as a rational response to diminishing returns on reputation building.

Inserting this into (C.1), we seek to maximize

$$\begin{aligned} &\int_0^T W(1+\gamma t)dt + (L-T)\delta T W(1+\gamma T) \\ &+ \int_0^T \int_0^t \Big(\frac{T-s}{\beta\alpha}\Big)^{\frac{1}{\beta-1}} ds dt - \alpha \int_0^T \Big(\frac{T-t}{\beta\alpha}\Big)^{\frac{\beta}{\beta-1}} dt. \end{aligned} \tag{C.6}$$

over all choices of T. Making the substitution $z = T - s$ in the integral with respect to s and $z = T - t$ in the last integral, the previous expression may be written

$$\begin{aligned} &\int_0^T W(1+\gamma t)dt + (L-T)\delta T W(1+\gamma T) \\ &+ \int_0^T \int_{T-t}^T \Big(\frac{z}{\beta\alpha}\Big)^{\frac{1}{\beta-1}} dz dt - \alpha \int_0^T \Big(\frac{z}{\beta\alpha}\Big)^{\frac{\beta}{\beta-1}} dz. \end{aligned} \tag{C.7}$$

So, the first order condition for optimality is

$$\begin{aligned} &W(1+\gamma T) + \delta W[L(1+2\gamma T) - 2T - (1+2\gamma)T^2] \\ &+ \int_0^T \Big(\frac{z}{\beta\alpha}\Big) dz + \int_0^T [\Big(\frac{T}{\alpha\beta}\Big)^{\frac{1}{\beta-1}} - \Big(\frac{T-t}{\alpha\beta}\Big)^{\frac{1}{\beta-1}}]dt - \alpha\Big(\frac{T}{\alpha\beta}\Big)^{\frac{\beta}{\beta-1}} = 0. \end{aligned} \tag{C.8}$$

The second integrand in the brackets, using the substitution $z = T - t$ again, cancels the first integral, leaving

$$\begin{aligned} &W(1+\gamma T) + \delta W[L(1+2\gamma T) - 2T - (1+2\gamma)T^2] + T\Big(\frac{T}{\alpha\beta}\Big)^{\frac{1}{\beta-1}} - \alpha\Big(\frac{T}{\alpha\beta}\Big)^{\frac{\beta}{\beta-1}} \\ &= W(1+\gamma T) + \delta W[L(1+2\gamma T) - 2T - (1+2\gamma)T^2] + \frac{1}{(\alpha\beta)^{\frac{1}{\beta-1}}}[1 - \frac{1}{\beta}]T^{\frac{\beta}{\beta-1}} = 0. \end{aligned} \tag{C.9}$$

The solution, we call T^* and rewrite equation (C.9) as follows.

$$\frac{1}{(\alpha\beta)^{\frac{1}{\beta-1}}}[1-\frac{1}{\beta}]T^{*\frac{\beta}{\beta-1}} = \delta W[2T^* + (1+2\gamma)T^{*2} - L(1+2\gamma T^*)] - W(1+\gamma T^*). \quad \text{(C.10)}$$

A unique solution for T^* exists in the range of $(0, L)$ for a wide range of reasonable parameter values.[20]

We would like to know how optimal effort responds to changes in δ, the rate at which an additional year of service accrues pension income as a fraction of the wage at the last year of service. This will tell us if pension generosity impacts effort even without the threat of displacement.

We will calculate the derivative of E^* with respect to δ by using the chain rule

$$\frac{dE^*}{d\delta} = \frac{dE^*}{dT}\frac{T^*}{d\delta}.$$

We have already established that $\frac{dE^*}{dT} > 0$ above, as increases in the time to retirement magnifies the reputational benefits (or costs) of expending effort (or shirking). Therefore, the relationship between effort and pension generosity hinges on the power of pension generosity to impact tenure duration. This relationship is not monotonic in our model, and pensions can either increase or decrease T^* depending on parameter values. Since (C.9) defines T^* as a function of δ, we take the derivative with respect to δ.

$$\frac{\partial T^*}{\partial \delta} = \frac{(\beta\alpha)^{\frac{1}{\beta-1}}W[2T^* + 3\gamma T^{*2} - L - 2LT^*]}{(\beta\alpha)^{\frac{1}{\beta-1}}W[\gamma + \delta(2\gamma L - 2 - 6\gamma T^*)] + T^{*\frac{1}{\beta-1}}} \quad \text{(C.11)}$$

A wide range of parameter values lead to $\frac{\partial T^*}{\partial \delta} > 0$. For instance, with $\alpha > 1$, $\beta > 2$, and W large, the sign is determined by the terms between the brackets. Let $bT^* = L$. One sufficient condition is that as long as $\frac{3\gamma T^*+2}{2\gamma T^*+1} < b < 3 - \frac{1}{2\delta T^*} + \frac{1}{\gamma T^*}$, additional pension generosity will increase years of service and thereby increase effort throughout a worker's career. Note that the minimum b may be as low as 1.5 depending on the rate of wage growth, γ, and the upper limit may take any value depending on γ and δ. Employers determine both parameters, giving them the latitude to tailor salary schedules and pension generosity to values that allow them to extract effort. In our context, we study a change in δ that occurs at 30 years of experience with an expected 18 more years of life such that $1.6\bar{3}T = L$, falling at the lower end but within the range above.[21] Thus, for teachers at the retirement notch and earlier in their careers, the model may predict the pension to increase the years

[20] When $T = 0$, $0 < W + \delta L$ and when $T = L$, $0 > (\alpha\beta)^{\frac{1}{\beta-1}}(W(1+\gamma L - \delta(L+\gamma L^2)) + (1-\frac{1}{\beta})L^{\frac{\beta}{\beta-1}}$, which is dominated by the term $-(\alpha\beta)^{\frac{1}{\beta-1}}\delta\gamma L^2 < 0$ with $\alpha > 1, \beta > 2$, and W and L being large. $\delta > \gamma$, $\delta\gamma L^2 > 1$, $\delta\gamma W > 1$ are sufficient conditions and each is plausible.

[21] With fewer years of life to collect potential pension income, more generous rates of accrual induce the worker to shorten years of service and increase years of higher pension income and no work.

of service and effort within the classroom. This is because a marginal increase in generosity induces workers to extend their years of service to bid up their wages and, ultimately, the pension income that they receive once they retire. Likewise, the precipitous fall in the rate of pension accrual is predicted to shorten the time to retirement and lead to a commensurate reduction in teacher effort.

This is a stylized model of deferred compensation in the absence of a threat of dismissal, adding incentives for costly effort from workers' reputations. In it, employers may induce workers to expend effort through marginal manipulation of pension generosity. Pension generosity may increase workers' years of service with the employer, thereby increasing the future benefits of expending effort today.