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

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Abstract

Despite an extensive literature on the link between pension programs and retirement timing, there is still no consensus on whether program features – like the relative reward for an additional year of work – have large or small effects on individual behavior. An important obstacle to identification is that individuals may sort into jobs with pension features that match their desired retirement timing, leading to potential biases in the observed cross-sectional relationship of pension parameters and retirement behavior. In this paper, I use the variation created by a major, unanticipated reform of the pension program for California teachers to provide quasi-experimental evidence on the link between pension generosity and retirement timing. Unlike most workers, California teachers are excluded from Social Security. They also have permanent job tenure, predictable wages, and face a "once for all" retirement decision. These features greatly simplify the interpretation of the impacts of the program reform. I use two large administrative datasets to conduct a reduced-form analysis of the pension reform, and to estimate a structural model of retirement timing. Both the reduced-form analysis, and the results of the structural model show 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 center around 0.02, with an upper bound at 0.10. These estimates suggest that deadweight losses associated with behavioral reactions to pension program parameters are relatively small. I also compare the predictions of the structural model to the predictions of the prevailing reduced-form alternative seen in the literature, the "peak value" model, and find that the structural estimation better captures the composition of the observed response to the reform.

1 Introduction

With the baby-boom generation approaching retirement age, there is a growing awareness of the role of public and private pensions in determining the labor force participation rate of the older population. Public officials and private pension managers are considering a variety of reforms to reduce the burden of pension obligations on younger workers and shareholders. Central to the debate surrounding pension reforms is the degree to which program features – like the reward for an additional year of work embedded in the pension formula – affect retirement timing.

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 retirement incentives. For example, while Rust and Phelan (1997) conclude that Social Security creates significant disincentives to labor force participation and is largely responsible for the observed peaks in retirement at ages 62 and 65, Krueger and Pischke (1992) find that changes in Social Security generosity cannot explain trends in labor force participation rates among older men. A key concern in this literature is 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. As in other contexts, endogenous sorting makes it very difficult to infer the true causal effects of the pension features.

I address this issue with a quasi-experimental approach and present new evidence on the effect of pension generosity on retirement behavior. The source of identifying variation is a large, unexpected reform to the California State Teachers' Retirement System (CalSTRS), which doubled the financial return to delaying retirement between the ages of 60 and 63. The CalSTRS system is the ideal environment for isolating the impact of pension financial incentives on retirement timing because California teachers do not participate in Social Security, they face a rigid wage schedule, and they have no discretion over per-period employment intensity.

In this simplified context, the teacher retirement decision is captured by a non-stochastic "lifetime budget constraint" model. This model makes strong predictions for the age and service distributions of retirements when the budget constraint is not linear, including bunching of retirements at convex kinks and at discontinuities. Looking at the data, the distributions of retirees in both the pre- and post-reform periods, where the reform altered the nonlinear features of the budget constraint, provide clear evidence that teacher response to the pension reform is consistent with theoretical predictions. Using a reduced-form method adapted from Saez (2002), I use the change in the kink point of the budget constraint to estimate the compensated elasticity of retirement age with respect to the financial return to working. The magnitude of these estimates is quite small, less than 0.02 in the medium-run with a long-run upper bound of 0.10. This implies that there is little efficiency cost from distortions created by the program

Next I apply nonlinear budget constraint estimation (Burtless and Hausman, 1978), extended to allow identification off the program reform, to estimate a full structural model. Using this method, the estimates of the elasticity of retirement age with respect to the annual financial return to working are centered around 0.02, on the same order as those obtained from the reduced-form. These estimates imply that the average teacher will delay retirement by $1\frac{1}{2}$ months if the annual financial return to working increases by 10 percent or about $7500.

Finally, I compare the predictions of the structural model to those of the prevailing non-structural estimation method seen in the literature, the "peak value" model. I find that the peak value predictions for retirement behavior following the CalSTRS reform deviate from the predictions of the standard lifetime labor supply model used in the structural estimation. Because the structural model better captures the behavioral response of California teachers to the reform, this suggests that the peak value method may not always be valid. The deviation of the two estimation methods is explored further, both theoretically, and through a simulation exercise.

The remainder of this paper is organized as follows. I begin in Section 2 with a brief review of the retirement timing literature, and in Section 3 I provide an overview of the CalSTRS defined benefit program, the reforms to the program, and the data used in this study. Given this setting, Section 4 introduces a simple lifetime budget constraint model to capture the teacher retirement decision. Results for the reduced-form analysis are provided in Section 5, and for the structural analysis in Section 6. Section 7 then compares the predictions of the structural estimation method to the reduced-from "peak value" approach, and Section 8 concludes.

2 Literature Review

Ideally, to identify the causal effect of retirement program financial incentives on retirement behavior, one must identify a source of variation in financial incentives that is exogenous to retirement preferences. However, there are few existing studies that identify the relationship between retirement timing and retirement program financial incentives from potentially exogenous reform-based variation. Krueger and Pischke (1992) is the only study to examine the effect of a permanent change in benefits. They examine the effect of Social Security on retirement timing using a decline in benefits for the "notch babies" as natural experiment. They find that the effect of Social Security financial incentives is small. The most closely related studies are those by Lumsdaine et al. (1990) and Pencavel (2001), which examine the response of employees when offered a temporary financial incentive to retire early. The Lumsdaine et al. study estimates a reduced-form accrual and option value model, the structural option value model, and a dynamic programming model in the cross-section and compares the predictions of these model to the actual retirement behavior under the retirement window plan. They find the structural models perform significantly better than the reduced-form models in predicting retirement under the window plan, and the option value model matched actual outcomes most closely. Pencavel, on the other hand, finds it is difficult to predict the response of individual retirement behavior under the University of California retirement incentive program.

The majority of studies do not use reform-based identification, but rather employ cross-sectional or longitudinal variation in pension incentives. The identifying assumption is that retirees facing these diverse incentives are otherwise identical. Yet, cross-sectional variation in pension incentives is driven by differences in wages, work history, and employing firm, which may be correlated with unobserved preferences over financial compensation and leisure. As these same preferences influence the retirement timing decision, the financial incentives will be endogenous and estimates of their impact biased. In the case of longitudinal studies, it is unclear if variation in benefits is spuriously correlated with existing trends in retirement age.

Although most studies are similarly identified, several reduced-form and structural estimation strategies have been employed. The advantage of the structural estimation is that it places the retirement decision firmly in a lifecycle framework and the estimation results are economic parameters of interest, such as price elasticity. Burtless (1986) used a lifetime budget constraint model to describe the retirement decision. He estimates the impact of Social Security on retirement during the 1970s when benefit levels were changed several times, and finds that Social Security generosity impacts the retirement . This work was criticized because it does not allow for uncertainty or updating of the retirement decision. Gustman and Steinmeier (1986) also estimate a model without uncertainty with RHS panel data and find that Social Security financial incentives predict observed retirement behavior.

More recent work has addressed the retirement decision as a dynamic process in an environment of uncertainty. In these models individuals re-evaluate their retirement date each period based on new information that may affect either disutility of or the financial return to working. Rust and Phelan (1997) is one of the most comprehensive treatments, linking the economic incentives of both Social Security and Medicare to the retirement behavior of males in the U.S., especially to the propensity to retirement at ages 62 and 65. Dynamic programming estimation tends to be computationally intensive, so their use has been limited.

In response to this complexity, Stock and Wise (1990) introduced the option value model[1], a less complex structural model. However, even this simplified structural estimation was not adapted in the literature, though it led Coile and Gruber (2000) to introduce new reduced form take-off of the option value framework. They define the "peak value" incentive measure as the difference between expected pension wealth for retirement today and the maximum expected pension wealth across all future retirement dates. This incentive measure is an explanatory variable in a simple probit or logit estimation. Since its introduction, the peak value approach has been used in many studies, including a volume of cross country comparisons edited by Gruber and Wise (2004) and work on the retirement of U.S. federal civilian employees by Asch et al. (2005). These studies typically find a strong negative relationship between the probability of retirement and the incentive measure. Ease of estimation is an advantage of this approach but the estimates can not be directly related to economic parameters of interest. Simulation is often used to give meaning to the estimates, but, as will be addressed in this paper, the predicted retirement outcomes may not match those of a standard utility maximizing model of lifetime labor supply, so the interpretation of the estimates remains unclear.

The vast retirement literature has greatly advanced our thinking about the effect of pensions and Social Security on retirement timing. However, there is still no firm consensus on the magnitude of this effect. This study uses a pension reform as a source of exogenous variation in retirement program financial incentives to overcome the potential biases faced in previous studies. The reform is also leveraged to compare the predictions of structural estimation with the prevalent reduced-form method.

[1] The "option value" measures the incentive to continue working as the difference between the lifetime utility for retiring today and the maximum lifetime utility for a future retirement date.

3 Background

3.1 CalSTRS Defined Benefit Program

Educators employed in the California K-12 public schools and state community colleges participate in the California State Teachers' Retirement System (CalSTRS). CalSTRS is the largest teacher retirement system and the third largest retirement system for public employees in the United States. As of June 30, 2005, CalSTRS membership included 450,282 active members and 176,008 service retirement benefit recipients[2] and the market value of CalSTRS net assets was over $129 billion[3]. The retirement system is financed through contributions from active members, employing school districts, the State General Fund, and investment earnings[4].

The Defined Benefit Program is the oldest and largest component of the retirement system. It is quite similar to many public and employer-sponsored defined benefit retirement programs. Participation in this program is mandatory for full-time employees. While employed, members contribute 8% of salary[5] and are vested after five years of CalSTRS covered employment. Each retired CalSTRS member receives a lifetime annuity with an annual value calculated according to the following formula:

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

This "unmodified allowance"[6] is a function of years of service S, final compensation[7] w^f,

[2] CalSTRS members also included 124,394 inactive members and 25,33 disability and survivor benefit recipients.

[3] CalSTRS (2005a)

[4] CalSTRS investments include stocks, bonds, and real estate. The fund earned an over 13% return on investments for the fiscal year ending June 30, 2006. (CalSTRS 2006)

[5] Beginning in January 2000, 25% 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, currently 5%, which is set annually by the Teachers' Retirement Board.

[6] Teachers can also purchase one of the program's joint survivor annuity options. Payments under this options are proportional to the size of the unmodified allowance.

[7] Final compensation is the average salary paid to the teacher over the final three years of service.

and a proportionality constant k. The value of the proportionality constant ranges from $1.4\% - 2.4\%$, and is increasing in retirement age R and years of service S. The earliest age at which a member can begin receiving this allowance is referred to as the "early retirement age," and is age 55 for most members[8].

The CalSTRS defined benefit program is relatively generous. A teacher that works for 20 years in the California public schools[9] and retires at age 60 will have a retirement allowance equal to 40% of her final salary[10]. Given the program generosity and the fact that California teachers do not participate in Social Security, it is conceivable that the response of California teachers to the CalSTRS reforms will reflect the sensitivity of retirement timing to pension financial incentives.

3.2 CalSTRS Reform: 1999 Benefit Improvements

In August of 1998, the California State Legislature passed two bills, AB 1102 and AB 11150, which increased the generosity of the CalSTRS Defined Benefit program. The two reforms mandated by these legislative bills are referred to as the Enhanced Age Factor and the Career Bonus. These reforms applied to the allowance calculations for teachers retiring on or after January 1, 1999 and their potential impact on retirement benefits was quite large. Post-reform the financial return to working an additional year at age 60 nearly doubled. The annual allowance increased by 20% for retirements at age 63 and by at least 10% for retirements after 30 years of service. Despite the anticipated increase in outlays, this legislation did not impose an increase in member contributions to the defined benefit program.

The 1999 reforms were unanticipated, but they were salient to CalSTRS members. Both

[8] Members that are at least age 50 and have a minimum of 30 years of service may retire under the "30 and Out" alternative. The proportionality constant is reduced, from 2.0%, by .0012% for each year before age 60 that the individual retires. The first retirements under this alternative are observed in 2004.

[9] Teachers are able to move freely between schools throughout the state without affecting CalSTRS enrollment.

[10] This is likely more generous than the average Social Security payment, which is 40% of average annual *lifetime* earnings at the later retirement age of 65. Social Security Administration (2006)

AB 1102 and AB 1150 were introduced in their final form just days before the legislative vote. The success rate of prior legislative initiatives was quite low; there had been no changes to allowance calculations since 1972. After the bills passed, the CalSTRS population was quickly and effectively informed via the Fall 1998 Bulletin[11]. The front page of this document is shown in Figure 1. The newsletter contained a detailed description of the reforms along with examples of how these reforms created a change to both the allowance level and its growth for continued work at different age and service combinations.

The legislated reforms altered the pension program solely through changes to the proportionality constant, k in equation (1), while the structure of the program and the general allowance formula remained intact. The Enhanced Age Factor raised the maximum value for the proportionality constant from 2.0% to 2.4%. The effect of this change can be seen by comparing the pre-reform schedule in column (1) of Table 1 with the post-reform schedule in column (2). The schedules are identical up to age 60 with the proportionality constant increasing at an annual rate of .12% from 1.4% at age 55 to 2.0% at age 60. In the post-reform schedule, the new cap is reached by continuing to work beyond age 60, during which time the proportionality constant increases by .133% annually to 2.4% at age 63. The second reform, the Career Bonus provides a onetime increase of .2% in k when 30 years of service is completed. Column (3) of Table 1 shows the continuation of the post-reform schedule after 30 years of service is reached.

The interaction of the two reforms creates cross-sectional variation in the post-reform proportionality schedule. For all individuals the k cap is no longer reached at age 60, however the age location of the post-reform cap of 2.4% 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 of service are not worked before this age. Also, the .2% jump in k only occurs at thirty years of service if the cap of 2.4% has not already been reached, so the Career Bonus only affects those that will have thirty years of service before age 63.

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

3.3 Data Description

Two administrative datasets are used to study the response of retirement timing to the CalSTRS pension financial incentives. The first dataset was constructed using information supplied by the CalSTRS administrative office. The advantage of this data is that it covers the entire CalSTRS population for several years before and after the 1999 reforms. However, in order maintain member confidentiality, only aggregate data was provided. The constructed dataset includes counts of new retirees in quarter-year age by half-year service bands for each year 1995-2003. There are over 74,000 retirement observations during this nine year period. Brief summary statistics for this data are presented in Table 2a. 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 was compiled from information provided by the Office of Personnel Research and Assessment in the Los Angeles Unified School District (LAUSD). LAUSD is the largest California public school district, employing over 10% of CalSTRS members. This district data is at the individual level and covers the district population of active teachers age 45+ and new retirees for the years 1997-2004. The data includes age, years of service within LAUSD, and salary for each teacher. Summary statistics for both the active population that is age eligible for retirement and for retirees are shown in Table 2b. The primary advantage of this data over the aggregate data is that it includes each teacher's salary, which is essential for the structural analysis. However, only the number of years that each teacher has worked in the LAUSD is available, while it is total CalSTRS covered service that is used to calculate the defined benefit allowance[12].

[12] All estimation results presented treat LAUSD service as total CalSTRS service. Using imputed values of total CalSTRS service did not change results.

4 Model of Lifetime Labor Supply

A simple lifetime budget constraint model captures the major financial incentives of the CalSTRS defined benefit program 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 tradeoff between retirement leisure and consumption of market goods. Although this non-stochastic framework does not allow for uncertainty, it is adequate to describe 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 or days of work per year, so the only decision is to work full-time or to retire. Also, retirement financial incentives are easy to calculate because CalSTRS members do not participate in Social Security.

4.1 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 labor S. An individual's utility in each period is assumed to be additively separable in consumption and leisure, so that $u(c_t, l) = v(c_t) - \phi_t \times l$, where ϕ_t is the disutility from working in period t and l takes the value 1 if the individual works in that period and is zero otherwise. As utility is separable the individual's lifetime utility is given by

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

where T is the last period of life. 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

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

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 for each period of work, is the solution to the following constrained utility maximization problem:

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

Here the interest rate is assumed to be zero[13] and the budget constraint is linear with slope w. The lifetime labor supply S^* that solves the first order condition, so that $\frac{-U_S}{U_C}|_{S^*} = w$, will reflect the utility maximizing retirement date provided the budget constraint is smooth and convex and $U_{SS} = -\phi'_S < 0$, which indicates that the disutility of labor is increasing in lifetime labor supply. The utility maximizing career length, S^*, is given by the tangency of the indifference curve to the budget constraint. The slope of the budget constraint can also be interpreted as the price of retirement.

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. As the wage increases, the individual is able to consume more for any retirement date. This creates the incentive to retire earlier. However, as the wage increases, the consumption payoff for an additional year of work is also greater. This encourages substitution away

[13]This assumption can be loosened, with a similar outcome.

from time in retirement toward consumption.

Even with this simple framework, any variation across the population in wages and preferences will create a distribution of observed retirement ages in aggregate. With this heterogeneity, the ratio of marginal utilities and the price of retirement at each age are individual specific, so the point at which the first order condition holds and retirement occurs is also individual specific. The exact nature of the distribution of retirements will be a function of underlying population wage and preference distributions. However, given smooth underlying distributions, the observed retirement pattern will also be smooth.

4.2 Retirement Decision with CalSTRS Defined Benefit Program

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 plan. Assuming an interest rate of zero and a known length of life T the pension wealth for any retirement date R, the budget constraint for a CalSTRS member can be written

$$C = \int_{t=0}^{S} w_t(1 - t_c) \quad dt \ + \int_{t=R}^{T} B(R, S) \quad dt \tag{2}$$

where $B(R, S) = k(R, S) \times S \times w^f$ is the annual retirement allowance as given by equation (1). Consumption is a function of earnings w and w^f, the contribution rate t_c, years of work S, retirement age R, and the retirement program parameter k. With the defined benefit plan, consumption is not only a function of the total years of work before retirement but also depends explicitly on age at retirement. However, this relationship can be simplified by assuming that one additional year of work is equivalent to retiring one year later, specifically $R = S + a_0$, where a_0 is a constant[14]. With this assumption, the retirement decision can

[14] This is equivalent to assuming that the individual will not have a discontinuous work history preceding the official retirement date. It is a reasonable assumption in this study, which examines behavior very close

be rewritten as either a choice over service alone or over retirement age alone. Throughout the paper, retirement age and years of work will be used interchangeably and the choice of specification will be determined by the incentive under study.

The CalSTRS defined benefit system alters the shape of the budget constraint by changing both the price of retirement and the level of consumption at each retirement age. It is clear from equations (1) and (2) that consumption is increasing in salary w and in the proportionality constant k that is used to calculate the retirement allowance, however its relationship to retirement age R in varies. 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 defined benefit system and the change in pension wealth for delay of retirement. For any retirement age R, this "net wage" can be written as

$$\frac{dC}{dR} = w_R \times (1 - t_c) + \frac{d}{dR} \int_{t=R}^{T} (k(R) \times (R - a_0) \times w_R^f) \quad dt$$

If wage earnings are assumed to be constant, the slope can be rewritten as

$$\frac{dC}{dR} = w_R \times [1 - t_c - k(R) \times (R - a_0) + (\frac{dk}{dR} \times (R - a_0) + k)(T - R)] \tag{3}$$

The budget constraint slope, or price of retirement, is a multiple of annual salary. The first component inside the square brackets, t_c, is the contribution rate to the defined benefit program. The second and third terms taken together are the total change to pension wealth for a small increase in retirement age. The second term is the retirement allowance, as a fraction of annual salary, 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. The distortion created by the defined benefit program is given by the sum of these three terms. If the sum is positive the defined benefit program acts as a subsidy to wage earnings, and if the sum is negative it acts

to retirement from a career position.

as a tax. The net wage is increasing in w and decreasing in t_c, while the relationship to R is again unclear. The net wage is increasing in k if time spent working $R - a_0$ is smaller than time that will spent in retirement $T - R$, and decreasing in k otherwise. A key feature is that the net wage is also positively related to the growth of the proportionality constant for an additional year of work $\frac{dk}{dR}$.

The relationship of the budget constraint to k is of particular interest because the schedule of the proportionality constant creates nonlinearities in the individual budget constraint at the same ages and service levels for all CalSTRS members. The CalSTRS reforms, which are effected through the proportionality constant, create and dissolve these nonlinearities. This is a strong source of identification as the nonlinear features generate unambiguous predictions for aggregate retirement behavior in the pre- and post-reform period.

The first of these nonlinearities is a budget constraint kink that occurs at the age where the proportionality constant cap is reached. Once k takes the maximum value allowed under each regime, it's growth which was constant and positive to this point at $\frac{dk}{dR} > 0$, immediately falls to zero, $\frac{dk}{dR} = 0$. At this age the third term of equation (3) will fall causing the slope of the budget constraint to decrease sharply. This change in slope creates a convex kink in the lifetime budget constraint, at age R_K, as depicted by the solid line in Figure 2. At younger ages, $\frac{dk}{dR} > 0$, so that the net wage w_H^{net} on the portion of the budget constraint preceding R_K is greater than the slope w_L^{net} at older ages. An individual will find R_K optimal if $w_L^{net} \leq \frac{-U_R}{U_C}|_{R_K} \leq w_H^{net}$. That is, when faced with a linear budget constraint of slope w_H^{net} and intercept zero, the individual would retire at $R_H \geq R_K$ as shown by indifference curve H. If instead the budget constraint had slope w_L^{net} and intercept Y_L^v, she would retire at $R_L \leq R_K$ as shown by indifference curve L.

If the kink is located at the same age, R_K, for all member, this retirement age will be favored even when preferences and wages are distributed smoothly across the population. This occurs because the budget constraint kink is the optimal retirement age for individuals with a range of preferences, anyone for whom the marginal utility of working relative the marginal utility of consumption at R_K is between w_H^{net} and w_L^{net}. This is in contrast to the case of a linear budget constraint, in which individuals will only retire at R_K if their first order condition holds with equality. The additional retirements observed at R_K when the budget constraint is kinked, relative the linear budget constraint, are "excess retirements". The extent of the bunching at the kink point is proportional to the the compensated elasticity of retirement timing with respect to the net wage.

The second nonlinearity is a discontinuity in the budget constraint that occurs when k increases sharply at a threshold value of service S_D, as it does with the Career Bonus. At this point the change in the proportionality constant is positive for an infinitesimal change in service. As a result, the growth of the proportionality constant which was constant and positive up to this point at $\frac{dk}{dS} > 0$ goes to $\frac{dk}{dS} \to \infty$. As this jump in the value of the proportionality constant occurs at a particular level of service, its impact on the individual lifetime budget constraint will also be discussed in the service dimension. The slope of the budget constraint can be redefined over service by replacing $R - a_0$ in Equation. 3 with S, with the result that

$$\frac{dC}{dS} = w_S \times [1 - t_c - k(S) \times S + (\frac{dk}{dS} \times S + k)(T - S - a_0)] \tag{4}$$

At labor supply S_D, the slope of the budget constraint will be driven to infinity through the third term of equation (4). This change in slope will create a discontinuity in the lifetime budget constraint at S_D, as depicted in Figure 3.

Like the budget constraint kink, the discontinuity will be the optimal retirement date for 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 move to S_D if $U(S_D) > U(S^*)$. The indifference curve in Figure 3 shows the case where utility at $S^* = S_c$ is exactly equal to utility for retirement at S_D. Anyone for whom $S^* > S_c$ will retire at S_D. If the discontinuity appears at the same service level S_D for all individuals, a reduction in the density of retirements preceding the discontinuity and an excess of retirements at the discontinuity, relative the distribution with a linear budget constraint, will be observed.

5 Reduced-form Analysis

As was shown in the previous section, when budget constraint nonlinearities exist, the lifetime budget constraint model makes strong predictions for the shape of the aggregate retirement distribution across age and service. The reforms to the CalSTRS defined benefit program alter the age and service location of budget constraint nonlinearities, and do so 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. The changing shape of the retirement distribution is exploited to test that individuals respond to retirement program financial incentives and to estimate the compensated elasticity of retirement timing with respect to price. The magnitude of the compensated elasticity determines the potential of the CalSTRS retirement program to distort the individual choice over consumption and retirement and create deadweight burden.

In order to examine these predictions, the pre- and post-reform retirement distributions must be compared. The age and service retirement distributions are constructed using the aggregate system-wide CalSTRS administrative data for the pre-reform years 1995-1998 and the post-reform years 1999-2003. 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 to construct the distributions for the pre- and post-reform periods.

5.1 Pre-reform Retirement Timing

Individuals with differing work histories face different budget constraints near retirement, both in terms of level of consumption and slope. However, one feature that is uniform across all individuals in the pre-reform period is a convex kink in the budget constraint at age 60.

This occurs because the proportionality constant reaches its cap of 2.0% here, so $\frac{dk}{dR} = 0$ and, as was shown in the previous section, this causes the net wage beyond age 60 to be lower than it is at ages less than 60. The net wage for continued work is approximately 1.2 times the annual salary[15] before age 60. After age 60, the net wage falls to only about 60% of the annual salary. This 50% decline in the financial return to work creates a kink in the budget constraint [16]. A stylized budget constraint[17] for a CalSTRS member with the median service history is shown by the dashed gray line in Figure 4. As was shown in Section 4, the lifetime budget constraint model predicts a bunching of retirements at the age 60 kink.

The average age distribution of annual retirements for the pre-reform period is shown in Figure 5. For each retirement age R, the fraction includes all retirees retire at ages $\epsilon[R, R + .25)$. In the pre-reform period, over 8.5% of retirements take place within the three months following the individuals' 60^{th} birthdays. If the three month period before age 60 is included, 13.5% of retirees are found to retire at the kink point. This is over twice the fraction of retirees found in any other six month age range.

This distribution provides evidence that CalSTRS members have a strong preference for retirement at age 60 under the pre-reform defined benefit program. Yet, it is not clear how prominent the financial incentives of the defined benefit program are in the formation of this preference. The inclination to retire at age 60 may be attributable to other characteristics of the retirement program, such as a focal effect of age 60 as it is considered the "normal" retirement age, or to factors outside the retirement program that make this a desirable retirement age for many members. It is not possible to disentangle the impact of financial incentives from these other factors through analysis of a static defined benefit

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

[16] The net wage is also declining by about .04 times salary for each year retirement is delayed, but this change is very small relative the difference in net wage to either side of the budget constraint kink.

[17] This and all "stylized" budget constaints were constucted as seen from age 55, assuming an annual discount factor of .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.

system. These confounding factors and unobserved variable bias in the cross-section may cause an overestimation of the impact of financial incentives on retirement timing.

5.2 Post-reform Retirement Timing

The Enhanced Age Factor and the Career Bonus alter the individual budget constraint on both the age and service dimensions, and do so differentially across various age by service groups. The two features that generate the strongest predictions for post-reform retirement behavior are the shift in the age location of the budget constraint kink and the creation of a discontinuity in the budget constraint at thirty years of service.

The Enhanced Age Factor increased the cap on the proportionality constant from 2.0% to 2.4% , but did not change the rate at which the proportionality constant grows between ages 55 and 60. As a result, the cap is no longer reached at age 60 and the proportionality constant continues to increase at roughly the same rate $\frac{dk}{dR} > 0$ at age 60 and beyond until the new cap of 2.4% is reached and $\frac{dk}{dR}$ falls to zero. This change removed the budget constraint kink at age 60 for all individuals, and created a new kink where the 2.4% cap is reached.

The age location of the post-reform kink varies by years of service. 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 minimum 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% of the retiring population in each year, and will be the focus of the following discussion. The dark line in Figure 4 demonstrates the stylized post-reform budget constraint for a CalSTRS member. The kink at age 60 is removed and a new kink appears at a later age. The net wages preceding and following the kink are similar in value across reform periods.

The implications of the shift in kink point location are clear in the simple lifetime budget constraint model. In the pre-reform, the difference in the financial return to work or the price of retirement to either side of the age 60 kink was predicted to cause many individuals, with a range of preferences, to retire at this age. With the kink removed, there is no financial incentive in the defined benefit program that would generate excess retirements at age 60. The post-reform kink, at age $61\frac{1}{2}$ for the High Service group and at age 63 for the Low Service group, is now optimal for individuals with a range of preferences. It is predicted, then, that following the reform the density of retirements at age 60 will fall as the excess retirees delay retirement, while bunching will begin to occur at each group's new kink point. It should be noted that the behavior of the Low Service group provides a cleaner test of this prediction. The budget constraint of the Low Service group is altered by only a shift in the kink point. However, the High Service group attains 30 years of service before age $61\frac{1}{2}$, so there is a discontinuity[18] in the post-reform budget constraint, in addition to the shift in kink location. Due to this additional change to the budget constraint, the composition of the population that is still working at age 60 may have also changed, so the interpretation of the observed response is not as clear.

The average annual age distributions of retirement in the pre- and post-reform periods for High and Low Service groups are shown in Figures 6a and 6b respectively. Again, these figures show the fraction of annual retirees at each age. A common feature in the figures is that the density of retirements at age 60 ± 3 months drops by over $\frac{1}{3}$in the post-reform period, with 5% of retirees in the High Service group and 3% of retirees in the Low Service group moving away from the kink. 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% to 8%. In Figure 6b, the increase in retirements at the new kink of age 63 is not as clear, about a 50% increase from 2% to 3%. The smaller effect at this later age may be partially attributable to delayed transition between the pre- and post-reform equilibriums. This will be discussed in greater detail in Section 5.4. Evidence of new bunching at the age that coincides with the group-specific post-

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

reform kink further supports the causal link between the reform-based change in financial incentives and the observed change retirement timing.

The second reform, the Career Bonus, added .2% to the proportionality constant at 30 years of service, provided the cap on k had not already been reached. This creates a discontinuity in the budget constraint at the 30 years of service for those subject to the reforms. The stylized budget constraint, with consumption as a function of service, is shown in Figure 7[19]. The effect of the reform is reflected by the shift from the gray dashed line to the solid black line. Everyone in the affected population has a discontinuity at exactly thirty years of service. The magnitude of the discontinuity is approximately equal to the annual salary for the median CalSTRS retiree.

This change makes a strong prediction for the retirement pattern observed on the service dimension following the reform. Prior to the reform, the CalSTRS budget constraint did not contain any nonlinear features that occurred at the same level of service for a large fraction of the population. A smooth distribution of retirees is expected under the pre-reform structure of incentives. With the introduction of the discontinuity, it becomes optimal for some individuals that were previously retiring with less than 30 years of service to delay retirement until thirty years of service. In aggregate, as individuals move from $S^* < 30$ to $S = 30$, this would be observed as a decrease in the density of retirements at service levels directly preceding 30 years of service. Additionally, these delayed retirements are predicted to be located at exactly 30 years of service, creating excess density at this point.

Members of the CalSTRS population are differentially affected by the Career Bonus. Those that reach age 63 before attaining 30 years of CalSTRS service credits, the Low Service group, do not have a discontinuity because they will reach the cap on the proportionality constant before they would have the service necessary for the Career Bonus. The High Service group on the other hand will have a discontinuity at exactly 30 years of service.

[19] The budget constraint kink does not occur at the same service level across individual budget constaints, 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.

The average annual service distribution of retirements in the pre- and post-reform periods for the affected High Service group is shown in Figure 8a. Comparing the post-reform to the pre-reform, 4% 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 post-reform. 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 post-reform, but the post-reform density does not quite catch-up to the pre-reform density until 31 years of service. Transition factors that might account for retirements at 30 years of service falling short of predictions will be discussed in the following section.

For the Low Service group, there was no change to the budget constraint on the service dimension. The retirement density of this group is not expected to change following the reforms, and there are no retirement dates that members are predicted to avoid or to find any particularly attractive. The retirement pattern for this group is depicted in Figure 8b. The pre- and post-reform distributions are similar and show no preference for retirement at a particular service level.

5.3 Non-parametric Elasticity Estimation

The distribution of CalSTRS retirements, over both age and service, shifted following the defined benefit reforms. These changes can be quantified in a meaningful way by adapting a method introduced by Saez (2002) to estimate the compensated elasticity of retirement timing. This method exploits the magnitude of excess retirements at budget constraint kinks, making it apt for the CalSTRS reform. The adapted model is briefly outlined and estimated below.

The compensated elasticity of lifetime labor supply for a small change in the slope of the lifetime budget constraint[20] at a point S is

$$e = \frac{dS}{S} \times \frac{w^{net}}{dw^{net}}$$

The net wage faced by CalSTRS members is the annual salary net of contributions plus the change in pension wealth for delayed retirement. Due to the highly structured salary schedule and simple pension formula, this value is easily calculated. Only the change in lifetime labor supply, dS, is needed to estimate the compensated elasticity.

The change in lifetime labor supply for a given change in net wage can be estimated from the bunching that occurs at a budget constraint kink when this feature is introduced to a linear budget constraint. Consider a population faced with a linear budget constraint of slope w_H^{net}, with each individual retiring at the service level S^*, such that for each the ratio of marginal utility of labor to marginal utility of consumption is equal to the net wage. Preferences are assumed to be smoothly distributed across the population so that the S^* is smoothly distributed $\tilde{}f(s)$. If a kink is introduced to the budget constraint, so that the slope falls to $w_L^{net} < w_H^{net}$ for $S\epsilon[S_K, T - a_0]$ individuals with $S^* > S_K$ may adjust their retirement dates. There exists an individual that will adjust retirement from S_H^* to S_K, and who's indifference curve will be exactly tangent to the upper segment of the budget constraint at S_K, so that $\frac{-U_S}{U_C} = w_L^{net}$, as shown in Figure 9. The change in lifetime labor supply for this individual is $dS = S_H^* - S_K$, is the one relevant to calculating the compensated elasticity for the change in price of retirement $dw^{net} = w_H^{net} - w_L^{net}$. Though S_H^* is not observed, it can be estimated by noting that all individuals with a lifetime labor supply of $S^*\epsilon[S_K, S_H^*]$ when faced with the linear budget constraint of slope w_H^{net} will also locate at S_K when the kink is introduced. These individuals are the excess kink retirements and their total number is given by $N^E = \int_{S_K}^{S_H^I} f(s)ds$, where $f(s)$ is the density of retirees when the budget constraint is linear.

The CalSTRS reform removes (rather than introduces) the kink at age 60 for all members,

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

replacing it with an approximately linear continuation of the first segment of the pre-reform budget constraint. As the kink is on the age dimension, the compensated elasticity of *retirement age* with respect to price will be estimated[21]. The excess retirements at the kink, N^E, can be simply estimated as the change in the retirement density at age 60 moving from the pre- the post-reform 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 post-reform period. Assuming this density to be uniform in the vicinity of age $R_K = 60$[22], $dR = \frac{N^E}{f(r)}$ and the elasticity of retirement age with respect to price is

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

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 .6 times the annual salary, an over 50% decline in price. Therefore, the above formula can not be applied directly. Rather, a constant compensated elasticity 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 A.

The compensated elasticity is estimated for the entire CalSTRS population and also for the Low Service group alone. 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 post-reform budget constraint. However, estimations on the Low Service group are not necessarily representative of the full population behavior.

[21] 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 4, that $R = S + a_0$, and evaluating the expression at the average years of service for retirees of age 60.

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

Estimates for the compensated elasticity of retirement age with respect to net wage, based on the system-wide count data, are shown in columns (1) and (2) of Table 3. In the estimation individuals 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 groups 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 timing and the elasticity of years of work are less than .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% increase. Though noticeable, the decrease in retirements that occurred at age 60 following the reform was small relative the change in financial incentives.

5.4 Transition to New Equilibrium

In order for the estimated elasticities of the previous section to represent the long-run elasticity, the CalSTRS system must reach its post-reform equilibrium during the period under study. However, this may not occur for both mechanical and behavioral reasons. This section will discuss these sources of delayed response, evaluate the period for which the estimated elasticity is valid, and estimate an upper bound on the long-run elasticity.

The first reason the observation of the post-reform equilibrium retirement distribution may be delayed is simply mechanical. It is clear that 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, 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. For example, if all those that retired at age 60 in the pre-reform period would delay retirement to age 63 in the post-reform period, the increased density at age 63 would not be observed for 3 years. This is because the would-be movers that are ages 61 and 62 at the time of the reform had already retired at age 60. This alone could explain why the expected increases in retirements at age 63 and at 30 years of service were not observed in the post-reform retirement distributions.

The second reason that observation of the post-reform equilibrium retirement distribution may be delayed is behavioral. It may not be optimal for individuals to adjust their plans to the retirement date they would have chosen under the post-reform regime. Individual savings outside the pension system will be optimal for the planned pre-reform retirement age. If individuals have incentive to delay (accelerate) retirement in the post-reform period, the wealth effect of having "over-saved" ("under-saved") for the later retirement date (earlier), will mitigate their response. There may also be fixed costs for changing a planned retirement date that will outweigh the financial gain of adjustment. These costs may be associated with coordination of retirement with a spouse, sale/purchase of a home, or health care arrangements.

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 mechanical or behavioral factors were driving the delayed response. However, a large unknown behavioral delay would cause the retirement elasticity estimates to understate the true sensitivity of the population to the retirement program financial incentives. The portion of the delay that is attributable to behavioral factors 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 is plotted in Figure 10a. The time of the reform is marked by a break in the solid line. In the first year after the reform, retirements within three months of age 60 fell from about 12.5%

of the retiring population to about 9.5%, and trended slightly downward to 8% over the next 4 years. There was also a slight drop 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% of the total 5 year change in retirement density at age 60 occurred immediately after the reform became effective. The same plot is shown for the High Service group and the Low Service group separately in Figure 10b. A similar pattern is seen, aside from a more pronounced downward trend for the Low Service group from 2000-02. These figures suggest that the elasticity of retirement timing estimated from the change in retirement behavior following the reforms captures the medium-run response.

An upper bound on the long-run response can be estimated using the same "bunching method" employed in Section 5.3. In this case, it is assumed that the spike at age 60 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[23]. The difference between the pre-reform retirement density at age 60 and the baseline density are considered the excess retirements generated by the budget constraint kink. The excess retirements at age 60 are just over 8.5% 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 A.

These results are presented in columns (3) and (4) of Table 3. 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 .1 in all but one case[24].

[23] 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.

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

6 Structural Estimation

In the previous section the compensated elasticity of retirement timing was estimated using only information from the change in density of retirements at one age and service level. Structural estimation uses all the information conveyed by the changes in the retirement behavior of CalSTRS members and is able to accommodate additional controls.

The structural estimation extends the work of Burtless and Hausman (1978) to estimate a nonlinear budget constraint model with reform-based identification. This econometric method was developed to overcome the bias in estimates that resulted from estimating a linear model when the individual budget constraint had sharp nonlinearities. However, as discussed in the literature review, even when budget constraint nonlinearities are accounted for, estimates that rely on cross-sectional variation for identification may still be biased. The reform-based identification addresses this additional source of bias.

6.1 Empirical Model

A teacher's preferences over lifetime consumption (C) and retirement age[25] (R) are assumed to be described by the CES utility function

$$U(C,R) = C - \frac{R^{1+\frac{1}{e}}}{1+\frac{1}{e}} \times \alpha \tag{5}$$

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 are observable characteristics that influence preferences and η is an unobserved taste shifter. In the resulting specification the retirement age is chosen

[25] Equivalently, preferences could be described over consumption and *years of service.*

according to

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

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

The CalSTRS defined benefit program distorts members' lifetime budget constraints so that they are not linear. The member budget constraints can take one of three general shapes, determined by whether it is pre- or post-reform and by the individual service history. Estimation will be done only for the Low Service group, which faces a two-segment kinked budget constraint in both the pre- and post-reform periods.

The individual budget constraint is treated as piecewise linear[26], and defined over the eligible retirement ages[27] as follows

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

where Y^v and w^{net} are the intercept at age 55 and slope for each segment of the budget constraint. 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 ordinary least squares regression will result in perverse estimates. OLS estimates are presented in

[26] 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.

[27] Recall age 55 is the CalSTRS early retirement age.

Appendix B.

Hausman (1985) comprehensively addresses the econometrics of estimation with nonlinear budget constraints. In order to correct the bias described above, behavior around budget constraint nonlinearities must be explicitly incorporated into the model. The resulting model is estimated by maximum likelihood methods. Whereas previous work used this econometric advancement to overcome an estimation problem, it is used here to also best exploit the exogenous variation in financial incentives introduced by the reform.

Assuming η ˜$N(\mu, \sigma^2)$ across the Low Service population, the likelihood[28] for this group over the pre- and post-reform period period is

$$\begin{aligned}\ln L \quad = \quad & \sum_i s_i \times \ln\{\phi(\ln R_i - e\ln w_i^{net} + X_i\widetilde{\beta}, \mu_{\widetilde{\eta}}, \sigma_{\widetilde{\eta}})\} + \\ & \sum_i K_i \times \ln\{\Phi(\ln R_K - e\ln w_{L,i}^{net} + X_i\widetilde{\beta}, \mu_{\widetilde{\eta}}, \sigma_{\widetilde{\eta}}) \\ & -\Phi(\ln R_K - e\ln w_{H,i}^{net} + X_i\widetilde{\beta}, \mu_{\widetilde{\eta}}, \sigma_{\widetilde{\eta}})\}\end{aligned} \tag{6}$$

Here, s_i is an indicator for retirement on a budget constraint segment and K_i is an indicator for retirement on a kink. R_K is the age at which the kink occurs, age 60 in the pre-reform period and age 63 in the post-reform period, and w_H^{net} and w_L^{net} are the net wages just before and after the kink age. The parameters that will be estimated are the compensated elasticity $\widehat{e}$ and the mean and standard deviation of the unobserved taste parameter $\widetilde{\eta}$, $\widehat{\mu}_{\widetilde{\eta}}$ and $\widehat{\sigma}_{\widetilde{\eta}}$.

6.2 Implementation with Reform Identification and Results

By pooling the pre- and post-reform data and controlling for salary in a flexible way the elasticity of retirement timing with respect to the financial return to work is effectively identified from reform variation[29]. A final technical point for estimation is the assignment of retirements to the kink. Individuals that are responding to the financial incentives at

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

[29] This model was also estimated in the pre-reform cross-section, as it has been estimated in non-reform studies. Results are presented in Appendix Table D for comparison.

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[30] or processing the paperwork for retirement may take longer than expected. The likelihood derived above does not allow for this type of error[31], so only individuals that retire exactly at the kink location will 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.

The model in equation (6)[32] is estimated using the LAUSD individual-level administrative data. The maximum likelihood estimates for the Low Service population are presented in Table 4. The magnitude of the estimated elasticity echoes the small values of the nonparametric estimates. Six specifications are estimated and the point estimates are similar across all specifications, .0211-.0254, and are always significantly different from zero. Specification (1) includes no control variables. Salary controls are added to specifications (2) and (3) to limit identification to the reform-induced variation in financial incentives. The point estimate for elasticity decreases slightly once the controls are salary controls are added. Though the change is not significant, it suggests that elasticity estimates identified from cross-section variation would be upward biased. Specifications (4) - (6) add an indicator for retirement at age 60 to the first three specifications. The dummy for age 60 takes the value of 1 for retirements within 3 months of age 60 and is zero otherwise. When the age 60 indicator is the only control variable it is large and significant, however with the addition of wage controls it becomes small and highly insignificant.

The defined benefit program significantly alters the individual budget constraint and imposes strong nonlinearities. However, the small elasticity estimates imply that the program has only a small effect on teacher retirement.

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

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

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

7 Methodological Implications

Structural and reduced-form methods for empirically estimating the relationship between retirement timing and pension financial incentives each have different advantages. Typically the tradeoff considered is between ease of computation and interpretation of the estimates. The interpretation of the parameter estimates of the structural model is clear[33]; however these models quickly become difficult to estimate as the extent of the retirement incentives modeled increases. Structural models are prone to misspecification and may extenuate bias caused by unobserved heterogeneity.[34] Reduced-form models have the advantage of being easier to estimate and easily accommodate many explanatory variables which may improve the fit of the model. While the identification may be more transparent, the precise interpretation of the coefficient estimates is often unclear[35]. This is usually circumvented by simulating the response to reforms using model estimates.

With the introduction of the "peak value" model by Coile and Gruber (2000), a reduced-form offshoot of the Stock and Wise (1990) option value structural model[36], has advanced reduced-form estimation. This reduced-form application is innovative because, unlike earlier models, it explicitly recognizes that retirement terminates the option to work in the future, so the financial return to working in the current period may not capture the true tradeoff between lifetime consumption and leisure. The pension incentive measure - representing the reward to working an additional year - in this method summarizes the individual's forward-looking budget constraint as a single explanatory variable. The incentive measure, termed the peak value, is included with pension wealth and other explanatory variables, in a probit estimation[37]. This model has gained favor in the literature as it seems

[33] It is clear how they contribute the relationship through the structural model, though their identification may not be transparent.

[34] Gruber and Wise (2004) make this point in their support of peak value estimation.

[35] Gruber and Wise (2004) and Gustman and Steinmeier (2001) note several reasons for this.

[36] The peak value model has been preferred to a reduced-form model with the calculated option value as the financial incentive measure. As Coile and Gruber argue (2000), variation in the option value is heavily driven by wages, which may act as proxy for tastes, biasing estimates.

[37] Asch et al. (2005) used a logit.

to include the best features of reduced-form and structural estimation.

7.1 Theoretical Evaluation of the Peak Value Model

The peak value incentive measure is the difference between the maximum expected pension wealth and the expected pension wealth for retirement in the current period. At ages greater than the retirement age that maximizes pension wealth, R^M, the peak value reduces to the change in pension wealth for an additional year of work

$$PV_t = \left\{ \begin{array}{ll} \sum_{s=R^M}^{T} \delta^{s-t} p_{s|t} B(R^M) - \sum_{s=t}^{T} \delta^{s-t} p_{s|t} B(t) & t < R^M \\ \sum_{s=t+1}^{T} \delta^{s-t} p_{s|t} B(t+1) - \sum_{s=t}^{T} \delta^{s-t} p_{s|t} B(t) & t \geq R^M \end{array} \right\}$$

Here, $R^M \epsilon [t+1, T]$ is the retirement age that would yield the highest pension wealth, $B(s)$ is annual retirement allowance for retirement in year s, δ is the discount rate, and $p_{s|t}$ is the probability of living to s given that the individual lived to period t. The peak value can be related to the incentive measure of the structural model, through the net wage. As defined earlier, the net wage at time t is $w_t^{net} = w_t \times (1 - t_c) + a_t$, where t_c is the contribution rate and a_t is the accrual rate defined as $a_t = \sum_{s=t+1}^{T} \delta^{s-t} p_{s|t} B(t+1) - \sum_{s=t}^{T} \delta^{s-t} p_{s|t} B(t)$. Then the peak value and net wage are related as

$$PV_t = \left\{ \begin{array}{ll} \sum_{s=t}^{R^M} a_s = \sum_{s=t}^{R^M} w_s^{net} - \sum_{s=t}^{R^M} w_s \times (1 - t_c) & t < R^M \\ a_t = w_t^{net} - w_t \times (1 - t_c) & t \geq R^M \end{array} \right\}$$

Variation in the incentive measure is used to identify the model and determines the behavior that will be predicted following a reform to a retirement program, so differential variation in these incentive measures will lead to different predictions across by the peak value and structural models. A retirement program will be adjusted through the accrual schedule, or the value that the accrual takes at each age s. Consider a change in accrual from $\{a_s\} \rightarrow \{a'_s\}$, where $a'_s = a_s + \Delta a_s$ for $s \epsilon [t, T]$. For such a change in the accrual the change in net wage at any retirement age t can be written as $\Delta w_t^{net} = \Delta a_t$, so that the percentage change in net wage is proportional to the percent change in accrual

$$\%\Delta w_t^{net} = \%\Delta a_t \times \frac{a_t}{w_t^{net}}$$

.The relationship between the change in accrual and the change in peak value is more complicated. A change in the accrual schedule may alter the peak value in two ways - directly through the accrual rate and also by changing the retirement age associated with the maximum expected pension wealth from $R^M \to R^M + \Delta R$. The percent change in peak value at any retirement age t can be written as

$$\%\Delta PV_t = \left\{ \begin{array}{ll} \%\Delta a_t \times \frac{a_t}{\sum_{s=t}^{R^M} a_s} + \frac{\sum_{s=t+1}^{R^M} \Delta a_s}{\sum_{s=t}^{R^M} a_s} + \frac{\sum_{R^M}^{R^M+\Delta R} a'_s}{\sum_{t}^{R^M} a_s} & t < R^M \\ \%\Delta a_t + \frac{1}{a_t} \sum_{s=t+1}^{R^M+\Delta R} a'_s & R^M \leq t < R^M + \Delta R \\ \%\Delta a_t & t \geq R^M + \Delta R \end{array} \right\} \quad (7)$$

In the simple case where the percent change in accrual is $\gamma\%$ and $\Delta R = 0$, the percent change in peak value at any age t is simply equal to $\gamma\%$; it is proportional to the change in accrual like the net wage. More generally, the percent change in peak value is equal to one term that is proportional to the percent change in accrual *plus* an additional term.

In the case of the CalSTRS reform for the Low Service population, the structural model and the peak value model will make qualitatively different predictions for the change to the age distribution of California teachers. This can be seen by comparing the change in the incentive measures of the two models for the CalSTRS reform. For the Low Service group, the reform shifted the budget constraint kink, where the net wage declines from about 1.2 to .6 times the annual salary, from age 60 to age 63. There is no change in the accrual between the ages of 55 and 60. With $\Delta a_t = 0$, Δw_t^{net} is also equal to zero and given that the budget constraint remains convex, the lifetime budget constraint model does not predict a change in the retirement age for those that located between these ages. Although the accrual rate does not change from age 55 to $R^M = 60$, the additive terms in equation (7), which are not proportional to the change in accrual, cause the peak value to increase at ages before 60. As the peak value increases at these earlier ages, the probability of retirement is predicted to decline.

7.2 Empirical Evaluation of the Peak Value Model

Using the CalSTRS reform the predictions of the peak value and structural estimation methods can be evaluated against the observed outcomes of the reform. Several specifications of the peak value equation were estimated, using both the pre-reform Low Service sample only, to mimic the cross-sectional estimates in the literature, and the pooled pre- and post-reform Low Service sample to better match the structural estimation. The peak value and pension wealth were calculated following the Coile and Gruber (2000). The estimation results are available in Table 5. The coefficient on the peak value is negative and statistically significant in all but one specification estimated with the pre-reform sample. The peak value estimate is likely not significant when a full set of age indicators is included because the CalSTRS pension formula is predominantly determined by age and there is little variation in salaries due to the structured schedule. This phenomena has been observed in other studies using this model.[38] The coefficient on pension wealth is also of the predicted sign and significant, which is often not the case in the literature. When the models are estimated using the pooled data, the estimates become weaker. Generally, the coefficient on the peak value is on the same order as those found in the literature and implies a -.001 to -.006 change in the probability of retirement for a $10,000 change in the peak value. Coile and Gruber (2004) and de Vos and Kapteyn (2004)[39] estimate, for men in the U.S. Social Security system and men in the Netherlands respectively, that the probability of retirement will decline by about .0004 for a $1,000 change in the peak value.

[38] Gruber and Wise (2004) summaries of the findings of Brugiavini and Peracchi (2004), Boldrin et al. (2004), Blundell et al. (2004), which appear in the same volume.

[39] Both are in Gruber and Wise (2004).

The actual and predicted change in average retirement age for the CalSTRS reform is shown in column (1) of Table 6. The actual change in retirement age is .26%. The predicted retirement pattern based on the structural estimates reproduce this change. The predictions of the peak value model, for both sample estimates over predict the change in retirement age at 1.6% and .7%. The over-prediction is greater for the estimates of the pre-reform sample. Both models predict a small change in the average retirement age, but the peak value predictions are 3-8 times larger.

The distributions of the actual outcomes and the predicted distributions demonstrate the source of these differences in predicted average retirement age. The pre- and post-reform retirement distributions for LAUSD are shown in Figure 11. There are two notable features of response to the reform. The first is that the bunching of retirements shifts from age 60 to age 63. The fraction of individuals retiring between ages 59.5 and 60.5, at the pre-reform kink, falls by over 50% in the post-reform period. There also appears to be spike forming at age 63, the post-reform budget constraint kink location. The density here increased by about 50%. This mimics the response that was seen for the full CalSTRS population in Section 5.2. The second feature is that prior to the pre-reform kink age there is no systematic change in retirement behavior. This is consistent with the predictions of the lifetime budget constraint model.

The predicted retirement distributions from the structural model, using the estimates in column (3) of Table 4, are shown in Figure 12a. The structural model captures the decrease in the spike at age 60 and an increase at age 63 with the financial incentive of the net wage alone, though the magnitudes of the kink point bunching do not match the empirical observations. The over-estimate of the kink at age 63 maybe a product of the transition effects that were discussed earlier. The underestimate at age 60 in both reform periods suggests that there may be something else that is causing individuals to retire at this age, and that an age 60 indicator could be included in the estimation to obtain a better fit. The predicted retirement distribution using the estimates in column (4) of Table 4 appears in Figure 12b. Here the age 60 dummy appears to over-compensate - over-predicting the retirements at this age in the pre- and post-reform. In both simulations, there is no predicted change in retirement behavior before the age of 60, matching the actual outcome.

The predicted retirement patterns of the peak value model are notably different. The prediction using estimates from the specification with a linear age control, column (7) of Table 5, is shown in Figure 13a. This prediction does not capture the preference for retirement at age 60, even in the pre-reform period when there is a financial incentive to retire at that age. As the peak value does not change sharply at the kink, it would be difficult for the model to predict the observed bunching. In the post reform period, the density at age 63 increases and the density at age 60 decreases, but this is a result of a rightward shift of the retirement distribution. This rightward shift indicates that the fraction of individuals retiring between ages 55 and 60 should also decrease, as was described in the theoretical discussion. This is a deviation from the predictions of the lifetime labor supply model, and it is not born out in the actual response of CalSTRS members to the reform. When age 60 indicator is added to the model, as in Figure 13b, the peak value model better captures the observed retirement pattern by maintaining the spike at age 60. However, the shift of the predicted distribution toward later retirement ages is still evident. In this case, the qualitative change in the distribution of retirees is better predicted by the structural model.

7.3 Simulation Results

In order to better understand the magnitude of this deviation of the peak value model from the predictions of the lifecycle labor supply model, I conduct a simulation exercise with four hypothetical retirement programs. The salaries and service characteristics of the CalSTRS Low Service population are used in the simulation and the structural and peak value estimates are used to predict the retirement outcomes under each retirement program. Retirement program 1 is a simple kinked budget constraint with a constant net wage of 1.2 times salary up to age 60 and .6 times salary after age 60. Program 2 has a shift in the kink to age 63. Programs 3 and 4 have a kink at age 60 like program 1, but the net wage is 10% and 20% higher, respectively, at all ages than in program 1

Table 6 columns (2)-(4) show the simulated percent change in average age in moving from retirement program 1 to each of the other programs. Both the structural and peak value estimates indicate the same ordinal change in average retirement age, the shift in kink increases the average retirement age by more than does the increase in the return to work with no shift in kink location. The relative differences between the models are also similar, the percent change in going from program 1 to program 2 is almost 3 times greater than in going from program 1 to 3 and program 1 to 3 is half as large as program 1 to 4. Both estimation methods predict very small changes in average retirement age, no more than 1.5%. However, the predicted response from the peak value estimation is 3 to 4 times greater than the structural estimate and the difference is greatest with the shift in kink location.

The predicted distributions, found in Figure 14, provide information on the source of this difference. When the reform does not shift the kink, moving from program 1 to program 3 or 4, the response predicted by the peak value and structural models is similar, Figures 14a and 14b. The density of retirements uniformly decreases at lower ages and increases across higher ages. One difference is that the peak value model predicts more retirees at age 60 while the structural model does not. However, when the budget constraint kink is shifted, moving from program 1 to 2, there is a definitive difference between the predictions of the two estimation methods, as seen in Figures 14c and 14d. Under the peak value model, the increase in average retirement age comes from a rightward shift of the retirement distribution. In the structural predictions, the driving factor is the dramatic decrease in retirements at age 60 and increase at age 63. Although the models predicted a small absolute difference in the change in average retirement age, the predictions for which portions of the population will be pushed to work longer when faced with a reform and how much the expected benefits paid will change are very different. These are likely to be relevant factors for policy formation.

8 Conclusion

In this paper, I exploit a reform of the pension for California teachers to identify the sensitivity of retirement age to retirement program financial incentives. The reform creates exogenous variation in 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. I find that although teacher response to the reforms was consistent with the predictions of the standard lifetime labor supply model, it was small in magnitude. The reduced-form analysis and structural estimation imply estimates of 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. This has extensive policy applications, both in the United States and around the world, where the future of public pensions is being debated.

I also compare the predictions of the structural estimation to the predictions of the prevailing reduced-form estimation method seen in the literature, the peak value model. I find that in the case of the CalSTRS reform the predictions of the peak value model deviate from the predictions of standard theory, and that the structural model better captures the observed response to the reform. This suggests that future research should further evaluate the peak value model, in order to determine settings in which it is valid.

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A Non-parametric Elasticity Formula

The individual's maximization problem is

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

$$s.t.$$

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

The individual considered here retires at a tangency between the lifetime budget constraint and his indifference curve in both the pre- an post-reform periods.

In the post-reform period the optimal retirement age is R_H^*, assuming a constant salary

$$\frac{dU}{dR} = w_R \times (1-t_c) + \frac{dk_R^{Post}}{dR} \times w_R \times (R-a_0) \times (T-R) + w_R \times (k_R^{Post} \times (T-R) - k_R^{Post} \times (R-a_0)) - R^{\frac{1}{e}}$$

Setting $\frac{dU}{dR}|_{R_H^*} = 0$, and defining

$$w^{Post} = w_{R_H^*} \times (1-t_c) + \frac{dk_{R_H^*}^{Post}}{dR} \times w_{R_H^*} \times (R_H^* - a_0) \times (T - R_H^*) + w_{R_H^*} \times (k_{R_H^I}^{Post} \times (T - R_H^*) - k_{R_H^*}^{Post} \times (R_H^* - a_0))$$

Then

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

The derivation for the pre-from period is identical except the growth is the proportionality constant at R_K is zero, $\frac{dk_{R_K}^{\Pr e}}{dR} = 0$. So

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

with

$$w^{\Pr e} = w_{R_K} \times (1-t_c) + w_{R_K} \times (k_{R_K}^{\Pr e} \times (T - R_K) - k_{R_K}^{\Pr e} \times (R_K - a_0))$$

Solving for e

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

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

B OLS Estimates of Elasticity of Retirement Timing

	Pre-reform (1997-1998)	Post-reform (1999-2000)	Post-reform (1999-2004)	Pooled (1997-2000)
log Net Wage	-0.108**	-0.090**	-0.082**	-0.089**
	(0.009)	(0.002)	(0.001)	(0.003)
w - w^4	Y	Y	Y	Y
Year	Y	Y	Y	Y
Observations	972	1141	3398	2113
R-squared	0.13	0.54	0.50	0.34

Standard errors in parentheses
* significant at 5% level; ** significant at 1% level

Source: LAUSD Administrative Data (1997-2003)

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 $\eta \tilde{} N(\mu_{\widetilde{\eta}}, \sigma^2_{\widetilde{\eta}})$ is

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

Segment Retirement ($s_i = 1$):
The probability of observing an individual retire at R on a budget constraint segment is the probability that $\ln R = \ln R_i^*$

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

where $\phi(x, \mu, \sigma)$ is the normal probability density function with mean μ and standard deviation σ.
Kink Retirement ($K_i = 1$):
The conditional probability of observing an individual retire at the kink R_K is the probability that $\ln R^*_{L,i} \leq \ln R_K \leq \ln R^*_{H,i}$

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

where $\Phi(x, \mu, \sigma)$is the normal cumulative density function with mean μ and standard deviation σ

Log Likelihood

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

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

D Cross-sectional Structural Estimates

	(1)	(2)	(3)	(4)
elasticity (e)	.0464**	.0446*	.0446*	.1889**
	(.0036)	(.0121)	(.0123)	(.0029)
mean of eta (μ)	3.6295**	3.5698**	3.5720**	2.0521**
	(.0395)	(.0429)	(.0432)	(.0321)
std dev of eta (σ)	.0920**	.0914**	.0914**	.1144**
	(.0004)	(.0004)	(.0004)	(.0014)
salary/$10k (*w*)		-.0140	-.0131	
		(.0414)	(.5433)	
w^2		-.0001	-.0002	
		(.0041)	(.3184)	
w^3			.0000	
			(.0626)	
w^4			.0000	
			(.0041)	
Age 60				-.0111
				(.0251)
# Observations	509	509	509	509
log Likelihood	-315	-316	-316	-254

**significant at 1% level, * significant at 5% level

Source: LAUSD Administrative Data (1997-98)

Table 1
Proportionality Constant *(k)* as a Function of Retirement Age and Service

Retirement Age	Pre-reform	Post-reform	
		S < 30 years	S = 30+ years
55	1.400%	1.400%	1.600%
56	1.520%	1.520%	1.720%
57	1.640%	1.640%	1.840%
58	1.760%	1.760%	1.960%
59	1.880%	1.880%	2.080%
60	2.000%	2.000%	2.200%
61	2.000%	2.133%	2.333%
62	2.000%	2.266%	2.400%
63 and over	2.000%	2.400%	2.400%

Note: The annual allowance, $B(R,S) = k(R,S) \times S \times w^f$ is an increasing function of *k*. In the post-reform period at the age an individual attains 30 years of service s/he transitions from column (2) to (3).

Table 2
Summary Statistics for Administrative Data

a. System-wide Count Data for CalSTRS New Retirees

	Pre-reform (1995-1998)	Post-reform (1999-2003)
Number of Retirees per Year	6,819.75	9,459.20
Average Age	60.73	61.08
Average Service	26.75	27.73

b. LAUSD Individual-level Data for Teachers Age 55+

	All	Active	New Retirees		
	(1997-2004)	(1997-2004)	(1997-2004)	Pre-reform	Post-reform
Retirement rate			8.25%	8.42%	8.20%
Age	59.98	59.77	62.28	62.10	62.33
LAUSD service	20.14	19.58	26.88	25.66	27.21
Salary	60,402	60,174	62,938	56,078	64,887
% Female	71.80%	71.78%	72.01%	69.78%	72.65%
# of Observations	56,389	51,737	4,652	1,029	3,623

Note: The LAUSD pre-reform period is 1997-98 and the post-reform period is 1999-2004.

Table 3
Non-parametric Elasticity Estimates

	Reform-based Estimates		Long Run Upper Bound	
Expected	Total Population	Low Service	Total Population	Low Service
Lifetime in Years	e(R)	e(R)	e(R)	e(R)
70	0.010	0.018	0.037	0.127
80	0.007	0.011	0.024	0.062
90	0.006	0.009	0.020	0.048

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 pre-reform budget constraint kink location.

Table 4
Structural Estimates

	(1)	(2)	(3)	(4)	(5)	(6)
elasticity (e)	.0254**	.0233**	.0233**	.0198**	.0229**	.0211**
	(.0024)	(.0027)	(.0028)	(.0022)	(.0027)	(.0026)
mean of eta (μ)	3.8615**	3.7930**	3.7865**	3.9258**	3.7926**	3.8442**
	(.0263)	(.0296)	(.0308)	(.0247)	(.0298)	(.0311)
std dev of eta (σ)	.0886**	.0874**	.0874**	.0881**	.0873**	.0873**
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
salary/$10k (*w*)		-.0146	-.0168		-.0160	-.0133
		(.0076)	(.0444)		(.0090)	(.0457)
w^2		-.0001	.0001		.0000	.0004
		(.0006)	(.0188)		(.0008)	(.0195)
w^3			.0000			.0000
			(.0027)			(.0028)
w^4			.0000			.0000
			(.0001)			(.0001)
Age 60				.1169**	.0008	.0089
				(.0069)	(.0921)	(.0648)
# Observations	2180	2180	2180	2180	2180	2180
log Likelihood	-1587	-1608	-1608	-1426	-1608	-1600

**significant at 1% level, * significant at 5% level

Standard errors in parentheses
Source: LAUSD Administrative Data (1997-2003)

Table 5
Peak Value Estimates

	Pre-reform Population					Pooled Population				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
PV ($10k)	-0.00674**	-0.00415**	-0.00473**	-0.00658**	-0.00174	-0.00384**	-0.00103*	-0.00060	-0.00378**	-0.00019
	(0.00060)	(0.00108)	(0.00169)	(0.00061)	(0.00195)	(0.00028)	(0.00048)	(0.00055)	(0.00028)	(0.00056)
DBW ($10k)	0.00061**	0.00087**	0.00083**	0.00062**	0.00105**	0.00109**	0.00122**	0.00122**	0.00109**	0.00123**
	(0.00022)	(0.00024)	(0.00025)	(0.00022)	(0.00026)	(0.00013)	(0.00013)	(0.00012)	(0.00013)	(0.00012)
Age		0.00324**	-0.01074				0.00527**	0.02923		
		(0.00114)	(0.03152)				(0.00076)	(0.01529)		
Age^2			0.00011					-0.00019		
			(0.00024)					(0.00012)		
Age 60				0.01377	0.06585				0.02393**	0.08054**
				(0.00869)	(0.04447)				(0.00659)	(0.01945)
w, w^2, w^3, w^4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
All Age Indicators	N	N	N	N	Y	N	N	N	N	Y
Observations	7137	7137	7137	7137	7137	15608	15608	15608	15608	15608

Standard errors in parentheses
* significant at 5%; ** significant at 1%
Source: LAUSD Administrative Data (1997-2003)

Table 6
Percent Change in Average Retirement Age

	Pre to Post	Program 1 to 2	Program 1 to 3	Program 1 to 4
Actual	0.26%			
MLE	0.23%	0.38%	0.14%	0.26%
PV Pre	1.66%	1.48%	0.50%	0.94%
PV Pooled	0.75%	0.85%	0.32%	0.62%

Source: LAUSD Administrative Data (1997-2003)
Note: In Program 1 the net wage is 1.2 times annual salary before age 60 and .6 times annual salary after age 60. Program 2 offers a net wage of 1.2 times annual salary until age 63, and then the net wage falls to .6 times annual salary. Programs 3 and 4 offer a 10% and 20% increase in net wage at all ages relative to Program 1.

Figure 1

CalSTRS Newsletter Announcing the 1999 Pension Reforms

STRS

State Teachers' Retirement System

Bulletin

Volume 13 No. 1 Fall 1998

Social Security Debate Heats Up

News out of Washington indicates Social Security reform has become a front-burner discussion. One proposal under review is to extend Social Security coverage to all new state and local government employees. The Teachers' Retirement Board opposes mandatory coverage because it would threaten STRS' financial well being.

With mandatory Social Security coverage, there is no guarantee funds would be available to provide the same level of benefits STRS now provides. In fact, actuarial studies undertaken for STRS show the current Defined Benefit Plan produces a much greater benefit than a plan coordinated with Social Security for the same level of contribution. This is in part because STRS is more soundly funded than Social Security. Employer and employee contributions are invested according to solid portfolio management principles in a range of assets providing a greater return than the returns on government bonds held by the Social Security "trust fund."

If Social Security is substituted for a large portion of the STRS DB Plan benefit, contributions to the plan will have to increase to fund the same level of benefits. The increase, according to STRS actuarial studies, would be an additional 3 percent to 6 percent of payroll to fund a supplemental retirement tier that, when combined

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Wide-Ranging Array of Benefit Improvements Signed Into Law

STRS Benefits Package

Suddenly at the end of the state legislative session, all forces came together to create fundamental and wide-ranging improvements to the STRS Defined Benefit Plan retirement benefit structure.

A coalition of educator and employer groups, working with the Teachers' Retirement Board, shepherded the measures making up the benefits package through the legislative session. Governor Pete Wilson signed the bills, dubbed the Teacher Recruitment and Retention Benefits Package, in September. Each will take effect on January 1, 1999, generally for members who retire on or after that date. The new benefit structure will put STRS retirements benefits on a par with comparable systems in California and around the nation.

"We were surprised and delighted that all our efforts came together in the closing days of the legislative session. These benefit improvements mean a new day has dawned for retiring STRS career educators," said Emma Zink, Chairperson of the Teachers' Retirement Board, and a high school teacher from La Jolla.

Teacher Retention is the Goal

The retirement benefit picture has changed for STRS members as they move through their education careers and make their retirement plans. For the first time, the STRS retirement benefit structure provides an attractive reward for continuing in public education at least 30 years or past age 60. Members with long careers will see sizable increases in their STRS retirement allowances. These increases will enhance member retirement lifestyles and make retirement years more secure.

<u>Enhanced Age Factor</u>

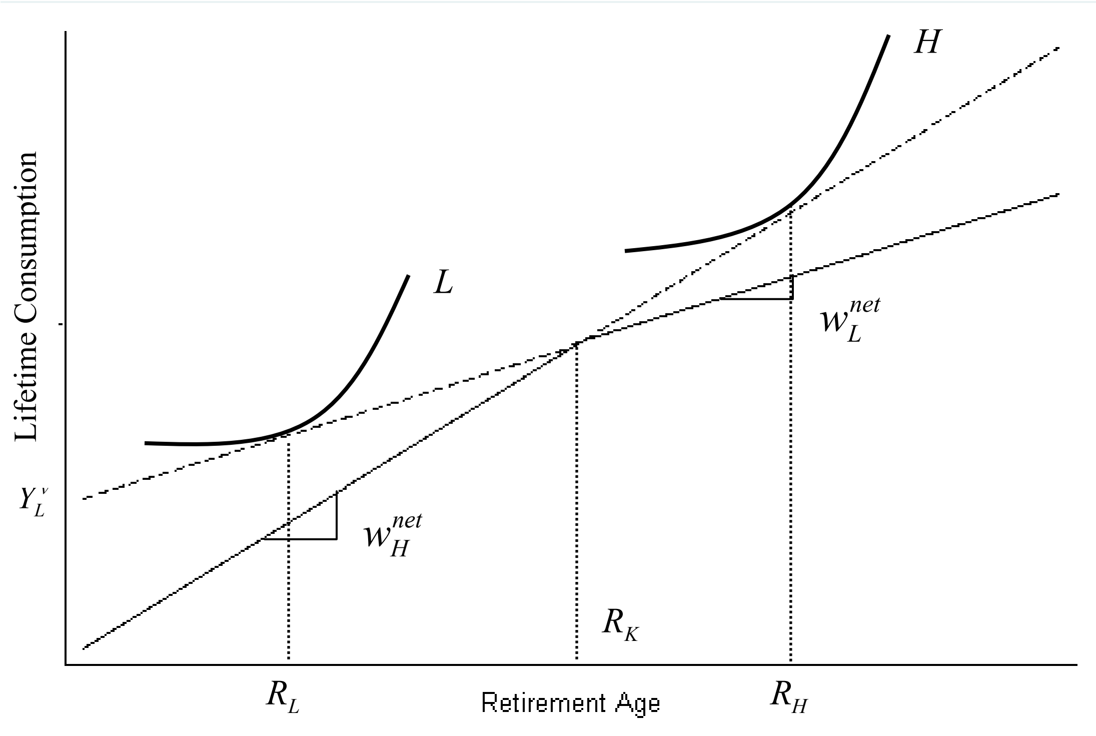
Retirement allowances for members retiring on or after January 1, 1999, at ages 60 1/4 through age 63 and older will be considerably higher than in previous years due to an increased age factor schedule. The age factor, an element in calculating the monthly allowance, will be increased for each quarter year of age from 2.0 percent at

continued on page 4

What's Inside

Note: This is the front page of the Fall 1998 newsletter that announced the reforms to the defined benefit program. This newsletter was mailed to all CalSTRS members that had not yet retired. The complete newsletter can be found at http://www.calstrs.com/Help/forms_publications/printed/fbull98.pdf.

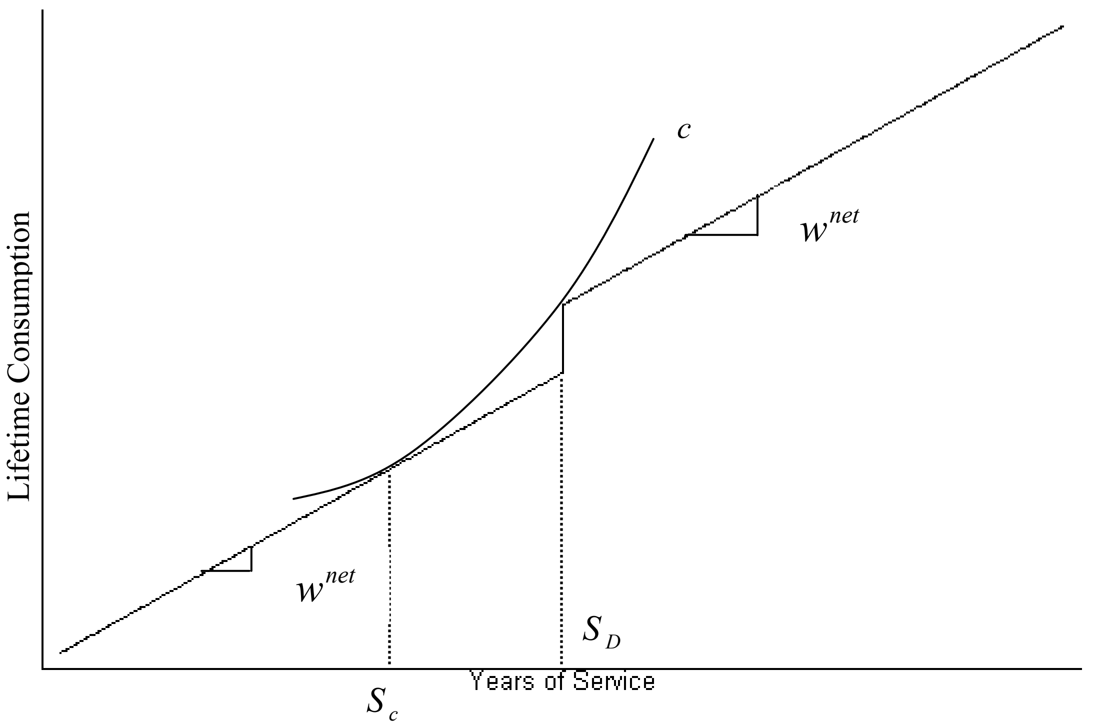
Figure 2
Optimal Retirement on a Kinked Budget Constraint



Note: This figure depicts the retirement decision on a piecewise linear budget constraint. The solid line is the budget constraint, while the dashed lines are the linear extensions of each segment. The optimal retirement ages on the linear extensions of the high wage and low wage segments are given by the tangencies of indifference curve H and L respectively. The budget constraint kink is the optimal retirement age for the range of preferences for which $R_H > R_K$ and $R_L < R_K$.

Figure 3

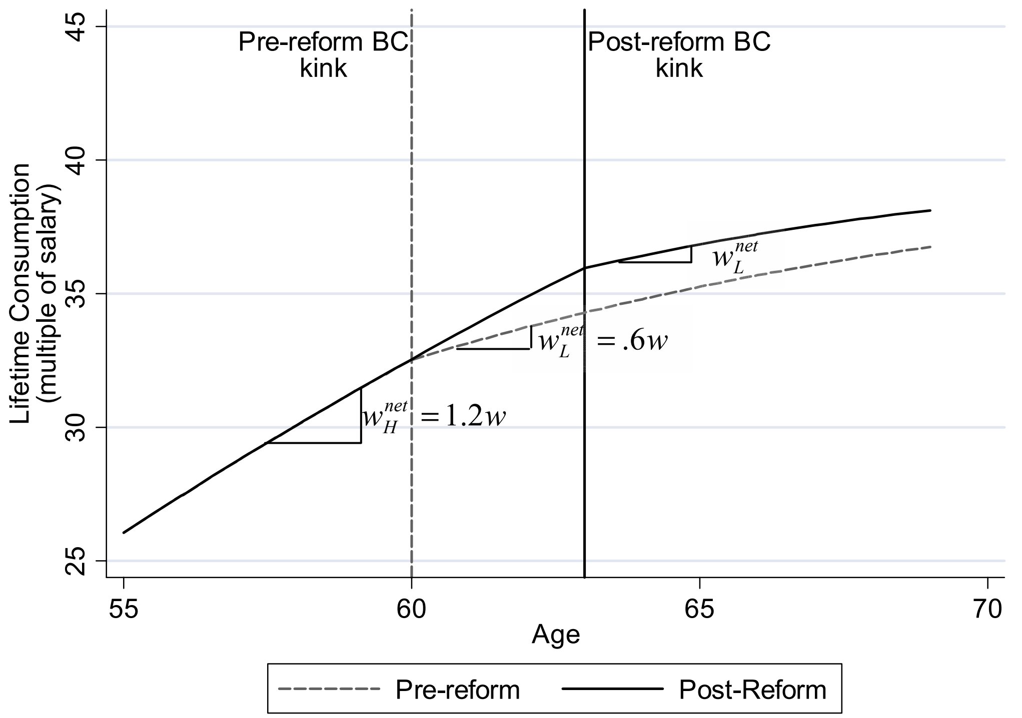
Optimal Retirement on a Budget Constraint with a Discontinuity



Note: This figure depicts the retirement decision on a discontinuous budget constraint. The indifference curve *c* represents the preferences of an individual that gets equal utility from the lifetime labor supply where his first order condition holds $S^* = S_c$ and from delaying retirement to the discontinuity. The budget constraint discontinuity is the optimal retirement age for the range of preferences for which $S^* > S_c$ and $S^* < S_D$.

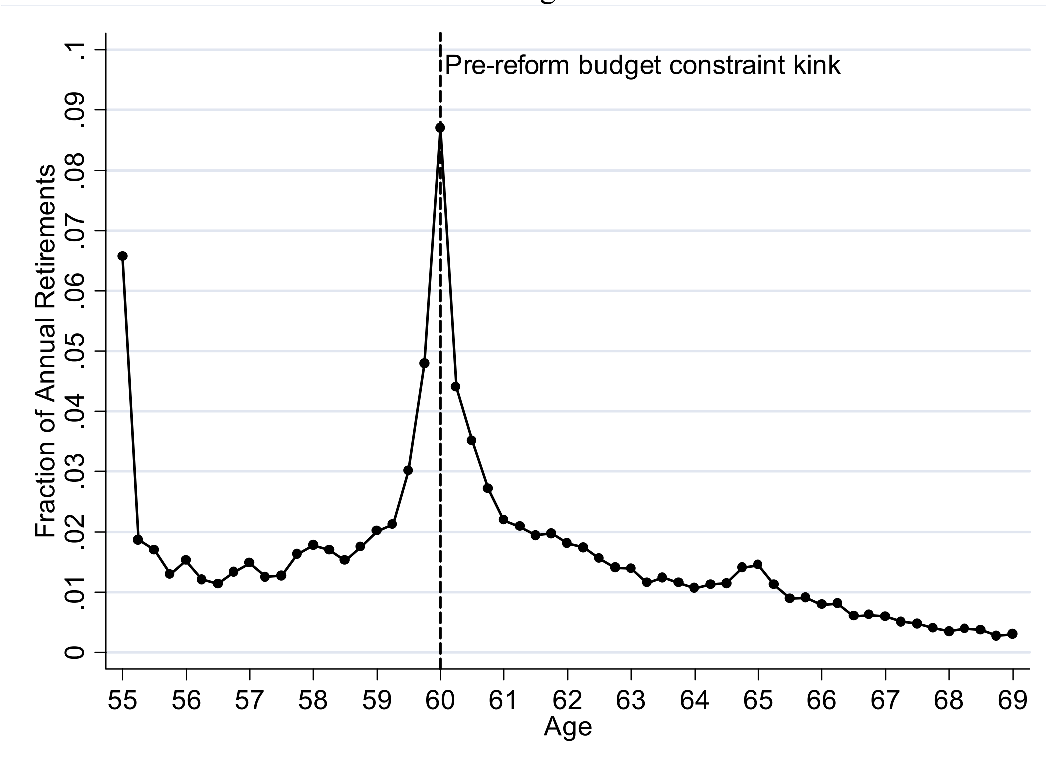
Figure 4

Stylized Budget Constraint in Age for a Representative CalSTRS Member



Note: 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 assumed discount rate is .97 and salary is assumed to grow by $1000 annually. The pre- and post-reform budget constraints coincide for ages 55 to 60. The continuation of the pre-reform budget constraint is denoted by the dashed line and the solid line denotes the continuation of the post-reform budget constraint. The pre-reform budget constraint has a kink at age 60, indicated by the dashed vertical line. Generally, the age location of the post-reform kink depends on service, but will be between ages 61 ½ and 63. For the combination of service and age depicted here, it will appear at age 63.

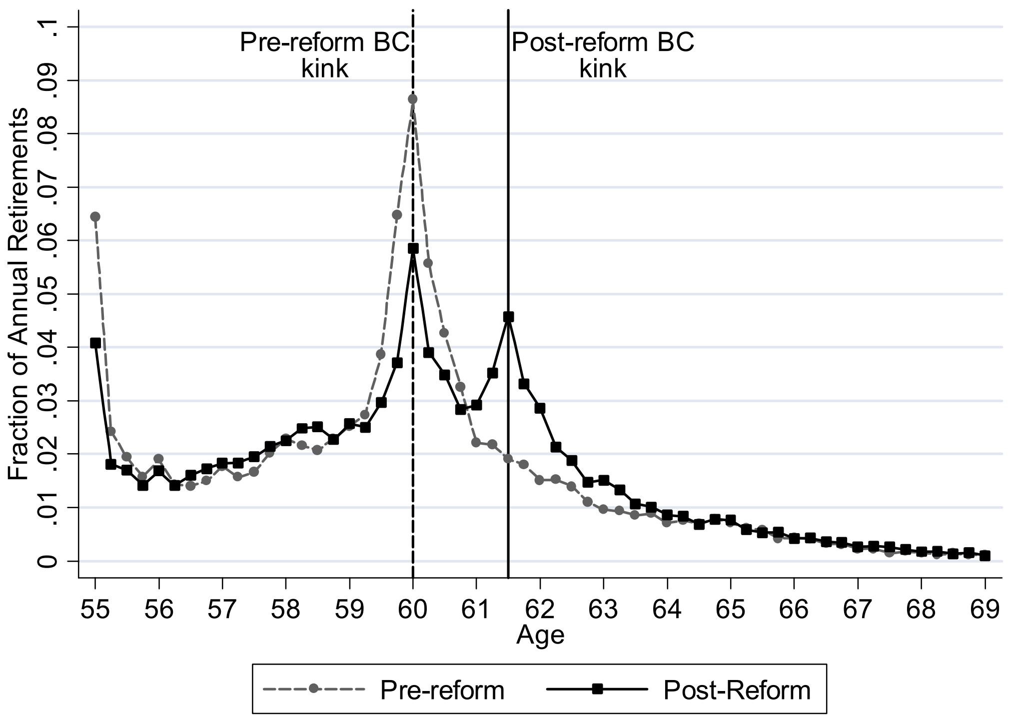
Figure 5
Pre-reform Age Distribution of Retirees



Source: System-wide CalSTRS retirement count data (1995-1998)
Note: This figure shows the average fraction of all annual retirements that occur at each quarter-age between ages 55 and 69. The age distribution of retirements was created for each year 1995-1998. These were averaged, with equal weight, to create the pre-reform distribution. The pre-reform budget constraint kink is at age 60 (as indicated by the dashed vertical line). The financial return to work drops by 50% at the kink.

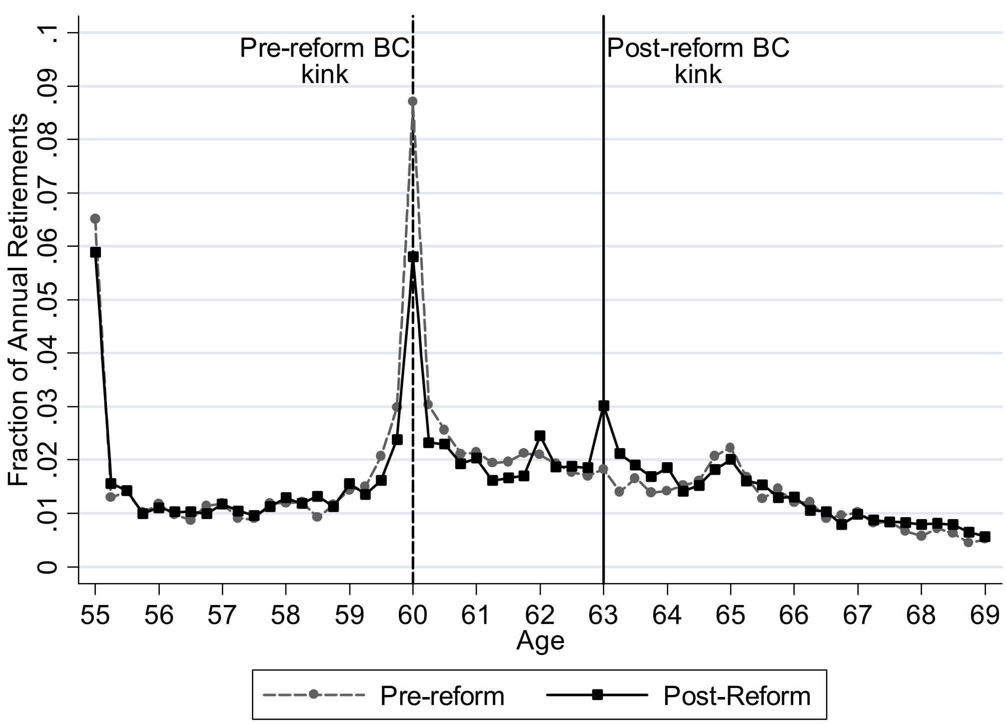
Figure 6
Post-reform Age Distribution of Retirees by Service Group

a. Age Distribution of High Service Retirees



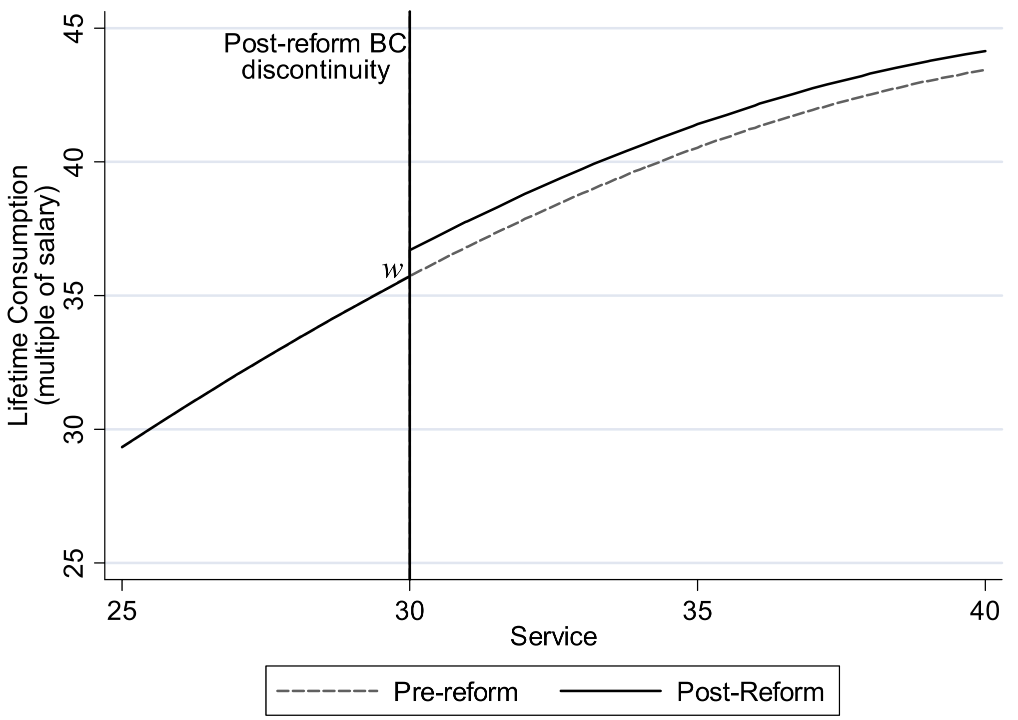
Source: System-wide CalSTRS retirement count data (Pre-reform:1995-1998; Post-reform: 1999-2003)
Note: This figure depicts the pre- and post-reform retirement age distributions for the High Service subpopulation. The distributions were constructed in the same manner as in Figure 4. The High Service population is defined as being able to attain 30 years of service before age 61 ½. The pre-reform budget constraint kink is at age 60 (indicated by the dashed vertical line) and the post-reform budget constraint kink is at age 61 ½ (indicated by the solid vertical line). At each of the kinks, the financial return to continued work decreases by 50%.

b. Age Distribution of Low Service Retirees



Source: System-wide CalSTRS retirement count data (Pre-reform:1995-1998; Post-reform: 1999-2003)
Note: This figure depicts the pre- and post-reform retirement age distributions for the Low Service subpopulation. The distributions were constructed in the same manner as in Figure 4. The Low Service population is defined as not being able to attain 30 years of service before age 63. The pre-reform budget constraint kink is at age 60 (indicated by the dashed vertical line) and the post-reform budget constraint kink is at age 63 (indicated by the solid vertical line). At each of the kinks, the financial return to continued work decreases by 50%.

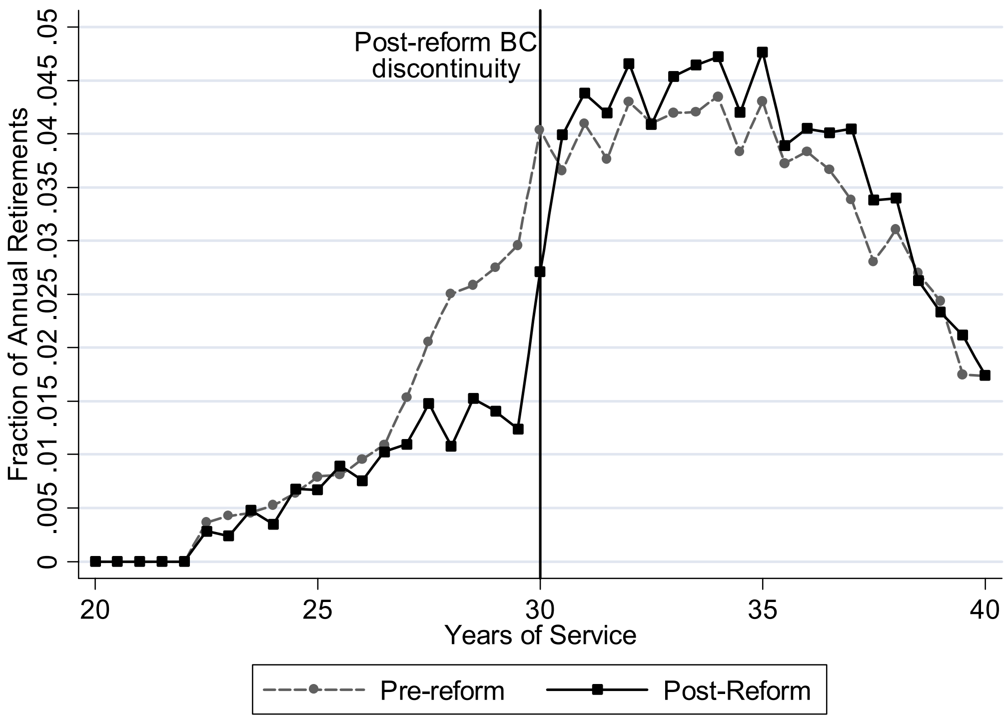
Figure 7
Stylized Budget Constraint in Service for a Representative CalSTRS Member



Note: 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 .97 and salary is assumed to grow by $1000 annually. The pre- and post-reform budget constraints coincide for ages 55 to 60. The continuation of the pre-reform budget constraint is denoted by the dashed line and the solid line denotes the continuation of the post-reform budget constraint. The post-reform budget constraint has a discontinuity at 30 years of service, indicated by the vertical line. This figure abstracts from a kink that occurs after the discontinuity because this feature does not appear at the same service location across the population.

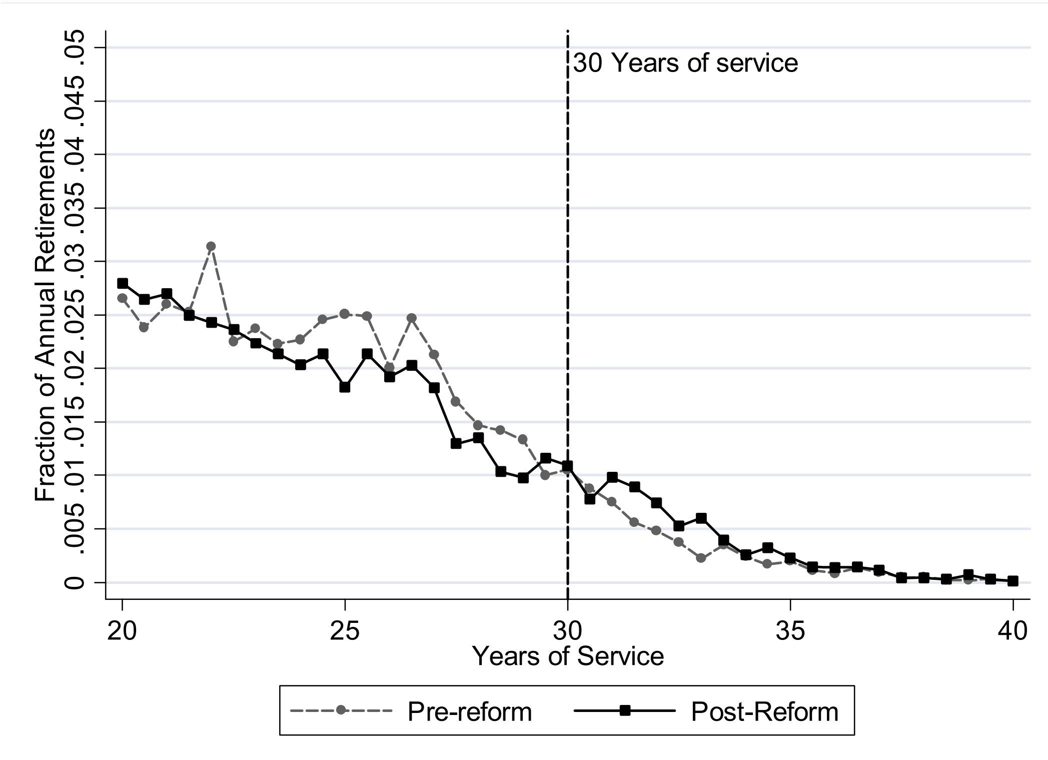
Figure 8
Post-reform Service Distribution of Retirees by Service Group

a. Service Distribution of High Service Group



Source: System-wide CalSTRS retirement count data (Pre-reform:1995-1998; Post-reform: 1999-2000)
Note: This figure depicts the pre- and post-reform retirement service distributions for the High Service subpopulation. The distributions were constructed in the same manner as in Figure 4. The post-reform budget constraint discontinuity is at 30 years of service (indicated by the solid vertical line); there is no pre-reform discontinuity. The financial return at the discontinuity is equal to the annual salary.

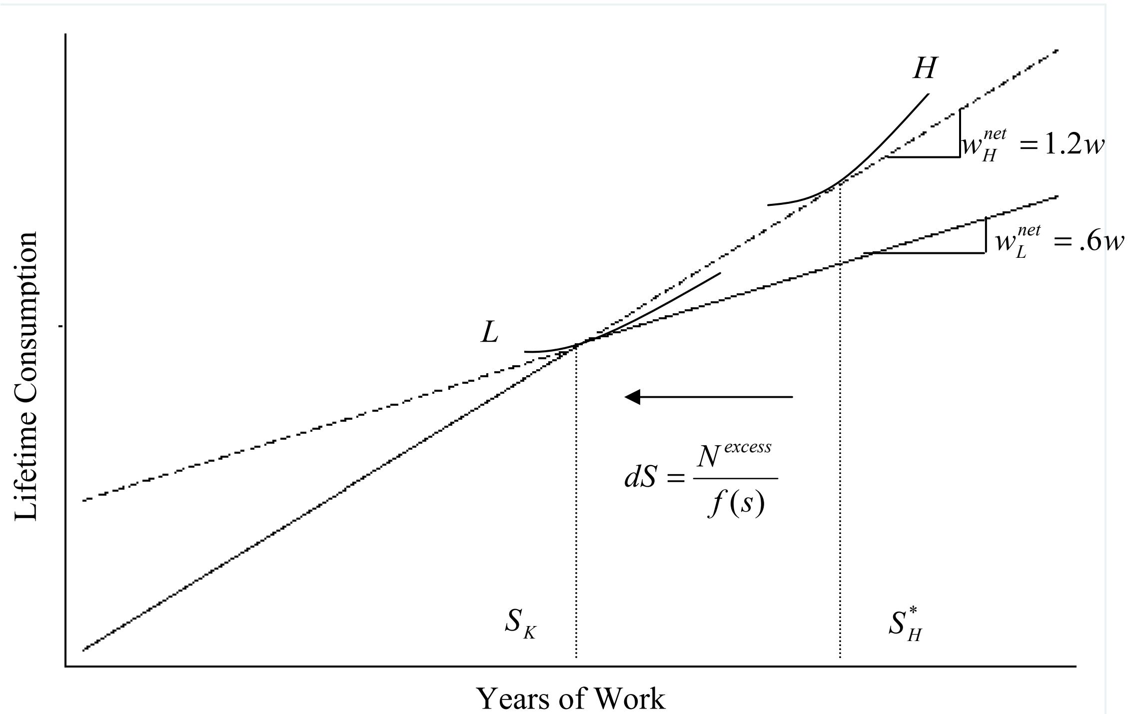
b. Service Distribution of Low Service Group



Source: System-wide CalSTRS retirement count data (Pre-reform:1995-1998; Post-reform: 1999-2000)

Note: This figure depicts the pre- and post-reform retirement service distributions for the Low Service subpopulation. The distributions were constructed in the same manner as in Figure 4. This group does not have a budget constraint discontinuity in either period.

Figure 9
Non-parametric Elasticity Estimation

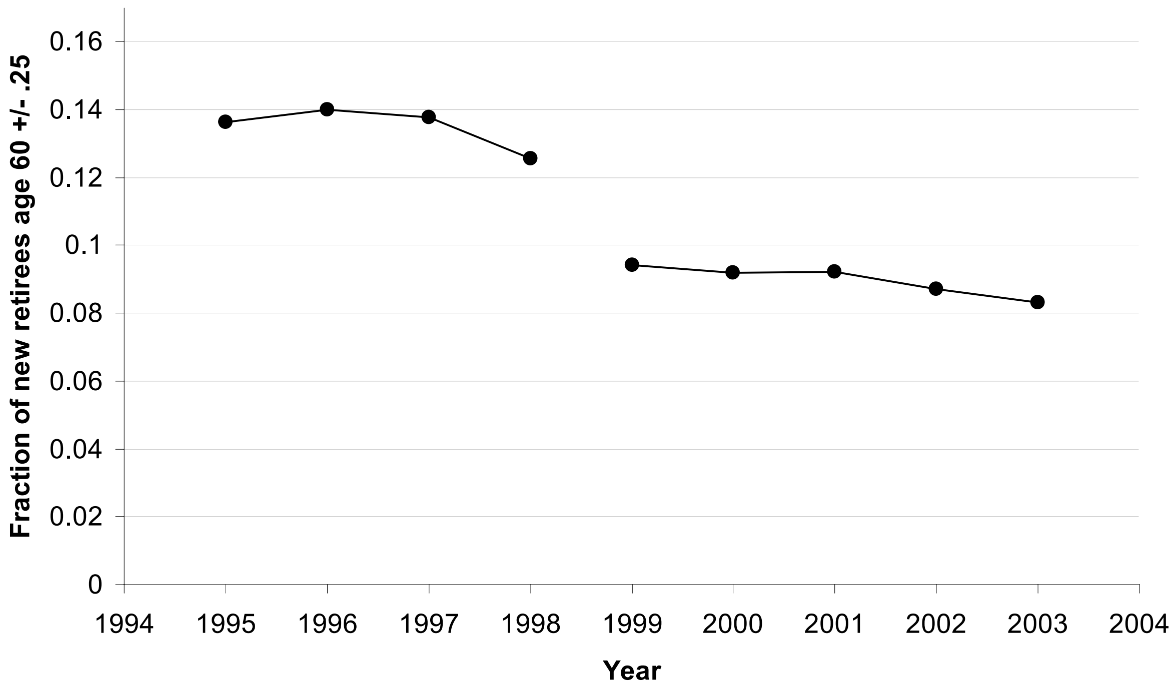


Note: This figure depicts the retirement decision when a kink is introduced to the budget constraint at S_K. With the introduction of the kink all those with $S_K < S^* < S_H^*$, will move to S_K. The distance between S_H^* and S_K is the total movers, N^{Excess}, divided by the retirement density across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

Figure 10

Time Trend in Fraction of Retirees Age 60 ± 3

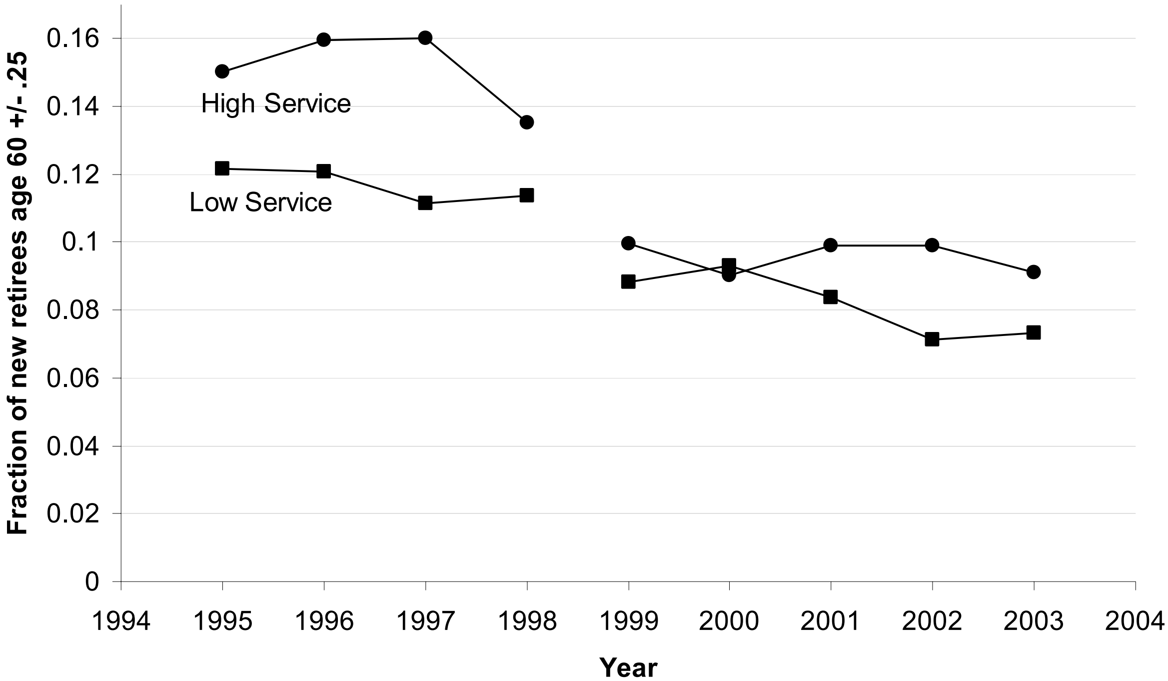
a. Total CalSTRS Population



Source: System-wide CalSTRS retirement count data (1995-2003)

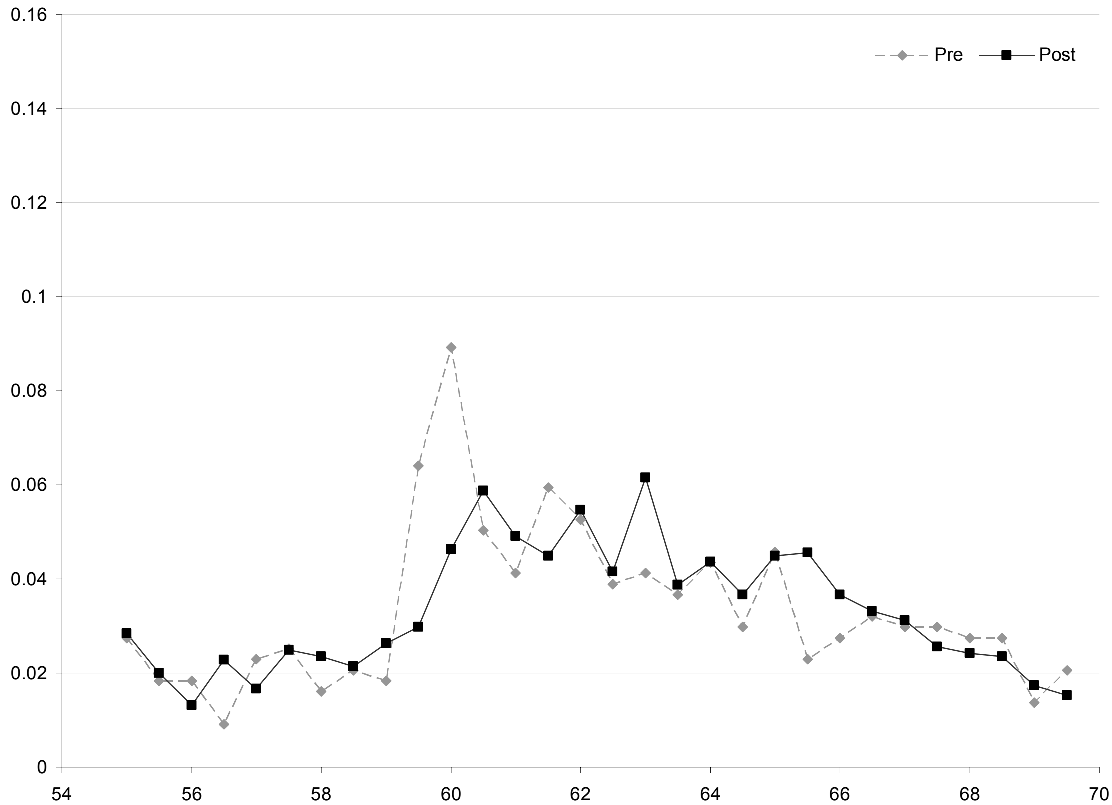
Note: This figure depicts the time trend in retirements, as a fraction of annual retirements, at the pre-reform budget constraint kink. The effective date of the reforms is denoted by the break in the solid trend line.

b High and Low Service Groups



Source: System-wide CalSTRS retirement count data (1995-2003)
Note: This figure depicts the time trend in retirements, as a fraction of annual retirements, at the pre-reform budget constraint kink. The effective date of the reforms is denoted by the break in the solid trend line. The Low Service group has a post-reform kink at age 63 and the High Service group has a post-reform kink at age 61 ½.

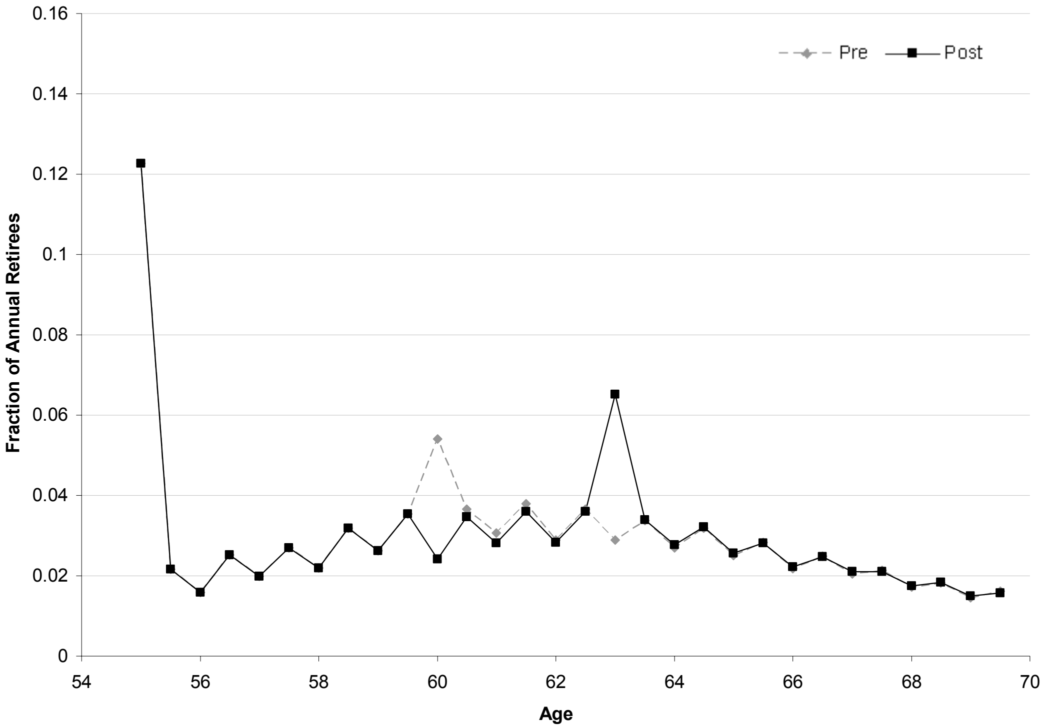
Figure 11
LAUSD Pre- and Post-reform Retirement Distributions



Source: LAUSD Administrative Data (1997-2003)
Note: Sample includes the Low Service group only. The pre-reform period is 1997-98 and the post-reform period is 1999-2003. Though noisier, these distributions are similar to those for the entire CalSTRS system. They indicate a shift in retirements away from age 60 and the beginnings of bunching at the new kink at age 63 after the reform.

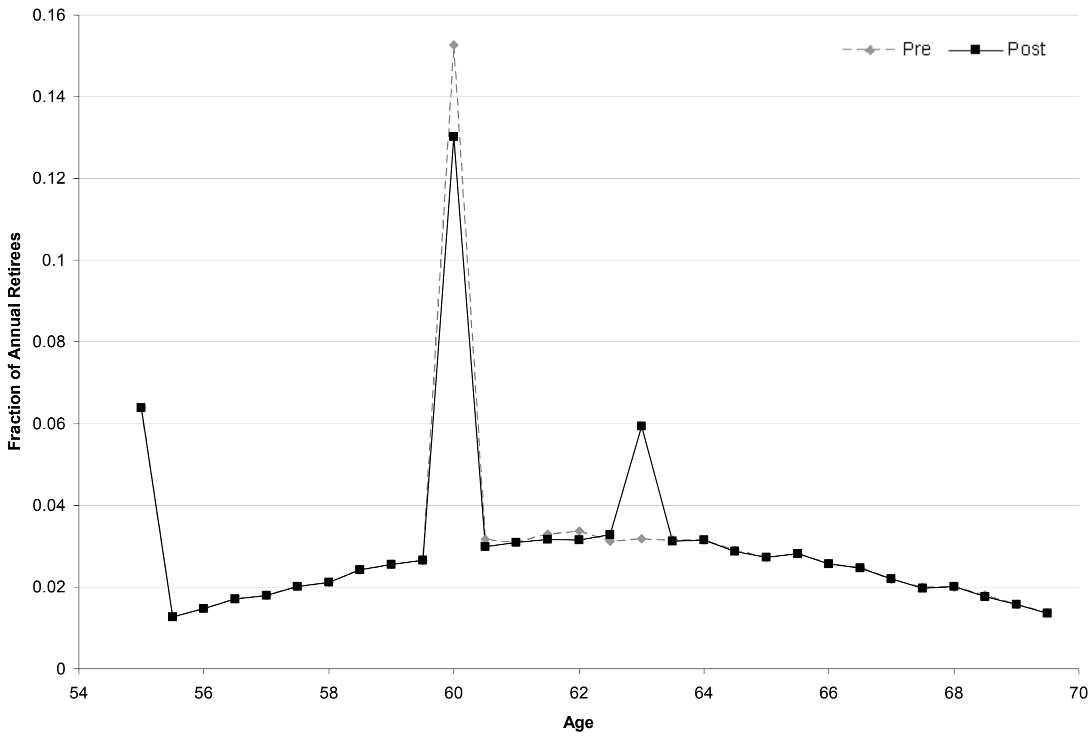
Figure 12
Structural Model Predictions for LAUSD Pre- and Post-reform

a.



Source: Simulation results using the LAUSD Administrative Data (1997-2003)
Note: The distributions are simulated with estimates from specification 3 of the structural model, which includes all salary controls. There is a shift in the bunching from age 60 to age 63, matching observed behavior following the reform.

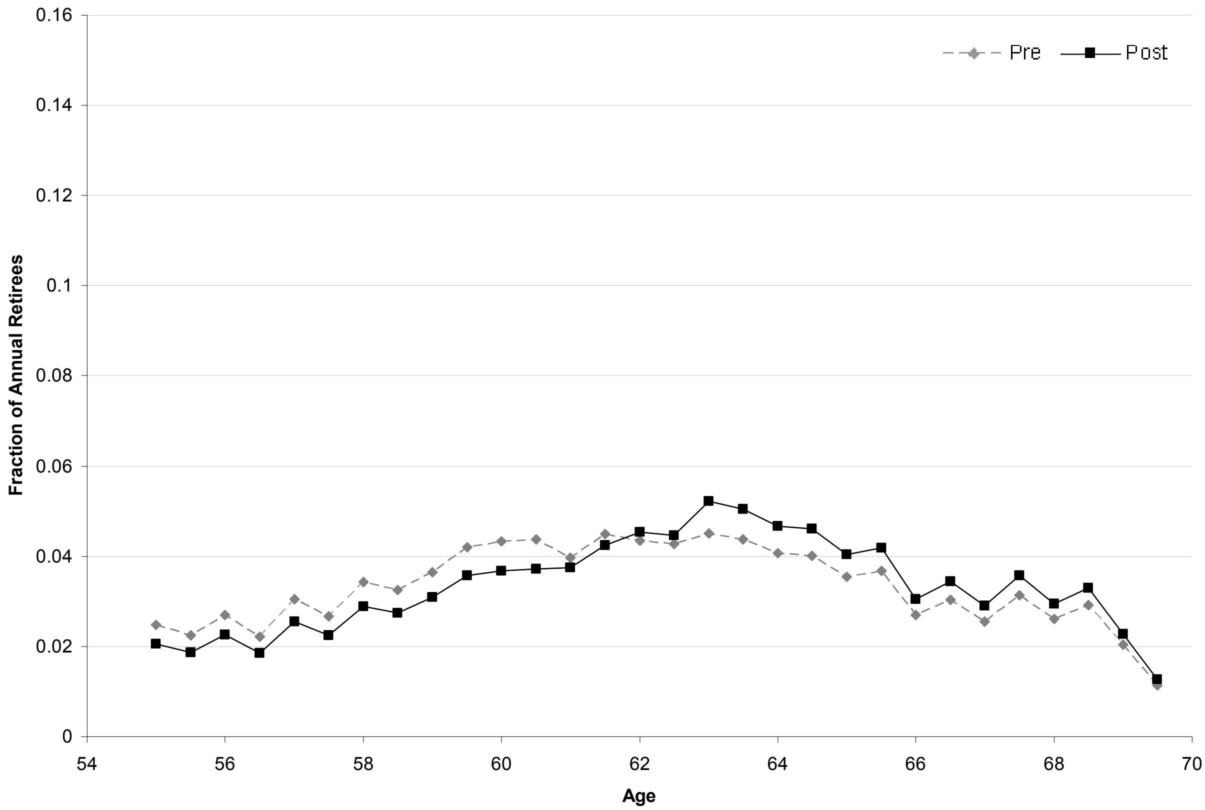
b.



Source: Simulation results using the LAUSD Administrative Data (1997-2003)
Note: The distributions are simulated with estimates from specification 4 of the structural model, which includes only an age 60 indicator as a control. There is again a shift in the bunching from age 60 to age 63, matching observed behavior following the reform, though the bunching at age 60 in both periods is over-predicted.

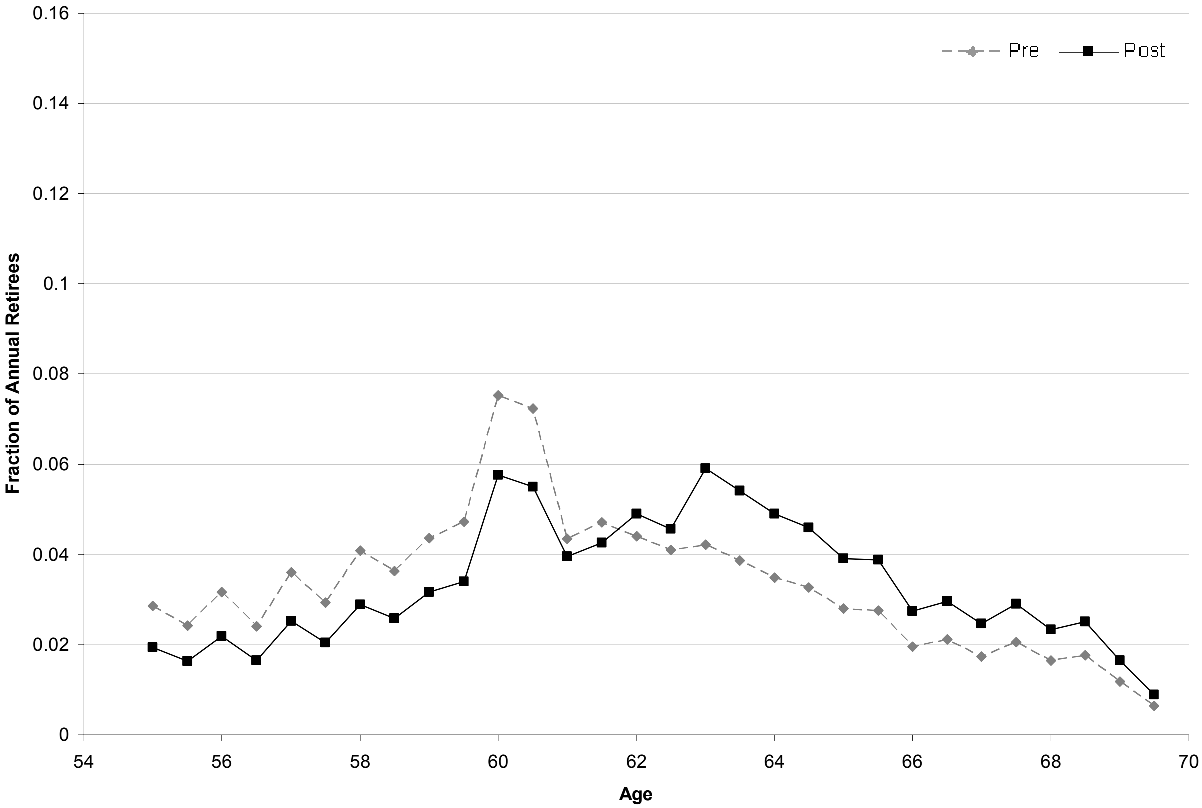
Figure 13
Peak Value Predictions for LAUSD Pre- and Post-reform

a.



Source: Simulation results using the LAUSD Administrative Data (1997-2003)
Note: The distributions are simulated with estimates from specification 2 of the peak value model on the pooled data, which includes salary controls and a linear age term. The peak value model predicts a rightward shift of the distribution following the reform. This prediction is not consistent with standard theory or the observed behavior of CalSTRS members.

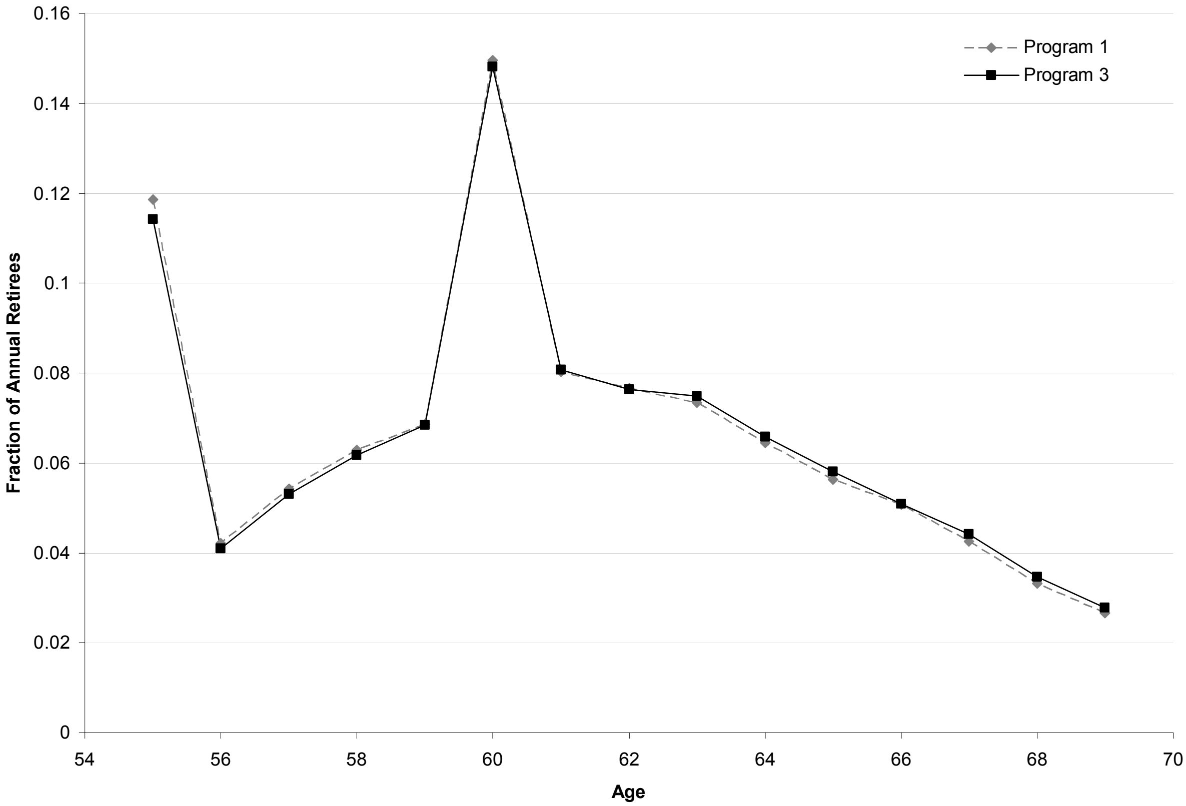
b.



Source: Simulation results using the LAUSD Administrative Data (1997-2003)
Note: The distributions are simulated with estimates from specification 4 of the peak value model on the pooled data, which includes salary controls and an indicator for age 60. Here, the change in density at age 60 is well-captured, however the model still predicts a rightward shift of the distribution, which is not consistent with standard theory or the observed behavior of CalSTRS members.

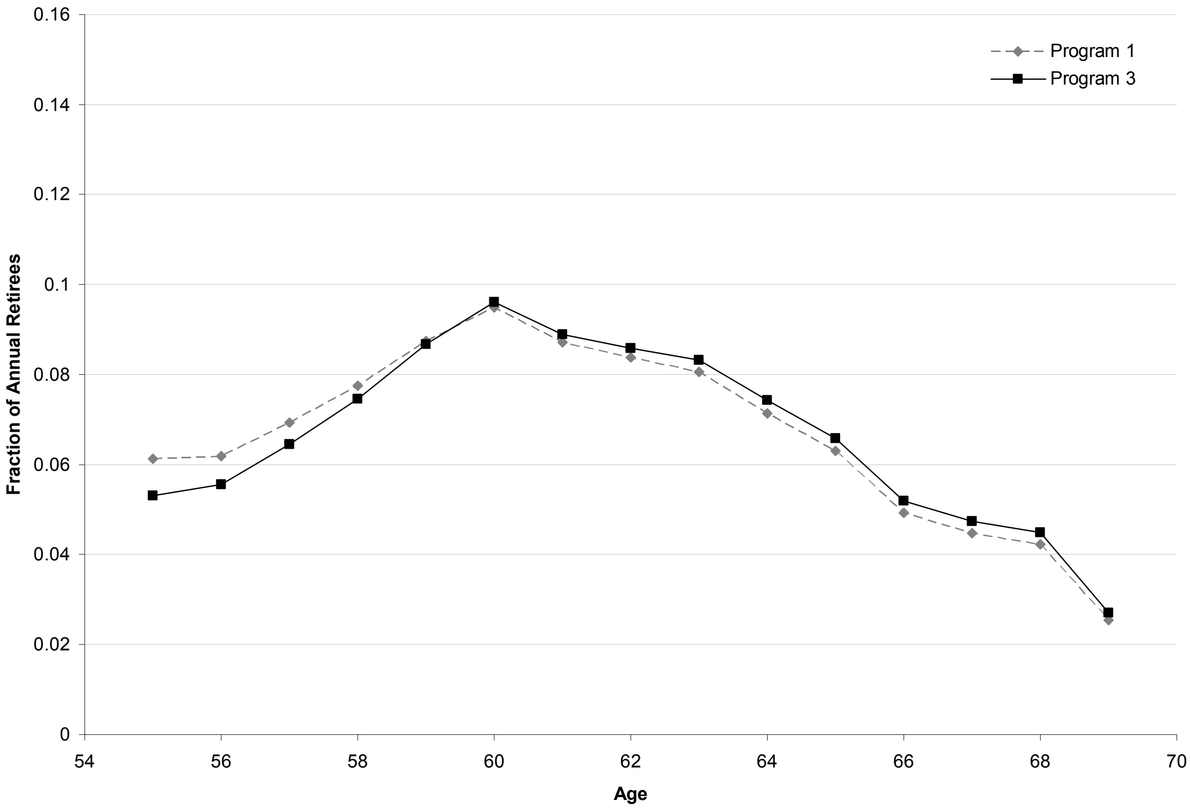
Figure 14
Predictions for LAUSD under Hypothetical Retirement Programs

a. Structural Predictions: Moving from Program 1 to 3, a 10% increase in net wage



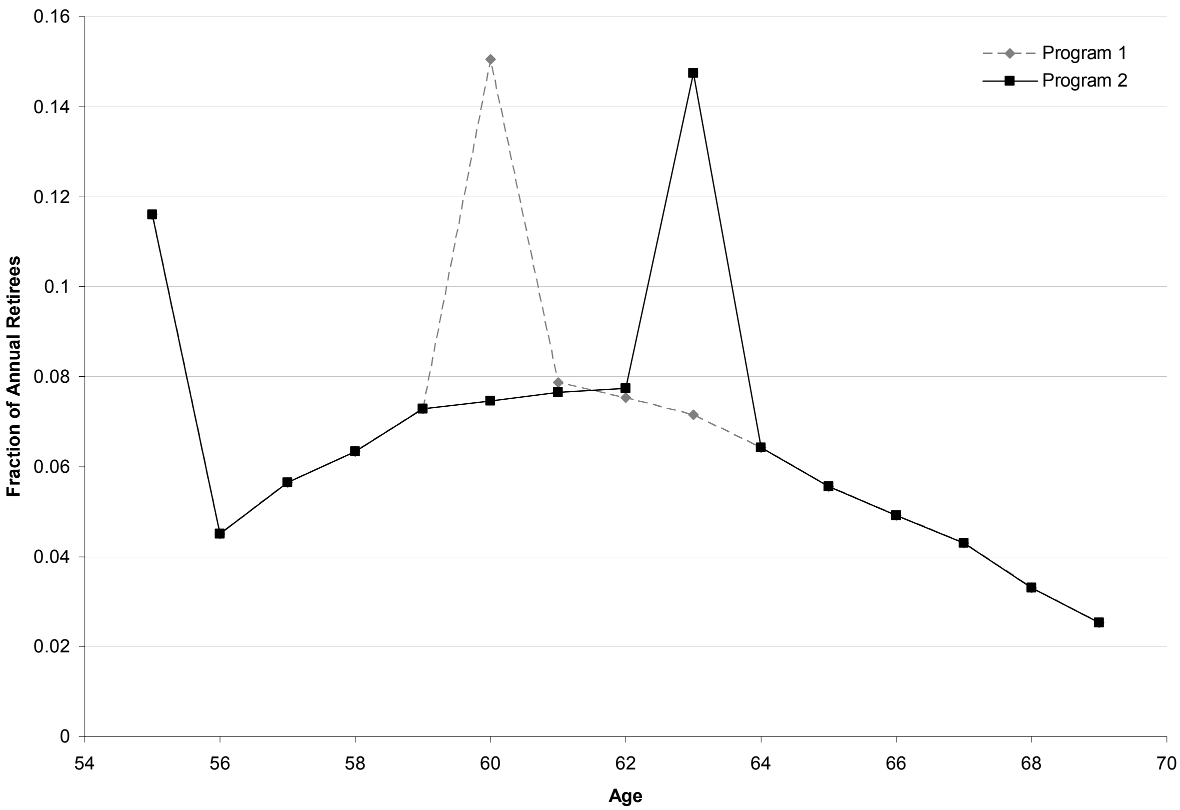
Source: Simulation results using the LAUSD Administrative Data (1997-2003)
Note: The distributions are simulated with estimates from specification 3 of the structural model, which includes all salary controls. There is very little change in the distribution. Retirements are delayed slightly, but the general shape of the distribution remains the same.

b. Peak Value Predictions: Moving from Program 1 to 3, a 10% increase in net wage



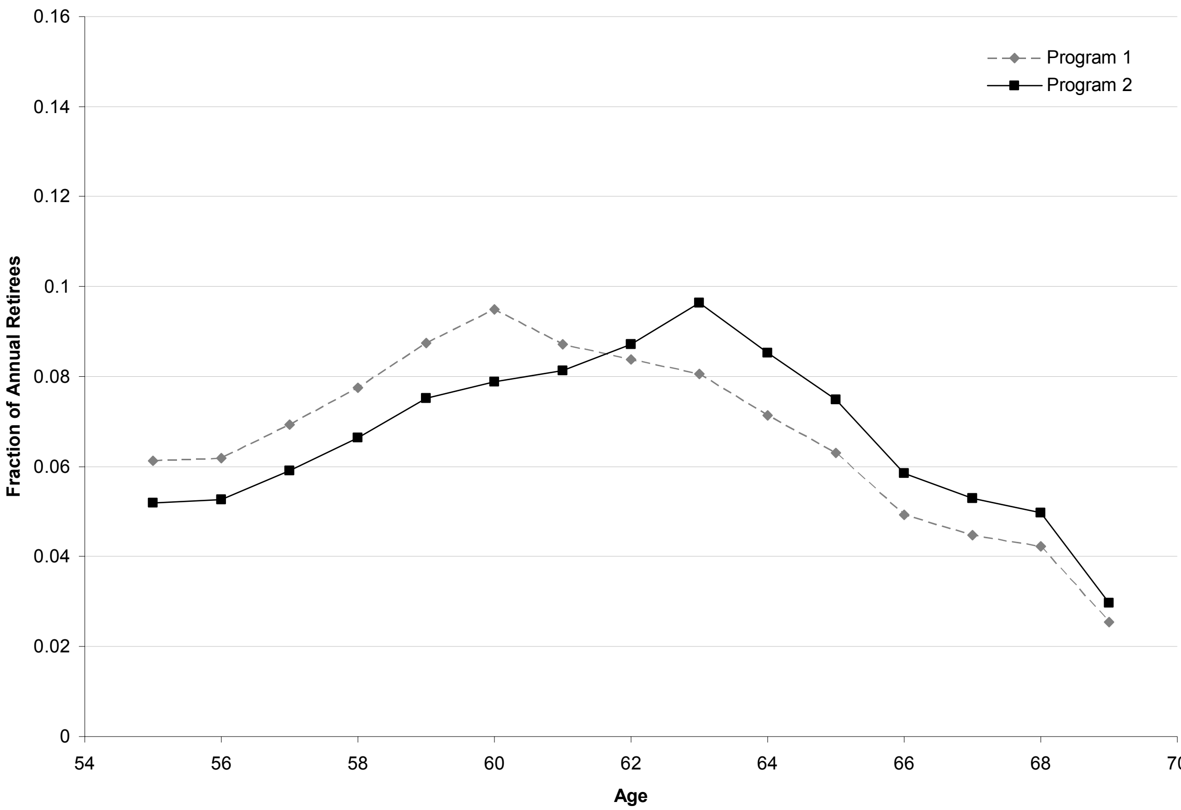
Source: Simulation results using the LAUSD Administrative Data (1997-2003)
Note: The distributions are simulated with estimates from specification 2 of the peak value model on the pooled data, which includes all salary controls and a linear age control. The change is similar to that predicted by the structural model. Retirements are delayed slightly, but the general shape of the distribution remains the same.

c. Structural Predictions: Program 1 to 2, shift in kink from age 60 to 63



Source: Simulation results using the LAUSD Administrative Data (1997-2003)
Note: The distributions are simulated with estimates from specification 3 of the structural model, which includes all salary controls. This model predicts the key shift from the kink at age 60 to the kink at age 63.

d. Peak Value Predictions: Program 1 to 2, shift in kink from age 60 to 63



Source: Simulation results using the LAUSD Administrative Data (1997-2003)
Note: The distributions are simulated with estimates from specification 2 of the peak value model on the pooled data, which includes all salary controls and a linear age control. The peak value model predicts a rightward shift of the distribution, distinctly different from the shift in bunching predicted by the structural model.