The Link between Pensions and Retirement Timing: Lessons from California Teachers

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Abstract

I exploit a major, unanticipated reform of the California teachers' pension to provide quasi-experimental evidence on the link between pension generosity and retirement timing. Using two large administrative datasets, I conduct a reduced-form analysis of the pension reform and estimate a structural model of retirement timing. With both methods, I find that the rise in the price of retirement had a positive, but relatively small effect on the fraction of people retiring later. The implied estimates of the elasticity of retirement age with respect to the price of retirement are 0.02 in the medium-run and 0.10 in the long-run.

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With the baby boomers reaching retirement age, public officials and private pension managers are scrambling to design policy that will reduce the burden of pension obligations on younger workers and shareholders, while still fulfilling the promises made to those nearing retirement. The proposed reforms will inevitably alter key pension financial incentives faced by members, such as the reward for an additional year of work, making the degree to which these incentives affect retirement timing central to the policy debate.

Although there is an extensive literature that addresses the relationship between pensions and retirement, there is no firm consensus on the magnitude of behavioral responses to pension incentives. Simple estimation techniques linking benefits to retirement prove unsatisfactory as endogenous sorting makes it difficult to infer the true causal effects of the pension features.

In this paper, I address this concern by using a quasi-experimental approach to estimate the compensated price elasticity of retirement age, a key parameter for measuring the deadweight loss associated with retirement programs. I exploit the features of the 1999 reform of the California State Teachers' Retirement System (CalSTRS) using two unique administrative datasets. The reform, a product of two 1998 close-of-session legislative bills, unexpectedly doubled the financial incentive to work beyond age 60 and provided a bonus for staying on for 30 years or more. Because the reform explicitly altered the financial return to an additional year of work and because California teachers do not participate in Social Security, it is easier here than in other contexts to isolate and interpret the impact of pension price incentives on retirement timing.

Given the minimal employment-related uncertainty faced by the teachers, I model their retirement decision within a nonstochastic "lifetime budget constraint" framework. One salient theoretical implication of this model is that "bunching" of retirements will be observed at budget constraint kinks and discontinuities. Because the pension reform under study alters the nonlinearities of the teachers' budget sets, the model generates precise predictions for the effect of the reform on retirement behavior. I present the results of two empirical approaches that take advantage of these sharp predictions.

In the first approach, I employ a reduced-form method and exploit the postreform shift of the retirement distribution at budget constraint nonlinearities to estimate an elasticity of retirement age.[1] The prereform and postreform distributions of retirees in age and service are constructed from CalSTRS systemwide retirement count data. With this method, I estimate that the compensated elasticity of retirement age is less than 0.02 in the medium-run and less than 0.10 in the long-run.

In the second approach, I estimate a structural model using individual-level data for teachers in California's largest school district, the Los Angeles Unified School District (LAUSD). The structural estimation uses changes in behavior at all ages to identify the price elasticity of retirement. I incorporate reform-based identification into the nonlinear budget constraint estimation method introduced by Gary Burtless and Jerry A. Hausman (1978) to estimate the elasticity of retirement age with respect to the annual financial return to working and find it to be 0.02.

With both datasets and estimation methods, I find a clear response of California teachers to the reform. However, these estimates imply that teacher retirement is strongly price inelastic. Specifically, the average teacher will delay retirement by only $1\frac{1}{2}$ months if the annual financial return to working increases by 10 percent or about \$7500 (in year 2000 dollars). I discuss how time and health insurance considerations may affect this estimate.

The remainder of this paper is organized as follows. The next section relates my study to the prior literature. In Section 2, I provide an overview of the CalSTRS defined benefit program, the reforms of the program, and the data used in this study. Section 3 introduces a simple lifetime budget constraint model that captures the teacher retirement decision. Sections 4 and 5 present the main results of the reduced-form and structural estimations. Section 6 considers the context of these findings and Section 7 concludes.

[1] Emmanuel Saez (2002)

1 Literature Review

There are a substantial number of studies that use cross-sectional and longitudinal variation in pension incentives to identify the response of retirement to Social Security and employer-provided pensions. Recent work has emphasized the importance of forward-looking pension financial incentives to individual retirement decisions and has utilized both structural[2] and reduced-form[3] estimation strategies to estimate the behavioral response to these incentives. The identifying assumption is that retirees facing these diverse incentives are otherwise identical after controlling for other observable characteristics. The empirical strategies employed in these papers do not address the key concerns that workers may sort into jobs based on the match between the pension provisions offered and their own retirement preferences, or that other factors that determine benefits (e.g. earnings history and time on the job) are correlated with current labor force attachment.

In order to determine the causal impact of pension financial incentives on retirement behavior, it is necessary to divorce individuals' preferences from the characteristics of their retirement plans. This paper builds more directly on work that uses the exogenous variation in pension financial incentives created by pension reforms to achieve this separation, enabling identification of the the causal effect. These studies, limited in number, generally find a smaller role for financial incentives than the non-reform studies. Gary Burtless (1986) uses a lifetime budget constraint framework to estimate the impact of Social Security on the distribution of retirement ages during a period of rising benefits in the 1970s and finds only a small role for Social Security in the declining labor force participation rate of older men. Alan B. Krueger and Jorn-Steffen Pischke

[2] John Rust and Christopher Phelan (1997) present one of the most comprehensive models incorporating financial incentives of Social Security and the additional incentives generated by Medicare. James H. Stock and David A. Wise (1990) introduce a new structural estimation method, the option value model. Gustman and Steinmeier (1986) estimate a model without uncertainty with the Retirement History Survey (RHS) panel data and find that Social Security financial incentives predict observed retirement behavior.

[3] Andrew A. Samwick (1998) develops a reduced-form variant of the option value model introduced by Stock and Wise (1990) to estimate the effect of Social Security and pensions on retirement behavior using the Survey of Consumer Finance and the Pension Providers Survey. Courtney Coile and Jonathan Gruber (2000, 2007) introduce a modification of the reduced-form option value model, which they use with the Health and Retirement Survey to disentangle the effect of Social Security financial incentives on retirement. This approach is also used extensively in a volume edited by Gruber and Wise (2004) to identify the effect of public pension programs on retirement around the world. Beth Asch, Steven J. Haider and Julie M. Zissimopoulos (2005) also employ this estimation strategy to examine the retirement of Federal civil service workers.

(1992) use the unexpected reduction in Social Security benefits for the so-called “notch-babies” to disentangle changes in Social Security benefits from labor force participation trends, finding a much smaller role for Social Security wealth in the trend toward earlier retirement than had been found by previous studies. To the author’s knowledge, these are the only studies prior to the current paper to exploit a reform that creates a permanent change in retirement benefits. The current paper uses an estimation strategy in the spirit of Burtless (1986), while offering a reform that is better suited to estimating the effect of the financial return to working an additional year on retirement age. A further advantage of studying California teachers is that their exclusion from Social Security and access to administrative data allows me to more accurately calculate the financial incentives faced.

There are also several papers that identify the responsiveness of retirement or separation to financial incentives using a shock created by a temporary retirement incentive program.[4] Of these, the one most closely related to this paper is Joshua Furgeson, Robert P. Strauss, and William B. Vogt (2006), as it uses administrative data to look at the retirement of Pennsylvania teachers. Using a reduced-form estimation strategy, the authors find that the substitution elasticity of retirement is strongly negative. However, as with all work that looks at temporary retirement incentive programs, it is not trivial to translate these findings into the context of a permanent pension reform.

2 Background and Data

2.1 CalSTRS Defined Benefit Program

CalSTRS serves educators employed in the California K-12 public schools and state community colleges. With a market value of over $170 billion and three quarters of a million members,[5] it ranks consistently among the top ten public retirement systems in the United States in terms of

[4]These include Robin L. Lumsdaine, Stock and Wise (1992) and John Pencavel (2001). Both find evidence that separation rates are responsive to the incentive but are unable to predict who will leave.

[5]California State Teachers’ Retirement System (2007). As of June 30, 2007, CalSTRS members included 455,693 active members and 188,659 service retirement annuitants, 141,540 inactive members and 26,982 disability and survivor benefit recipients.

net assets and membership. The retirement system is financed through contributions from active members, employing school districts, and the State General Fund, as well as with investment earnings.[6]

The Defined Benefit Program (DBP) is the oldest and largest component of the retirement system. Its main features closely resemble those of most employer-sponsored defined benefit retirement programs and also of Social Security. Participation is mandatory for teachers employed full time in California public schools and upon retirement each CalSTRS member receives a lifetime annuity with an annual value based on years of service, age and past salary.

The importance of employer-sponsored pensions in individual retirement portfolios varies, but a few factors make CalSTRS likely to be a prominent component for California teachers. First, CalSTRS members are not simultaneously covered by Social Security, so for career teachers this is their only source of employment-based retirement income. Also, in contrast to employer-sponsored pensions in the private sector, CalSTRS members' pensions are not disrupted as they move between employers (school districts within California). And CalSTRS is relatively generous; the average replacement rate for retired teachers is 59 percent of final annual salary,[7] while the replacement rate for the average Social Security annuitant is only 40 percent of average annual lifetime earnings.[8]

The details of the CalSTRS DBP are as follows. While employed, members contribute 8 percent of their salaries[9] and are vested after five years of CalSTRS covered employment. The earliest age at which a member can claim her pension annuity, referred to as the "early retirement age," is age 55 for most members,[10] and age 60 is considered the "normal retirement age." Each retired

[6]CalSTRS investments include stocks, bonds, and real estate. The fund earned an over 21 percent return on investments for the fiscal year ending June 30, 2007. (California State Teachers' Retirement System, 2007)

[7]Authors calculations using data in the statistical section of the CalSTRS Comprehensive Financial Report (2007)

[8]Social Security Administration (2006). The average replacement rate calculated for California teachers corresponds to an average retirement age that is just past 60, while the replacement rate reported for Social Security corresponds to retirement at age 65.

[9]Beginning in January 2000, 25 percent of mandatory member contributions are deferred to the new Defined Benefit Supplement (DBS) program. The DBS program is a cash balance program in which contributions are immediately vested and earn a guaranteed interest rate, 4.75 percent for the 2006-07 fiscal year, which is set annually by the Teachers' Retirement Board.

[10]Members that are at least age 50 and have a minimum of 30 years of service may now retire under the "30 and Out" alternative. The benefit factor is reduced, from 2.0 percent, by 0.12 percentage points for each year before age

CalSTRS member receives a lifetime annuity with an annual value calculated according to the following formula:

$$B(R,S) = k(R,S) \times S \times w_S^f \tag{1}$$

This "unmodified allowance" is a function of years of service S, retirement age R, final compensation w_S^f, and a benefit factor k.[11]

2.2 CalSTRS Reform: 1999 Benefit Improvements

In August of 1998, the California State Legislature increased the generosity of the CalSTRS DBP for those that would retire on or after January 1, 1999 with the passage of two bills, AB 1102 and AB 1150. The two reforms mandated by these legislative bills are referred to as the Enhanced Age Factor (EAF) and the Career Bonus (CB).

The legislated reforms altered the pension program solely through changes to the benefit factor, k in equation (1), while the structure of the program and the general allowance formula remained intact. The EAF raised the maximum value for the benefit factor from 2.0 percent to 2.4 percent. The effect of this change can be seen in Figure 1. The prereform schedule and the postreform EAF schedule are identical up to age 60 with the benefit factor increasing at an annual rate of 0.12 percentage points from 1.4 percent at age 55 to 2.0 percent at age 60. In the postreform EAF schedule the new cap is reached by continuing to work beyond age 60, during which time the benefit factor increases by 0.133 percentage points annually to 2.4 percent at age 63. The second reform, the CB, provides a onetime increase of 0.2 percentage points in k when 30 years of service is completed. The postreform schedule with the EAF and the CB is represented by the black solid line in Figure 1. In the postreform period, an individual moves from the "EAF Only" schedule to

60 that the individual retires. The first retirements under this alternative are observed in 2004.

[11] Final compensation is the average salary over the last three years of service for most teachers. The value of the benefit factor ranges from 1.4 percent to 2.4 percent, and is increasing in retirement age R and years of service S. Rather than receive the unmodified allowance, teachers can also purchase one of the program's joint survivor annuity options. Payments under these options are an actuarial conversion of the unmodified allowance.

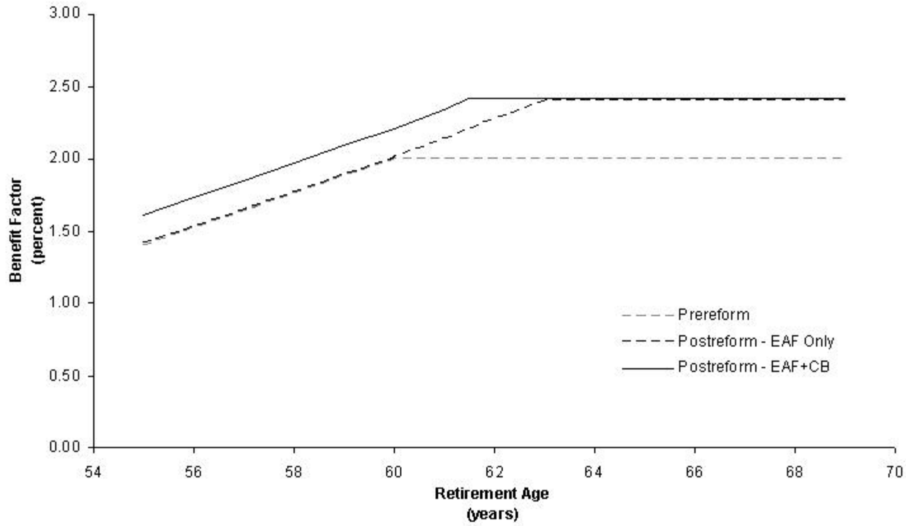


Figure 1: Benefit Factor Schedule by Retirement Age

the "EAF + CB" schedule when she attains 30 years of service.

The interaction of the two reforms creates cross-sectional variation in the postreform benefit factor schedule. For all individuals the k cap is no longer reached at age 60, however the age location of the postreform cap of 2.4 percent varies across the population. It occurs as early as age $61\frac{1}{2}$ if 30 years of service have been attained or as late as age 63 if 30 years are not worked before this age. Also, the 0.2 percent jump in k only occurs at thirty years of service if the cap of 2.4 percent has not already been reached, so the CB only affects those that will have thirty years of service before age 63.

Despite the seemingly small nature of the reforms, their potential impact on retirement benefits was quite large.[12] Postreform, the financial return to working an additional year at age 60 nearly doubled. The unmodified allowance increased by 20 percent for retirements at age 63 and by at least 10 percent for retirements after 30 years of service.

The 1999 reforms were both unanticipated and salient to CalSTRS members. Both AB 1102 and AB 1150 were introduced in their final forms just days before the legislative vote. The success rate of prior legislative initiatives aimed at altering the CalSTRS pension was quite low; there

[12]Despite the anticipated increase in outlays, this legislation did not impose an increase in member contributions to the defined benefit program.

had been no changes to allowance calculations since 1972. However, after the bills passed the CalSTRS population was quickly and effectively informed via the Fall 1998 Bulletin,[13] in which the reforms were front page news. The newsletter contained a detailed description of the reforms along with examples of how these reforms changed both the allowance level and its growth for continued work at different age and service combinations.

2.3 Data Description

Two administrative datasets, with complimentary features, are used to estimate the responsiveness of retirement timing to the CalSTRS reforms. The first dataset, constructed with the assistance of the CalSTRS administrative office, includes counts of new retirees in quarter-year age by half-year service bands for each year 1995-2003. The advantage of this data is that it covers the entire CalSTRS population and captures several years before and after the 1999 reforms. There are over 74,000 retirement observations during the nine year period covered by the data. Summary statistics for this data are presented in columns (1) and (2) of Table 1. The annual number of retirements grew over time in proportion to the growth of the California teacher population over age 55. Following the reforms, the average age at retirement increased by less than a year and the average number of years worked under CalSTRS increased by about one year.

The second dataset is individual-level administrative data for teachers that were employed by the LAUSD. This data, compiled with the assistance of the Office of Personnel Research and Assessment in LAUSD, covers new retirees for the years 1997-2004. Available variables include age, years of service within LAUSD, and salary for each teacher. The advantage of this data is that it is microdata and contains salary information, features necessary for the structural estimation. The primary drawbacks of this dataset are that it only covers one school district[14] and only the number of years of service in LAUSD is available for each teacher, while it is total CalSTRS covered service that is used to calculate the defined benefit allowance.[15] Summary statistics are

[13]CalSTRS (1998). This newsletter is mailed to all CalSTRS members that have not yet retired.

[14]LAUSD is the largest California public school district, employing over 10 percent of CalSTRS members.

[15]Deborah Reed, Kim S. Rueben, and Elisa Barbour (2006) find that 25 percent of California teachers transfer

	Systemwide		LAUSD	
	Prereform (1995-98)	Postreform (1999-2003)	Prereform (1997-98)	Postreform (1999-2004)
Mean Age	60.73	61.08	61.67	62.01
Mean Service	26.75	27.73	25.40	26.97
Percent Female			69.45	72.91
Mean Salary (Year 2000 $)			59,761	63,830
Observations	27,279	47,296	969	3,440

Table 1: Data Summary Statistics

shown in columns (3) and (4) of Table 1.

To provide a better picture of the characteristics of California teachers than is possible with the administrative data, Appendix A presents summary statistics for this population from the Census 2000.

3 A Model of Lifetime Labor Supply

A simple lifetime budget constraint model captures the major financial incentives of the CalSTRS DBP and generates a number of unambiguous predictions for the retirement behavior of CalSTRS members following the reform. In this model, retirement is treated as a once for all decision and the fundamental consideration in this decision is the trade-off between retirement leisure and consumption of market goods. Although this nonstochastic framework does not allow for uncertainty, it is arguably adequate to describe the retirement decision of CalSTRS members. California teachers face little uncertainty in retirement benefits and future wages. They are unionized so they have tenure and face a rigid wage schedule that is relatively flat at higher years of service. They also have little ability to adjust hours of work per day or days of work per year.

across school districts within their first four years of teaching, but there is little later career movement. They also find that each year (1996-1998) approximately 8 percent of all teachers transfer into another school district. All estimation results presented in this paper treat LAUSD service as total CalSTRS service. Using imputed values of total CalSTRS service, based on salary schedule location, did not change results.

3.1 Retirement Decision Absent a Retirement Program

In this simple lifetime budget constraint model, individual preferences are defined over two goods, lifetime consumption of market goods C and years of work S. An individual's utility in each period is assumed to be additively separable in consumption and leisure, so that $u_t(c_t, l) = v(c_t) - \phi_t \times l$, where ϕ_t is the disutility from working in period t and l takes the value one if the individual works in that period and is zero otherwise. As utility is separable, the individual's lifetime utility is given by

$$
\begin{aligned}
U(C,S) &= \underset{\{c_t\}}{Max} \int_{t=0}^{S} [v(c_t) - \phi_t] \quad dt \; + \int_{t=S}^{T} v(c_t) \quad dt \\
& \quad s.t. \\
C &= \int_{t=0}^{T} c_t \quad dt
\end{aligned}
\tag{2}
$$

where T is the last period of life, known with certainty. Assuming $v(.)$ is concave with respect to c_t, the individual will maximize utility for any retirement date by perfectly smoothing consumption over the lifecycle so $c_t = \frac{C}{T}$ for all t and lifetime utility can be written as

$$U(C,S) = T \times v(C/T) - \int_{t=0}^{S} \phi_t \quad dt \tag{3}$$

Then $U_C = v'(C/T) = v'(c)$, $U_S = -\phi_S$ and $U_{SS} = -\phi'_S$.

The optimal retirement date, in absence of a retirement program, for an individual that earns a wage of w_t for each period of work, is the solution to the following constrained utility maximization problem:[16]

$$
\begin{aligned}
& \underset{S}{Max} \quad U(C,S) \\
& s.t. \\
C &= \int_{t=0}^{S} w_t \quad dt
\end{aligned}
\tag{4}
$$

[16] The interest rate is assumed to be zero, without loss of generality.

The lifetime labor supply S^* that solves the first order condition, $\frac{-U_S}{U_C}|_{S^*} = w_{S^*}$, will reflect the utility maximizing retirement date provided the budget constraint is smooth and convex and $U_{SS} = -\phi'_S < 0$.[17] The slope of the budget constraint, which is simply equal to the wage, can be interpreted as the price of retirement. Heterogeneous preferences in the population will generate a distribution of retirement ages. When individuals are faced with an approximately linear budget constraint, the retirement distribution will be smooth as long as tastes are smoothly distributed in the population.

The response of retirement timing to an increase in the wage is ambiguous. The direction of change in career length depends on the relative strength of the income and substitution effects.

3.2 Retirement Decision with CalSTRS DBP

When the individual participates in a defined benefit retirement program, lifetime compensation is the sum of lifetime wage earnings net of contributions to the program *and* pension wealth. Pension wealth is defined as the present discounted value of the total payout expected from the pension program. The budget constraint for a CalSTRS member retiring at some retirement age R after S years of service can be written[18]

$$C = \int_{t=0}^{S} w_t(1-\tau_c) \quad dt \;\; + \int_{t=R}^{T} B(R,S) \quad dt \tag{5}$$

where $B(R,S)$ is the annual retirement allowance as given by equation (1). Consumption is a function of earnings through w_t and w_S^f, the contribution rate τ_c, years of work S, retirement age R, and the benefit factor k.

With CalSTRS, teachers' consumption is not only a function of the total years of work before retirement, but now because of the details of the pension, also depends explicitly on retirement age. I make the simplifying assumption that one additional year of work is equivalent to retiring one

[17] This indicates that the disutility of labor is increasing in lifetime labor supply.
[18] Again, I assume an interest rate of zero and also a known length of life T.

year later, specifically $R = S + a_0$, where a_0 is a constant.[19] With this assumption, the retirement decision can be rewritten as either a choice over service alone or over retirement age alone. In the theoretical discussion, the decision will be formulated as a choice of years of work, but in the empirical portion of the paper, retirement age and years of work will be used interchangeably with the choice of specification determined by the incentive under study.

The CalSTRS DBP distorts the shape of the lifetime budget constraint by changing both the price of retirement and the level of lifetime consumption at each possible retirement age. The slope of the budget constraint is no longer annual wage earnings, but is the sum of annual wage earnings net of contributions to the DBP and the change in pension wealth for delay of retirement. If the change in pension wealth net of contributions is positive, then the defined benefit program acts as a subsidy to wage earnings, whereas if the net change is negative, then the defined benefit program acts as a tax.

At any service level S, the slope of the budget constraint or the "net wage" can be written as

$$
\begin{aligned}
\frac{dC}{dS} &= w_S \times (1-\tau_c) + \frac{d}{dS}\int_{t=S+a_0}^{T} (k_S \times S \times w_S^f)\, dt \\
&= w_S \times (1-\tau_c) - w_S^f \times S \times k_S \\
&\quad + [w_S^f \times (\frac{dk_S}{dS} \times S + k_S) + \frac{dw_S^f}{dS} \times k_S \times S] \times (T - S - a_0)
\end{aligned} \tag{6}
$$

The net wage is roughly a multiple of annual salary. The second and third terms of equation (6) taken together are the total change to pension wealth for a small increase in retirement age. The second term is the retirement allowance that could have been collected in the current year, but is forfeited to continue working. The third term is the change in annual allowance for delayed retirement accumulated over the slightly shorter retirement period. A key feature for the analysis is that the net wage is positively related to the growth of the benefit factor for an additional year of work, $\frac{dk}{dS}$. The net wage is also increasing in w_S and decreasing in τ_c, while its relationship to S

[19] This is equivalent to assuming that the individual will not have a discontinuous work history preceding the official retirement date, which seems reasonable when examining labor supply near career end.

varies.[20]

Because $\frac{dk}{dS}$ affects the slope of the budget constraint, sharp changes in its value will result in nonlinear distortions to the budget constraint. One such distortion is the convex kink that occurs when the benefit factor cap is reached. If k takes the maximum value at a service level S_K, its growth which had been constant and positive to this point immediately falls to zero, causing the slope of the budget constraint to decrease sharply. This change in slope creates a convex kink in the lifetime budget constraint at S_K years of work. The budget constraint slope is w_H^{net} for $S < S_K$ and w_L^{net} for $S \geq S_K$, with $w_L^{net} < w_H^{net}$.

The kink will be the optimal retirement time for individuals with a range of preferences. An individual will find S_K optimal if $w_L^{net} \leq \frac{-U_S}{U_C}|_{S_K} \leq w_H^{net}$. If the kink is located at the same level of service, S_K, for all members, this retirement date will be favored even when preferences and wages are distributed smoothly across the population. This is in contrast to the case of a linear budget constraint, in which individuals will only retire at S_K if their first order condition holds with equality. The additional retirements observed at S_K when the budget constraint is kinked, relative to the linear budget constraint, are "excess retirements."

A second nonlinearity is the discontinuity in the budget constraint that occurs when k increases sharply at a threshold value of service, hereafter, S_D. At this point the change in the benefit factor is positive for an infinitesimal change in service. As a result, the growth of the benefit factor, which was constant and positive up to this point at $\frac{dk}{dS} > 0$, goes to infinity, $\frac{dk}{dS} \rightarrow \infty$. At labor supply S_D, the slope of the budget constraint will be driven to infinity through $\frac{dk}{dS}$. This change in slope will create a discontinuity in the lifetime budget constraint at S_D.

Like the budget constraint kink, the discontinuity will be the optimal retirement date for teachers with a range of preferences. All individuals for whom $S^* \leq S_D$, where S^* is defined as solving the first order condition $\frac{-U_S}{U_C}|_{S^*} = w^{net}$, will, with the introduction of a discontinuity, move to S_D if $U(S_D) > U(S^*)$. If the discontinuity is introduced to a linear budget constraint at the same service level S_D for all individuals, there will be fewer retirements just before S_D and a excess of

[20]Equation (6) can be rewritten in terms of R by replacing S with $R - a_0$ and $\frac{d}{dS}$ with $\frac{d}{dR}$.

retirements at S_D.

4 Reduced-Form Analysis

In this section, I evaluate the response of California teachers' retirement to a reform-induced (exogenous) change in financial incentives by examining the evolution of the aggregate retirement distributions, with particular attention to the action at budget constraint nonlinearities. The reforms of the CalSTRS defined benefit program changed $\frac{dk}{dS}$, altering the age and service location of budget constraint nonlinearities differentially across segments of the population. This feature of the CalSTRS reform provides the key advantage for identifying the relationship between defined benefit program financial incentives and retirement timing.

4.1 Graphical Analysis

First, I provide visual evidence of the response of CalSTRS members to the pension reform by comparing the prereform and postreform distributions of retirements across age and years of service relative to the change in budget constraint faced. The retirement distributions are constructed for the prereform period (1995-98) and the postreform period (1999-2003) using the aggregate systemwide CalSTRS administrative data. For each year, the number of retirements in each age or service band as a fraction of total retirements is calculated. The annual densities are averaged with equal weight to construct the distributions for the prereform and postreform periods.

In the prereform period all individuals have a convex kink in their budget constraint at age 60, where the benefit factor reaches the 2.0 percent cap and $\frac{dk}{dR} = 0$ as they continue to delay retirement. The net wage for continued work is approximately 1.2 times the annual salary[21] before age 60. After age 60, the net wage falls to only about 0.6 times the annual salary. This is a 50 percent decline in the financial return to work at the budget constraint kink.[22]

[21]The scaling factor is annual salary as measured at age 60.

[22]The net wage is also declining by about 0.04 times salary for each year retirement is delayed, but this change is very small relative to the difference in net wage to either side of the budget constraint kink.

The location of the kink in the postreform period is the age at which the benefit factor hits the cap of 2.4 percent and $\frac{dk}{dR}$ again falls to zero. This age varies with years of service due to the interaction between the Enhanced Age Factor legislation and the Career Bonus legislation. The earliest possible kink age is $61\frac{1}{2}$, for individuals with 30 years of service by this age. For the remainder of the population, the kink occurs at the lesser of the age at which 30 years of service is reached and age 63. Those that have a kink at age $61\frac{1}{2}$ will be referred to as the "High Service" group and those with a kink at age 63 as the "Low Service" group. These two groups include over 95 percent of the retiring population in each year, and will be the focus of the following discussion.

A stylized budget constraint,[23] with consumption as a function of age, for a CalSTRS member with the median service history depicts this reform in Figure 2. The kink shifted from age 60 to a later age by the reform. However, the net wages, as a fraction of salary, preceding and following the kink are similar in value across reform periods.

Based on the lifetime budget constraint model of retirement, as illustrated in Section 3, retirements are predicted to be bunched at budget constraint kink points, so a shift in the distribution of retirements should be observed after the reform if teachers are responding to the pension financial incentives. The average age distribution of annual retirements for the prereform and postreform periods are shown for the High Service group (Figure 3a) and the Low Service group (Figure 3b). For each retirement age R, the fraction includes all retirees that retire at ages $\in [R, R+.25)$. A feature common to both figures is that the density of retirements at age 60 ± 3 months drops by over $\frac{1}{3}$ in the postreform period.[24] For the High Service group, the fraction of retirees locating at the new kink of $61\frac{1}{2} \pm 3$ months has doubled from 4 percent to 8 percent. For the low service group, the increase in retirements at the new kink of age 63, from 2 percent to 3 percent, is not as

[23] This and all stylized budget constraints were constructed as seen from age 55, assuming an annual discount factor of 0.97 and salary increases of $1000 annually. Total consumption is the PDV of salary and future pension payments at age 55. Changes to the discount rate change the level of the budget constraint but percentage changes in the slope at the kink point remain the same.

[24] An additional feature common to both figures in the prereform and postreform periods, is the high number of retirements at the early retirement age 55. This is similar to the high number of Social Security claims made at age 62. In the CalSTRS case, these "retirements" represent both individuals that have left service at this age and those that retired early but were forced to wait until age 55 to claim their retirement benefits.

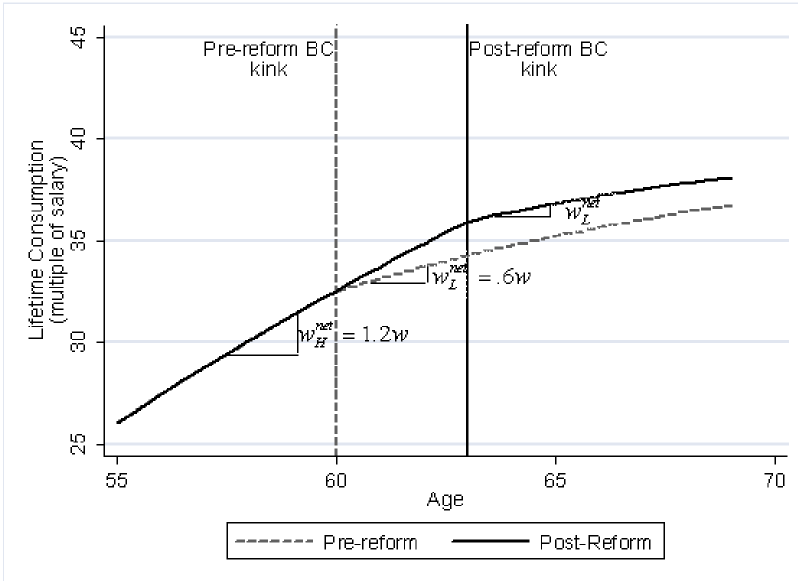


Figure 2: Stylized Budget Constraint in Age for a Representative CalSTRS Member

Notes: This figure depicts the lifetime budget constraint for a CalSTRS member that would have 27 years of service at age 60. All consumption values are discounted to age 55 and scaled by the salary at age 60 ($55,000). The discount rate is assumed to be 0.97 and salary is assumed to grow by $1000 per year.

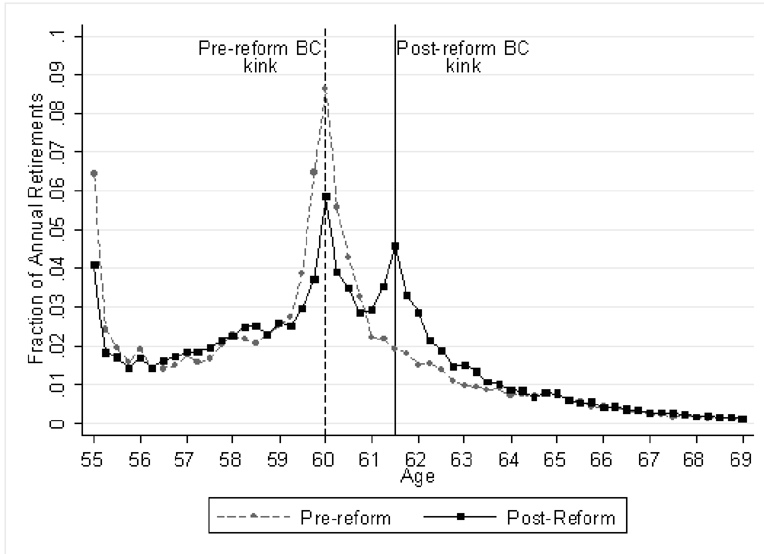
pronounced.[25]

It should be noted that the behavior of the Low Service group provides a cleaner test of the predicted shift of the retirement distribution because their budget constraint is altered by only a shift in the kink point. The budget constraint for the High Service group, on the other hand, as is described in more detail below, gains a discontinuity[26] in addition to the shift in kink location. Due to the additional change in incentives, the composition of the population that is still working at age 60 may have changed, so the interpretation of the observed response is not as clear.

The shift of the spike in the retirement distribution from age 60 to the age that coincides with the group-specific postreform kink (age $61\frac{1}{2}$ or 63) is the key evidence supporting the existence of a causal link between pension financial incentives and retirement timing. While CalSTRS members display a strong preference for retirement at age 60 in the prereform period, coinciding with the

[25] The smaller effect at this later age may be partially attributable to delayed transition between the prereform and postreform equilibriums. This will be discussed in greater detail in Section 6.

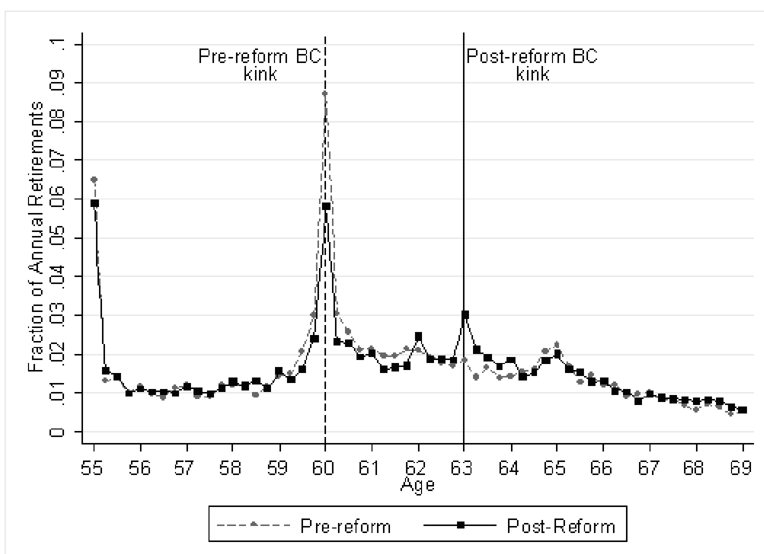
[26] This discontinuity does not occur at the same age across individual budget constraints, so it does not make any clear predictions for the retirement distribution along the age dimension.



(a) High Service Retirees

Figure 3: Age Distribution of Retirees by Service Group

Notes: This figure depicts the density of retirements between ages 55 and 69. The annual age distributions were constructed using the CalSTRS systemwide administrative data. These were then averaged, with equal weight, to create the prereform (1995-98) and postreform (1999-2003) distributions. The High Service group is defined as having the ability to work 30 years by age $61\frac{1}{2}$ and the Low Service group is defined as being unable to work 30 years before age 63. The prereform and postreform budget constraint kinks are indicated by the dashed vertical line and the solid vertical line, respectively. The return to working an additional year falls by 50 percent at the kinks.



(b) Low Service Retirees

Figure 3: Age Distribution of Retirees by Service Group (contd)

budget constraint kink, it is not clear that financial incentives alone are responsible for this common preference.[27] Through analysis of a static defined benefit system, it is not possible to disentangle the impact of financial incentives from confounding factors that are not included in the model.

In the prereform period there were no common discontinuities in the budget constraint on the service dimension. The second reform, the CB, changes this by adding 0.2 percentage points to the benefit factor at 30 years of service, provided the cap on k had not already been reached. This creates a discontinuity in the budget constraint at 30 years of service for those eligible for the bonus. The High Service group is eligible and has a budget constraint discontinuity at exactly 30 years of service. The stylized budget constraint for the High Service group, with consumption as a function of service, is shown in Figure 4.[28] The effect of the reform is reflected by the shift from the gray dashed line to the solid black line. The magnitude of the discontinuity at 30 years of service is approximately equal to the annual salary for the median CalSTRS retiree. There is no change in the budget constraint in service for the Low Service group.

As discussed in Section 3, with the introduction of a budget constraint discontinuity, it becomes optimal for some individuals that were previously retiring just before the new discontinuity to delay retirement. The lifetime budget constraint model predicts that the density of retirements at service levels directly preceding 30 years of service will decrease and an excess of retirements at exactly 30 years of service will appear. The prereform and postreform retirement distributions along the service dimension for the affected High Service group and for the Low Service group are shown in Figures 5a and 5b respectively. Comparing the postreform distribution to the prereform distribution for the High Service group, 4 percent of the population is no longer retiring between 28 and 30 years of service. Also the increasing density of retirees over 26-27 years of service is absent in the postreform period. The ratio of the fraction of retirements occurring at 30 years of service to the fraction at 29 years of service is larger in the postreform period, but the postreform density does

[27] As has been frequently noted in the retirement literature, the desire to retire at a common age might be the result of a focal effect of the program "normal" retirement age, or of shared incentives outside the retirement program.

[28] The budget constraint kink does not occur at the same service level across individual budget constraints, so it does not make any clear predictions for the aggregate retirement distribution on this dimension and is abstracted from in the stylized budget constraint.

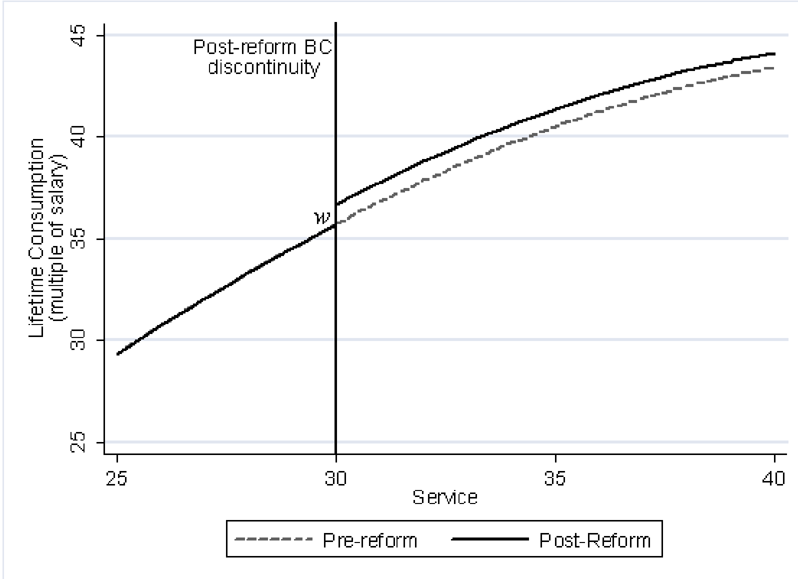


Figure 4: Stylized Budget Constraint in Service for a Representative CalSTRS Member

Notes: This figure depicts the lifetime budget constraint for a CalSTRS member that would have 30 years of service at age 60. All consumption values are discounted to age 55 and scaled by the salary at age 60 ($55,000). The discount rate is assumed to be 0.97 and salary is assumed to grow by $1000 per year.

not quite catch up to the prereform density until 31 years of service.[29] For the Low Service group, the prereform and postreform distributions are similar and reveal teachers have no preference for retirement at a particular service level; this is in line with their financial incentives.

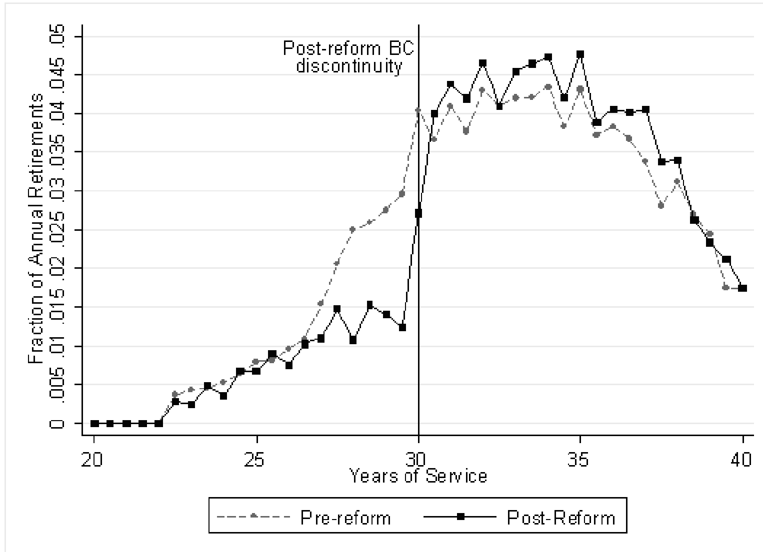
4.2 Quantifying the Spike: Retirement Elasticity Estimation

Supported by the visual evidence that the teachers responded to the change in pension financial incentives created by the reform, I quantify their sensitivity to these incentives by estimating the compensated elasticity of retirement age with respect to the price of retirement.[30] The compensated elasticity of retirement age for a small change in the slope of the lifetime budget constraint[31] at a

[29] Transition factors that might account for retirements at 30 years of service falling short of predictions will be discussed in Section 6.

[30] As the CalSTRS budget constraint kink is on the age dimension, the compensated elasticity of *retirement age* with respect to price will be estimated. This can also be transformed into an estimate of the compensated elasticity of years of work with respect to price by maintaining the assumption made in Section 3, that $R = S + a_0$, and evaluating the expression at the average years of service for retirees of age 60.

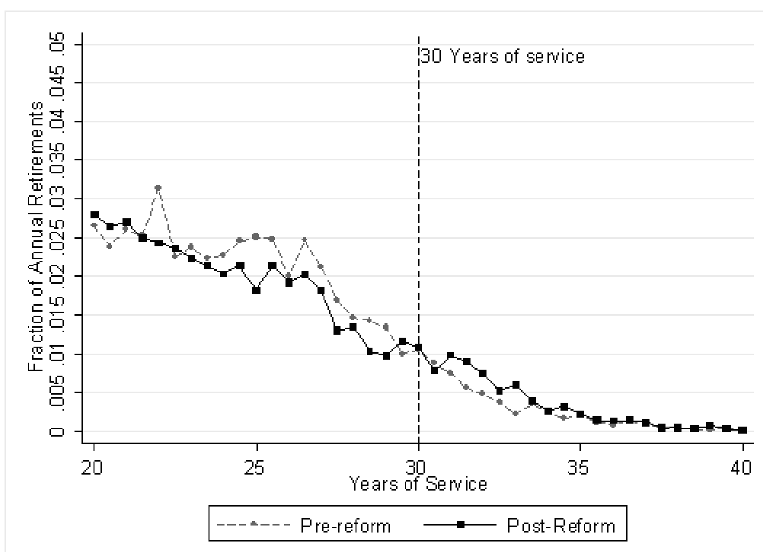
[31] If the change is very small, income effects and be ignored.



(a) High Service Retirees

Figure 5: Service Distribution of Retirees by Service Group

Notes: This figure depicts the density of retirements between 20 and 40 years of service. The annual service distributions were constructed using the CalSTRS systemwide administrative data. These were then averaged, with equal weight, to create the prereform (1995-98) and postreform (1999-2000) distributions. The High Service group is defined as having the ability to work 30 years by age $61\frac{1}{2}$ and the Low Service group is defined as being unable to work 30 years before age 63. The postreform budget constraint discontinuity for the High Service group is indicated by the solid vertical line.



(b) Low Service Retirees

Figure 5: Service Distribution of Retirees by Service Group (contd)

retirement age R is

$$(7) \qquad e = \frac{dR}{R} \times \frac{w^{net}}{dw^{net}}$$

The net wage faced by CalSTRS members can be easily calculated due to the highly structured salary schedule and simple pension formula, leaving dR to be estimated.

I adapt the method developed in Saez (2002) to estimate dR from the excess retirements at the budget constraint kink. I describe this method here, closely following the original exposition. Consider a population that faces a linear budget constraint with a slope of w_H^{net}. Each individual retires at the age R^*, such that his ratio of marginal utility of labor to marginal utility of consumption is equal to the net wage. With heterogeneous preferences smoothly distributed across the population, R^* is also smoothly distributed according to some function $f(r)$. If a kink is introduced to the budget constraint, so that the budget constraint slope falls to $w_L^{net} < w_H^{net}$ for $R \in [R_K, T]$ individuals with $R^* > R_K$ may adjust their retirement dates. In this context, there exists an individual that will adjust retirement from R_H^* to R_K, and who's indifference curve will be exactly tangent to the upper segment of the budget constraint at R_K, so that $\frac{-U_R}{U_C}|_{R_K} = w_L^{net}$, as shown in Figure 6.

The change in lifetime labor supply for this individual, $R_H^* - R_K$, is dR for $dw^{net} = w_H^{net} - w_L^{net}$. R_H^* can be estimated by noting that all individuals with a lifetime labor supply of $R^* \in [R_K, R_H^*]$ when faced with the linear budget constraint of slope w_H^{net} will also locate at R_K when the kink is introduced. These individuals are the excess kink retirements and their total number is given by $N^E = \int_{R_K}^{R_H^*} f(r)dr$, where $f(r)$ is the density of retirees when the budget constraint is linear.

In the CalSTRS case, the excess retirements, N^E, can be simply estimated as the change in the retirement density at age 60 (the prereform kink) moving from the prereform period to the postreform period. The estimated excess retirements at age 60 are equal to $N^E = \int_{R_K}^{R_K+dR} f(r)dr$, where $f(r)$ is the density of retirements in the postreform period. Assuming this density to be uniform[32] in the vicinity of age $R_K = 60$, $dR = \frac{N^E}{f(r)}$ and the elasticity of retirement age with

[32]This assumption appears reasonable for the observed retirement distributions.

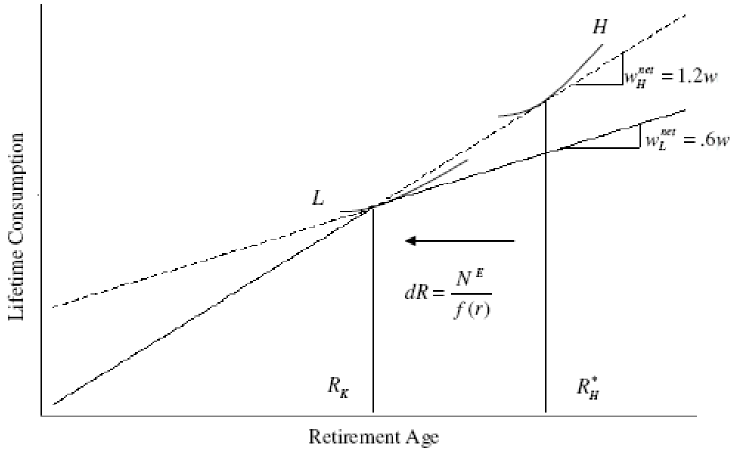


Figure 6: Non-parametric Elasticity Estimation

Note: This figure depicts the retirement decision when a kink is introduced to the budget constraint at R_K. With the introduction of the kink all those with $R_K < R^* < R_H^*$, will move to R_K. The distance between R_H^* and R_K is the total movers, N^E , divided by the retirement density across these service levels when the budget constraint is linear.

respect to price is

$$e = \frac{\frac{N^E}{f(r)}}{R_K} \times \frac{w^{net}}{dw^{net}} \tag{8}$$

The compensated elasticity of retirement timing with respect to the net wage is proportional to the extent of the bunching at the kink point.

This method of estimating the elasticity is only valid in the case of small price changes. In the CalSTRS case the change in the price of retirement at the kink point is not small. In fact, the price of retirement falls from about 1.2 times the annual salary to less than 0.6 times the annual salary, an over 50 percent decline in price. Therefore, the above formula can not be applied directly. Rather, a constant elasticity of substitution lifetime utility function of the form $U = C - \frac{R^{1+1/e}}{1+1/e}$ will be assumed in the estimation. A formula for the compensated elasticity, as a function of kink-point bunching, salary, and defined benefit program parameters, specific to this utility function is derived in Appendix B.

Estimates for the compensated elasticity of retirement age with respect to net wage, based on the systemwide count data, are shown in columns (1) and (2) of Table 2. In the estimation, indi-

	Reform-based Estimates		"Potential" Long-run	
Expected Lifetime in Years	Total Population e(R)	Low Service e(R)	Total Population e(R)	Low Service e(R)
70	0.0105**	0.018**	0.0375**	0.1307**
	(0.0007)	(0.0022)	(0.0015)	(0.0105)
80	0.0075**	0.0116**	0.0241**	0.063**
	(0.0005)	(0.0014)	(0.0008)	(0.0035)
90	0.0065**	0.0096**	0.0205**	0.0487**
	(0.0004)	(0.0011)	(0.0007)	(0.0024)

Table 2: Non-parametric Elasticity Estimates

Note: e(R) is the compensated elasticity of retirement age with respect to price. Estimates are based on the bunching of retirees at age 60, the prereform budget constraint kink location.
Bootstrapped standard errors are in parentheses.
** significant at 1 percent level, * significant at 5 percent level

viduals that retire within three months of age 60 are assumed to be locating at the kink age. The elasticities have been calculated for both the full population and the Low Service[33] group for varying life expectancies. The estimates vary slightly across populations and assumed lifetimes. The elasticities for the Low Service group are larger than for the full population and the magnitude of the elasticities are declining in expected lifetime. However, in all cases the elasticity of retirement age is less than 0.02.

Such small estimated elasticities may not have been expected, given the visually perceptible change in the distribution of retirements. However, the reform induced change in the financial return to work at age 60 was very large, almost a 100 percent increase. Though noticeable, the decrease in retirements that occurred at age 60 following the reform was small relative to the change in financial incentives.

[33] Again the Low Service group provides a cleaner sample for the estimation as the reforms only shifted the kink from age 60 to age 63 for this group, while other CalSTRS members also incur a discontinuity in their postreform budget constraint. However, estimations on the Low Service group are not necessarily representative of the full population behavior.

5 Structural Estimation

In this section, a structural estimation method that builds on the work of Burtless and Hausman (1978) is used to estimate the price elasticity of retirement free from two types of bias. By explicitly modeling the full budget constraint faced by each teacher, including the nonlinearities, the endogeneity of the net wage that is due to its simultaneous determination with the retirement age is removed, as in Burtless and Hausman's original context. Additionally, this model best exploits the the exogenous variation in the financial return to working introduced by the pension reform, allowing me to address the bias that may arise from endogenous sorting. Unlike the estimation of the previous section, this method makes full use of the data available and accommodates the inclusion of control variables.

This model is estimated by maximum likelihood with the individual level LAUSD administrative dataset of all teachers that retired in 1997-2004. Recall, this dataset has only service in LAUSD for each teacher, rather than total service in California public schools. The latter is the relevant figure for CalSTRS calculation of retirement income. This makes it difficult to accurately incorporate the CB, so I restrict the estimation to the Low Service group.[34]

5.1 Empirical Model

The empirical model for the structural estimation is also based on the lifetime budget constraint model introduced in Section 3. A teacher's preferences over lifetime consumption (C) and retire-

[34]Even within the restricted sample, having only district level service measures presents two possible problems. The first is that the budget constraint is misspecified, and the return to working an additional year is likely slightly higher than what is reflected by the data. This would bias estimates of price elasticity upward. The second is that individuals that change district may be different from those that do not, so it is a select group for which the budget constraint is misspecified.

ment age[35] (R) are assumed to be described by the CES utility function[36]

$$U(C,R) = C - \frac{R^{1+\frac{1}{e}}}{1+\frac{1}{e}} \times \alpha \tag{9}$$

The elasticity of retirement age with respect to price is denoted by e and α represents individual-specific heterogeneity in taste. When faced with a linear lifetime budget constraint with slope w^{net}, an individual will choose R so that $-\frac{U_R}{U_C} = w^{net}$. The optimal retirement age is then a function of elasticity, net wage, and the taste parameter and is given by $\ln R = e \ln w^{net} - e \ln \alpha$. The taste parameter can be further decomposed by rewriting it as $\alpha = \exp(X\beta - \eta)$, where X is observable characteristics that influence preferences and η is an unobserved taste shifter. In the resulting specification the retirement age is chosen according to

$$\ln R = e \ln w^{net} - X\widetilde{\beta} + \widetilde{\eta} \tag{10}$$

where $\widetilde{\beta}$ and $\widetilde{\eta}$ are $e \times \beta$ and $e \times \eta$ respectively.

The Low Service group faces a two segment piecewise (approximately) linear budget constraint[37] both before and after the reform. The kink is at age 60 in the prereform period and at age 63 in the postreform period, as depicted in Figure 2. The empirical specification of the budget

[35]For the Low Service group, retirement age is the only relevant dimension for estimating the response to the CalSTRS pension reform.

[36]The reform is not well suited to identifying the income effects, however a second specification that incorporates income effects will also be estimated.

[37]The budget constraint is not strictly linear on each segment. However, as noted earlier, the evolution of the slope over age is small in magnitude compared to the nonlinear features.

constraint, defined over the eligible retirement ages, is as follows[38]

$$(11) \qquad C = \left\{ \begin{array}{ll} Y_H^v + w_H^{net}(R-55) & 55 \leq R \leq R_K \\ Y_L^v + w_L^{net}(R-55) & R_K \leq R \end{array} \right\}$$

Y^v and w^{net} are the budget constraint intercept at age 55 and slope for each segment of the budget constraint.

Assuming η is distributed $N(\mu, \sigma^2)$ across the Low Service population, the log likelihood[39] for this group over the prereform and postreform period is written

$$(12) \qquad \begin{aligned} \log L \; = \; & \sum_i s_i \times \log\{\phi(\frac{\ln R_i - e \ln w_i^{net} + X_i\widetilde{\beta} - \mu_{\widetilde{\eta}}}{\sigma_{\widetilde{\eta}}})\} + \\ & \sum_i K_i \times \log\{\Phi(\frac{\ln R_K - e \ln w_{L,i}^{net} + X_i\widetilde{\beta} - \mu_{\widetilde{\eta}}}{\sigma_{\widetilde{\eta}}}) \\ & -\Phi(\frac{\ln R_K - e \ln w_{H,i}^{net} + X_i\widetilde{\beta} - \mu_{\widetilde{\eta}}}{\sigma_{\widetilde{\eta}}})\} \end{aligned}$$

Here, s_i is an indicator for retirement on a budget constraint segment and K_i is an indicator for retirement on a kink. The parameters that will be estimated are the price elasticity e and the mean and standard deviation of the unobserved taste parameter $\widetilde{\eta}$, $\mu_{\widetilde{\eta}}$ and $\sigma_{\widetilde{\eta}}$.

5.2 Implementation with Reform Identification and Results

By pooling the prereform and postreform retirement observations and controlling for salary in a flexible way, the elasticity of retirement timing with respect to the financial return to work is

[38]Here it is easy to see that retirement age and the financial return to work are simultaneously determined. Individuals that are observed retiring before the kink, at a relatively high net wage, must have a higher taste for retirement - a small η, while those that are observed retiring after the kink, when the net wage is relatively low, have a low taste for retirement - a large η. This negative correlation of the unobserved taste parameter and net wage will bias the elasticity estimate. This is especially important in the CalSTRS case as the kink is large and occurs at the same age for all members, so much of the variation in observed net wages faced by individuals is determined by the location of the retirement along the budget constraint. In this context, estimating the compensated elasticity by an ordinary least squares regression results in perverse estimates. When equation (10) is estimated with OLS for the LAUSD teachers, the coefficient on log of net wage is negative and statistically significant.

[39]The log likelihood for this subgroup is derived in Appendix C.

effectively identified from reform variation.[40] The net wage at a potential retirement age t is calculated as

$$
\begin{aligned}
(13) \qquad w_t^{net} &= w_t \times (1-\tau_c) + \sum_{s=t+1}^{100} \delta^{s-t} p_{s|t} \left(k_{t+1} \times (t+1-a_0) \times w_{t+1}^{f} \right) \\
&\quad - \sum_{s=t}^{100} \delta^{s-t} p_{s|t} \left(k_t \times (t-a_0) \times w_t^{f} \right)
\end{aligned}
$$

where $p_{s|t}$ is the probability of living to each age s given that the individual is alive at age t and δ is the discount factor, assumed to be 0.97.[41]

A final technical point for estimation is the assignment of retirements to the kink. Individuals that are responding to the financial incentives at the kink may not be able to retire at the exact kink age. For example, a teacher may not want to leave her students in the middle of the school year[42] or processing the paperwork for retirement may take longer than expected. The likelihood derived above does not allow for this type of error,[43] so only individuals that retire exactly at the kink age would be counted as retiring on the kink. This likely understates the intended number of kink retirements. For this reason, individuals that retire within three months of the kink will be assigned to the kink for estimation.[44]

The estimates of equation (12) are presented in Table 3.[45] The point estimate of the price elasticity (e) is similar across all specifications, with a range of 0.0175-0.0203 in the six specifications

[40] Leora Friedberg (2000) uses a very similar approach to exploit reforms of the Social Security earnings test to estimate its impact on elderly labor supply.

[41] The model was also estimated for a discount factor of $\frac{1}{1+r}$ with r equal to 0.05 and 0.07. The estimated price elasticities increased as the discount factor declines with a maximum point estimate around 0.03. The estimated price elasticities are not statistically different at the 5 percent level of significance moving from $r = 0.03$ to $r = 0.05$ or from $r = 0.05$ to $r = 0.07$, but they are different between the cases $r = 0.03$ and $r = 0.07$.

[42] Seventy-five percent of annual teacher retirements occur over the summer and over 85 percent of these take place in June.

[43] A second "optimization" error term could be added as in Hausman (1985). This would increase the complexity of estimation.

[44] The model was also estimated assigning individuals retiring within 6 months of their sixtieth birthday to the kink. In all specifications, the estimated price elasticity is statistically different from the base case at the 5 percent level of significance and is 1.8 to 2 times larger than the base case. The estimated models with this assignment rule did not fit the data as well as the base case.

[45] A model that explicitly incorporates the censoring of observations at age 55 was also estimated. The results are not statistically distinguishable.

	(1)	(2)	(3)	(4)	(5)	(6)
μ	3.9249**	3.9134**	3.921**	3.9678**	3.9400**	3.9475**
	(0.0215)	(0.0407)	(0.0423)	(0.0392)	(0.0428)	(0.0396)
σ	0.0805**	0.0797**	0.0797**	0.0793**	0.0796**	0.0795**
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
e	0.0203**	0.0193**	0.0194**	0.0175**	0.0194**	0.0185**
	(0.0019)	(0.0023)	(0.0024)	(0.0024)	(0.0024)	(0.0024)
$ln(Y^v)$					0.0007	0.0008
					(0.0007)	(0.0007)
w		0.0081	-0.0024	-0.0033	-0.0002	0.0019
		(0.0076)	(0.1400)	(0.1396)	(0.1407)	(0.1405)
w^2		-0.0019*	-0.0016	0.0050	0.001	-0.0006
		(0.0008)	(0.0715)	(0.0710)	(0.0719)	(0.0718)
w^3			0.001	0.0013	-0.0007	0.0007
			(0.0121)	(0.0115)	(0.0120)	(0.0122)
w^4			-0.0001	-0.0002	0.0000	-0.0001
			(0.0007)	(0.0006)	(0.0007)	(0.0007)
mob				0.0005		0.0007
				(0.0005)		(0.0005)
age 60				0.0070		0.0026
				(0.0049)		(0.0036)
Log Likelihood	1699.80	1714.34	1716.23	1717.23	1716.71	1718.42
N	2114	2114	2114	2114	2114	2114

Table 3: Structural Estimates

Notes: Results of the maximum likelihood estimation of the structural model using LAUSD administrative data (1997-2004)

Standard errors are in parentheses.

** significant at 1 percent level, * significant at 5 percent level shown. It is always significantly different from zero at the 1 percent level of significance and the magnitude echoes the small values of the nonparametric estimates.

In the first four specifications the coefficient on log net wage is interpreted as the compensated elasticity. In specifications (2) and (3) salary controls are added to the base case to limit identification to the reform-induced variation in financial incentives. The point estimate for the elasticity decreases slightly once the salary controls are added. Though the change is not significant, it suggests that elasticity estimates identified from the cross-sectional variation in financial incentives may be upward biased. Specification (4) adds an indicator for retirement at age 60 and month of birth to the third specification. The dummy for age 60 takes the value of one for retirements within 3 months of age 60 and is zero otherwise and it is included to capture the persistence in retirements at this age following the reform. The estimates of the coefficient on the age 60 indicator are always positive but not statistically significant and the point estimate is an order of magnitude smaller than the coefficient on log net wage. Month of birth is added to control for the fact that teachers are not apt to retire mid-school year, so those without summer birthdays are less likely to retire exactly at their birthday. Theoretically, teachers may retire earlier or later in response to this nonfinancial constraint. The coefficient on month of birth is statistically zero.

The final two specifications add log virtual income[46] to specifications (3) and (4).[47] The estimate of the coefficient on the log net wage does not change when log income is added, however it is now interpreted as the uncompensated price elasticity of retirement age. The point estimate of income elasticity is wrong-signed in both specifications, but it is also two orders of magnitude smaller than the price elasticity and is not statistically significant. These findings should be read with caution, as the reform does not lend itself to identification of the income effect, so the coefficient on log virtual income is identified from cross-sectional variation. Further, measurement error in the total service of the teachers may introduce error to the calculation of pension wealth.

The CalSTRS DBP significantly alters the individual budget constraint and imposes strong

[46]The virtual income is the budget constraint intercept at age 55. It incorporates pension wealth and earnings after age 55, but does not take into account earnings that may have been saved before this age.

[47]Here the labor supply equation is $\ln R = e \ln w^{net} + \gamma \ln Y^V - X\widetilde{\beta} + \widetilde{\eta}$. A similar specification is used by Burtless (1986).

nonlinearities on the financial return to work. However, the small elasticity estimates imply that the program changes had only a small effect on teacher retirement. Although the model incorporating income elasticity is not well identified, the results suggest that the compensated price elasticity is small, meaning that the pension program creates only small deadweight loss.

6 Long-run Implications and Concerns

6.1 Transition to New Equilibrium

Both the reduced-form and structural estimation of the elasticity of retirement age assumed that the CalSTRS system reached its postreform equilibrium during the period under study. However, this may not have occurred for both mechanical and behavioral reasons, which would cause the elasticity to be understated. This section will discuss these sources of delayed response, evaluate the period for which the estimated elasticity is valid, and estimate the potential long-run elasticity.

The first reason the observation of the postreform equilibrium retirement distribution may be delayed is mechanical. If the density of retirements is expected to decrease at a given age or service level, i.e. at age 60, and if CalSTRS members adjust their retirement plans immediately to the postreform equilibrium, the retirement distribution at these points will reflect the long-run response. However, if the retirement density is instead expected to increase due to individuals delaying retirement, i.e. at age 63, the increase will be observed with a lag.

The second reason that observation of the postreform equilibrium retirement distribution may be delayed is behavioral. There may be fixed costs for changing a planned retirement date, for example, those associated with coordination of retirement with a spouse, sale/purchase of a home, or health care arrangements. For individuals who chose their retirement dates optimally in the prereform period, it may not be optimal for them to adjust their plans following the reform despite the financial incentive.

As individuals that learned of the reforms earlier in their careers begin to retire, the observed retirement pattern will more closely resemble the new equilibrium, regardless of whether mechan-

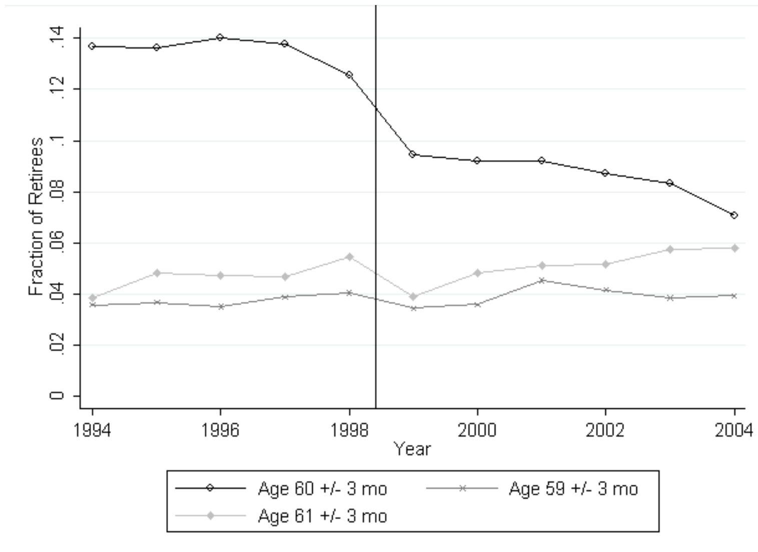


Figure 7: Time Trend in Retirement Density at Prereform Budget Constraint Kink

Note: The density includes those that retire within three months of their sixtieth birthday. The break in the line separates the prereform and postreform trends.

ical or behavioral factors were driving the delayed response. The delay attributable to behavioral factors, arguably the more interesting portion, can be isolated by examining the time trend in retirement density at an age or service where it is expected to decrease following the reform. At these points there will be no mechanical delay.

The time trend of the fraction of CalSTRS retirees that retire within 3 months of age 60 (and within 3 months of ages 59 and 61 for comparison) is plotted in Figure 7. The solid vertical line divides the prereform and postreform observations. In the first year after the reform, retirements within three months of age 60 fell from about 12.5 percent of the retiring population to about 9.5 percent, and trended slightly downward to 8 percent over the next 4 years. There was also a decline in the fraction retiring at this age in 1998, consistent with the announcement of the reforms in 1998. Even disregarding the response before 1999, over 60 percent of the total 5 year change in retirement density at age 60 occurred immediately after the reform became effective. This figure suggests that the elasticity of retirement timing estimated from the change in retirement behavior following the reforms captures the medium-run response.

The "potential" long-run response can be estimated using the same adapted Saez (2002) method employed in Section 4. In this case, it is assumed that if the spike at age 60 is caused solely by financial incentives, it would disappear completely in the long-run, leaving only the baseline retirement density. The baseline density from age 60 to 61 is predicted from a linear extrapolation of the densities at the preceding ages.[48] The difference between the prereform retirement density at age 60 and the baseline density is considered the excess retirements generated by the budget constraint kink. The excess retirements at age 60 are just over 8.5 percent in both the total population and in the Low Service group. The elasticity is then calculated using the same formula as was used earlier and derived in Appendix B.

These results are presented in columns (3) and (4) of Table 2. The potential long run compensated elasticity of retirement age with respect to the price of retirement is 3.5 times larger than the estimated medium-run elasticity for the total population and 5 - 7 times larger for the Low Service group. Though this difference is large, the estimated elasticity of retirement age remains less than 0.1 in all but one case.[49]

6.2 Health Insurance

Health insurance is perhaps the most notable form of compensation excluded from the preceding modeling and analysis of the retirement decision. Employer-sponsored health insurance may be valued, especially by older workers, because it reduces the cost of coverage through risk pooling and premium sharing and may even open access to those that would be denied coverage under an individual policy.

By law, all California teachers may continue their employer-sponsored health insurance in retirement.[50] However, the health insurance system, unlike the pension system, is not centralized. The extent to which the employing district contributes to retiree health insurance premiums or even whether or not retirees are included in the same risk pool as active teachers is determined by

[48]The budget constraint is linear over ages 55-60 and the reform does not affect incentives at in this range. Retirement behavior here is considered to represent the equilibrium along a linear budget constraint.

[49]In this case a very low life expectancy has been assumed.

[50]The date of separation from employment must be coincident with the pension claim date.

each school district. The most common retiree health benefit includes some district contribution toward premiums until age 65.[51] The premium sharing is often a function of service in the district, age, or both. LAUSD is one of the most generous districts. It pays 100 percent of health insurance premiums for the life of its retirees, provided that the retiree meets a minimum service requirement, 5-15 years depending on date of hire. However, retirees are required to enroll in Medicare when they become eligible.

In LAUSD, teachers have an incentive to continue working until eligibility for "free" retiree health insurance is attained.[52] This is both because with continued employment a teacher remains eligible for subsidized insurance in the current period and because eligibility for free retiree health insurance has value.

In the preceding analysis, the elasticity of retirement age with respect to the net wage is identified from the reform of the defined benefit program and the corresponding changes in retirement behavior. In this context, the exclusion of health insurance from the budget constraint will not pose an identification problem unless eligibility for retiree health insurance (or its importance, due to changes in the health insurance status of a spouse for example) is also changing over the period.[53] The bias introduced to the elasticity by excluding health insurance will depend on the sensitivity of retirement age to the health insurance incentives and the correlation between the changes in health insurance eligibility and the pension reform.

In the sample of retired Low Service LAUSD teachers, 86.8 percent retire with free health insurance in the prereform period, while only 75.9 percent retire with free health insurance in the postreform period. Eligibility at retirement is of course endogenous to the retirement decision itself, so age of eligibility for free retiree health insurance should better capture the different in-

[51] According to a survey conducted by CalSTRS in 2006, 65 percent of districts offer this type of continued health insurance. Nineteen percent offer no assistance with insurance premiums.

[52] The evidence of the importance of health insurance coverage in the retirement decision is mixed. Several studies (David M. Blau and Donna B. Gilleskie, 2001; French and John Bailey Jones, 2007; Jonathan Gruber and Madrian, 1995; Richard W. Johnson, Amy J. Davidoff, and Kevin Perese, 2003; Rust and Phelan, 1997) find that health insurance availability increases retirement a moderate to significant amount, while others (such as Gustman and Steinmeier, 1994) find a much smaller role for health insurance in explaining retirement behavior.

[53] It is the case that service requirements for retiree health insurance are changing for those hired in the late 1980's and early 1990's. These changes may be relevant for some of teachers eligible for retirement in the sample period.

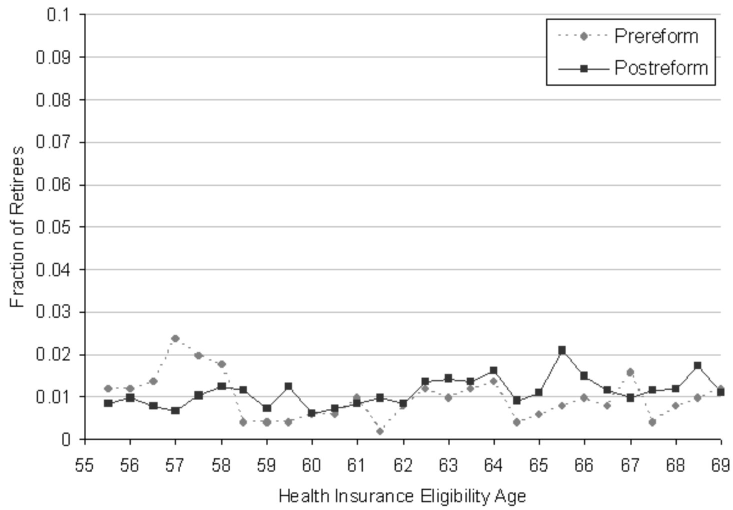


Figure 8: Distribution of Retiree Health Insurance Eligibility Age

Notes: This figure depicts the density of free retiree health insurance eligibility across the ages of 55.5 to 69. The prereform and postreform distributions were constructed using the LAUSD administrative data. This sample only includes Low Service retirees.

centives faced by the teachers. The majority of teachers are eligible for free health insurance at the early retirement age of 55, 66.6 percent in the prereform period and 63.1 percent in the postreform period. The fraction of total teachers eligible for retiree health insurance at each half age after age 55 is shown in Figure 8. Importantly, there does not appear to be a shift in eligibility from age 60 to 63, which would correspond with the key ages of the pension reform.[54] Though, on average, teachers become eligible for free retiree health insurance at later ages in the postreform period. The change in the labor supply incentives due to changes in health insurance are positively correlated with the changes in incentives created by the pension reform. In the preceding analysis, all changes in retirement timing were attributed to changes in the pension program. To the extent that teachers are also responding to the incentive to delay retirement created by changes in the health insurance program, the elasticity estimates overstate the sensitivity of retirement timing to the pension parameters.

[54] Although there is no information in the data about health insurance available through a spouse, general trends are unlikely to target the incentives for retirement at the key ages of 60 and 63.

7 Concluding Remarks

In this paper, I exploit a reform of the California teachers' pension to identify the sensitivity of retirement age to retirement program financial incentives. The reform exogenously altered the financial return to work, which together with the fact that California teachers are not covered by Social Security and face little uncertainty in wages and employment, allows me to isolate the causal effect of the CalSTRS program parameters on member retirement timing. Using the precise predictions generated by a standard lifetime labor supply model to inform the analysis, I find that the teachers' response to the reform was small in magnitude. The reduced-form analysis and structural estimation imply an elasticity of retirement age with respect to the price of retirement centered at 0.02 in the medium-run and bounded at 0.10 in the long-run. The small magnitude of the compensated elasticity implies that defined benefit retirement programs do not greatly distort retirement timing, and so the deadweight burden of such programs is minimal.

Although California teachers are a select group, the features of their pension are similar to those of Social Security, a program that covers a broader population. Social Security serves as the only defined benefit plan for a growing number of workers in the United States and it is both important and salient to this population as coverage is retained when individuals change jobs. Also like the California teachers' pension, Social Security has key program ages at which covered workers exhibit a propensity to retire. Given these strong parallels, the finding that California teachers' retirement behavior was little affected by a large pension reform raises concerns about how much of an impact the recent increase in the Social Security "full retirement age" will have on the labor supply of older workers.

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A Census Tabulations

	California Teachers	California Workers	All Californians
Wage Income			
$0	0.09	0.23	0.43
$1-50k	0.54	0.55	0.41
$50k-100k	0.36	0.17	0.13
$100k-150k	0	0.03	0.02
Greater than $150k	0	0.02	0.02
Homeownership Rates	0.87	0.76	0.74
House Value			
Less than $500k	0.76	0.65	0.64
Greater than $500k	0.25	0.35	0.36
Difficulty Working	0.08	0.13	0.15
Fraction Female	0.72	0.47	0.52
Marital Status			
Married	0.69	0.67	0.6
Separated	0.02	0.03	0.03
Divorced	0.18	0.18	0.19
Widowed	0.05	0.05	0.12
Never married/Single	0.07	0.07	0.06
Race			
White	0.85	0.72	0.7
Black	0.06	0.06	0.06
American Indian or Alaska Native	0	0.01	0.01
Chinese	0.02	0.03	0.03
Japanese	0.02	0.01	0.01
Other Asian or Pacific Islander	0.02	0.07	0.07
Other or Multiple	0.04	0.1	0.11
Weighted Obs	151,306	4,094,681	5,516,039
Actual Obs	7,783	210,899	284,422

Table A.1: Comparison of California Teachers and Population

Notes: Sample restricted to those age 50-69. Ruggles, Steven, Matthew Sobek, Trent Alexander, Catherine A. Fitch, Ronald Goeken, Patricia Kelly Hall, Miriam King, and Chad Ronnander (2004).

A greater fraction of California teachers are women than the general working population. California teachers are also more likely to own a house and are less likely to report health-related difficulty working. These last two factors are likely important in retirement decisions. However, they will work in opposite directions on retirement age, with real estate wealth enabling a earlier retirement and good health enabling a longer career.

B Non-parametric Elasticity Formula

The individual's maximization problem is

$$\underset{C,R}{Max} \quad U = C - \frac{R^{1+\frac{1}{e}}}{1+\frac{1}{e}}$$

$$s.t.$$

$$C \;=\; \int_{a_0}^{R} w_t \times (1-\tau_c) \quad dt \;+ \int_{R}^{T} B(R) \quad dt$$

where $B(R) = k_R \times (R - a_0) \times w_R^f$. The individual considered here retires at a tangency between the lifetime budget constraint and his indifference curve in both the prereform and postreform periods, so

$$\frac{dU}{dR}|_{R_H^*} = \frac{dU}{dR}|_{R_K} = 0$$

In the postreform period

$$(R_H^*)^{\frac{1}{e}} = w^{Post}$$

and in the prereform period

$$(R_K)^{\frac{1}{e}} = w^{\mathrm{Pr}e}$$

Solving for e

$$\frac{(R_H^*)^{\frac{1}{e}}}{(R_K)^{\frac{1}{e}}} = \frac{w^{Post}}{w^{\mathrm{Pr}e}}$$

$$e = \frac{\ln R_H^* - \ln R_K}{\ln w^{Post} - \ln w^{\mathrm{Pr}e}}$$

where w^{Pre} and w^{Post} are the net wages at retirement age R_K in the prereform period and R_H^* in the postreform period respectively.

From equation (6), with the assumption that $\frac{dw}{dS} = 0$,

$$
\begin{aligned}
w^{Post} = \quad & w_{R_H^*} \times (1-\tau_c) + \frac{dk_{R_H^*}^{Post}}{dR} \times w_{R_H^*} \times (R_H^* - a_0) \times (T - R_H^*) \\
& + w_{R_H^*} \times (k_{R_H^*}^{Post} \times (T - R_H^*) - k_{R_H^*}^{Post} \times (R_H^* - a_0))
\end{aligned}
$$

and

$$
w^{\mathrm{Pre}} = w_{R_K} \times (1-\tau_c) + w_{R_K} \times (k_{R_K}^{\mathrm{Pre}} \times (T - R_K) - k_{R_K}^{\mathrm{Pre}} \times (R_K - a_0))
$$

C Derivation of Empirical Likelihood Function

The likelihood function for retirement on a kinked two-segment budget constraint considers retirement on a budget constraint segment and on the kink.

The individual labor supply as derived from the first order condition, for utility $U(C,R) = C - \frac{R^{1+\frac{1}{e}}}{1+\frac{1}{e}} \times \alpha$, $\alpha = \exp(\beta X - \eta)$, and $\eta \tilde{} N(\mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}}^2)$ is

$$
\ln R_i^* = e \ln w_i^{net} - \tilde{\beta} X_i + \tilde{\eta}
$$

Segment Retirement ($s_i = 1$)**:**

The probability of observing an individual retire at R_i on a budget constraint segment is the probability that $\ln R_i = \ln R_i^*$

$$
\Pr(R_i = R_i^* | w_i^{net}, X_i) = \phi(\frac{\ln R_i - e \ln w_i^{net} + \tilde{\beta} X_i - \mu_{\tilde{\eta}}}{\sigma_{\tilde{\eta}}})
$$

where $\phi(x)$ is the normal probability density function with mean 0 and standard deviation 1.

Kink Retirement ($K_i = 1$):

The conditional probability of observing an individual retire at the kink R_K is the probability that

$\ln R^*_{L,i} \leq \ln R_K \leq \ln R^*_{H,i}$

$$\begin{aligned}
\Pr(R_i &= R_K | w^{net}_{H,i}, w^{net}_{L,i}, X_i) = \Phi(\frac{\ln R_K - e \ln w^{net}_{L,i} + \widetilde{\beta} X_i - \mu_{\widetilde{\eta}}}{\sigma_{\widetilde{\eta}}}) \\
&- \Phi(\frac{\ln R_K - e \ln w^{net}_{H,i} + \widetilde{\beta} X_i - \mu_{\widetilde{\eta}}}{\sigma_{\widetilde{\eta}}})
\end{aligned}$$

where $\Phi(x)$is the normal cumulative density function with mean 0 and standard deviation 1

Log Likelihood

$$\begin{aligned}
\log L(R_i) &= s_i \times \log(\phi(\frac{\ln R_i - e \ln w^{net}_i + \widetilde{\beta} X_i - \mu_{\widetilde{\eta}}}{\sigma_{\widetilde{\eta}}})) \\
&+ K_i \times \log(\Phi(\frac{\ln R_K - e \ln w^{net}_{L,i} + \widetilde{\beta} X_i - \mu_{\widetilde{\eta}}}{\sigma_{\widetilde{\eta}}}) \\
&- \Phi(\frac{\ln R_K - e \ln w^{net}_{H,i} + \widetilde{\beta} X_i - \mu_{\widetilde{\eta}}}{\sigma_{\widetilde{\eta}}}))
\end{aligned}$$

where s_i is an indicator for retirement on a segment and K_i is an indicator for retirement on the kink.