Essays on the Economics of 
Public Sector Retirement Programs

by

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B.A., Swarthmore College, 2006

Submitted to the Department of Economics 
in partial fulfillment of the requirements for the degree of

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Abstract

This thesis investigates the influence of retiree health and pension policies on the retirement decisions of public sector employees. Chapter one documents the central role of eligibility for subsidized retiree health insurance. Using administrative records obtained from the Pennsylvania State Employees Retirement System, the analysis finds that the well-documented spike in the separation rate at the normal retirement age almost completely disappears in the population of workers not yet eligible for subsidized retiree health insurance. A second set of results exploits quasi-experimental variation in plan design to show that increasing the service requirement for subsidized retiree health insurance stretches the distribution of separations: early separations occur earlier and late separations occur later.

Chapter two presents a structural analysis of the retirement decision for the same employees. Existing models of the retirement decision treat eligibility as a fixed characteristic of the worker rather than one that evolves over the career. This chapter estimates a model of life-cycle labor supply and uses it to simulate labor supply behavior under different health and pension policies. Changes in the eligibility requirements for subsidized retiree health insurance induce dramatic changes in retirement timing that would be missed in models that do not account for an employer’s eligibility criteria.

Chapter three turns to the defined benefit pension plans common in the public sector. These plans create complicated incentives in favor of continued work at some ages and in favor of retirement at others. The strength of these incentives depends on many factors, such as the age of initial employment and the number of years on the job. Because employees differ along these dimensions, the value of the pension benefits earned over the course of a career varies substantially—even among employees with the same total earnings. This chapter investigates the incentive effects and distributional consequences of four stylized plan designs. It derives simple formulas for the accrual rate of pension wealth and the distribution of benefits under each of the plans and uses these formulas to gain insight into the incentives and risks they create.

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Chapter 1

Retiree Health Insurance and Job Separations: Evidence from Pennsylvania State Employees

Abstract

This chapter documents the central role that eligibility for subsidized retiree health insurance plays in retirement decisions. Using administrative records obtained from the Pennsylvania State Employees’ Retirement System, the analysis finds that the well-documented spike in the separation rate at the normal retirement age almost completely disappears in the population of workers not yet eligible for subsidized retiree health insurance. Similarly, workers eligible for subsidies before the normal retirement age separate at much greater rates than comparable workers who are not eligible. A second set of results exploits quasi-experimental variation in plan design to show that increasing the service requirement for subsidized retiree health insurance stretches the distribution of separations: early separations occur earlier and late separations occur later. However, younger employees respond exclusively by delaying separation. Finally, simulations of alternative eligibility requirements for subsidies reveal important financial links between the health and pension plans. Restricting eligibility before the normal retirement age encourages continued work when pension accruals are highest. The resulting increase in pension obligations partially offsets the savings obtained from reduced health benefits.

This project would not have been possible without the invaluable assistance of the open records team at the Pennsylvania State Employees’ Retirement System. I also thank Jim Poterba, Jon Gruber, Peter Diamond, Isaiah Andrews, Aviva Aron-Dine, Dan Barron, Matt Fiedler, Sally Hudson, Adam Sacarny, Joe Shapiro, Tyler Williams, seminar participants at MIT, and the open records staff at the Pennsylvania Office of Administration. This research was supported by the National Institute on Aging, Grant Number T32-AG0000186, and by the Lynde and Harry Bradley Foundation. All mistakes are my own.
1.1 Introduction

State governments face unfunded liabilities of more than $600 billion arising from the retiree health benefits they have promised to current and past employees (Pew Center on the States (2012)). The assets currently set aside to pay for these benefits cover only five percent of the accrued liability. Furthermore, struggling with reduced revenues and other spending priorities, states are choosing not to make the contributions necessary to fully fund their plans. In fiscal year 2010, Arizona was the only state to do so. Rather than increase taxes or reduce spending on other programs, many states are choosing to continue on a pay-as-you-go basis and cut future benefits.

Unlike pensions, retiree health benefits (RHB) have few legal protections and can be modified for both current workers and retirees (Clark and Morrill (2010)). For this reason, reductions in RHB offer the possibility of substantial short-term savings for cash-strapped state governments. At the same time, any modifications to retiree health benefits implemented for current workers will have important effects on the state workforce. Age and service requirements in many plans create large financial incentives in favor of continued work in the years immediately preceding eligibility. Completing the last year of service required can be worth hundreds of thousands of dollars to employees who intend to retire immediately after doing so. After meeting the eligibility requirements, workers can keep their health coverage whether or not they remain on the job. As a result, employees' effective compensation rate decreases sharply. Understanding the labor supply response to these incentives is both interesting in its own right and critical to projecting the financial implications of any potential changes in retiree health benefits.

To gain insight into the effect of retiree health benefits on labor supply behavior, this chapter analyzes the experience of Pennsylvania state employees. Pennsylvania's retiree health benefits come in two forms: guaranteed access to the state's pool for all annuitants and highly subsidized insurance policies for annuitants meeting additional age and service criteria. In the last decade, the state has introduced new fees, restricted plan choices, and restricted eligibility for subsidized retiree health insurance. This analysis focuses on Pennsylvania for two reasons. First, when the state restricted eligibility for subsidized retiree health insurance (RHI), it grandfathered employees meeting certain age and service criteria under the existing eligibility rules. This grandfathering provision created exogenous variation
in plan design that can be used to understand the role of eligibility for subsidized RHI in employee separation decisions. Second, Pennsylvania’s public records law provides extensive access to the employment records maintained by the state pension system, allowing for detailed analysis of the effect of the state’s retirement benefits on employee behavior. Though obtained for a population of Pennsylvania employees, this chapter’s findings are relevant for a much larger set of public sector employees. The structure of the eligibility requirements for subsidized RHI in Pennsylvania is typical of one of the three common forms in which retiree health benefits are provided to public sector employees in the U.S.\footnote{The three most common forms of retiree health benefits in the public sector are (i) access to the state’s pool with generous subsidies for the purchase of insurance if a retiree meets certain age and service criteria, (ii) access to the state’s pool with a per-year-of-service subsidy for the purchase of insurance, and (iii) access to the state’s pool with little or no premium assistance. Intermediate and hybrid forms also exist.}

The primary data for the analysis is drawn from the member records of the Pennsylvania State Employees’ Retirement System (SERS) and was obtained via public records requests. The extract contains quarterly earnings, annual hours, and key dates in the careers of more than 200,000 individuals who worked for the state between 2000 and 2011. The period captures 115,000 separations including nearly 70,000 retirements. The data is rich enough to allow for the determination of an employee’s eligibility for retiree health and pension benefits on any date in the 12-year period with a high degree of accuracy.

The chapter first investigates the effect of eligibility for subsidized retiree health insurance on the separation hazard. The eligibility rules for pension and health benefits partition the age and service space into five distinct regions. Employees who separate in each region are entitled to a different combination of benefits: no benefits, an early retirement pension with self-paid health insurance, an early retirement pension with subsidized health insurance, and so forth.\footnote{Throughout this chapter I refer to the insurance available to all annuitants regardless of age and service as self-paid. However, the state contributes $5 per month toward the cost of this coverage.} I estimate the separation hazard for each combination of age and service and examine changes in the hazard at the boundaries between the age and service regions defining eligibility for different benefits.

The striking finding of this analysis is that while the widely-documented spike in the separation hazard at the normal retirement age is clearly present in the aggregate data for Pennsylvania state employees, it nearly disappears for the population that is not yet eligible for subsidized retiree health insurance at the normal retirement age. Eligibility for subsidized RHI at the normal retirement age during the years used in the hazard estimation required...
at least 15 years of service. For the cohort of employees reaching normal retirement age with exactly 15 years of service, the probability of separation increases from 4 percent in the year before eligibility to 26 percent in the first year of eligibility. In contrast, for the cohort of employees reaching the normal retirement age with 14 years of service—and therefore ineligible for subsidized RHI—the separation probability is essentially unchanged. However, one year later, when this second cohort of employees becomes eligible for subsidized RHI, it jumps 31 percentage points.

The hazard analysis also reveals the importance of eligibility for subsidized RHI in motivating early retirement. Employees in their late 50s begin separating in meaningful numbers only after they become eligible for subsidized RHI. For example, the probability of separation for employees becoming eligible for subsidized RHI at age 57 increases from 3 percent at 56 to 15 percent at 57. Furthermore, this increase in the hazard largely persists in the years between eligibility for subsidized RHI and the normal retirement age. The effect of eligibility for subsidized RHI on employees in their late 50s found in this analysis is far larger than that found in previous studies. However, prior work has generally pooled all employees at firms that offer retiree health insurance, regardless of current eligibility status, and compared them with employees at firms that do not offer RHI. The data for Pennsylvania employees shows that this can be quite misleading. Less than half of the state workforce is eligible for subsidized RHI at any age before the normal retirement age.

The chapter next turns to the analysis of a quasi-experiment arising from an increase in the service requirement for subsidized RHI. Effective July 1, 2008, the state increased the service requirement for subsidized RHI at or after the normal retirement age from 15 to 20 years. A population of employees nearing eligibility was grandfathered under the existing rules, thus allowing for sharp identification of the effect of the new eligibility rules using discontinuity methods. The more restrictive service requirement decreased the probability that an employee on January 1, 2003 just short of the grandfathering threshold would separate over the next nine years by 10 percentage points, from 73.4 percent to 63.8 percent.

As the decision to separate is a choice of when, not if, the object of fundamental interest is the distribution of separations over time. Using the same grandfathering variation, I es-

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3 To facilitate comparisons across age and service levels and comparisons with prior work, I report annual separation probabilities rather than the instantaneous hazard.

4 The analysis examines the population of employees on January 1, 2003 because the increased service requirement was formalized in collective bargaining agreements beginning in 2003.
estimate the effect of the policy change on the distribution of separations for workers exactly at the grandfathering threshold. I find that the increased service requirement stretches the distribution of separations: early separations occur earlier and late separations occur later. Facing a more stringent service requirement, some employees who would have worked until eligibility before the reform decide that the benefits are not worth the additional years of work required after the reform. These employees separate even sooner under the post-reform eligibility rules than they would have under the pre-reform rules. At the same time, other workers with identical characteristics decide that the value of the subsidies is large enough that the additional work required is worth it. These employees work longer under the post-reform rules than they would have under the pre-reform rules. The relative importance of these two effects depends on the age and the binding eligibility requirement for the affected workers in the pre-reform period. Older workers already eligible for a pension respond primarily by accelerating separations while younger workers not yet eligible for any pension benefits show no evidence of acceleration. In all age groups, some employees delay separations, but the number of employees delaying separation is modest at older ages.

Finally, I adapt the hazard estimation procedure to simulate the effect of two additional restrictions in eligibility for subsidized RHI on employee separations and on the value of the state’s health and pension obligations. I show that a five-year increase in the service requirement for subsidized RHI before the normal retirement age would reduce the present value of obligations by nearly $500 million, or 7 percent. However, as such a policy would encourage additional work at exactly the ages when pension accruals are highest, I find that it would also increase pension obligations by $100 million. That is, the increase in pension liabilities associated with the restriction in eligibility for subsidized RHI would offset about 20 percent of the reduction in retiree health liabilities. In contrast, for a restriction in eligibility after the normal retirement age the pension plan provides additional savings. Pension accruals at these ages are low and the additional employee contributions made by the individuals who choose to work longer in response to the eligibility restriction more than offset the increase in pension benefits.

5For reasons discussed in section seven, this calculation assumes a different discount rate than that used in the state’s valuations of its retiree health obligations. As a result, the estimates presented here would not match official estimates of identical policies. In addition, the simulations performed in this chapter limit attention to a subset of active employees on December 31, 2011. To the extent that a proposed policy affects individuals not in this sample—including, but not limited to, retirees and hazardous duty employees—the estimated financial impact would also differ.
The remainder of this chapter proceeds as follows. Section two situates this analysis in the existing literature on retiree health benefits. Section three details the retiree health plan and pension plan covering Pennsylvania state employees and summarizes the financial incentives the two plans create. Section four describes the member data. Section five presents the hazard estimates, and section six presents the analysis of the quasi-experiment. Section seven discusses the policy simulations. Section eight concludes.

1.2 Previous studies of retiree health benefits

This analysis advances our understanding of the role of retiree health and pension benefits in the separation behavior of public sector employees. It is the first work to explore the impact of subsidized RHI on separations with full knowledge of the eligibility rules for both health and pension benefits. While the complicated work incentives created by defined benefit pensions have been extensively studied, the analogous incentives created by retiree health benefits have been largely ignored. The studies that have attempted to investigate the effect of RHI on separations accounting for the evolution of eligibility at the individual level have encountered severe data problems.

Reduced form analyses typically estimate models for the probability of separation or retirement over one or two-year periods. Estimates for the effect of retiree health insurance on the one-year probability of separation for individuals in their 50s range from two to six percentage points (Karoly and Rogowski (1994), Blau and Gilleskie (2001), Marton and Woodbury (2007)). Analyses that allow the effect to vary by age find little effect in the early 50s and large effects in the early 60s. The age at which studies first find a large effect varies.

6See, for example, Karoly and Rogowski (1994), Rust and Phelan (1997), Blau and Gilleskie (2001, 2008), Robinson and Clark (2010), and French and Jones (2011), who treat retiree health insurance coverage as a fixed characteristic of the worker. For a review of the literature on pensions and retirement see Lumsdaine and Mitchell (1999).

7Gustman and Steinmeier (1994) specify a theoretical model of retirement incorporating the eligibility rules for retiree health insurance into the budget constraint, but lack data on the actual rules. Similarly, Marton and Woodbury (2013) pursue a reduced form investigation of the role of RHI in determining separations explicitly motivated by dynamic concerns but only have data on firm decisions to offer RHI. In contrast, Nyce et al. (2011) have data on the eligibility rules for most retiree health plans in their sample but have only limited information on the eligibility rules for pension benefits and do not use either in their estimation.

8Madrian (1994) takes a different approach, estimating censored regression specifications for the retirement age. Her results suggest a 6-14 month reduction in the retirement age for individuals with retiree health insurance.
Nyce et al. (2011) find large effects at 62 and 63 while Blau and Gilleskie (2001) and Marton and Woodbury (2013) find large effects beginning at age 60.\footnote{The timing in Blau and Gilleskie (2001) could be sensitive to the choice of functional form in the estimation, but the results of Nyce et al. (2011) and Marton and Woodbury (2013) should not be.}

Analyses with information on the relative generosity of different plans find effects concentrated among those plans offering larger subsidies. Blau and Gilleskie (2001) estimate that the effect of RHI on the separation hazard is 2 percentage points when the employer and the employee share the cost and 5 percentage points when the employer pays the full cost. Similarly, Nyce et al. (2011) find that the effect at age 62 is 3.7 percentage points overall and 5.9 percentage points when the employer subsidy exceeds 50 percent of the premium.

A parallel structural literature has estimated dynamic life-cycle models to better understand the role of retirement benefits in separations. Of particular note is the analysis of Gustman and Steinmeier (1994) who explicitly recognize the importance of the evolution of eligibility for retiree health insurance over the career. However, lacking data on the eligibility rules, they assume that eligibility for RHI coincides with eligibility for early retirement. They conclude that RHI increases the aggregate hazard by 2 percentage points at age 62 with roughly one third of their sample covered. Rust and Phelan (1997) and French and Jones (2011) investigate richer specifications incorporating models of medical expenditures and, in the case of French and Jones, allowing for self-insurance through savings. However, both analyses treat eligibility for retiree health insurance as a fixed characteristic of the worker. In each study, the estimation assigns a crucial role in separation behavior to health coverage. French and Jones estimate that the job exit rate at age 62 if all employees had retiree health coverage would be 8.5 percentage points higher than if all employees had coverage tied to their job.

This study also makes an important contribution in offering effects identified from quasi-experimental variation in plan design.\footnote{Prior work on COBRA has made use of quasi-experimental variation as well (see, for example, Gruber and Madrian (1995)).} Existing reduced form studies rely on the presence of adequate controls to identify the causal effect of offer, may well be contaminated by the dynamic selection problem raised in Diamond and Hausman (1984), and often impose strong assumptions about the functional form of the separation hazard.\footnote{Madrian and Beaulieu (1998) use quasi-experimental variation in benefits, but not plan design, to investigate the role of Medicare benefits in retirement decisions.} Structural studies depend on the adequacy of the choices made in specifying the model.
Implicitly, public sector employees are an important part of the sample in all of the cited studies as they make up a disproportionate share of employees with retiree health benefits. However, I am unaware of any empirical studies directly examining the labor market effects of retiree health benefits in the public sector. Numerous authors have investigated the effect of pensions on the labor supply of public school teachers including Brown (2013) for teachers in California, Ni and Podgursky (2011) for teachers in Missouri, and Furgeson et al. (2006) for teachers in Pennsylvania. Asch et al. (2005) consider the effect of pensions on the separation behavior of civil service employees in the Department of Defense.

1.3 Institutions and financial incentives

The state of Pennsylvania offers health and pension benefits to its employees after they retire. State employees are also covered by both Social Security and Medicare. This section outlines the major provisions of the state’s retirement programs as they existed between 2000 and 2011 and discusses the financial incentives the two programs create. It limits attention to the rules for general employees hired before January 1, 2011 and working at agencies participating in the Retired Employees Health Plan (REHP). The description in this section is drawn primarily from the publications of the Pennsylvania Employees Benefit Trust Fund (PEBTF), which administers the REHP, and the State Employees’ Retirement System (SERS), which administers the pension plan.

1.3.1 Retiree health benefits

Pennsylvania provides retirees access to group health insurance through the PEBTF. The existence of a retiree health plan, the eligibility rules, and the employer and employee con-

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12 The financial challenges of public sector retiree health benefits have received extensive attention. See, for example, Clark and Morrill (2010), which also includes a theoretical discussion of the potential impacts on labor supply.

13 The rules for the benefit programs are complex, differ across unions and over time, and almost always have exceptions. This summary provides an overview of the most important rules, but ignores many details and special cases.

14 The restriction to general employees excludes from the sample, among others, corrections officers, state police officers, judges, and legislators. Pension benefits for each of these populations are computed according to a distinct set of rules. Legislation enacted in late 2010 made major changes in the pension benefits for employees hired on or after January 1, 2011. The REHP is the largest (by enrollment) post-retirement medical benefit plan for Pennsylvania state employees, but does not cover all employees covered by the pension plan.
tributions are specified in collective bargaining agreements. The details of coverage are determined by the Fund’s Board of Trustees.15

Retirees may choose from a menu of plans determined by their date of retirement, eligibility for Medicare, and county of residence. For 2011, non-Medicare-eligible annuitants in every Pennsylvania county could choose between an indemnity plan, an HMO, a PPO, and a consumer-directed health plan (CDHP). These options vary somewhat from year to year. In the early 2000s, PPO coverage was limited to a small number of counties, retirees in many counties had a choice between two or three HMOs, and the CDHP was not offered. The indemnity plan is available only to employees who retired before July 1, 2004 and the CDHP only to those who retired on or after that date. Non-Medicare-eligible retirees living out of state have access to an indemnity plan or PPO with appropriate geographic coverage. Medicare-eligible retirees must enroll in Medicare and pay the Part B premiums. The REHP provides supplemental medical and drug coverage.

Any retiree receiving a pension benefit from SERS may purchase coverage through the REHP at full price less a $5 per month subsidy from the state. I refer to this case as self-paid due to the nominal nature of the state’s contribution. Retirees meeting additional age and service criteria qualify for substantial subsidies from the state. Eligible employees retiring before July 1, 2005 pay nothing for health insurance after retirement. Eligible employees retiring between July 1, 2005 and June 30, 2007 make contributions equal to 1 percent of final annual salary. Eligible employees retiring on or after July 1, 2007 make contributions at the same rate as active employees, currently 3 percent.16 Retirees first hired on or after August 1, 2003 must pay an additional cost if they choose a health plan other than the least expensive plan or plans in their county of residence. The HMO and CDHP are typically considered the least expensive plans in each county and the additional cost applies to those who choose the PPO.

For employees retiring prior to July 1, 2008, eligibility for state subsidies required 15 years of service at or after the normal retirement age and 25 years of service before the normal retirement age. For retirements effective on or after July 1, 2008, eligibility for state

15The PEBTF Board of Trustees consists of seven members designated by the Pennsylvania Secretary of Administration and seven members designated by unions.

16Contributions for retirees who retired on or after July 1, 2007 were reduced effective January 1, 2012. Under the 2011-2015 labor contracts, the contribution rate falls to 1.5 percent once a retiree becomes eligible for Medicare. In addition, the measure of earnings used to compute the contributions was changed from final salary to the pension plan’s definition of final average salary.
subsidies at or after the normal retirement age requires 20 years of service. Employees were grandfathered under the existing eligibility rules if they had accumulated at least 15 years of service by June 30, 2008 or had accumulated 13 years of service and were within one year of the normal retirement age. Service requirements are waived for members who retire with a disability benefit. Figure 3.1 illustrates eligibility for the different benefits before July 1, 2008 as a function of an employee’s age and service at retirement. While any retiree receiving a pension is eligible for self-paid coverage, very few retirees choose coverage on a self-pay basis. In practice, most employees work until eligibility for subsidized RHI or do not obtain health insurance coverage through the REHP after retirement. When a retiree dies, a surviving spouse may continue coverage through the REHP but loses any subsidy for which the state retiree was eligible.

To make this discussion more concrete, Table 3.1 summarizes the retirement benefits available to a hypothetical male employee who joins the state workforce at age 33, assuming the full career takes place under the policies in effect between 2005 and 2007. Each row in the table presents the benefits to which the employee would be entitled if he separates at the age shown in the left-most column. The calculations assume a fixed (in real dollars) premium for the health plans both before and after eligibility for Medicare. In the first five years of employment the individual would not be eligible for a pension and therefore could not buy into the health plan. After five years of service, the individual is eligible for an early retirement pension and thus could purchase coverage through the REHP at full price. After 25 years of service, the individual becomes eligible for subsidized RHI and pays only the 1 percent of final salary required contribution. The required contribution increases modestly with each additional year of work as the employee’s salary increases. The present value of the subsidy for retiree health insurance is zero at all ages before eligibility. Upon reaching eligibility the value jumps to $172,000. Thereafter, each additional year of work reduces the value of the subsidy. Working longer reduces the expected length of retirement and thus the expected number of years in which a subsidy would be received.

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17 Individuals could count service that they were eligible to purchase but had not yet purchased against the requirements for grandfathering. Service purchases are discussed in the next section.
18 The table ignores the $5 per month contribution from the state for retirees electing self-paid health insurance so as to avoid small but potentially confusing changes in the insurance premium as the individual ages resulting from the declining real value of a $5 subsidy.
19 The details of this present value calculation are discussed in section 3.3.
1.3.2 The pension plan

The state operates a traditional defined benefit pension plan using a final average salary formula. The initial benefit is equal to the product of (i) an accrual factor, (ii) average earnings in the three highest-earning years of the career, and (iii) years of service. For retirements before July 1, 2001 the accrual factor was 2 percent. For retirements on or after July 1, 2001 the accrual factor is 2.5 percent.20 Service is accumulated on an hourly basis with one year of service defined as 1650 hours. However, no more than one year of service can be earned in a single calendar year. Employees may purchase service credit for military service, out-of-state public school teaching service, and prior state service for which contributions were withdrawn or that was not covered by the pension system.21 The initial pension benefit is limited to 100 percent of an employee’s highest annual earnings. The pension does not have automatic post-retirement cost of living adjustments, but the state legislature has periodically implemented ad hoc adjustments. The most recent of these increases was implemented in two stages in 2002 and 2003.

Members become eligible for a normal retirement benefit at the earlier of age 60 with at least 3 years of service or any age with 35 years of service. Employees may retire with a reduced benefit at any age once they have completed five years of service. These eligibility requirements are illustrated along with those for retiree health benefits in Figure 3.1. Early retirement benefits are computed according to the final average salary formula and reduced by an actuarial adjustment using a four percent interest rate. The mortality tables used in the adjustment depend on when the service was performed, the date of hire, and the date of retirement.

Active members contribute 6.25 percent of salary to the pension system.22 Members’ contributions accumulate interest at a rate of 4 percent. Employees can take a refund of their accumulated contributions upon separation if they are not eligible for pension benefits. Members may also choose to leave their accumulated contributions in the system should they expect to return to state employment.

20 Employees hired before July 1, 2001 had to elect into the new service class with the higher accrual rate, which also involved paying higher employee contributions. Most members chose to do so.

21 State employees who have previously worked as a public school employee in Pennsylvania have the option of combining their service in the Public School Employees’ Retirement System (PSERS) with their service in the State Employees’ Retirement System (SERS) and receiving a single pension benefit reflecting service in either system.

22 Employees who did not elect the new service class in 2001 pay only 5 percent.
The preceding discussion applies to the initial benefit if an employee elects a single life annuity. Members may alternatively take a 100 percent joint and survivor annuity, a 50 percent joint and survivor annuity, or construct a payout schedule of their choice subject to approval by SERS. Individuals can also withdraw part or all of their accumulated contributions at retirement as a lump sum. In all cases, the initial benefit is adjusted so that these alternative payment options provide an actuarially equivalent benefit to the single life annuity using a 4 percent interest rate.

Table 3.1 also provides a concrete example of the pension benefits available to a hypothetical employee. Each row shows the pension benefit and the present value of the benefit to which the employee would be entitled if he separates at the age shown in the left-most column. All values assume immediate claiming of the pension benefit upon separation. In the first five years of employment, the worker is not eligible for a pension. After five years of service, the individual is entitled to an early retirement benefit, the value of which increases smoothly with each additional year of work. At age 60, the individual becomes eligible for normal retirement. The benefit continues to increase after that age, but at a much slower rate. Similarly, the rate of increase in the present value of the benefit slows dramatically. After accounting for the changing age at which the present value is computed, each additional year of work is associated with an extremely modest increase in the value of the benefit. Assuming a slower rate of salary growth or a higher discount rate would change the modest increase into a modest decrease.

1.3.3 The financial incentives

Pennsylvania’s retiree health and pension plans create large and varied financial incentives for and against continued work. This section quantifies these incentives to provide context for the behavioral analysis that follows.

The premium for health coverage varies across plans and over time. Figure 3.2 plots the average cost of a policy for a married couple ineligible for Medicare and for a married couple eligible for Medicare for the years 2002-2012. Costs increase over the decade, but growth...
rates exhibit substantial year-to-year variation. In 2011, the average premium for retirees ineligible for Medicare was $21,575; for Medicare-eligible retirees it was $10,327.

The subsequent analysis will focus on the effect of eligibility for subsidized retiree health insurance. To summarize the value of the state subsidy, I compute the present value of the difference between the full premium and the required retiree contribution for retirees eligible for subsidies.\(^25\) For a retiree of age \(t\), this present value is given by

\[
V_{HI}(t) = \sum_{s=t}^{T} \beta^{s-t} \pi(s | t) \{ m(s) \times H_{\text{married}}(s) + (1 - m(s)) \times H_{\text{single}}(s) - r(s) w\},
\]

where \(\beta\) is the discount factor, \(\pi(s | t)\) the probability of survival until age \(s\) from age \(t\), \(m(s)\) the probability of being married at age \(s\), \(H_{\text{married}}(s)\) the full premium for a multi-party policy at age \(s\), \(H_{\text{single}}(s)\) the full premium for a single policy at age \(s\), \(r(s)\) the retiree contribution rate at age \(s\), and \(w\) the final annual salary of the individual.\(^26\) I use a discount rate of 6 percent, the RP-2000 mortality tables, and the scale BB mortality improvement factors.\(^27\) I set \(m(s)\) equal to the share of individuals married at each age in the pooled March CPS files for the years 2000 through 2011.\(^28\) Both survival probabilities and marital probabilities differ by gender.

Figure 3.3 presents the value of the state subsidy for males at each age between 45 and 75 assuming retirement on January 1, 2006. These retirees pay 1 percent of final salary in required contributions for health insurance.\(^29\) As the value of the subsidy is simply a measure of the portion of the premiums financed by the state in all years until death it decreases the average cost of a single policy as most plans offered to the Medicare-eligible population are priced on an individual basis.

\(^25\)In general, the value of an insurance policy can exceed the expected value of covered services. However, once eligible for a pension benefit of any kind, Pennsylvania state employees have guaranteed access to the state's pool. As a result, the value of eligibility for subsidized RHI is only the difference between the full premium and the required retiree contributions. This analysis will have nothing to say about the value of access to the state's pool.

\(^26\)Projected premiums assume growth of five percent for non-Medicare policies and 6 percent for Medicare policies from a baseline level that best fits the observed premiums between 2002 and 2012. I do not model the additional payments required for employees hired on or after August 1, 2003 who choose more generous plans.

\(^27\)The RP-2000 tables, developed by the Society of Actuaries, provide mortality probabilities for the year 2000 estimated from data on the mortality experience of uninsured pension plans in the years 1990 through 1994.

\(^28\)I use \(m(s)\) rather than a mortality table because, through divorce and remarriage, spouses can be replaced. Former spouses must be dropped from a retiree's health insurance policy after a divorce.

\(^29\)The value of the subsidy for females differs slightly from that of males for two reasons: (i) females have modestly lower mortality rates and (ii) females are much less likely to be married at older ages.
smoothly with age. At age 65 the rate of decrease slows because Medicare eligibility reduces the amount of coverage financed by the state and therefore the value of the corresponding annual subsidy. For an individual who retires at age 45, the value of the state’s subsidy is nearly $350,000. For an individual who retires at age 60, the value is about $125,000. As the premiums are not age-rated, the monetary value of the subsidy for younger retirees may exceed the expected value of medical services received.

To summarize the incentive for continued work created by the retiree health plan, I compute the present value of future subsidies to which an employee would be entitled if he continued working until the age of initial eligibility for subsidized RHI. Under Pennsylvania’s rules for eligibility, this measure of incentives is identical to the peak value measure of incentives proposed by Coile and Gruber (2007) for pensions. Figure 3.4 presents the subsidy peak value as a function of age and service. Young individuals close to the eligibility requirements have the highest value of potential future benefits, reaching $340,000 in the lower-right region of the figure. These employees are not currently eligible for any benefits, will become eligible in the near future, and upon becoming eligible could expect to collect benefits for many years. As service decreases and age increases the value of potential future benefits decreases. Employees must work longer before they become eligible and, once eligible, would receive benefits for a smaller number of years.

To compare the financial incentives arising from the health plan with those for the pension plan I compute the pension peak value

\[
P(V) = \max_{t > t} \sum_{s = t}^{T} \beta^{s-t} \pi(s \mid t) b(s; t) - \sum_{s = t}^{T} \beta^{s-t} \pi(s \mid t) b(s; t),
\]

where the variables are defined as before with the addition of \( b(s; r) \) to denote the pension benefit at age \( s \) conditional on retirement at age \( r \). The pension peak value measures the additional pension wealth that can be earned by working from the current age until the age that maximizes pension wealth. Figure 3.5 shows this value as a function of age and service.

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30 The formula and figure assume no age difference between the employee and his spouse. If there is an age difference it introduces an additional kink in the figure when the spouse crosses the eligibility threshold for Medicare.

31 Note that when age is the binding eligibility requirement, service has no effect on the value of potential future benefits.

32 For consistency with the measurement of incentives computed for the health plan, I adopt the convention that peak value is zero after the peak (i.e. the age that maximizes the present value of benefits). Previous analyses have also used the convention that peak value is equal to the annual accrual after the peak.
on the same axes and using the same scale as Figure 3.4.

For the age and service regions shown, the pension peak value is highest for younger employees with roughly 20 years of service. However, at $250,000, it is substantially smaller than the largest subsidy peak value for this population of employees. The pension peak value decreases as both age and service increase. In each case, the employee is now closer to eligibility for normal retirement and the pension plan offers less potential wealth in the years remaining. For all employees, the pension peak value decreases rapidly as the normal retirement age approaches. For short service employees, however, it remains substantial even after the normal retirement age. Because the pension benefit for short-service employees is small, the increase in the value of the benefit resulting from additional service and a higher salary is quite valuable even in the absence of an actuarial adjustment for delayed retirement. Sharp reductions in the value of future benefits are apparent at vesting, which occurs at five years before the normal retirement age and three years after.\(^{33}\)

Because retirees are eligible for either a generous state subsidy for retiree health insurance or a negligible subsidy, the subsidy peak value is highest immediately before eligibility and drops to zero immediately after. In contrast, as pension benefits accrue smoothly throughout the career, the pension peak value decreases in advance of the normal retirement age.\(^{34}\) The shaded regions in Figures 3.4 and 3.5 indicate age and service combinations at which the subsidy peak value is positive and exceeds the pension peak value. The value of potential future health benefits exceeds that of potential future pension benefits in the years shortly before eligibility for subsidized RHI. The value of potential future pension benefits is larger for individuals who have already become eligible for subsidized RHI but are not yet eligible for normal retirement and for individuals who will need to work for many additional years to become eligible for subsidized RHI.

\(^{33}\)The pension incentive computations assume no cost of living adjustments. In addition to increasing the level of benefits, an automatic COLA can substantially reduce the incentive for continued work after the normal retirement age in plans that base benefits on nominal salary at the end of the career.

\(^{34}\)If the value of future benefits is instead measured as a markup on the present value of compensation between the current age and the age that maximizes the present value of retirement wealth, there is a cliff at the normal retirement age.
1.4 Member data

The data for this analysis is drawn from the member records maintained by the Pennsylvania State Employees’ Retirement System (SERS) and was obtained via public records requests. The data cover all members who worked between January 1, 2000 and December 31, 2011. The records include name, year of birth, sex, summary employment information prior to 2000, detailed information on all jobs held since 2000, a quarterly salary history since 1997, annual hours since 2000, detailed information on the date and type of retirement, and various additional fields relating to the administration of the pension system.

The raw data contains records for 213,190 individuals. I exclude from the sample people who never work in the sample period, who retire before January 1, 2000, who have service in special service classes, who have class A-3 or A-4 service, and who elect to combine service in the state retirement system with service in the public school employees retirement system. Individuals in special service classes consist primarily of hazardous duty employees, legislators, and judges. The pension benefits for these individuals follow distinct rules, including earlier retirement ages and/or different accrual factors. Employees with class A-3 or A-4 service are affected by the major pension legislation enacted in late 2010 and also follow different eligibility and benefit rules. I further restrict the sample to employees at agencies participating in the Retired Employees Health Plan (REHP). The remaining sample consists of 158,785 individuals.

Figures 4.1-4.2 summarize the distribution of retirements between January 1, 2000 and December 31, 2011 by age and by service, respectively. Retirements are clustered between age 55 and age 62 with a clear mass at the normal retirement age. The number of retirements increases rapidly in the early 50s, is roughly constant between 55 and 60, spikes at age 60, remains somewhat elevated at 61 and 62, and then decreases rapidly. The distribution of retirements by service is more dispersed. Retirements occur in significant quantities from five years of service, the eligibility requirement for early retirement, through 36 years of service.

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35 The data also include individuals who worked prior to 2000 and had not retired by January 1, 2000, but they are not used in the analysis.
36 I also exclude a small number of individuals with missing or inconsistent data.
37 Participation in the REHP is determined at the bargaining unit level for the State System of Higher Education. However, the SERS member records do not indicate the bargaining unit. I include SSHE members in the sample as sample size will be a binding constraint in the quasi-experimental analysis. Excluding SSHE employees does not meaningfully affect any of the point estimates, but modestly increases standard errors for some of the quasi-experimental results.
A large number of retirements occurs at exactly 35 years of service, when individuals become eligible for normal retirement at any age, and at 15 and 25 years of service, the two eligibility thresholds for subsidized retiree health insurance. The number of retirements increases somewhat after 30 years of service, which may reflect rounding, a persistent response to an early retirement incentive at 30 years of service that was eliminated in 1999, or some other reason.

The major limitation of the data available for this analysis is that it does not include month and day of birth. Access to this information has been restricted due to concerns about identity theft in the release of employee records. I treat all individuals as if their birthday is on January 1 in the analysis of section five and I exclude individuals from the analysis of section six in cases where more detailed date of birth information is required.

1.5 Nonparametric hazard estimation

This section documents the relationship between the eligibility rules for retiree health and pension benefits and the separation behavior of Pennsylvania state employees. I estimate the empirical separation hazard in the age and service space that determines eligibility for the different retirement benefits and examine changes in the hazard at the boundaries between regions of eligibility for different benefits.

1.5.1 Empirical implementation

Define $T$ as the duration (in days) of a single employment spell. The separation hazard is then

$$ h(t) = \lim_{\Delta t \to 0} \frac{\Pr (t < T < t + \Delta t \mid T \geq t)}{\Delta t}, $$

the rate at which employees separate at time $t$ conditional on employment until $t$. I estimate the empirical hazard at each combination of age and service (both measured in whole years) as

$$ \hat{\lambda}_{as} = \frac{\sum_i d_i (a, s)}{\sum_i (t'_i (a, s) - t_i (a, s))}, $$

where $d_i (a, s)$ indicates separation by individual $i$ at age and service combination $(a, s)$, and $t'_i (a, s) - t_i (a, s)$ is the number of days individual $i$ is employed at age and service
The age and service space in which the hazard is estimated is also the space in which eligibility for the various retirement benefits is determined. Recall Figure 3.1. Each region identifies a set of age and service combinations at which employees are eligible for a particular package of benefits: an early retirement pension with self-paid retiree health insurance, an early retirement pension with subsidized RHI, a normal retirement pension with subsidized RHI, and so forth. The fine grid over the entire age and service space in the figure indicates the cells for which the hazard is estimated. I interpret changes in the hazard at the boundaries between regions as the effect of changes in eligibility status. To facilitate comparisons across age and service levels, allow for easier interpretation of the findings, and maintain comparability with the existing literature, I report the estimation results in the form of annual separation probabilities. The annual separation probability at age and service combination \((a, s)\) is defined as

\[
\hat{p}_{as} = 1 - e^{-365.25 \lambda_{as}}.
\]

A key advantage of this reduced form approach is that it imposes no restrictions on the interaction between health and pension benefits in determining separation behavior. In addition, the empirical hazard estimation has a close relationship with the methods employed in actuarial experience studies performed for pension plans, thus providing results potentially of interest to a broader community.

Separation may occur for reasons other than traditional retirement, including departure for a different full or part-time job, death, and disability. Since the structure of retirement benefits affects both the timing and the classification of separations, studying total separa-

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38This intuitive specification of the hazard can be motivated as the maximum likelihood estimate of the piecewise constant hazard \(h(t) = \lambda_k\), where \(k\) indexes non-overlapping regions in the domain. The likelihood for this hazard specification is \(L = \prod_i \prod_k \lambda_k^d_i(k) e^{-\lambda_k(t_i(k) - t_i(k))}\) and the MLE is \(\hat{\lambda}_k = \frac{\sum_i d_i(k)}{\sum_i (t_i(k) - t_i(k))} - \lambda_k\). I report robust standard errors clustered at the individual level.

39Retirement benefits may affect decisions about when and whether to take jobs with different employers. Interpretation of the separation probabilities could be confounded if individuals attempt to get a job with the state at a particular time based on their knowledge of the detailed rules for the state’s retirement benefits. In such cases, while the hazard would still provide information about the effect of the state’s retirement benefits on employee behavior, it would not be the effect of the benefits on the timing of separations by otherwise similar people, but rather their effect on the composition of the workforce in the first place. However, a tabulation of the age at first hire for new employees suggests this is not a problem. The distribution is smooth and the number of hires remains high into the 50s.

40Note that individuals will only spend a full year at a particular combination of age and service if their service increments on January 1, the assumed date of birth.
tions is most appropriate for examination of the impact of benefits on labor market outcomes. However, this aggregation necessarily prevents the analysis of substitution between different types of separations that may be motivated by the benefit programs. In particular, as approved disability retirements waive the service requirement for subsidized RHI, employees who are not yet eligible for subsidized RHI may attempt to classify a voluntary separation as a disability retirement in order to obtain health benefits. In addition, unlike studies that consider exit from the labor force or reported retirement status, this analysis will include individuals who continue to work after leaving state employment.

To avoid contamination from the restriction in eligibility for subsidized RHI analyzed in section six, I use only a subset of the worker-days observed in the data. I limit the sample to worker-days between January 1, 2000 and December 31, 2002, worker-days for employees grandfathered under the pre-2008 eligibility rules for subsidized RHI regardless of date, and worker-days when the employee is under age 60 regardless of date.41 I also require that a separation last for at least 180 days as many employment spells with the state have short gaps and may include scheduled returns.

1.5.2 Estimation results

The hazard estimation reveals several striking facts about employee behavior. First, the widely-documented spike in the separation hazard at the normal retirement age (NRA) nearly disappears in the subpopulation of employees who reach the NRA before eligibility for subsidized RHI. Instead, a late-career spike in the separation hazard occurs at the age of eligibility for whichever benefit is reached last, a normal retirement pension or subsidized retiree health insurance. Second, even though the pension plan offers a partial lump-sum

41 The increase in the service requirement for subsidized RHI analyzed in section six was formalized in new collective bargaining agreements beginning in 2003, exempted a population of grandfathered employees, and appears to have had minimal effects before the normal retirement age. The three sample restrictions follow from these three observations. The hazard results are highly robust across alternative sample selection criteria. While the estimation sample for the separation hazard excludes worker-days subject to this eligibility restriction, other changes in labor contracts and retirement benefits affecting workers in the sample could have affected the results. In particular, policy changes might be a disproportionately important factor in motivating separations that occur away from the eligibility thresholds. In a robustness analysis not included in the chapter, I estimate separation hazards in all months and excluding months associated with the expiration of labor contracts and changes in retirement benefits. More than one-fifth of all retirements in the 12-year period occur in the six affected months. The results indicate that, while these changes have important effects on the level of the separation hazard, they do not affect the nature of the changes in the separation hazard near the eligibility thresholds.
option at retirement that allows individuals to accelerate consumption, there remains an
interaction with the Social Security early retirement age: employees becoming eligible for
subsidized retiree health insurance before age 62 separate at a substantially lower rate than
those becoming eligible at or after age 62. Finally, eligibility for subsidized RHI has a
quantitatively important effect on separations before the normal retirement age beginning
in the mid 50s.

Figure 5.1 plots the separation probabilities for cohorts of employees approaching normal
retirement age with varying levels of service. Each line shows the separation probabilities for
a particular cohort of employees as they advance through the career. Employees who reach
normal retirement age with 15, 16, or 17 years of service—enough to be eligible for subsidized
RHI—follow very similar separation patterns. Each cohort shows a dramatic increase in the
probability of separation exactly at age 60. In contrast, employees who reach age 60 before
becoming eligible for subsidized RHI are unaffected by eligibility for normal retirement.
Separation probabilities for these cohorts remain flat until eligibility for subsidized RHI, at
which point they jump sharply. Table 5.1 presents the change in the separation probability
for each cohort at eligibility for normal retirement, at eligibility for subsidized retiree health
insurance, and by age. For employees with exactly 15 years of service at the NRA, the
probability of separation increases by 22 percentage points, from 4 percent at 59 to 26
percent at 60. For the cohorts with 16 and 17 years of service the increases are 24 and 26
percentage points respectively. However, for employees who reach the NRA with only 14
years of service the separation probability decreases by 1 percentage point, from 4.6 percent
at 59 to 3.7 percent at 60. (The decrease is not statistically significant.) Similarly, the
probability of separation increases by 2 percentage points for employees reaching the NRA
with 12 or 13 years of service. In all cases where eligibility for subsidized RHI occurs after
the normal retirement age, a dramatic increase in the separation probability occurs at that
time.

Additionally, even though retirees may accelerate consumption by taking a partial lump
sum at retirement, there still appears to be an interaction with the Social Security early
retirement age. Figure 5.2 presents separation probabilities for six cohorts becoming eligible
for subsidized RHI at or after the normal retirement age. For cohorts becoming eligible at age
60 and 61, the separation probability increases by about 30 percentage points at the point of
initial eligibility and then remains elevated after eligibility. In contrast, for cohorts becoming
eligible for subsidized RHI at or after age 62, the increase in the separation probability is larger—about 50 percentage points—and falls sharply in the year after eligibility.

Eligibility for subsidized RHI also increases separations before the normal retirement age. Figure 5.3 presents the separation probabilities by age for cohorts of employees becoming eligible for subsidized RHI in their late 50s. The separation probability increases sharply for all cohorts at exactly the point of eligibility for subsidized RHI. Table 5.2 presents the estimated change in these probabilities at eligibility for subsidized retiree health insurance and by age. For the cohort becoming eligible at age 56, the separation probability increases by 8 percentage points, from 2 percent at 55 to 10 percent at 56. For the cohort becoming eligible at age 58, the probability increases by 15 percentage points. The effects are large at all ages and increase with age. Results in the early 50s (not shown) are smaller, suggesting that remaining on the job is sufficiently attractive at younger ages that eligibility for subsidized RHI alone is insufficient to motivate many separations.

For employees in their late 50s, the increase in the separation probability at the point of eligibility for subsidized RHI largely persists until the normal retirement age. If the eligibility threshold served only to select out of the workforce individuals with the lowest attachment, the probability should rise at eligibility and fall subsequently. While there is a drop in the hazard after eligibility, it is only partial. The difference between the probability at any post-eligibility age and the probability prior to eligibility remains economically and statistically significant. This suggests that the effect of eligibility before the normal retirement age is not exclusively about selection out of the workforce. This contrasts with behavior after eligibility for Social Security, in which case the hazard drops sharply in the year after eligibility. The small number of people still working at these older ages are likely quite different from those who have already separated.

The results to this point have focused on the impact of becoming eligible for subsidized retiree health insurance. They have established the crucial role of eligibility for subsidized RHI in determining separations, particularly when it occurs after eligibility for normal retirement. However, eligibility for normal retirement also plays a role in the separation decisions of workers who become eligible for subsidized RHI first. Figure 5.4 follows the cohorts shown in Figure 5.3 until age 60, at which point the employees in these cohorts become eligible for normal retirement. The effect of the staggered eligibility thresholds for subsidized RHI is clear. Employees begin exiting in quantity as soon as they become eligible for subsidized
RHI. However, many also remain on the job until the normal retirement age. Taken as a whole, this analysis suggests the intuitive conclusion that the separation hazard spikes most dramatically at the age of eligibility for whichever benefit is reached last.

1.5.3 Comparison with prior work

In contrast with previous studies of retiree health insurance, this analysis offers no control group that will never become eligible for RHI. Instead, it examines the change in behavior when employees at a firm that offers subsidized retiree health insurance first become eligible for it. That is, this chapter focuses attention on the dynamics of individual eligibility for retiree health insurance rather than the impact of firm offer decisions. To highlight the importance of the distinction between eligibility and offer, Figure 5.5 plots the share of employees eligible for subsidized RHI by age. Employees first become eligible for subsidized RHI in the early 40s, and the share eligible increases steadily through the mid 50s. As long-service employees begin to retire in the late 50s, the fraction of the workforce eligible for subsidized RHI actually falls. It then jumps up discretely at age 60, when many employees become eligible for subsidized RHI simultaneously, before varying modestly at older ages. At most, roughly 60 percent of active employees are eligible for subsidized retiree health insurance. Before the normal retirement age, the largest fraction of eligible workers occurs at age 55, when 41 percent are eligible.

Analyses that use firm-level variation obtain an estimate of the effect of working for an employer that offers retiree health benefits. To compare the effects found here to the existing estimates, I approximate the effect of Pennsylvania’s decision to offer benefits on the separation probability at any age as the product of the effect of becoming eligible at that age and the fraction of the workforce eligible. Table 5.3 shows the effect of becoming eligible at each age, the fraction eligible at each age, and the corresponding estimate of the effect of firm offer at each age. The effect ranges from 3-6 percentage points in the late 50s and from 17-24 percentage points in the early 60s. The effects in the 50s are in line with those found in prior reduced form work while those in the 60s are larger.\footnote{Accounting for the decrease in the probability of separation after the first year of eligibility for cohorts becoming eligible in their 60s moderates these effects, but they remain larger than those found previously.}

The extremely large separation probabilities found in this analysis for individuals becoming eligible for subsidized RHI at or after age 62 suggest that the aggregate hazard for older
employees may provide little information about the effect of RHI on labor supply. Instead, it may primarily contain information about the distribution of tenure in the workforce relative to the eligibility rules for retiree health benefits.

This analysis also offers a potential reconciliation of discrepancies between previous studies in the estimated effect of RHI on separations at different ages. Prior reduced form studies of RHI frequently control for pensions only roughly through the use of dummy variables for offer, type, and other features of the plan or with linear terms for the number of years until eligibility. Implicitly, these studies are imposing strong separability assumptions on the effect of pensions and retiree health benefits. This analysis suggests that such an approach may be inappropriate. Eligibility for normal retirement is an input into the effect of RHI on separations. Structural analyses can overcome this problem, as they will generate interdependence between health and pension benefits through the implicit computation of financial incentives, provided the analysis maintains sufficient accuracy in the plan rules in the estimation. Studies that find large effects of RHI at ages 60-61 and those that find large effects at ages 62-63 may be investigating the effect of RHI in populations with different pension characteristics and inadequately accounting for that fact.

1.6 The employment response to a change in plan rules

In 2008, the state of Pennsylvania increased the service requirement for subsidized retiree health insurance at or after the normal retirement age from 15 years to 20 years. Employees who had accumulated 15 years of service or who were within one year of retirement and had accumulated 13 years of service by June 30, 2008 were grandfathered under the existing rules. The variation in eligibility rules generated by the grandfathering provision identifies the causal effect of the increased service requirement on employees at the grandfathering threshold. The analysis of the last section investigated changes in behavior associated with changes in eligibility status; the analysis of this section examines changes in behavior resulting from changes in plan rules.

I first estimate the effect of the change in eligibility rules on the probability of employment through the end of 2011 using standard methods for regression discontinuity designs. I then estimate employment survival functions for workers at the grandfathering threshold under the pre and post-reform eligibility criteria, interpreting the difference between them as the
effect of the reform on the distribution of separations.

1.6.1 The effect on employment through 2011

Empirical strategy

An employee's grandfathering status was determined by her accumulated service on June 30, 2008. However, the increased service requirement for subsidized retiree health insurance effective on that date was formalized in collective bargaining agreements beginning in 2003. To capture all potential responses to the change in the state's eligibility criteria, including those that occurred in advance of the grandfathering date, I analyze the eligibility restriction as a quasi-experiment performed on the population of state employees at the end of 2002.

Figure 6.1 illustrates the grandfathering requirements as a function of age and service on June 30, 2008. Any individual with at least 15 years of service was grandfathered under the existing eligibility rules. Employees age 59 or older with at least 13 years of service were also grandfathered. Because the service requirement for grandfathering depends on age and the member data contain only year of birth, I discard all individuals who turn 59 in 2008 as it is impossible to determine their grandfathering status with certainty. I limit attention to full-time employees on December 31, 2002 and project service forward from that date until June 30, 2008 assuming a full-time work schedule. Using the projected service, I compute the additional service needed to meet the grandfathering requirements for each individual. This measure of additional service provides the continuous assignment variable for a regression discontinuity design. Graphically, the additional service needed is the horizontal distance between an individual's accumulated service and the age-specific grandfathering requirement shown in Figure 6.1. Employees whose projected service exceeds the age-specific grandfathering requirement are not affected by the increased service requirement for subsidized RHI. All other employees are subject to the new, more restrictive service requirement.

Despite the restriction to full-time employees, it remains possible that individuals could manipulate their grandfathering status and the financial incentive to do so is large. Since

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43 For purposes of the sample restriction I define full time as at least 1900 hours. A full-time schedule for most state employees is 1950 hours per year (52 weeks at 37.5 hours per week). Service that an employee was eligible to purchase on June 30, 2008 could be counted against the grandfathering requirements even if the employee had not yet purchased it. To account for this option, I add to the projected service any service purchased between January 1, 2003 and December 31, 2011 for periods of employment before June 30, 2008.

44 The more restrictive service requirement reduced the subsidy peak value for employees 51 and older at

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employees can earn no more than one year of service in a single calendar year, manipulating service would require working extra hours in the first half of 2008 so as to accrue service in excess of the projected amount before the June 30th deadline. Extra work in the years 2003 through 2007 would not result in any additional service credit beyond that which would already be earned on a full-time schedule. Because the running variable is computed using ex ante values, I test for manipulation by examining hours in 2008 as an outcome in the same regression discontinuity design. The evidence does not suggest any unusual overtime behavior. In addition, the member records can be used to determine whether an employee is receiving subsidies at retirement. If individuals manipulate service, there should be evidence of retirees claiming benefits for which they would not be eligible based on the ex ante values. There is no evidence to support this concern.\textsuperscript{45}

To formalize the estimation strategy, let $\bar{S}_i(0)$ and $\bar{S}_i(1)$ denote employment status on January 1, 2012 when untreated (grandfathered) and treated (not grandfathered), respectively, and let $X_i$ denote the additional service needed to meet the grandfathering requirements. Treatment status, $W_i$, is a deterministic function of $X_i$, $W_i = 1(X_i > 0)$. I estimate specifications of the form

$$\bar{S}_i = f_0(x_i) + f_1(w_i x_i) + w_i \tau + z_i' \beta + \varepsilon_i,$$

where $\bar{S}_i$ is the observed employment status, $f_0$ and $f_1$ are polynomial functions, and $z_i$ is a vector of covariates.\textsuperscript{46} With standard continuity assumptions for RD designs, $\tau$, the coefficient on $w_i$, is the effect of the increased service requirement. The plausibility of the required continuity assumption relies on the inability of employees to manipulate service at the end of 2002 and the absence of differential selection into the state labor force by date of hire on factors correlated with the desired retirement date.\textsuperscript{47} (The previous discussion refers to employees who just missed the grandfathering requirements by 25 percent, from $92,000$ to $67,000.$\textsuperscript{45} Even if individuals manipulate their treatment status, because I use pre-announcement values to compute the running variable, the estimates would retain an intent to treat interpretation. However, the data is sparse enough that, were this a concern, estimation would be difficult.\textsuperscript{46} Because $w_i \tau$ is included as a separate term for clarity, the function $f_1$ has no constant term.\textsuperscript{47} New labor contracts in 2007 increased retiree health premiums for retirements after July 1, 2007. This change led to a surge in retirements ahead of that date among the population eligible for subsidized RHI at that time. While not invalidating the identifying assumption, this mass of separations could introduce a discontinuity in the survival probability away from the grandfathering threshold (individuals near the threshold were not eligible to retire with benefits prior to the deadline). This discontinuity could badly bias results using larger bandwidths. The simplest way to avoid this problem is to use a bandwidth small enough that no eligible individuals are included. Alternatively, and plausibly, if the excess retirements were shifted...
garding employees’ inability to manipulate grandfathering status conditional on the running variable supports treating the reform as a sharp RD rather than a fuzzy RD, but not the regression discontinuity design itself.) As the increase in the eligibility requirements was not announced until after the end of 2002, there is no reason to expect intentional manipulation of the running variable at that time. In addition, the discontinuity test of McCrary (2008) does not reject the null of no discontinuity at the grandfathering threshold. Together, these observations suggest the continuity assumption underlying the RD design is reasonable.

I exclude from the sample employees who retire before January 1, 2003, even if they subsequently return to work. I also limit attention to individuals who were born before 1952. Younger individuals near the grandfathering threshold will not be eligible to retire with subsidized RHI until 2012 at the earliest and data is available only through the end of 2011.

Results

Figure 6.2 presents the results for the basic RD specification. The scatter plot shows the average probability of continuous employment from December 31, 2002 through December 31, 2011 in bins with width equal to half a year of service. Overlaid on the scatter plot is a piecewise linear fit of the employment probability as a function of the additional service needed to meet the grandfathering requirements. As would be expected, the survival probability increases as service decreases. Clearly visible in the plot is the sharp break in the survival probability at the grandfathering threshold. The estimated increase in the probability of employment through 2011 as a result of the increased service requirement for a member at the threshold is 10 percentage points, from a pre-reform level of 26.6 percent to a post-reform level of 36.2 percent.

Table 6.1 shows the estimated treatment effect for a variety of polynomial orders and bandwidths, using a rectangular kernel. Estimates range from 9 to 12 percent across a variety of reasonable specifications. Estimates using low bandwidths and high orders are noisy and visual inspection of the results shows them to be overfitting the data. The Imbens and Kalyanaraman (2012) optimal bandwidth is approximately 6.2 and yields a point estimate of 9.9. Inclusion of additional covariates, such as age, sex, employing agency, and salary, has forward in time by no more than 4.5 years, the survival probability may not have a discontinuity in spite of the earlier rush into retirement. The results presented in the next section are stable across bandwidths and do not suggest a discontinuity in the survival probability.
no effect on the estimated treatment effect. While the covariates do not affect the estimated causal effect, the full set of age dummies is highly significant as age has an important direct effect on the survival probability.

1.6.2 The effect on the distribution of separations

Empirical strategy

The object of ultimate interest is the effect of the increased service requirement for subsidized retiree health insurance on the distribution of separations. To gain insight into this effect, I estimate employment survival functions for individuals employed at the end of 2002 under the pre and post-reform eligibility rules. Let $T_i(0)$ and $T_i(1)$ denote the number of days after January 1, 2003 that an employee separates when untreated (grandfathered/pre-reform) and treated (not grandfathered/post-reform), respectively. As before, let $X_i$ denote the additional service needed to meet the grandfathering requirements and $W_i$ the treatment status, $W_i = 1(X_i > 0)$. Note that $X_i$ is time invariant. Let $S$ denote the survival function associated with the joint distribution of $T$ and $X$. Using this notation, the employment survival function for an employee at the grandfathering threshold under the pre-reform eligibility criteria is $S_{T(0)|X}(t \mid x = 0)$ and for an employee at the grandfathering threshold under the post-reform eligibility criteria the survival function is $S_{T(1)|X}(t \mid x = 0)$. I interpret the difference $S_{T(1)|X}(t \mid x = 0) - S_{T(0)|X}(t \mid x = 0)$ as the causal effect of the reform.

To estimate the employment survival functions, I use the nonparametric techniques of Beran (1981) and Dabrowska (1987). Beran and Dabrowska study an extension of the Kaplan-Meier product limit estimator of the conditional survival function for use in environments with continuous covariates and possible right-censoring. To develop intuition, first consider a setting without censoring. The estimator for the conditional survival function under treatment status $j$ at $x = 0$ for a sample of $n$ observations is

$$
\hat{S}_{T(j)|X}(t \mid 0) = \prod_{s \leq t} \left(1 - \frac{\sum_{i=1}^{n} \mathbf{1}(T_i(j) = s) K(x_i)}{\sum_{i=1}^{n} \mathbf{1}(T_i(j) \geq s) K(x_i)}\right)
$$

where $K(\cdot)$ is a kernel function and $\mathbf{1}(T_i(j) = s)$ identifies separations at time $s$. Intuitively, the product limit estimate of the employment survival function at time $t$ is the product of the survival probability at every time before $t$ at which an employee separated. Assuming
a rectangular kernel, this product reduces to the empirical survival probability at time $t$ for the population within the support of the kernel. Introducing censoring simply necessitates a correction for the changing number of people at risk when individuals are censored before separation.

As with any discontinuity design, only one outcome, $T_i(0)$ or $T_i(1)$, is observed for each observation depending on the treatment status. Estimation of the post-reform (treated) survival function relies on data for non-grandfathered employees and estimation of the pre-reform (untreated) survival function relies on data for grandfathered employees.

I estimate employment survival functions separately for three groups: employees age 51-52 at the end of 2002, employees age 54-59 at the end of 2002, and employees age 60 and older at the end of 2002. As documented in section five, separation probabilities are strongly influenced by the set of retirement benefits for which employees are eligible. That eligibility in turn depends on age and service. Because employees in each of the three age groups cross eligibility thresholds on different dates, survival functions estimated for the entire sample are difficult to interpret. By splitting the sample and estimating separate survival functions for each group, I obtain results that can be interpreted more easily.

Under the pre-reform eligibility criteria, employees at the grandfathering threshold in the 51-52 year-old population become eligible for subsidized RHI on their 60th birthday, some time in 2010 or 2011. Under the post-reform criteria they become eligible on July 1, 2013. In the 54-59 year-old population employees at the grandfathering threshold become eligible for subsidized RHI on July 1, 2010 pre-reform and July 1, 2015 post-reform. Employees at the grandfathering threshold in the oldest population likewise become eligible for subsidized RHI on July 1, 2010 pre-reform and July 1, 2015 post-reform. However, these employees are already eligible for normal retirement at the end of 2002 and thus may be differentially selected in their taste for retiree health insurance.

Finally, when estimating the employment survival function at time $t$ for a population in which employees at the grandfathering threshold at time $t$ are not eligible for subsidized RHI, I ignore separations by employees who have already become eligible. I do this by artificially censoring employees when they first meet the eligibility requirements for subsidized RHI. After employees at the grandfathering threshold become eligible for subsidized RHI I again

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48 Individuals who are 53 at the end of 2002 are not used in the estimation as they turn 59 in 2008 and therefore the year of birth alone is insufficient to determine the grandfathering status precisely.
use all available data in the estimation.

Figure 6.3 offers a visual representation of the censoring scheme. Suppose the goal is to estimate the pre-reform survival function, \( S_{T(0)|X}(t \mid x = 0) \). This estimation relies on data for grandfathered (untreated) employees, who populate the bottom half of the figure. The dashed lines indicate the range of data that would be used to estimate the survival function assuming a rectangular kernel and a bandwidth of two. The gray region identifies employees who have accumulated sufficient service to be eligible for subsidized RHI if they retire.\(^{49}\) The censoring is essential because, at any time before July 2010, the survival function of interest reflects the behavior of an employee who is not yet eligible for subsidized RHI, but, between July 2008 and July 2010, individuals who have already become eligible for subsidized RHI are included in the support of the kernel. Since employees separate at a high rate once they become eligible for subsidized RHI, including these workers in the estimation would introduce substantial bias. I therefore censor employees when they become eligible for subsidized RHI (i.e. when they enter the gray region of the figure). Consequently, only data for individuals with the same eligibility status for subsidized RHI as the hypothetical individual for whom the survival function is being estimated will be used. The extension of the Kaplan-Meier estimator for use with censored data is

\[
\hat{S}_{T(j)|X}(t \mid 0) = \prod_{s \leq t} \left( 1 - \frac{\sum_{i=1}^{n} \mathbf{1}(T_i(j) = t, C_i(j) = 0) K(x_i)}{\sum_{i=1}^{n} \mathbf{1}(T_i(j) > t) K(x_i)} \right) \quad j = 0, 1,
\]

where \( T_i(j) \) now records the shorter of the time until individual \( i \)'s employment spell is censored or the time until she separates and \( C_i(j) \) equals one if the employment spell observed for individual \( i \) is censored and zero otherwise. The other terms remain as before.\(^{50}\)

I estimate the survival functions using the sample developed for the regression discontinuity analysis in the last section. The baseline results use a rectangular kernel and a bandwidth of two. I bootstrap standard errors.

\(^{49}\)For simplicity, the figure abstracts from the potential for uneven accumulation of service within a calendar year.

\(^{50}\)In light of the theoretical results establishing that local linear regression reduces bias in the estimation of treatment effects in an RD design, it would be preferable to implement analogous methods for the estimation of the survival functions in this section. However, the analog of the censoring strategy used in the survival estimation is a bandwidth restriction in RD estimation. In practice, imposing the required bandwidth restriction results in sample sizes that are too small to obtain useful results prior to the date of pre-reform eligibility for subsidized RHI for grandfathered employees. Results computed for dates after pre-reform eligibility are consistent with the results presented in the next section.
Results

In all three age groups, the post-reform distribution of separations reflects different combinations of two responses: accelerated separations and delayed separations. Employees who accelerate their separations likely worked or expected to work until eligibility for subsidized RHI under the pre-reform criteria. However, after accounting for the additional work required to become eligible as a result of the reform, the promised subsidies are no longer sufficient to make continued work with the state their most attractive option. Employees who respond to the reform in this fashion decrease the post-reform employment survival function in advance of the pre-reform eligibility date. Workers who delay their separations likely left at or after meeting the eligibility requirements for subsidized RHI under the pre-reform criteria. As a result of the increased service requirement, these individuals now find continued employment with the state more attractive than any other option. Workers who respond in this fashion increase the post-reform employment survival function after the pre-reform eligibility date.

Figure 6.4 presents the estimated employment survival functions $S_{T(0)|X=0}$ and $S_{T(1)|X=0}$ for employees at the grandfathering threshold age 51-52 at the end of 2002. Under the pre-reform eligibility rules, these employees become eligible for subsidized RHI on their 60th birthday, some time in 2010 or 2011. Under the post-reform rules, they become eligible for subsidized RHI on July 1, 2013. The survival curves track each other closely through early 2010. In the latter half of 2010 the curves begin to separate, and they diverge sharply at the end of June 2011. By the end of the period, employees under the post-reform rules are significantly more likely to remain the job. On June 30, 2011, the date just before which both curves drop sharply, the labor contracts covering a large fraction of the state workforce expired.51

Figure 6.5 presents the estimated survival functions for employees at the grandfathering threshold age 54-59 at the end of 2002. Under the pre-reform eligibility rules, these employees become eligible for subsidized RHI on July 1, 2010. Under the post-reform rules, they become eligible on July 1, 2015. The estimated survival functions for the two policy regimes are similar through early 2007. However, beginning in July 2007, post-reform employees are less likely to remain on the job. On July 1, 2010, the date at which pre-reform employees become

51 A mass of separations occurs in advance of the date on which labor contracts expire in 2003, 2007, and 2011. In 2007, there is a clear, contract-driven reason for the separations. In other years, the reason is not so obvious. However, the possibility of changes could be sufficient to increase separations.
eligible for subsidized RHI, the relative employment probabilities reverse. After this point, post-reform employees are more likely to remain on the job. As with employees age 51-52 at the end of 2002, the effect of expiring labor contracts at the end of June 2011 is visible in the figure.

Finally, Figure 6.6 presents the results for employees at the grandfathering threshold age 60 and older at the end of 2002. These employees become eligible for subsidized RHI on the same dates as the 54-59 year-old employees, but were eligible for normal retirement at the end of 2002 when the sample was selected. As with the 54-59 year-old sample, the survival functions track each other closely through early 2007. Again, beginning in July 2007, post-reform employees are less likely to remain on the job. However, in this population, when the pre-reform employees become eligible for subsidized RHI, the pre and post-reform employment probabilities converge. In July 2010, there is no significant difference between the two employment probabilities. But, by the end of 2011, the post-reform employees are somewhat more likely to remain on the job.

The relative importance of acceleration and delay differs across the three age groups examined. In the 51-52 year-old sample there is no evidence of accelerated separations. In the population 60 and older, acceleration is far more prevalent than delay. The largest population of affected employees, those age 54-59 at the end of 2002, contains both employees who accelerate separation and those who delay. Through the combination of accelerated and delayed separations, the mass of separations immediately after the pre-reform eligibility date in the 54-59 and 60 and older populations disappears as a result of the reform.

These findings parallel previous results regarding the labor supply response to kinked and notched compensation schedules. Kinks occur when the compensation rate (i.e. the effective wage) changes discontinuously. Notches occur when total accrued compensation (i.e. the value of all past and future payments due to the worker) changes discontinuously. Late in the career, the retirement benefits for Pennsylvania state employees create both a kink, at eligibility for normal retirement, and a notch, at eligibility for subsidized RHI. As

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52 The sharp drop at this date results from the relaxation of the artificial censoring on July 1, 2010. This estimate should be viewed as an approximation to the underlying function which is likely steeply sloped at the point of eligibility, but not vertical as shown in the figure.


54 Workers who turn 60 with 15-24 years of service become eligible for both normal retirement and subsidized retiree health insurance on their 60th birthday. Otherwise, the two eligibility events occur on different
just discussed, the notch associated with eligibility for subsidized RHI reduces separations in the years before eligibility and increases separations immediately after eligibility. When Pennsylvania increased the service requirement for subsidized RHI in 2008, it held fixed the location of the pension kink and moved the RHI notch later in an employee’s career. (For all affected employees, the RHI notch occurs at or after eligibility for normal retirement.) This shift both eliminated the compression of the distribution of separations near the notch’s original location and made work until older ages more attractive. The result was a stretching of the distribution of separations.

While the observed response reflects a stretching of the distribution, near the notch’s new location the reform likely compresses the distribution. Unfortunately, as individuals whose eligibility was delayed by the reform will not become eligible for subsidized RHI until July 1, 2013 at the earliest, the data required to validate this conjecture does not yet exist.

Table 6.2 reports the effect of the increased service requirement on the employment probability at three dates for five bandwidths. The effects shown in the table are generally robust to the choice of bandwidth. However, there is some sensitivity to the bandwidth in the oldest population after the pre-reform eligibility date for subsidized RHI.

The estimated employment survival curves show the importance of the policy change for the distribution of separations. Unfortunately, the estimated effect on mean weeks worked over the five-year period is imprecise. For the entire population, the point estimate is an increase of 3.5 weeks with a standard error of 8 weeks. Though noisy, the estimate can reject large responses to the increased service requirement. Since the analysis focuses exclusively on populations that are affected by the policy change, a large response might have been expected.

An important limitation of the results in this section is that they are strictly valid only for employees at the grandfathering threshold. This population consists of older workers with either 13 or 15 years of service on June 30, 2008. While the estimates may be approximately valid for similar workers in other contexts, benefit restrictions that affect longer-tenured career employees could have quite different effects. In particular, since career employees are often eligible to retire with a full pension benefit at younger ages, the loss of retiree health benefits would be a substantially greater financial hit. Likewise, if career employees are more likely to be the source of health insurance for an entire family, separating without retiree dates.
health benefits and with the intention of relying on a spouse’s insurance may be a less viable option.

1.7 The effect of RHI eligibility restrictions on liabilities

States facing large unfunded liabilities for promised retiree health benefits may look to benefit cuts for current employees as a way of reducing expenditures. This section applies the insights of the preceding analysis to estimate the impact of further restrictions in the eligibility requirements for subsidized retiree health insurance on the value of Pennsylvania’s health and pension obligations.

1.7.1 Methodology

The estimates of sections five and six provide local evidence on the behavioral response to Pennsylvania’s retiree health plan. Section five considers behavior near the current eligibility thresholds and section six studies behavior near the grandfathering threshold associated with the eligibility restriction implemented in 2008. Determining plausible separation patterns for the entire population under alternative eligibility rules requires some form of extrapolation. I adapt the hazard estimation procedure of section five to obtain an estimate of the number of total separations under alternative policy regimes. I estimate active member deaths using the actuarial assumptions from the most recent SERS experience study, and I compute an age-specific disability hazard assuming individuals are at risk if they are ineligible for a normal retirement pension, subsidized retiree health insurance, or both. Voluntary separations are computed as the difference between the total number of separations estimated from the hazard model and the number of death and disability retirements.

55Because superannuation and disability retirement provide the same pension benefit once an employee is eligible for normal retirement, the 2006-2010 SERS experience study (Hay Group (2011b)) does not develop rates of disability after eligibility for normal retirement. However, since disability retirement waives the service requirement for subsidized retiree health insurance, this analysis requires rates of disability even after eligibility for normal retirement.
I model total separations using the reduced form hazard specification

\[ h(t) = \beta_1 (\text{threshold}_{+1}) (\text{age} \geq 60) \times \beta_2 (\text{threshold}_{+2}) (\text{age} \geq 60) \times \{\gamma_{as} (\text{service} \leq 5) + \gamma_a (\text{service} > 5) + \gamma_{as} (\text{subsidy-eligible, age} \geq 50)\} , \]

where \(\text{threshold}_{+i}\) indicates that the eligibility threshold for subsidized RHI occurs \(i\) years in the future, the \(\gamma_{as}\) are age-service effects, and \(\gamma_a\) is an indicator for age alone.\(^{56}\) The separation hazard of section five allowed for different values of the hazard at each combination of age and service (more than 700 cells for the population between 50 and 70). This more restrictive specification of the separation hazard only allows equivalent freedom in the first five years of service, when separations are high and vary substantially by both age and service, and for individuals eligible for subsidized RHI after age 50. It assumes an identical hazard for all individuals of the same age with more than five years of service and either ineligible for subsidized RHI or under age 50 (except in the two years before eligibility for subsidized RHI). Doing so makes clear the basic nature of the extrapolation that will be used to simulate behavior under alternative eligibility criteria. Individuals who lose eligibility under the alternative policies will be assumed to separate at the same rate as do individuals of the same age who are ineligible for subsidized RHI under the current policies. However, to account for the fact that very few individuals separate in the years immediately preceding eligibility for subsidized RHI, I introduce the proportional scaling factors \(\beta_1\) and \(\beta_2\). These scaling factors provide additional flexibility in the hazard for employees age 60 and older and nearing eligibility for subsidized RHI. I estimate the hazard model using the sample of worker-days covered by the pre-2008 eligibility rules described in section five.

I simulate separation patterns under the current eligibility policies and under alternative policies in four steps. First, using the fitted values, I compute the probability of separation under the pre-2008 eligibility rules at every future age for each employee. I then redefine the explanatory variables based on the eligibility rules for the policy of interest and recompute the separation probabilities at each age. However, these recomputed probabilities are used only for ages at which employees are not yet eligible for subsidized RHI. Since a more restrictive eligibility requirement does not change the level of retirement benefits available

\(^{56}\)I collapse all ages greater than 70, all service levels greater than 40, and all service levels greater than 20 at or after age 65 to avoid problems arising from small samples when using the fitted values to perform simulations.
to an employee once she meets the new requirement, I assume that the distribution of separations after eligibility is unaffected by the policy. That is, in the third step, I set the probability of separation at each age after an employee becomes eligible for subsidized RHI equal to its value before the restriction (using the pre-2008 probabilities). Finally, I determine the probability of separation for the age at which an employee first becomes eligible for subsidized RHI such that the employment probability in the year after eligibility matches that before the restriction (again using the pre-2008 probabilities). Effectively, this last step assumes that any net increase in employment at the new eligibility threshold as a result of the eligibility restriction is eliminated by an increase in separations immediately after the threshold.\footnote{Because the probability that a non-grandfathered employee not yet eligible for subsidized RHI remains on the job at the end of 2011 increased for certain employees as a result of the state's 2008 eligibility restriction, this computation will slightly overstate the pre-2008 employment probabilities. Since the employment probabilities after eligibility under the current and alternative policies are set to match these pre-2008 probabilities, they will show a modestly delayed distribution of separations. This concern affects only a very small number of employees and should have only a minor impact on the results. It will have no effect on the estimated financial impact for the restriction in eligibility before the NRA as these individuals were unaffected by the eligibility restriction imposed in 2008.}

I follow this procedure to simulate separations under the current eligibility rules and under each alternative policy. I assume each alternative policy was implemented on December 31, 2011 with no advance notice. Using the simulated separation probabilities, I compute the present value of benefits, the present value of required retiree contributions for health insurance, and the present value of employee pension contributions.\footnote{There is an unavoidable asymmetry in that future employee contributions to the pension plan and required retiree contributions for health insurance are included in the analysis, but past contributions are not. Including future receipts is necessary because changes in eligibility policies will affect both the benefits paid out and the contributions made by employees and retirees. Note, also, that this analysis does not consider the budgetary impact of changing employment patterns on salaries and health benefits for active employees.} Appendix A describes the full set of assumptions used to value the health and pension obligations.

1.7.2 Simulation results

Table 7.1 reports the present value of benefits, receipts, and net obligations for the health and pension plans under current policy and under two alternative policy regimes as of December 31, 2011 using a discount rate of six percent.\footnote{The 2011 actuarial valuation of the pension plan uses a 7.5 percent discount rate while the 2011 actuarial valuation of the REHP uses a discount rate of 4.75 percent (Hay Group (2012, 2011a)). It is crucial to use the same discount rate for both plans in this analysis as otherwise shifting a dollar of expenditures on the}
members with no class A-3 or A-4 service working at agencies participating in the REHP. Currently, the state provides subsidized retiree health insurance to retirees with 20 years of service at or after the normal retirement age and to retirees with 25 years of service at any age. The first alternative policy restricts eligibility before the normal retirement age to retirees with 30 years of service. The second restriction requires 25 years of service regardless of the age at retirement.

Under the baseline policies, the present value of future health benefits is $6.8 billion. As the present value of required contributions is less than $60 million, the present value of the net obligations is also roughly $6.8 billion. The present value of future pension benefits is $19.7 billion. The present value of employee contributions is $1.8 billion, and the present value of the net obligations is $17.9 billion.

I first simulate the impact of restricting eligibility for subsidized RHI before the normal retirement age to employees with at least 30 years of service. Restricting eligibility in this way would decrease the present value of future health benefits by $500 million, or approximately 7 percent. It would also decrease future retiree contributions for health insurance, however, the financial impact of this effect is small. At the same time, by encouraging additional work before the normal retirement age, this more restrictive service requirement would increase pension benefits by $115 million and employee contributions by $15 million. Combined, these two effects would increase the net obligations for the pension plan by about $100 million. The increase in pension obligations would offset approximately 20 percent of the savings from reduced health benefits. As is typical for final average salary plans, pension accruals for Pennsylvania state employees are high in the years immediately preceding eligibility for normal retirement. Restricting access to health benefits before eligibility for normal retirement encourages continued work in exactly these years. The result is an increase in

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60 Recall that Pennsylvania enacted significant pension legislation in late 2010. This legislation created the A-3 and A-4 service classes. The normal retirement age for these classes is greater and the level of benefits lower than for the comparable existing classes. With some exceptions, employees hired on or after January 1, 2011 earn service in class A-3 or A-4 while those hired before January 1, 2011 earn service in other classes.

61 These results differ from those reported in the 2011 actuarial valuations for the health and pension plans for several reasons. Most importantly, this analysis uses the same discount rate for both benefit programs, reports results only for active employees and only for employees participating in both plans, and develops a different set of assumptions about future retirement patterns.
costs for the pension system.

The second alternative policy I consider imposes a service requirement of 25 years regardless of an employee's age at retirement. This restriction has no effect on eligibility for subsidized RHI before eligibility for normal retirement, but increases the service requirement after normal retirement. Cutting benefits in this manner decreases the present value of future health benefits by $850 million, or approximately 12 percent. While it has a small positive effect on pension benefits, the increase in employee pension contributions is even larger, resulting in net savings for the plan. In this case the pension offset is -4 percent. Because the pension plan does not have an automatic COLA, pension accruals after eligibility for normal retirement are low but remain positive for many workers. Pension plans that feature automatic COLAs typically have strongly negative accrual rates after eligibility for normal retirement. In such plans, the additional savings for the pension plan resulting from an eligibility restriction that encourages additional work after normal retirement could be substantial.

Table 7.2 presents the estimated pension offset for the first eligibility restriction using discount rates of 4, 6, and 8 percent. The value of the offset depends on the discount rate chosen, and, in particular, a higher discount rate decreases the offset from the pension plan. The eligibility restriction saves money by reducing expenditures on medical benefits in the years before the normal retirement age. The pension offset arises from the increased pension benefits paid to workers who decide to remain on the job when they lose eligibility. Since these increased pension payments necessarily occur after the forgone health benefits would have been received, they will be more heavily discounted. As a result, increasing the discount rate will reduce the importance of the increase in pension benefits relative to the reduction in health benefits and thus the size of the offset.

The results of sections five and six document the significant effects that eligibility for subsidized RHI has on labor supply behavior. The simulation results presented in this section show that, through these labor supply effects, the increase or decrease in costs for the health plan resulting from a change in benefits can be either partially offset or magnified by an associated change in costs for pension plans covering the affected workers.
1.8 Conclusion

This chapter uses the experience of Pennsylvania state employees to gain insight into the effects of retiree health benefits on late-career separations. I find that the widely-documented spike in the separation hazard at the normal retirement age disappears when individuals reach eligibility for normal retirement before becoming eligible for subsidized retiree health insurance. Instead, the separation hazard for these employees spikes only after they have become eligible for both benefits. Then, exploiting quasi-experimental variation in the eligibility rules for subsidized retiree health insurance, I show that the imposition of a more restrictive service requirement stretches the distribution of separations. Early separations occur earlier and late separations occur later. Facing more stringent eligibility requirements for subsidized RHI, some individuals who would have stayed until eligibility under the existing policies give up, while others remain on the job longer hoping to become eligible for benefits in the future.

Motivated by these behavioral findings, I simulate the impact of two further restrictions in the eligibility requirements for subsidized RHI on the state workforce and on the present value of the state's health and pension obligations. While pension benefits have substantial legal protections, cuts in retiree health benefits can affect current employees and offer the possibility of meaningful short-term savings for cash-strapped state and local governments. The simulations reveal a close relationship between the two programs. If eligibility restrictions for retiree health benefits encourage additional work before the normal retirement age—when pension accruals are high—the resulting increase in pension obligations offsets a portion of the savings derived from the reduction in health benefits. In contrast, if the eligibility restrictions encourage additional work when pension accruals are negative, the pension plan can magnify the savings.

These results can inform the development of future reforms to public sector retirement benefits. In particular, when designing changes to retiree health programs intended to reduce expenditures, it is important to keep in mind the rate at which the affected workers accrue pension benefits. If the reforms encourage continued work when accruals are high, greater reductions in health benefits will be required to achieve a given savings target. Similarly, when considering changes in pension benefits, knowledge of the eligibility rules for retiree health benefits is essential. If a large fraction of workers at the normal retirement age are
not yet eligible for retiree health benefits, increases in the normal retirement age may have a smaller effect on the average retirement age than expected.

Moving forward, research on the labor market effects of retiree health benefits can extend these results in two important directions. First, in focusing on the eligibility requirements for a plan that offers either negligible or generous subsidies for RHI, this analysis has little to say about plans that offer a partial subsidy for each year of work completed. However, not only is an understanding of the behavioral response to such plans directly relevant to policy, studying them could also provide evidence on employees' valuation of a marginal dollar in subsidies for retiree health insurance. That valuation could then be used to examine whether public sector employers are achieving the right balance between health and pension benefits or should reallocate resources between the two. Second, while previous work has established the important role of health status in retirement behavior, the data available for this analysis does not include any medical information. In order to understand the effect of changes in retiree health benefits on state budgets and well-being, knowledge of health status is essential. If the employees who delay separation in response to increased eligibility requirements are healthier than average, the restriction will save more money than a forecast using average health expenditures would predict. Alternatively, if the individuals who delay separation are those in relatively worse health, the eligibility restrictions will save less money than a forecast using average expenditures would predict.
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1.A Actuarial appendix

The valuation of heath and pension benefits in section seven requires numerous demographic and economic assumptions. I start from the assumptions described in the Hay Group's most recent experience study for the State Employees' Retirement System as modified and extended in the actuarial reports for each benefit plan. I deviate from the assumptions used in these reports for two major reasons: (i) to put the valuations on equal footing (e.g. using the same interest rate for both health and pension obligations) and (ii) to enable a consistent analysis of employee behavior under alternative policy regimes. This section outlines the assumptions used either by reference to the Hay Group reports or with a short description of the methodology.

Population: Active general employees on December 31, 2011 at an agency participating in the Retired Employees Health Plan and covered by the State Employees' Retirement System. Excludes members with class A-3 or A-4 service.

Mortality after separation

Nondisabled annuitants, beneficiaries, and survivors. Cohort mortality constructed from the RP-2000 mortality tables for healthy annuitants using scale BB mortality improvements. Employee tables used to construct mortality rates before 50 with smoothing applied between 40 and 50 (males) and between 46 and 50 (females).


Mortality before separation: Hay Group recommended assumptions for active member mortality rates with no adjustment for mortality improvements (Table A-2 in Hay Group (2011b)).

Rates of disability: Age-specific probabilities defined as $1 - e^{-365.25\lambda_a}$, where $\lambda_a$ is the observed disability hazard for individuals at age $a$ eligible for disability retirement and not eligible for a normal retirement benefit, subsidized retiree health insurance, or both.

Claiming behavior: Employees claim benefits immediately after separation. Individuals eligible for early retirement take early retirement. Individuals not eligible for early or normal retirement benefits take a refund of accumulated deductions.

Retirement options: 33 percent of members take the maximum single life annuity, 41 percent of members take the maximum joint life annuity, 6 percent of members take the maximum joint and survivor annuity, 2 percent of members take other benefits, and 51 percent of members take no benefits.

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63 This specification implicitly assumes exogenous disability retirements that are diverted to superannuation retirement after eligibility for both normal retirement and subsidized retiree health insurance and to withdrawal before eligibility for disability retirement.
take the single life annuity with present value guarantee, 13 percent take a 50 percent joint and survivor annuity, and 13 percent take a 100 percent joint and survivor annuity. 85 percent of members choosing each option elect a withdrawal of accumulated deductions and all individuals electing a withdrawal withdraw the maximum.

Pension beneficiaries: Beneficiaries are of the opposite sex and females are two years younger than males.

Marital status for retiree health benefits: Marital status at each age (sex-distinct) tabulated from the pooled March CPS files for the years 2000 through 2011.

Career salary schedule: Hay Group recommended assumptions (Table A-1 in Hay Group (2011b)).

Medical expenditures: Per capita claims costs in 2010 and projected growth rates as reported in Hay Group (2011a). 64

Actuarial equivalence: All actuarial equivalence calculations use the GAM 83 unisex mortality tables (i.e. the calculations ignore the alternative mortality tables available to members with service prior to August 1983).

Maximum career length: All members remaining on the job are assumed to retire at age 78, upon reaching 50 years of service, or in 2052, whichever occurs first.

Provisions not valued: The valuation does not include Social Security Integration (SSI) benefits available to employees hired on or before March 1, 1974. It reflects credit for service already purchased, but assumes no additional service purchases by existing employees. Death benefits do not include supplemental benefits payable when the retirement benefit is limited to 100 percent of the highest salary. The analysis ignores the additional required contributions for members hired on or after August 1, 2003 who choose health plans other than the least expensive plan in their geographic region.

64 Note that the analysis of section two used a forecast of premiums to determine the value of the subsidy for a single individual. This reflects the fact that for a single individual that premium is the price that would be required for self-paid retiree health insurance. In contrast, the valuation uses expected medical expenditures as it seeks to compute the costs for the state.
Figure 3.1. Eligibility Requirements for Health and Pension Benefits, Retirements Between January 1, 2000 and June 30, 2008

Note: Eligibility rules for general employees with class AA service. Effective July 1, 2008, the service requirement for subsidized retiree health insurance at or after the normal retirement age increased from 15 years to 20 years, excluding certain grandfathered employees.
Table 3.1. Pension Benefit and Retiree Health Premiums by Age of Separation for a Hypothetical Male Beginning State Employment at Age 33 (Inflation-Adjusted Dollars, Assuming 2005-2007 Policies for the Full Career)

<table>
<thead>
<tr>
<th>Age</th>
<th>Service</th>
<th>Wage</th>
<th>Pension Benefit</th>
<th>Present Value of Pension</th>
<th>Insurance Premium (pre-65)</th>
<th>Insurance Premium (post-64)</th>
<th>Present Value of HI Subsidy</th>
<th>Notes</th>
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<tbody>
<tr>
<td>33</td>
<td>0</td>
<td>35,000</td>
<td>0</td>
<td>0</td>
<td>Ineligible</td>
<td>Ineligible</td>
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<tr>
<td>34</td>
<td>1</td>
<td>37,208</td>
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<td>0</td>
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<tr>
<td>35</td>
<td>2</td>
<td>38,996</td>
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<td>Ineligible</td>
<td>Ineligible</td>
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<td></td>
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<tr>
<td>36</td>
<td>3</td>
<td>40,674</td>
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<tr>
<td>37</td>
<td>4</td>
<td>42,323</td>
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<td>0</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>5</td>
<td>43,932</td>
<td>1,442</td>
<td>22,125</td>
<td>Ineligible</td>
<td>Ineligible</td>
<td>0</td>
<td>Eligibility for early retirement and self-paid RHI</td>
</tr>
<tr>
<td>39</td>
<td>6</td>
<td>45,492</td>
<td>1,890</td>
<td>28,837</td>
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</tr>
<tr>
<td>40</td>
<td>7</td>
<td>47,085</td>
<td>2,405</td>
<td>36,656</td>
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</tr>
<tr>
<td>41</td>
<td>8</td>
<td>48,710</td>
<td>2,993</td>
<td>45,073</td>
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<tr>
<td>42</td>
<td>9</td>
<td>50,367</td>
<td>3,665</td>
<td>54,801</td>
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</tr>
<tr>
<td>43</td>
<td>10</td>
<td>52,029</td>
<td>4,342</td>
<td>65,783</td>
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</tr>
<tr>
<td>44</td>
<td>11</td>
<td>53,695</td>
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<tr>
<td>45</td>
<td>12</td>
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<td>5,786</td>
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</tr>
<tr>
<td>46</td>
<td>13</td>
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<td>6,547</td>
<td>107,505</td>
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<tr>
<td>47</td>
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<tr>
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</tr>
<tr>
<td>49</td>
<td>16</td>
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<td>10,105</td>
<td>165,531</td>
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<td>Ineligible</td>
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</tr>
<tr>
<td>50</td>
<td>17</td>
<td>63,553</td>
<td>11,706</td>
<td>165,531</td>
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<td>Ineligible</td>
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<tr>
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<td>18</td>
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<td>13,502</td>
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</tr>
<tr>
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<tr>
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<td>16,766</td>
<td>245,114</td>
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</tr>
<tr>
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<td>20,283</td>
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</tr>
<tr>
<td>55</td>
<td>22</td>
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<td>312,750</td>
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<td>0</td>
<td></td>
</tr>
<tr>
<td>56</td>
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</tr>
<tr>
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<tr>
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<tr>
<td>59</td>
<td>26</td>
<td>75,804</td>
<td>37,961</td>
<td>491,371</td>
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<td></td>
<td></td>
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<tr>
<td>60</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>28</td>
<td>79,002</td>
<td>50,806</td>
<td>630,924</td>
<td>757</td>
<td>757</td>
<td>144,405</td>
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</tr>
<tr>
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<td>53,468</td>
<td>653,909</td>
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<td>769</td>
<td>134,567</td>
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</tr>
<tr>
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<td>793</td>
<td>113,340</td>
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<tr>
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<td>718,170</td>
<td>805</td>
<td>805</td>
<td>107,446</td>
<td></td>
</tr>
</tbody>
</table>

Note: The calculations assume fixed (in real dollars) premiums for the health plans and a single policy regime in order to better illustrate the basic structure of the eligibility rules. Premiums without any state subsidy are assumed to be $16,000 before Medicare eligibility and $8,000 after Medicare eligibility. This presentation ignores the $5 per month state payment available to retirees not eligible for subsidized retiree health insurance. Pension benefits assume class AA service and a normal retirement age of 60. The required retiree contribution for health insurance is 1% of final salary. Prior to eligibility for an early retirement benefit, members are entitled to a refund of their accumulated contributions to the pension plan credited with four percent interest. The value of this refund is not shown. Pension benefits assume immediate claiming at the time of separation. Present value calculations assume a discount rate of six percent, male mortality according to the RP-2000 tables for healthy annuitants, scale BB mortality improvement, and a birth date of January 1, 1965. Inflation and wage growth follow the recommended assumptions of the 2006-2010 SERS experience study.
Figure 3.2. Average Family Health Insurance Premium Before Subsidies for Policies Offered Through the Retired Employees Health Plan, 2002-2012

Note: Simple average premium for all plans offered to in-state retirees by year. The non-Medicare average is computed from data on multi-party policies. The Medicare-eligible average is computed from data on single policies and multiplied by two.

Figure 3.3. Present Value of State Health Insurance Subsidy by Age at Retirement for Retirements Effective January 1, 2006

Note: The state subsidy is the difference between the full premium for the health insurance plan and the required retiree contributions. Retirements effective January 1, 2006 required retiree contributions equal to 1 percent of final salary. Projected premiums assume growth of 5 percent for non-Medicare policies and 6 percent for Medicare policies from a baseline level that best fits the observed premiums between 2002 and 2012. Present value calculations assume a discount rate of six percent, male mortality according to the RP-2000 tables for healthy annuitants, and scale BB mortality improvement. Required retiree contributions assume a $50,000 salary.
Figure 3.4. Health Insurance Subsidy Peak Value by Age and Service on January 1, 2006, Assuming Continuation of 2006 Policies

Note: The health insurance subsidy is the difference between the full premium for the health insurance plan and the required retiree contributions. The peak value is the present value assuming retirement on the earliest date at which the employee is eligible for subsidized RHI less the present value assuming immediate retirement. Shaded regions indicate age and service combinations at which the subsidy peak value is positive and exceeds the pension peak value. Retirements effective January 1, 2006 require retiree contributions equal to 1 percent of final salary. Projected premiums assume growth of 5 percent for non-Medicare policies and 6 percent for Medicare policies from a baseline level that best fits the observed premiums between 2002 and 2012. Present value calculations assume a discount rate of six percent, male mortality according to the RP-2000 tables for healthy annuitants, and scale BB mortality improvement. Required contributions assume a $50,000 salary in 2005 and 4.5 percent annual salary growth.

Figure 3.5. Pension Peak Value by Age and Service on January 1, 2006

Note: The pension peak value is the difference between the present value of benefits assuming retirement at the future age that maximizes the value of benefits and the present value of pension benefits assuming immediate retirement. Shaded regions indicate age and service combinations at which the subsidy peak value is positive and exceeds the pension peak value. Present value calculations assume a discount rate of six percent, male mortality according to the RP-2000 tables for healthy annuitants, and scale BB mortality improvement. Pension computations assume class AA service and a normal retirement age of 60, a $50,000 salary in 2005, and 4.5 percent salary growth. This presentation ignores the value of disability and death benefits. Small positive values for employees under 50 with more than 30 years of service are suppressed for clarity and to allow for labeling.
Figure 4.1. Retirements by Age, 2000-2011

Note: Number of death, disability, and superannuation retirements between January 1, 2000 and December 31, 2011. Employees who retire more than once are only counted at their first retirement. Sample consists of general employees with no service in class A-3 or A-4 who worked at some point in the 12-year period, never retired before 2000, and never elected to combine service as a public school employee in Pennsylvania with service as a state employee for purposes of pension benefits.

Figure 4.2 Retirements by Quarter Year of Service, 2000-2011

Note: Number of death, disability, and superannuation retirements between January 1, 2000 and December 31, 2011. Employees who retire more than once are only counted at their first retirement. Sample consists of general employees with no service in class A-3 or A-4 who worked at some point in the 12-year period, never retired before 2000, and never elected to combine service as a public school employee in Pennsylvania with service as a state employee for purposes of pension benefits.
Figure 5.1. Effect of Eligibility for Normal Retirement With and Without Eligibility for Subsidized Retiree Health Insurance

Note: Separation probabilities defined as $1 - e^{-365.25A} \lambda_a$, where $\lambda_a$ is the empirical hazard at age $a$ and service $s$. The empirical hazard is the total number of separations at age $a$ and service $s$ divided by the total number of worker-days employed at age $a$ and service $s$. Values for the cohort with $s_{60}$ years of service at age 60 taken from the set of age and service combinations such that $s - (a - 60) = s_{60}$. The sample is restricted to active general employees who (i) have never retired, (ii) have never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania, and (iii) have no service in class A-3 or A-4. The estimation uses only worker-days prior to 2003, worker-days for employees grandfathered under the pre-2008 eligibility requirements for subsidized RHI regardless of date, and worker-days when the employee is younger than 60 regardless of date.
Table 5.1. Separation Probabilities for Cohorts with 12-17 Years of Service at Age 60

<table>
<thead>
<tr>
<th>Cohorts (Defined by Service at Age 60)</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Change in Separation Probability at eligibility for normal retirement</strong></td>
<td>0.018</td>
<td>0.024</td>
<td>-0.009</td>
<td>0.224</td>
<td>0.242</td>
<td>0.261</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.014)</td>
<td>(0.012)</td>
<td>(0.022)</td>
<td>(0.022)</td>
<td>(0.023)</td>
</tr>
<tr>
<td><strong>eligibility for subsidized RHI</strong></td>
<td>0.519</td>
<td>0.473</td>
<td>0.314</td>
<td>0.224</td>
<td>0.242</td>
<td>0.261</td>
</tr>
<tr>
<td></td>
<td>(0.035)</td>
<td>(0.028)</td>
<td>(0.024)</td>
<td>(0.022)</td>
<td>(0.022)</td>
<td>(0.023)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Separation Probability at age</th>
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<th>60</th>
<th>61</th>
<th>62</th>
<th>63</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.054</td>
<td>0.046</td>
<td>0.045</td>
<td>0.041</td>
<td>0.043</td>
<td>0.046</td>
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<tr>
<td></td>
<td>(0.009)</td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.008)</td>
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<tr>
<td></td>
<td>0.044</td>
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<td>0.046</td>
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<td>0.038</td>
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</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.007)</td>
</tr>
<tr>
<td></td>
<td>0.062</td>
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<td>0.037</td>
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<td>0.279</td>
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<tr>
<td></td>
<td>(0.015)</td>
<td>(0.012)</td>
<td>(0.009)</td>
<td>(0.021)</td>
<td>(0.021)</td>
<td>(0.022)</td>
</tr>
<tr>
<td></td>
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<td>0.351</td>
<td>0.255</td>
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<tr>
<td></td>
<td>(0.016)</td>
<td>(0.012)</td>
<td>(0.023)</td>
<td>(0.024)</td>
<td>(0.023)</td>
<td>(0.024)</td>
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<tr>
<td></td>
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<td>(0.014)</td>
<td>(0.025)</td>
<td>(0.025)</td>
<td>(0.027)</td>
<td>(0.028)</td>
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<tr>
<td></td>
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<tr>
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<td>(0.032)</td>
<td>(0.032)</td>
<td>(0.030)</td>
<td>(0.033)</td>
<td>(0.035)</td>
<td>(0.036)</td>
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</table>

Note: Separation probabilities defined as $1 - e^{-365.25\lambda_{a,s}}$ where $\lambda_{a,s}$ is the empirical hazard at age $a$ and service $s$. The empirical hazard is the total number of separations at age $a$ and service $s$ divided by the total number of worker-days employed at age $a$ and service $s$. Values for the cohort with $s_{60}$ years of service at age 60 taken from the set of age and service combinations such that $s = (a - 60) = s_{60}$. Shaded cells indicate the year prior to and the first year of eligibility for subsidized retiree health insurance. The sample is restricted to active general employees who (i) have never retired, (ii) have never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania, and (iii) have no service in class A-3 or A-4. The estimation uses only worker-days prior to 2003, worker-days for employees grandfathered under the pre-2008 eligibility requirements for subsidized RHI regardless of date, and worker-days when the employee is younger than 60 regardless of date.
Figure 5.2. Effect of Eligibility for Subsidized Retiree Health Insurance 
After Normal Retirement Age

Note: Separation probabilities defined as $1 - e^{-365.25 \lambda_a}$ where $\lambda_a$ is the empirical hazard at age $a$ and service $s$. The empirical hazard is the total number of separations at age $a$ and service $s$ divided by the total number of worker-days employed at age $a$ and service $s$. Values for the cohort with $s_{60}$ years of service at age 60 taken from the set of age and service combinations such that $s - (a - 60) = s_{60}$. The sample is restricted to active general employees who (i) have never retired, (ii) have never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania, and (iii) have no service in class A-3 or A-4. The estimation uses only worker-days prior to 2003, worker-days for employees grandfathered under the pre-2008 eligibility requirements for subsidized RHI regardless of date, and worker-days when the employee is younger than 60 regardless of date.
Figure 5.3. Effect of Eligibility for Subsidized Retiree Health Insurance
Before Normal Retirement

Note: Separation probabilities defined as $1 - e^{-\frac{365 \cdot 25}{\lambda_{as}}}$ where $\lambda_{as}$ is the empirical hazard rate at age $a$ and service $s$. The empirical hazard is the total number of separations at age $a$ and service $s$ divided by the total number of worker-days employed at age $a$ and service $s$. Values for the cohort becoming eligible for subsidized RHI at age $a_{thi}$ taken from the set of age and service combinations such that $s - (a - a_{thi}) = 25$. The sample is restricted to active general employees who (i) have never retired, (ii) have never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania, and (iii) have no service in class A-3 or A-4. The estimation uses only worker-days prior to 2003, worker-days for employees grandfathered under the pre-2008 eligibility requirements for subsidized RHI regardless of date, and worker-days when the employee is younger than 60 regardless of date.
Table 5.2. Separation Probabilities for Cohorts Becoming Eligible for Subsidized Retiree Health Insurance Before Normal Retirement

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<th>57</th>
<th>58</th>
<th>59</th>
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<tbody>
<tr>
<td>Change in Separation Probability at eligibility for</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>subsidized RHI</td>
<td>0.084</td>
<td>0.122</td>
<td>0.152</td>
<td>0.169</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.014)</td>
<td>(0.015)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>Separation Probability at Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>0.021</td>
<td>0.033</td>
<td>0.024</td>
<td>0.020</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.006)</td>
<td>(0.005)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>56</td>
<td>0.105</td>
<td>0.031</td>
<td>0.034</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.006)</td>
<td>(0.007)</td>
<td>(0.006)</td>
</tr>
<tr>
<td>57</td>
<td>0.091</td>
<td>0.153</td>
<td>0.022</td>
<td>0.021</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.013)</td>
<td>(0.005)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>58</td>
<td>0.081</td>
<td>0.097</td>
<td>0.174</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.011)</td>
<td>(0.015)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>59</td>
<td>0.116</td>
<td>0.125</td>
<td>0.143</td>
<td>0.200</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.015)</td>
<td>(0.016)</td>
</tr>
</tbody>
</table>

Note: Separation probabilities defined as $1 - e^{-365.25 \lambda_{as}}$ where $\lambda_{as}$ is the empirical hazard at age $a$ and service $s$. The empirical hazard is the total number of separations at age $a$ and service $s$ divided by the total number of worker-days employed at age $a$ and service $s$. Values for the cohort becoming eligible for subsidized RHI at age $a_{whi}$ taken from the set of age and service combinations such that $s - (a - a_{whi}) = 25$. Shaded cells indicate the year prior to and the first year of eligibility for subsidized retiree health insurance. The sample is restricted to active general employees who (i) have never retired, (ii) have never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania, and (iii) have no service in class A-3 or A-4. The estimation uses only worker-days prior to 2003, worker-days for employees grandfathered under the pre-2008 eligibility requirements for subsidized RHI regardless of date, and worker-days when the employee is younger than 60 regardless of date.
Figure 5.4. Effect of Eligibility for Normal Retirement After Eligibility for Subsidized Retiree Health Insurance

Note: Separation probabilities defined as $1 - e^{-365.25\lambda_a}$ where $\lambda_a$ is the empirical hazard at age $a$ and service $s$. The empirical hazard is the total number of separations at age $a$ and service $s$ divided by the total number of worker-days employed at age $a$ and service $s$. Values for the cohort becoming eligible for subsidized RHI at age $a_{ret}$ taken from the set of age and service combinations such that $s - (a - a_{ret}) = 25$. The sample is restricted to active general employees who (i) have never retired, (ii) have never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania, and (iii) have no service in class A-3 or A-4. The estimation uses only worker-days prior to 2003, worker-days for employees grandfathered under the pre-2008 eligibility requirements for subsidized RHI regardless of date, and worker-days when the employee is younger than 60 regardless of date.
Figure 5.5. Fraction of Active Employees Eligible for Subsidized Retiree Health Insurance by Age

Note: Count of employees eligible for subsidized retiree health insurance by age on January 1 of each year between 2000 and 2008 divided by the total number of employees by age on January 1 of each year. Sample consists of active general employees who (i) have never retired and (ii) have never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania.

Table 5.3. Approximate Effect of RHB Offer on Separation Probabilities

<table>
<thead>
<tr>
<th>Age</th>
<th>Effect of Eligibility</th>
<th>Fraction Eligible</th>
<th>Effect of Offer</th>
</tr>
</thead>
<tbody>
<tr>
<td>56</td>
<td>0.084</td>
<td>0.405</td>
<td>0.034</td>
</tr>
<tr>
<td>57</td>
<td>0.122</td>
<td>0.394</td>
<td>0.048</td>
</tr>
<tr>
<td>58</td>
<td>0.152</td>
<td>0.381</td>
<td>0.058</td>
</tr>
<tr>
<td>59</td>
<td>0.169</td>
<td>0.362</td>
<td>0.061</td>
</tr>
<tr>
<td>61</td>
<td>0.314</td>
<td>0.544</td>
<td>0.171</td>
</tr>
<tr>
<td>62</td>
<td>0.473</td>
<td>0.510</td>
<td>0.241</td>
</tr>
<tr>
<td>63</td>
<td>0.519</td>
<td>0.462</td>
<td>0.239</td>
</tr>
<tr>
<td>64</td>
<td>0.520</td>
<td>0.438</td>
<td>0.228</td>
</tr>
</tbody>
</table>

Note: The effect of eligibility is the change in the separation probability upon becoming eligible for subsidized retiree health insurance as shown in Tables 4.1 and 4.2. The fraction of employees eligible is the count of eligible employees divided by the total number of employees as shown in Figure 5.5. The approximate effect of offer is the product of the effect of eligibility and the fraction eligible.
Figure 6.1. Required Age and Service on June 30, 2008 for Grandfathering
Under the Existing Eligibility Requirements for Subsidized RHI

Note: Members were grandfathered under the existing eligibility rules for subsidized retiree health insurance
if, as of June 30, 2008, they had accumulated at least 15 years of service or were at least 59 and had
accumulated at least 13 years of service. Service that an individual was eligible to purchase but had not
yet purchased could be counted against the requirements. Because the available data do not include each
employee’s exact date of birth, all employees who were age 59 in 2008 are discarded for purposes of the
quasi-experimental analysis as it is not possible to determine their grandfathering status precisely.
Figure 6.2. Effect of the Increased Service Requirement for Subsidized RHI on the Probability of Continuous Employment From December 31, 2002 Through December 31, 2011, Workers 51 and Older

Note: Scatter plot of the average probability of continuous employment in half-year bins overlaid with a piecewise linear fit of the same probability as a function of the additional service needed to meet the grandfathering requirements. Additional service needed to meet the grandfathering requirements defined as the difference between the age-specific service requirement and projected service on June 30, 2008. Projected service includes all service purchases for service prior to July 2008 regardless of the date of purchase. Estimation sample consists of active general employees of the state of Pennsylvania at the end of 2002 who (i) worked at least 1900 hours in both 2001 and 2002; (ii) had never retired; (iii) had never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania; and (iv) were born before 1949, in 1950, or in 1951.

<table>
<thead>
<tr>
<th>Polynomial Order</th>
<th>Bandwidth (Rectangular Kernel)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>0.120</td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
</tr>
<tr>
<td>1</td>
<td>0.136</td>
</tr>
<tr>
<td></td>
<td>(0.047)</td>
</tr>
<tr>
<td>2</td>
<td>0.172</td>
</tr>
<tr>
<td></td>
<td>(0.072)</td>
</tr>
<tr>
<td>3</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>(0.098)</td>
</tr>
</tbody>
</table>

Note: Estimate of the effect of the increased service requirement derived from linear regression discontinuity specification. The rectangular kernel is defined as $K(u) = 0.5/h \times \mathbb{1}_{\{u \leq h\}}$, where $h$ is the indicated bandwidth. All specifications are limited to employees with less than five years of additional service needed to meet the grandfathering requirements (i.e. bandwidths greater than five add additional observations on only one side of the discontinuity). Additional service needed to meet the grandfathering requirements defined as the difference between the age-specific service requirement and projected service on June 30, 2008. Projected service includes all service purchases for service prior to July 2008 regardless of the date of purchase. Estimation sample consists of active general employees of the state of Pennsylvania at the end of 2002 who (i) worked at least 1900 hours in both 2001 and 2002; (ii) had never retired; (iii) had never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania; and (iv) were born before 1949, in 1950, or in 1951.
Figure 6.3. The Censoring Strategy
Used to Estimate Pre-Reform Employment Survival Functions
on Dates Prior to July 1, 2010,
Schematic for Workers Age 60 and Older

Note: Data on grandfathered employees is used to estimate the pre-reform employment survival function at the grandfathering threshold. Directly computing the survival function using data on all employees within $h$ years of the threshold—the baseline estimation bandwidth $h = 2$ is shown in the figure—would include individuals who separate after becoming eligible for subsidized RHI (i.e. inside the shaded region) even when the individual at the grandfathering threshold has not yet become eligible. Because workers separate rapidly after becoming eligible, such an approach would lead to a badly biased estimate of the desired function. To obtain a better estimate on dates at which the marginal employee is not yet eligible for subsidized RHI, each employee is censored when he or she becomes eligible. For dates on or after which the marginal employee has become eligible, the estimation uses all available data for each individual (not shown in the figure). For simplicity, the figure abstracts from the potential for uneven accumulation of service within a calendar year.
Figure 6.4. Employment Survival Functions
Under the Pre and Post-Reform Eligibility Rules for Subsidized RHI,
Workers Age 51-52 on December 31, 2002
Projected to Exactly Meet the Grandfathering Requirements in 2008

Note: Product-limit estimates of the employment survival functions at the grandfathering threshold. The 
pre-reform estimates use data for grandfathered employees and the post-reform estimates use data for non-
grandfathered employees. In both cases, the estimates are computed using a rectangular kernel, defined as
\( K(u) = 0.5/h \times 1\{u \leq h\} \), and a bandwidth \( h = 2 \). Additional service needed to meet the grandfathering 
requirements defined as the difference between the age-specific service requirement and projected service on 
June 30, 2008. Projected service includes all service purchases for service prior to July 2008 regardless of 
the date of purchase. Estimation sample consists of active general employees of the state of Pennsylvania at 
the end of 2002 who (i) worked at least 1900 hours in both 2001 and 2002; (ii) had never retired; (iii) had 
ever elected to determine pension benefits jointly for service as a state employee and as a public school 
employee in Pennsylvania; and (iv) were born before 1949, in 1950, or in 1951.
Figure 6.5. Employment Survival Functions
Under the Pre and Post-Reform Eligibility Rules for Subsidized RHI,
Workers Age 54-59 on December 31, 2002
Projected to Exactly Meet the Grandfathering Requirements in 2008

Note: Product-limit estimates of the employment survival functions at the grandfathering threshold. The pre-reform estimates use data for grandfathered employees and the post-reform estimates use data for non-grandfathered employees. In both cases, the estimates are computed using a rectangular kernel, defined as $K(u) = 0.5/h \times I\{|u| \leq h\}$, and a bandwidth $h = 2$. For estimation of the pre-reform survival function prior to July 1, 2010 grandfathered employees are censored immediately prior to eligibility for subsidized RHI. For estimation on or after July 1, 2010 the full sample of employees is used. Additional service needed to meet the grandfathering requirements defined as the difference between the age-specific service requirement and projected service on June 30, 2008. Projected service includes all service purchases for service prior to July 2008 regardless of the date of purchase. Estimation sample consists of active general employees of the state of Pennsylvania at the end of 2002 who (i) worked at least 1900 hours in both 2001 and 2002; (ii) had never retired; (iii) had never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania; and (iv) were born before 1949, in 1950, or in 1951.
Figure 6.6. Employment Survival Functions
Under the Pre and Post-Reform Eligibility Rules for Subsidized RHI,
Workers Age 60 and Older on December 31, 2002
Projected to Exactly Meet the Grandfathering Requirements in 2008

Note: Product-limit estimates of the employment survival functions at the grandfathering threshold. The
pre-reform estimates use data for grandfathered employees and the post-reform estimates use data for non-
grandfathered employees. In both cases, the estimates are computed using a rectangular kernel, defined as
\( K(u) = 0.5/h \times 1\{u \leq h\} \), and a bandwidth \( h = 2 \). For estimation of the pre-reform survival function prior
to July 1, 2010 grandfathered employees are censored immediately prior to eligibility for subsidized RHI.
For estimation on or after July 1, 2010 the full sample of employees is used. Additional service needed to
meet the grandfathering requirements defined as the difference between the age-specific service requirement
and projected service on June 30, 2008. Projected service includes all service purchases for service prior to
July 2008 regardless of the date of purchase. Estimation sample consists of active general employees of the
state of Pennsylvania at the end of 2002 who (i) worked at least 1900 hours in both 2001 and 2002; (ii) had
never retired; (iii) had never elected to determine pension benefits jointly for service as a state employee
and as a public school employee in Pennsylvania; and (iv) were born before 1949, in 1950, or in 1951.
Table 6.2. Effect of the Increased Service Requirement for Subsidized RHI on the Employment Survival Probability on Select Dates, Workers Age 51 and Older on December 31, 2002 Projected to Exactly Meet the Grandfathering Requirements in 2008

<table>
<thead>
<tr>
<th>Date</th>
<th>Bandwidth (Rectangular Kernel)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Age 51-52: Eligible for Sub. RHI Jan. 1, 2010 - Dec. 31, 2011</strong></td>
<td></td>
</tr>
<tr>
<td>July 1, 2009</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td>(0.052)</td>
</tr>
<tr>
<td>July 1, 2010</td>
<td>0.026</td>
</tr>
<tr>
<td></td>
<td>(0.058)</td>
</tr>
<tr>
<td>July 1, 2011</td>
<td>0.124</td>
</tr>
<tr>
<td></td>
<td>(0.063)</td>
</tr>
<tr>
<td><strong>Age 54-59: Eligible for Sub. RHI on July 1, 2010, Ineligible for NR on December 31, 2002</strong></td>
<td></td>
</tr>
<tr>
<td>July 1, 2009</td>
<td>-0.019</td>
</tr>
<tr>
<td></td>
<td>(0.055)</td>
</tr>
<tr>
<td>July 1, 2010</td>
<td>0.127</td>
</tr>
<tr>
<td></td>
<td>(0.055)</td>
</tr>
<tr>
<td>July 1, 2011</td>
<td>0.144</td>
</tr>
<tr>
<td></td>
<td>(0.048)</td>
</tr>
<tr>
<td><strong>Age 60 and older: Eligible for Sub. RHI on July 1, 2010, Eligible for NR on December 31, 2002</strong></td>
<td></td>
</tr>
<tr>
<td>July 1, 2009</td>
<td>-0.131</td>
</tr>
<tr>
<td></td>
<td>(0.060)</td>
</tr>
<tr>
<td>July 1, 2010</td>
<td>-0.078</td>
</tr>
<tr>
<td></td>
<td>(0.053)</td>
</tr>
<tr>
<td>July 1, 2011</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>(0.043)</td>
</tr>
</tbody>
</table>

Note: Difference between the product-limit estimates of the post-reform employment survival function and the pre-reform employment survival function for the specified population. Shaded cells indicate baseline estimates as shown in the figures. The pre-reform estimates use data for grandfathered employees and the post-reform estimates use data for non-grandfathered employees. In both cases, the estimates are computed using a rectangular kernel, defined as \( K(u) = 0.5/h \times 1\{u \leq h\} \), and a bandwidth \( h = 2 \). For estimation of the pre-reform survival function in the two populations age 54 and older prior to July 1, 2010, grandfathered employees are censored immediately prior to eligibility for subsidized RHI. For estimation on or after July 1, 2010 the full sample of employees is used. Additional service needed to meet the grandfathering requirements defined as the difference between the age-specific service requirement and projected service on June 30, 2008. Projected service includes all service purchases for service prior to July 2008 regardless of the date of purchase. Estimation sample consists of active general employees of the state of Pennsylvania at the end of 2002 who (i) worked at least 1900 hours in both 2001 and 2002; (ii) had never retired; (iii) had never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania; and (iv) were born before 1949, in 1950, or in 1951.
Table 7.1. Present Value of Health and Pension Plan Obligations for Active General Employees on December 31, 2011 Under Current Eligibility Rules for Subsidized RHI and Under Two Alternative Policies, Six Percent Discount Rate

<table>
<thead>
<tr>
<th>Eligibility Requirements for Subsidized Retiree Health Insurance (age/service)</th>
<th>60/20, any/25</th>
<th>60/20, any/30</th>
<th>any/25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present Value (millions of dollars)</td>
<td>Health Plan</td>
<td>Pension Plan</td>
<td>Effect of Policy Change</td>
</tr>
<tr>
<td>PV of future benefits</td>
<td>6,838</td>
<td>6,348</td>
<td>5,989</td>
</tr>
<tr>
<td>PV of future retiree premiums</td>
<td>56</td>
<td>52</td>
<td>51</td>
</tr>
<tr>
<td>PV of net plan obligations</td>
<td>6,782</td>
<td>6,296</td>
<td>5,938</td>
</tr>
<tr>
<td>PV of future benefits</td>
<td>19,714</td>
<td>19,828</td>
<td>19,739</td>
</tr>
<tr>
<td>PV of future member contributions</td>
<td>1,780</td>
<td>1,796</td>
<td>1,835</td>
</tr>
<tr>
<td>PV of net plan obligations</td>
<td>17,935</td>
<td>18,032</td>
<td>17,904</td>
</tr>
<tr>
<td>Δ PV of health plan obligations</td>
<td>-486</td>
<td>-844</td>
<td></td>
</tr>
<tr>
<td>Δ PV of pension plan obligations</td>
<td>97</td>
<td>-30</td>
<td></td>
</tr>
<tr>
<td>Pension plan offset (percent)</td>
<td>20.0</td>
<td>-3.6</td>
<td></td>
</tr>
</tbody>
</table>

Note: Present value of future health and pension benefits, premiums, and member contributions for active general employees of the state of Pennsylvania covered by the State Employees’ Retirement System and working at agencies participating in the Retired Employees Health Plan. Excludes members with service in class A-3 or A-4. Pension plan offset is the fraction of savings from the reduction in health plan obligations lost in the form of increased obligations for the pension plan. See section six and appendix A for a detailed discussion of the methodology.
Table 7.2. Effect of Restricting Eligibility for Subsidized RHI
Before Normal Retirement to Employees with at least 30 Years of Service,
Discounting at 4, 6, and 8 Percent

<table>
<thead>
<tr>
<th>Change in Present Value (millions of dollars)</th>
<th>Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4%</td>
</tr>
<tr>
<td>Health Plan</td>
<td></td>
</tr>
<tr>
<td>( \Delta ) PV of future benefits</td>
<td>-804</td>
</tr>
<tr>
<td>( \Delta ) PV of future retiree premiums</td>
<td>-13</td>
</tr>
<tr>
<td>( \Delta ) PV of net plan obligations</td>
<td>-792</td>
</tr>
<tr>
<td>Pension Plan</td>
<td></td>
</tr>
<tr>
<td>( \Delta ) PV of future benefits</td>
<td>223</td>
</tr>
<tr>
<td>( \Delta ) PV of future member contributions</td>
<td>20</td>
</tr>
<tr>
<td>( \Delta ) PV of net plan obligations</td>
<td>203</td>
</tr>
<tr>
<td>Pension Plan Offset (percent)</td>
<td>25.7</td>
</tr>
</tbody>
</table>

Note: Change in the present value of future health and pension benefits, premiums, and member contributions for active general employees of the state of Pennsylvania covered by the State Employees' Retirement System and working at agencies participating in the Retired Employees Health Plan. Excludes members with service in class A-3 or A-4. Pension plan offset is the fraction of savings from the reduction in health plan obligations lost in the form of increased obligations for the pension plan. See section six and appendix A for a detailed discussion of the methodology.
Chapter 2

A Structural Analysis of Retirement with Retiree Health Insurance

Abstract

Eligibility for retiree health insurance is a crucial determinant of retirement behavior, but existing models of the retirement decision typically treat eligibility as a fixed characteristic of the worker rather than one that evolves over the career. Furthermore, analyses often simplify the structure of pension plans to make estimation more tractable at the expense of accuracy. This chapter estimates a structural model of life-cycle labor supply using administrative data for the Pennsylvania state workforce while maintaining a complete representation of the rich individual-level variation in health and pension benefits. The estimates are then used to simulate labor supply behavior under different health and pension policies. Changes in the eligibility requirements for subsidized retiree health insurance induce dramatic changes in retirement timing that would be missed in models that do not account for an employer's eligibility criteria.

This project would not have been possible without the invaluable assistance of the open records team at the Pennsylvania State Employees' Retirement System. I also thank Jim Poterba, Jon Gruber, Isaiah Andrews, Aviva Aron-Dine, Dan Barron, and Matt Fiedler. This research was supported by the National Institute on Aging, Grant Number T32-AG0000186, and by the Lynde and Harry Bradley Foundation. All mistakes are my own.
2.1 Introduction

In the United States, people obtain health insurance from a wide range of sources, including their employer, a spouse's employer, the government, unions or professional associations, and the private market (Fronstin (2012)). In each case, the price paid for an insurance policy reflects a complicated set of implicit cross-subsidies.\footnote{While these cross-subsidies can be much less pronounced in the private market, regulations forbidding pricing on specific characteristics have a similar effect.} Adding a spouse to an employer policy, for example, can cost much less than an actuarially fair premium. As a result, decisions not directly related to health insurance are affected by the provision of health insurance. One decision which is strongly influenced by individuals' desire to maintain health insurance coverage is that of when to retire (Rust and Phelan (1997), French and Jones (2011), Nyce et al. (2011), and Leiserson (2013)). Retirement often results in a change in the source of health insurance coverage, canonically from employer-provided insurance to Medicare.

Understanding the effect of health insurance on retirement behavior has become a critically important policy issue. Increasing per capita medical expenditures have led to numerous proposed and enacted policies intended to address concerns about coverage, cost, and quality. These proposals include both those intended to affect the health insurance of the retired population, such as increases in the eligibility age for Medicare, and those directed elsewhere but which will have important subsidiary effects on retirees or retirement behavior, such as subsidies for the purchase of insurance in the private market that facilitate retirement prior to eligibility for Medicare.

Using a sample of public sector employees in Pennsylvania whose decision to retire is strongly influenced by the eligibility rules for the subsidized retiree health insurance offered by their employer (Leiserson (2013)), this chapter estimates a structural model of the retirement decision that can be used to simulate counterfactual retirement distributions under alternative health and pension benefit policies. While previous work has documented the reduced form importance of retiree health insurance (see, e.g., Leiserson (2013), Nyce et al. (2011), Madrian (1994), and Karoly and Rogowski (1994)), it can be difficult to find reduced form evidence on policy impacts relevant to potential future policy changes as there is substantial heterogeneity in the design of health and pension plans across firms. Furthermore, existing structural work has lacked information about the eligibility requirements for bene-
fits within the firm. Such work is therefore unable to inform discussion of plausible policy options—like those recently implemented in Pennsylvania and under consideration in many other states—that would change benefits along exactly this dimension.

The estimates suggest that restrictions in eligibility for subsidized retiree health insurance (RHI) can be expected to induce dramatic shifts in the distribution of retirements. In contrast, reductions in the generosity of pension benefits may have more modest effects. This difference in the behavioral response arises because eligibility restrictions for health insurance typically involve very large reductions in benefits in a small number of years and thus a dramatic increase in the financial incentive for continued work in those years. Changes in pension benefits tend to have a much more diffuse impact over a much larger number of years. Of course, one could design cuts in pension benefits that do not have this characteristic. Crucially, the simulated retirement distributions produced by the model capture the interactions between the state’s retiree health and pension benefits and indicate that changes in employee behavior in response to changes in either health or pension benefits depend substantially on the employee’s eligibility for the other benefit.

The key contribution of this analysis is to exploit detailed knowledge of the institutional regime in Pennsylvania, where different employees become eligible for subsidized retiree health insurance at different ages, in order to estimate a structural model of retirement behavior that can be used to simulate counterfactual retirement distributions under alternative policy regimes. This exercise contrasts with existing structural analyses of the effect of health insurance on retirement, which typically assume that eligibility for retiree health benefits is a fixed characteristic of each employer-employee pair. In addition to the rich variation in eligibility for retiree health insurance at the individual level, a second advantage of the current setting is the large size of the population covered by a single institutional regime. Because all individuals used in the analysis work under the same regime, there is no need to map the rules of a pension plan into a low-dimensional state space and no consequent reduction in accuracy.

This chapter builds on an extensive literature estimating structural models of the retirement decision. Like much of the early work on pensions (Kotlikoff and Wise (1989), Stock and Wise (1990)), it uses data for only a single firm where the rules are well known and can be implemented accurately in the empirical analysis. More recent work incorporating medical expenses (Rust and Phelan (1997), French and Jones (2011)) has tended to
use samples drawn from the entire population, allowing for a more general result but also forcing the authors to abstract from important institutional detail in the estimation for reasons of tractability and therefore sacrificing accuracy. None of the existing structural work incorporates data on the evolution of individual-level eligibility for retiree health insurance.

The remainder of this chapter proceeds as follows. Section two outlines the model. Section three describes the data, identification, and estimation. Section four discusses the fit and the results. Section five presents the results of several policy simulations and section six concludes.

2.2 Model

I estimate a simple dynamic programming model of the retirement decision in the spirit of Stock and Wise (1990).

2.2.1 Preferences

At time $t$, agents maximize the present value of future utility

$$
\sum_{s=t}^{T} \beta^{s-t} \pi (s \mid t) u (C_t, L_t),
$$

(2.1)

where $\beta$ is the discount factor, $\pi (t_1 \mid t_0)$ the probability of survival from period $t_0$ to $t_1$, and $u (C_t, L_t)$ the period utility derived from consumption $C_t$ and leisure $L_t$. (Periods represent years of life and will be referred to interchangeably as ages, dates, and periods.) All agents still alive at $T = 100$ are assumed to die with certainty at the end of the period. Survival probabilities are unaffected by any choices or actions taken by the individuals.³

Period utility exhibits constant relative risk aversion in the consumption-leisure aggregate,

$$
u (C_t, L_t) = (1 - \sigma)^{-1} (C_t L_t)^{1-\sigma}.$$

Leisure is defined as $L_t (e_t) = 1 - e_t \times (k + v_t)$, where $e_t$ is employment status. The parameters $k$ and $v_t$ capture the utility cost of work; $k$ is homo-

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²The model estimated in Gustman and Steinmeier (1994) allows for the evolution of eligibility at the individual level, but the authors are forced to impute the eligibility rules because the data used in the paper does not contain the relevant information.

³Survival probabilities are drawn from the RP-2000 tables representing mortality for the population covered by defined benefit pension plans in the year 2000.
geneous in the population while \( \nu_t \) varies at the individual level and over time.\(^4\) The cost of work reflects a combination of tangible costs (e.g. commuting, meals, and substitution from home production to services) and intangible costs (e.g. tastes, alternative employment opportunities, the value of time, and the quality of the current job). The idiosyncratic component is assumed to follow the form

\[
\nu_t = \rho \nu_{t-1} + \epsilon_t
\]

\[
\epsilon_t = N\left(0, \sigma^2_\epsilon\right).
\]

Putting all of these pieces together results in the utility specification

\[
u(C_t, L_t(\epsilon_t)) = \frac{1}{1 - \sigma} (C_t (1 - e_t \times (k + \nu_t)))^{1-\sigma}.
\]

The model is used to explain the behavior of a sample of employees selected at age 50. The cost of work is the key source of heterogeneity in the model. The model must rationalize the decisions made by different individuals with the same tenure at age 50 to retire at different ages, even though they are eligible to retire with the same package of benefits at any age. All characteristics at age 50 are assumed to be unrelated to the individual-specific cost of work and the value \( \nu_{50} \) is drawn from the same normal distribution, i.e. \( \nu_{50} \sim N(0, \sigma^2_\nu) \).\(^5\)

### 2.2.2 Choices

Agents choose when to retire. Once retired, they may not return to the workforce. However, since the data are drawn from only a single firm, retirement may involve continued work elsewhere. This is particularly true for younger employees, for whom the cost of work likely reflects the value of alternative employment possibilities.

Private savings is forbidden. This simplification reflects several economic and practical considerations. First, from a practical perspective, introducing a choice of consumption and assets dramatically increases the computational complexity of the model. In contrast with

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\(^4\)Since employment status is a binary variable, the value of leisure for an individual takes on one of only two values: \( 1 - e \times (k + \nu) \) if the individual continues working and 1 if the individual retires.

\(^5\)It is straightforward to allow additional flexibility in the baseline distribution of heterogeneity, but with few retirements before age 55, the additional parameters introduced are poorly identified. For this reason, the specification of the model here simply assumes that the baseline distribution of heterogeneity follows the same distribution as all subsequent innovations.
previous work, this analysis incorporates a detailed representation of employee service in
the state space, allowing for the precise determination of eligibility for health and pension
beneﬁts. This ﬁne detail is essential for simulating counterfactual distributions of retirement
behavior under alternative policy regimes as it is needed to capture the changes in eligibility,
but it limits what can be done along other dimensions.

Second, the employee data used to estimate the model contains no asset information. Using
asset-related moments to identify the model would require imputation of asset infor-
mation from another source. As a result, no information about the correlation between
assets and separation behavior would be available for identiﬁcation.

Third, introducing a simple savings technology would not necessarily improve the model’s
ability to ﬁt the data. If allowed to save, low pension wealth individuals would build up
substantial savings to supplement their retirement consumption. That is, allowing savings
would reduce some of the gap in retirement consumption between those individuals with
large pensions and those with small pensions. However, tabulations from the Health and
Retirement Study indicate that, within age, net worth correlates positively with tenure in
the population of individuals covered by deﬁned beneﬁt pension plans. This reduced-form
correlation is not surprising, but it indicates that a simple model of savings would not
necessarily lead to a more realistic model.

Finally, allowing savings makes it more difﬁcult for the model to explain retirements by
low pension wealth individuals. With access to savings, the wages from an additional year of
work can be spread over an entire retirement of low consumption and therefore high marginal
utility.6 Restricting savings forces the individuals to consume wages immediately and thus
reduces the utility value of continued work.

2.2.3 Cash income

Agents in the model receive cash income from wages, the state’s deﬁned beneﬁt pension, and
Social Security.

6Of course, the low pension wealth individuals could have large stocks of private savings that they rely
on for retirement consumption, but this is exactly what the reduced-form correlation in the HRS rules out.
Wages

Wage growth is assumed to follow the actuarial assumptions used by the state's pension plan. The growth rate in any period is a deterministic function of the employee's service:

\[ w_{t+1} = (1 + g(s_{t})) w_t. \]  

(2.4)

Growth rates are high at the beginning of the career and decrease over the course of the career. The assumptions are described in Hay Group (2011). As a very large share of the state's workforce is unionized and compensation for such employees follows negotiated salary schedules, deterministic salary growth is a reasonable assumption. Uncertainty in the outcome of contract negotiations over the course of the career will, of course, generate deviations from the forecast.

Pensions

Pennsylvania provides a traditional defined benefit pension to its retired employees. The initial benefit at retirement is the product of four pieces: (i) a 2.5 percent accrual factor specified in the plan statutes, (ii) average earnings over the employee’s three highest-earning years, (iii) the number of years of service for the state, and (iv) an early retirement reduction, if applicable. Expressed mathematically,

\[ b_t = 0.025 \times \frac{1}{3} \sum_{t-3}^{t-1} w_t \times s_{t} \times \frac{c_{NRA}}{c_t} \times (1.04)^{t-NRA}, \]  

(2.5)

where \( b_t \) denotes the benefit at time \( t \), \( w_t \) the wage at time \( t \), \( s_{t} \) service at time \( t \), \( c_t \) the cost of a $1 annuity for an individual of age \( t \), and \( NRA \) the plan’s normal retirement age. The normal retirement age is the minimum of 60 and the year in which an employee reaches 35 years of service. As expressed in the formula above, the high-three average earnings

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7 The rules described here are those in effect for employees hired before January 1, 2011, and thus unaffected by the benefit reductions implemented by the state legislature in late 2010, and retiring on or after July 1, 2001. The estimation sample is restricted to employees retiring in this period. Selection into the sample based on the policy regime existing prior to July 1, 2001 is ignored. In practice, because most individuals retire relatively quickly after they become eligible for full benefits, the problems arising from this abstraction should not be severe.

8 This specification implicitly assumes immediate claiming of the pension benefit at the time of retirement. Doing so will be optimal both in the sense of maximizing the present value of benefits and in the sense of maximizing the utility value of benefits in nearly all cases.
incorporates the fact that under the assumed pattern of wage growth, the highest-earning years will necessarily be the most recent years. Individuals must have five years of service to be eligible for this benefit before the normal retirement age and three years of service at or after the normal retirement age. Cost of living adjustments (COLAs) for the pension benefit are provided on an ad hoc basis by the state legislature. The impact of the COLA structure on retirement behavior depends primarily on the probability that the state will offer a COLA in the first few years after retirement. For this reason, the modeling assumes that there is no COLA. This will slightly understate the level of pension benefits that an employee expects to receive during retirement, but will capture the relevant incentives affecting retirement behavior. The model assumes an inflation rate of two percent.

The pension plan offers employees a partial lump-sum at retirement. Between 2006 and 2010, 85 percent of retirees chose to take it. However, because the model rules out private savings, the choice to take this lump sum is ignored in the implementation. This simplification could create a problem if retirees use the accelerated benefits to increase consumption in the years before the Social Security early retirement age and thus smooth consumption more effectively. While it is not possible to determine whether individuals are pursuing this strategy from the data, since so many retirees take this option—including those retiring at or after 62—smoothing consumption across the Social Security early retirement age is likely not the primary motivation.

Social Security

The computation of Social Security benefits follows a simplified formula motivated by the limited data available and the need to maintain a tractable state space. For employees retiring at or after age 60, average earnings are assumed to equal 75 percent of the current wage. For each year an employee retires before age 60 one zero is added to the earnings history. However, the number of zeros introduced is limited to the number of years less than 35 the individual has worked for the state. This approximation to Social Security’s average earnings computation will tend to overestimate the correct value for individuals who join the state workforce because it offers a better salary than their previous job and will tend to underestimate the correct value for individuals who had slower salary growth in previous employment than is assumed in the valuation of the state’s pension plan. The value for average earnings is expressed in 2005 dollars and the bend points for 2005 are applied to
determine the benefit. The normal retirement age for all individuals is assumed to be 66.\(^9\) Spousal and disability benefits are ignored.

Taxes

Federal income taxes are computed according to the schedule for a single individual in 2005 with one dependent who claims the standard deduction. Credits are ignored. Social Security benefits are included in income at a 50 percent rate above $25,000. Additional taxation of Social Security benefits at higher income levels is ignored. Pennsylvania state income taxes apply a flat rate to a broad definition of income. However, state pension benefits are exempt. For modeling purposes, the exemption of state pension benefits is the only exclusion allowed.

While information on marital status is exempt from public records requests, it is reasonable to believe that most of the individuals in the sample are married. However, computing taxes under the joint schedule while including income from only one spouse would substantially understate the true tax liability. Since the model ignores the presence of a spouse and the potential for joint retirement decisions, computing taxes according to the single schedule provides a reasonable projection of the world onto the model.

2.2.4 Health insurance

Active employees receive health benefits from the state. All retired employees receiving a pension benefit can purchase coverage through the state at full price. Retired employees meeting additional age and service criteria receive highly subsidized health insurance policies. Eligibility for subsidized health insurance requires 15 years of service at or after age 60, or 25 years of service at any age.\(^10\) Once employees meet these additional age and service requirements, they need pay only 0-3 percent of their salary at the time of retirement in

\(^9\)A complete implementation of the rules determining Social Security benefits would require including both calendar time and birth year in the state space. Calendar time affects wage indexed values, including the bend points, and an employee's birth year determines her normal retirement age. However, as this would increase the computational burden associated with solving the model and the computation of Social Security benefits will only ever be an approximation due to the incomplete knowledge of the earnings history, I exclude both calendar time and year of birth from the state space and approximate Social Security benefits based on the bend points in a single calendar year and an assumed normal retirement age.

\(^10\)The description of retiree health benefits here applies to all employees retiring prior to July 1, 2008 and grandfathered employees retiring on or after July 1, 2008. Employees were grandfathered if, by June 30, 2008, they had at least 15 years of service or were at least 59 and had at least 13 years of service. The estimation sample is restricted to these populations.
order to receive health coverage in retirement. The contribution rate varies with age and the
date of retirement. Retiree contributions are ignored in the implementation of the model as
including them would require including calendar time in the state space. Since contributions
are small relative to the value of the premium and the potential variation in the value of the
insurance to the individual, this is unlikely to meaningfully affect the results.

Health insurance is treated as additional consumption for the individual. That is, medical
expenses are not directly modeled and there is no insurance against risk resulting from
coverage. This choice is motivated by the fact that relatively few individuals retiring in this
population are uninsured regardless of whether they receive insurance from the state. Instead
they either depart for another job that provides coverage, have access to coverage through a
spouse, purchase coverage from the state, or purchase coverage in the private market. As a
result, treating individuals without access to retiree health coverage as uninsured would be
a mistake.\footnote{Even if it were desirable to model medical conditions directly, the member data available from the
pension plan does not include any medical information so it would not be possible.}

The value of the health insurance is set to the average premium for a multi-party policy
prior to eligibility for Medicare in 2005. This value will be assumed constant in real terms
in the estimation. While this is clearly inconsistent with the recent and likely future path of
medical expenditures, it is not clear that individual employees have sophisticated projections
of premiums throughout their retirement years (or even necessarily know the actuarial value
of the health benefits they currently receive). For that reason I do not worry about the
details of future premium projections.

Individuals become eligible for Medicare at age 65. The value of Medicare is assumed
to be proportional to the value of comprehensive insurance. The constant of proportionality
is given by the ratio of the reduction in premiums for Medicare-eligible retirees to the
premium for comprehensive insurance prior to eligibility for Medicare. This may provide an
underestimate of the value of Medicare as the first dollar of coverage is likely substantially
more valuable to the retiree than the last dollar of coverage.

\subsection*{2.2.5 Recursive problem}

Because all retirees are assumed to die at the end of period $T$, the problem admits a straight-
forward solution via backwards induction. Substituting into the utility specification shown
in equations (2.1) and (2.3) yields the value of retirement at age $t$ for an individual with pension benefit $b$, Social Security benefit $ss$, and retiree health coverage status $h$:

$$V^R_t(b, ss, h) = \sum_{s=t}^{T} \beta^{s-t} \pi(s \mid t) \frac{1}{1 - \sigma} \left( b (1 + i)^{s-t} + ss + 1(t < 65) hm ight)$$

$$+ 1(t \geq 65) \max(hm, \overline{m})^{1-\sigma}. \tag{2.6}$$

The nominal pension benefit $b$ is adjusted for inflation at rate $i$. Prior to age 65, individuals receive comprehensive health insurance with premium value $m$ if they are eligible for retiree health benefits. After reaching age 65, they continue to receive comprehensive health insurance if they are eligible for retiree health benefits but, in addition, ineligible employees receive Medicare benefits valued at $\overline{m}$.

An individual who enters a period employed has the option of remaining on the job or choosing to retire. The value of entering period $t$ employed for an individual with service $s$, wage $w$, and idiosyncratic cost of work $v$ is therefore

$$V_t(s, w, v) = \max \left\{ V^R_t(b, ss, h), \frac{1}{1 - \sigma} \left( C(1 - (k + v)) \right)^{1-\sigma} + \beta \pi(t + 1 \mid t) EV_{t+1} \right\} \tag{2.7}$$

$$b = f_b(t, w, s) \quad s' = s + e$$

$$ss = f_{ss}(t, w, s) \quad w' = (1 + g(s)) w$$

$$h = f_h(t, s) \quad v' = \rho v + \varepsilon.$$ 

$C = w + b + m - \tau$

The functions $f_b$, $f_{ss}$, and $f_h$ map age, wage, and service into the initial pension benefit, Social Security benefit, and eligibility for retiree health benefits according to the rules described above. $C$ denotes total consumption, equal to the sum of wages, pension benefits, and health insurance, less the computed income taxes. Primes indicate values of the state variable one year later. Service increments by one if the individual works, wage growth follows equation (2.4), and labor disutility evolves according to (2.2).
2.3 Data, identification, and estimation

I estimate the model via the method of simulated moments (MSM), matching the density of retirements by age and service in the data to those produced by the model.

2.3.1 Member data

I fit the model to data drawn from the member records of the Pennsylvania State Employees' Retirement System (SERS), which was obtained via a series of public records requests. The data was first used in Leiserson (2013) and the description here comes from that analysis. The data cover all members who worked between January 1, 2000 and December 31, 2011.12 The records include name, year of birth, sex, summary employment information prior to 2000, detailed information on all jobs held since 2000, a quarterly salary history since 1997, annual hours since 2000, detailed information on the date and type of retirement, and various additional fields relating to the administration of the pension system.

The raw data contains records for 213,190 individuals. I exclude from the sample people who never work in the sample period, were under age 50 at the end of 2011, who had part-time or intermittent employment, who retire before July 1, 2001, who have service in special service classes, who have class A-3 or A-4 service, who were affected by restrictions in eligibility for subsidized retiree health benefits taking effect in 2008, or who elect to combine service in the state retirement system with service in the public school employees retirement system.13 Individuals in special service classes consist primarily of hazardous duty employees, legislators, and judges. The pension benefits for these individuals follow distinct rules, including earlier retirement ages and/or different accrual factors. Employees with class A-3 or A-4 service are affected by major pension legislation enacted in late 2010 and also follow different eligibility and benefit rules. I further restrict the sample to employees at agencies participating in the Retired Employees Health Plan (REHP). The resulting sample contains information on 48,271 people.

The major limitation of the data available for this analysis is that it does not include month and day of birth. Access to this information has been restricted due to concerns about

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12The data also include individuals who worked prior to 2000 and had not retired by January 1, 2000, but they are not used in the analysis.

13I also exclude a small number of individuals with missing or inconsistent data.
identity theft in the release of employee records. I treat all individuals as if their birthday is on January 1. Because behavioral responses to changes in eligibility associated with changes in age appear to occur very rapidly after each birthday, this treatment minimizes the importance of measurement error.

The initial distribution of service and wages at age 50 used to simulate histories in the estimation of the model is the empirical distribution in the data. Table 1 shows the distribution of service and salary for employees at age 50. Salaries for most employees lie between $20,000 and $60,000. Roughly 40 percent of employees have salaries between $20,000 and $40,000 and a similar share have salaries between $40,000 and $60,000. Most of the remaining employees have salaries between $60,000 and $100,000, though a small number of individuals with very low salaries or higher salaries are present in the data.

Service is distributed much more uniformly. At least 9 percent of the sample has service in each five year bin between zero and 35 years of service. The most common group is that with 25-30 years of service, who make up 23 percent of the sample. This group consists of employees who joined the state workforce in their early 20s and have remained with it for their entire career. However, 12 percent of the sample of 50-year-old employees joined the state workforce in the last five years. As would be expected, there is a strong, positive correlation between the wage at age 50 and service at age 50.

2.3.2 Identification

The parameters of the baseline model are \((\beta, \sigma, k, \rho, \sigma^2)\). I identify the model using the distribution of retirements by age within cohorts defined by service at age 50. Because individuals are only observed between 2000 and 2011, I introduce an indicator for non-missing observations into the moment condition to ensure that it can be computed for all observations. Thus the moment functions are

\[
g_{aki} = 1 \{i \text{ non-missing at age } a\} \\
\times (1 \{\text{retire at age } a, \text{ member of service cohort } k\} - \mu_{ak}), \quad (2.8)
\]

where \(a\) denotes age, \(k\) denotes the cohort defined by service at age 50, \(i\) denotes the individual, and \(\mu_{ak}\) denotes the retirement rate simulated from the model. Let \(g(\theta)\) be the vector of mean values for each \(g_{ak}\) and candidate parameter vector \(\theta = (\beta, \sigma, k, \rho, \sigma^2)\). I use all com-
binations of $a \in [53, 67]$ and $k \in \{3, 4, 5, 15, 16, 17, 18, 24, 25, 26\}$ in the estimation. These particular service cohorts are chosen so as to capture the important differences in eligibility. Service cohorts with 3, 4, and 5 years of service become eligible for subsidized retiree health insurance at age 62, 61, and 60. All three become eligible for normal retirement at age 60. Service cohorts with 15, 16, 17, and 18 years of service become eligible for subsidized retiree health insurance at 60, 59, 58, and 57. Again all three cohorts become eligible for normal retirement at age 60. Finally, cohorts with 24, 25, and 26 years of service become eligible for retiree health benefits before age 53, but become eligible for normal retirement at 60, 60, and 59, respectively.

2.3.3 Estimation

I estimate the model via the method of simulated moments (MSM).\textsuperscript{14} The MSM estimation procedure selects parameters such that the difference between the simulated moments arising from the model and their counterparts in the data is as small as possible. Distance is measured by a generalized method of moments (GMM) objective function. For any candidate value $\theta$ of the parameter vector, calculating the objective takes five steps:

1. Solve via backwards recursion the dynamic programming problem described in equations (2.6) and (2.7) conditional on $\theta$.

2. Sample, with replacement, 2.5 million observations from the distribution of wages and service at age 50 in the data.

3. Use the decision rules associated with the solution to the dynamic programming problem to simulate retirement behavior for these observations.

4. Evaluate the moments $g(\theta)$ defined in equation (2.8) using the simulated work histories.

5. Compute the objective, $g(\theta)' W g(\theta)$.

The fitted values are obtained by minimizing this objective. While analytic results for the variance of this estimator exist, in this application their performance appears poor, most

\textsuperscript{14}MSM estimation has been extensively applied in the retirement literature (see, e.g., Berkovec and Stern (1991), Gustman and Steinmeier (2005), French and Jones (2011)). The formal properties were developed in Pakes and Pollard (1989).
likely due to a poor approximation to the gradient of the objective function. I therefore obtain standard errors via bootstrapping.

Because the model is a simple representation of a complicated life-cycle decision, it will necessarily be misspecified. In misspecified models, the choice of the weighting matrix can have an important influence on the estimated parameter values. In order to ensure meaningful estimates, I use the identity matrix. This choice means that the estimation will seek to minimize squared deviations between the simulated retirement densities and the observed values. The estimation will therefore penalize any given deviation between the observed retirement density and the simulated retirement density the same, regardless of the age at which it occurs. This is an intuitively appealing approach as it fits the model based on the regions where the economically interesting behavior takes place. In contrast, efficient estimation techniques, which weight the moments according to their variance, place greatest weight on the moments with the least variance. In this application, low-variance moments tend to be those combinations of age and service where few individuals retire. Fitting the model with the greatest emphasis on combinations of age and service where few people retire seems undesirable.\footnote{For the purpose of computing the overidentification test statistic, it is, of course, necessary to use the efficient estimator. In practice, it turns out that the differences between the estimated parameter values using different weighting matrices are relatively modest.}

### 2.4 Fit and results

The parameter estimates for five variants of the life-cycle model described are shown in Table 2. In the first specification, values for the discount factor and the coefficient of relative risk aversion are imposed rather than estimated. In the second, the coefficient of relative risk aversion is estimated, and in the third, both the discount factor and the coefficient of relative risk aversion are estimated. All parameters are of the expected sign and of reasonable magnitude, though the utility cost of work is modest. Values between 0.06 and 0.13 indicate that work is equivalent to a 6-13 percent reduction in consumption. In all three specifications, the persistence of disutility shocks is high, in excess of 0.80. Innovations in the cost of work attenuate only modestly over extended periods. The estimated discount factor of 0.82 is substantially less than one, indicating that utility realized several years in the future has relatively little weight in determining behavior today, but is consistent with
previous estimates of the option value model. The parameter estimates are quite precise, except for the coefficient of relative risk aversion. (The estimated standard errors shown in the table are preliminary and subject to revision.)

Column four presents the baseline specification. It introduces an exogenous probability of separation at each age. The estimated value for this parameter is 0.016. As turnover remains positive even in the years immediately before large pension payoffs, this addition to the model substantially improves its explanatory power and is consistent with the empirical facts. It may capture events, such as a medical condition in the family, that induce seemingly inexplicable retirements because the response is relatively insensitive to financial incentives. In the baseline specification, the discount factor is 0.80, the coefficient of relative risk aversion 5.3, and the utility cost of labor 0.11.

Compared to estimates of the option value model reported in Stock and Wise (1990), the coefficient of relative risk aversion estimated here is larger and the utility cost of labor somewhat smaller. The estimated discount rates are quite similar and the utility innovations are not directly comparable as a result of differences in the modeling. Fitting the option value model to data for Missouri teachers, Ni and Podgursky (2011) estimate a much smaller discount rate (i.e. \( \beta \) closer to 1), lower risk aversion, and greater utility cost of work in a slightly different specification of the model.

To provide a transparent assessment of the fit, Figure 1 presents the empirical and simulated moments for the 10 service cohorts used to estimate the model. The empirical moments are computed from the data and the simulated moments are computed from the baseline specification. Recall that the service cohorts are defined by service at age 50 and the moments are the retirement densities multiplied by a non-censorship indicator. For example, the first plot shows the observed density of retirements by age for employees who have three years of service at age 50 multiplied by the censorship indicator. The second plot does the same for the cohort with four years of service at age 50. Because the probability of observing an individual at each age is smoothly decreasing in age, the density's overall shape can be interpreted as if it were the true density, but the absolute level at older ages will be reduced.

There are two key takeaways from Figure 1. First, comparing the black and gray lines within each plot allows for an assessment of the model's ability to match the empirical retirement density for that cohort. While obviously imperfect, the overall quality of the fit is quite good for a parsimonious model such as the one estimated in this chapter. Second,
looking across plots, as the shape of the empirical retirement density changes the simulated density closely tracks these changes.

The height of the y-axis in each plot reflects the number of people in each cohort in the estimation sample. There are many more 50 year-olds with 26 years of service than 50 year-olds with three years of service and thus the retirement density for the 26-year cohort exceeds that for the 3-year cohort. As a result, comparing the size of the spikes across plots is relatively uninteresting. Instead the insight is obtained from comparing their shapes. The shapes are determined by the features of the retirement benefit programs.

The dominant feature of the empirical retirement density for the cohorts with 3, 4, and 5 years of service is a large increase in the number of retirements at the age of eligibility for subsidized retiree health insurance, age 62, 61, and 60 respectively, followed by an elevated level of retirements through age 62, the Social Security early retirement age. The simulated densities show the same qualitative behavior, but they have difficulty matching the empirical magnitudes. In addition, the 4 and 5-year cohorts show a larger number of retirements at age 62 than at age 60.\textsuperscript{16} Because low tenure individuals have relatively little pension wealth, the simulated work histories produced by the model tend to involve somewhat later retirement than those in the data. Many of these individuals likely leave for another employment opportunity, because of resources available via a spouse, or for a similar reason. All of these potential channels are beyond the scope of the current model.

The cohorts with 15, 16, 17, and 18 years of service become eligible for normal retirement at age 60 and subsidized retiree health insurance at ages 60, 59, 58, and 57 respectively. The empirical retirement densities show a sharp increase in retirements at the eligibility age for subsidized retiree health insurance and an even greater increase at the normal retirement age. The simulated densities provide an excellent fit to these two features. They slightly understate the number of retirements exactly at the normal retirement age. In addition, when the eligibility age for subsidized retiree health insurance occurs in the late 50s and there is a gap between that age and the normal retirement age, the frequency of retirements in the data falls off between the two eligibility ages. In contrast, the simulated densities level off between the two eligibility ages, but do not decrease outright.

\textsuperscript{16}Modeling the ability of retirees to take a partial lump sum to smooth consumption around the Social Security early retirement age could alleviate this behavior, but would reduce the ability of the model to explain retirements at the Social Security early retirement age. Understanding exactly when individuals respond to the early retirement age under this institutional regime is an interesting and open question.
Finally, the cohorts with 24, 25, and 26 years of service at age 50 are eligible for subsidized retiree health insurance at all ages shown and become eligible for normal retirement at ages 60, 60, and 59 respectively. In each case the empirical density shows a large spike in retirements at the age of eligibility for normal retirement. The simulated densities show a similar shape; however, they also show a large number of retirements one year before the normal retirement age that is not present in the data. These are individuals who intended to work to the normal retirement age, but who are hit with a substantial (positive) innovation in the utility cost of work at age 59. As a result of the shock, they decide the relatively modest additional pension benefit associated with one additional year of work is not worth it and they retire immediately. In addition, the empirical densities show a sharply increasing density of retirements at age 55. This is particularly pronounced in the 25-year cohort. I am unaware of any institutional explanation for this behavior. It may simply reflect individuals using age 55 as a focal age before which they are relatively unwilling to consider retirement.

As would be expected from the visual evidence, a formal overidentification test of the model using the fitted moments strongly rejects in all specifications. Given the quantity of data available (nearly 50,000 employees) and the parsimonious nature of the model, this result is not surprising. The parameters are estimated precisely and the model is surely an incomplete representation of reality. Despite this test result, the model can still help us think about behavior under alternative policy regimes. It clearly captures some underlying economic influences on decision-making as shown in Figure 1.

To provide an additional test of the model’s fit and some additional assurance that policy simulations performed with the model offer useful insights, Figure 2 presents a comparison of the empirical and simulated moments parallel to that shown in Figure 1 for 10 service cohorts not used in the estimation of the model. These service cohorts have 6, 7, 8, 12, 13, 14, 19, 20, 22, and 23 years of service at age 50. As these moments were not used in the estimation, there is no reason that the simulated moments must necessarily match the empirical moments except to the extent that the underlying model is able to capture something about the forces driving individual behavior. Again, the overall quality of the match is quite good, though the comparison shows some of the same limitations as were evident in Figure 1. The cohorts with 6-14 years of service all become eligible for normal retirement and subsidized retiree

17 For example, consider an individual who planned to work until the normal retirement age, but whose spouse receives a negative medical diagnosis when the employee is 59. Quite reasonably, the employee may decide that the final year of work is not worth it.
health insurance at age 60 and Social Security at age 62. In each case, the empirical cohorts show a sharp spike at age 60. In the lower-tenure cohorts, there is an additional spike at age 62 and an elevated but not quite as large number of retirements at age 61. In the 12, 13, and 14-year cohorts, there is an elevated level of retirements at age 62, but it is substantially lower than the level at age 60. For the lower-tenure cohorts the simulated densities again understate the importance of the normal retirement age relative to the Social Security early retirement age. For the higher-tenure cohorts, the model provides a good fit with the normal retirement age becoming relatively more important as the employee's level of pension wealth increases. The 20, 22, and 23-year cohorts become eligible for normal retirement at age 60. In each case the spike in the simulated density closely matches the spike in the empirical density. The 20-year cohort also becomes eligible for subsidized retiree health insurance at age 55. The empirical density shows a somewhat larger spike than the simulated density.

It is quite common in the retirement literature for models to be unable to explain the full size of the spikes at key eligibility ages if they do not include an ad hoc age-specific effect (see, e.g. Coile and Gruber (2007)). While the model estimated here does a reasonably good job of matching behavior at key eligibility ages and tracking those eligibility thresholds when they occur at different ages for different individuals, it leaves room for improvement. As one way of examining how much behavior remains to be explained, the final specification shown in Table 2 introduces an ad hoc utility bonus for working at age 59. The estimated value of 0.07 for the utility bonus reduces the mean cost of work by nearly two-thirds. Introducing this ad hoc parameter reduces the value of the GMM criterion function by about 40 percent, indicating that it substantially improves the explanatory power of the model. Figure 3 presents the same comparison of empirical and simulated moments under this alternative specification. It offers a modest improvement in fit for the 3, 4, and 5-year cohorts. However, as the challenge for the model with these cohorts is finding enough individuals willing to leave the workforce, a utility bonus for continued work is of relatively little use. There is a notable improvement in fit for each of the remaining cohorts. For the 15 through 18-year cohorts the simulated and empirical densities match almost exactly. For the 24 through 26-year cohorts, the understatement of the spike in the hazard at the normal retirement age is reduced and the elevated level of retirements in the year before the normal retirement age is eliminated.
2.5 The effect of alternative policy regimes

This section presents simulated retirement distributions for a set of 50-year-old employees under three alternative policy regimes. Each of the three policies reduces the generosity of retirement benefits along the lines of current policy discussion. The simulation results are computed using the parameter estimates for specification four as shown in Table 2.

2.5.1 The effect of eliminating subsidized RHI before age 60

Employees become eligible for subsidized retiree health insurance regardless of age once they reach 25 years of service. The first alternative policy eliminates subsidized health insurance prior to age 60. Regardless of service, employees must now work until age 60 to become eligible for subsidized RHI.

Figure 4A shows the distribution of retirements by age for 10 service cohorts. The service cohorts are defined by service at age 50. For example, the first plot shows the distribution of retirements by age for the set of employees who had worked for the state for three years at age 50. The dashed line in each plot indicates age 60. Figure 4B shows the change in the distribution of retirements relative to current policy.¹⁸ Employees with 3, 4, and 5 years of service at age 50 become eligible for subsidized retiree health insurance under the alternative policy at age 62, 61, and 60, respectively. In each case the number of separations occurring before eligibility is quite low. Then, at the age of initial eligibility for subsidized RHI, the number of separations jumps dramatically. It jumps further at the Social Security early retirement age before declining slowly through the late 60s. Since these employees were not eligible for subsidized RHI prior to age 60 under current policy, their behavior was unaffected by the change in policy. This is confirmed by the first three plots in Figure 4B. Each of the remaining cohorts becomes eligible for subsidized RHI under the alternative policy at age 60. For each cohort, Figure 4A shows a large mass of retirements exactly at age 60. For cohorts with less service, and therefore less pension wealth, some employees remain on the job until age 62 when they become eligible for Social Security benefits. However, as service increases retirements are clustered more and more tightly at age 60. The cohort with 15 years of

¹⁸ To avoid unnecessarily convoluted language, the discussion in this section will refer to the pension and health benefits described in section two as current policy. However, many employees are now (i.e. in 2013) covered by a less generous pension plan and/or subject to more stringent eligibility requirements for subsidized RHI. Recall that these employees are excluded from the estimation sample.
service would become eligible for subsidized RHI at age 60 under current policy and so, like the first three cohorts considered, is unaffected by the policy. All of the remaining cohorts are affected by the policy. The plots of Figure 4B indicate that in each case, the effect of the more restrictive eligibility requirement is a nearly complete elimination of retirements prior to the eligibility threshold with the overwhelming majority of the delayed retirements occurring in the first year of eligibility under the new regime.

These stark findings about the elimination of subsidized RHI reflect the empirical fact that very few individuals retire before eligibility for subsidized RHI under current law. The absence of pre-eligibility retirements can be seen in the empirical densities shown in Figures 1-3 and is discussed at great length in Leiserson (2013).

2.5.2 The effect of a flat 20 percent cut in pension benefits

The current pension computation provides an initial benefit at the normal retirement age equal to 2.5 percent of average earnings for each year of service. The second alternative policy imposes a flat 20 percent cut in benefits by reducing the initial benefit to 2 percent of average earnings for each year of service. This policy makes no changes in the eligibility rules for benefits, but reduces the level of benefits provided at all potential retirement dates.

Figures 5A and 5B present the distribution of retirements by age and the change in the distribution relative to current policy for the same 10 service cohorts considered previously. Unlike the change in eligibility for subsidized RHI, this across-the-board cut in pension benefits affects all cohorts. Figure 5B indicates the reduction in benefits induces a shift in the distribution towards older ages. By reducing the level of retirement consumption available to the state’s employees, the policy leads to longer careers and delayed retirement. While the change in eligibility for subsidized RHI shifted a large number of retirements into the first year of eligibility under the new policy, the effect of the benefit cut is much more disperse. Retirements over a range of ages are delayed and the delayed retirements appear over a range of older ages. However, the small number of retirements that occur before eligibility for subsidized RHI are basically unaffected. A reduction in retirements first appears at age 62 for the 3-year cohort, at age 61 for the 4-year cohort, and at age 60 for the

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19The pension cuts enacted by the Pennsylvania state legislature in 2010 included this change in the computation of benefits. New employees could choose to receive benefits under the 2.5 percent formula if they made contributions to the plan at a higher rate.
5-year cohort. Each of these ages is the age of eligibility for subsidized RHI. While there is a small reduction in the number of retirements at age 59 in the 15-year cohort, a quantitatively significant effect first appears at age 60, when the members of this cohort become eligible for subsidized RHI. The effect shows up at age 59 in the 16-year cohort, 58 in the 17-year cohort, and 57 in the 16-year cohort, again tracking eligibility for subsidized RHI. As individuals in the 24, 25, and 26-year cohorts are eligible for subsidized RHI throughout their 50s, delayed retirements appear over a broad range of ages. The results emphasize the interaction of the health and pension benefits in determining retirement behavior. The effect of an across-the-board cut in pension benefits on retirement depends in an important way on whether the individuals are eligible for subsidized RHI or not.

2.5.3 The effect of delaying the normal retirement age to 62

The third and final alternative policy increases the normal retirement age from 60 to 62. Under this alternative policy, employees continue to become eligible for normal retirement at any age with 35 years of service. This policy reduces pension benefits for all employees retiring before age 62 by increasing the early retirement reduction, while leaving benefits unchanged for those retiring at or after 62.

Figure 6A shows the distribution of retirements under this alternative policy and Figure 6B shows the change in the distribution of retirements relative to current policy again for the same 10 service cohorts. The 3-year cohort is unaffected by the policy. Employees were not eligible for subsidized RHI until age 62, and the individuals choosing to retire before that age are not induced to continue working as a result of the reduction in pension benefits. Employees in the 4 and 5-year cohorts show very small effects of the policy. Many of these employees were choosing to delay retirement until age 62 because they could not receive Social Security benefits until that age and the individuals retiring before 62 are relatively insensitive to the change in the normal retirement age. The cohorts with 15, 16, 17, and 18 years of service show a modest effect of the increase in the normal retirement age. In each case, a small number of individuals who would have retired after becoming eligible for subsidized RHI but before age 62 choose to delay their retirement. A similar effect is

--This is a more modest version of a benefit cut imposed by the Pennsylvania state legislature in 2010. The normal retirement age for new employees was increased to 65 and additional restrictions were placed on eligibility for long-service employees.
apparent in the 24-year cohort, but with a longer tail. In all cases, the delayed retirements overwhelmingly occur at age 62, when employees become eligible for normal retirement.\textsuperscript{21} The 25 and 26-year cohorts are unaffected by the policy as they become eligible for normal retirement upon reaching 35 years of service at or before age 60.

2.5.4 Qualifications of the simulation results

The model is unable to perfectly fit the data under current policy, and, as discussed in the previous section, an overidentification test rejects. For these reasons, it is important to consider how the model’s weaknesses may manifest themselves in the quality of the policy simulations. One weakness of the model is its inability to explain the number of retirements before eligibility for subsidized RHI among short-service (i.e. low pension wealth) employees. This weakness suggests that the simulation results for restrictions in eligibility for subsidized RHI may conclude that too few retirements would occur before the delayed eligibility threshold. It would be reasonable to expect a somewhat higher level of separations in the late 50s under the new regime.

A second weakness of the model is its tendency to place too much emphasis on the Social Security early retirement age for short-service employees. Because these employees have relatively little pension wealth, the assumptions of the model would suggest they should retire somewhat later.\textsuperscript{22} Incorporating this limitation would suggest that the increase in the normal retirement age from 60 to 62 might have a somewhat larger effect as some individuals the model expects to already wait until 62 in order to retire would not be doing so.

2.6 Conclusion

Financial pressures on public sector budgets have motivated an array of policy proposals relating to the provision of health care and health insurance. Because health care represents a large share of consumption at older ages, these policies can be expected to have important implications for individual retirement decisions. This chapter estimates a simple life-cycle

\textsuperscript{21}The delayed retirements for the 24-year cohort show up at age 61 because individuals become eligible for normal retirement under the 35 years of service provision at that age.

\textsuperscript{22}This weakness could reflect the assumption that individuals do not use the pension plan’s partial lump-sum option to smooth consumption around the Social Security early retirement age. However, since an effect of the Social Security early retirement age is apparent in the data, no perfect option exists.
model of retirement behavior using data for state employees in Pennsylvania. The model successfully reproduces the three key features of the data: a very low rate of retirement prior to eligibility for retiree health benefits, a sharp jump in the rate of retirement at the eligibility threshold for retiree health benefits, and a large mass of retirements at the normal retirement age.

The fitted model is used to simulate retirement behavior under alternative policy regimes. Restricting eligibility for retiree health benefits sharply reduces retirements in the years between the current eligibility threshold and the new eligibility threshold. Motivated by their desire for health insurance, these employees instead retire in the first year of eligibility under the new rules. Changes in pension benefits generate smaller responses. A two-year increase in the normal retirement age shifts the distribution of retirements between the old and new normal retirement age, but, in contrast to the restriction in eligibility for RHI, many individuals continue to retire before eligibility for normal retirement. An across-the-board cut in pension benefits leads to a more disperse shift in the distribution of retirements towards older ages.

The findings point to the shortcomings of existing models that do not incorporate eligibility requirements for retiree health benefits or their interaction with eligibility for pension benefits. These institutional features are first-order determinants of retirement behavior. Evaluating policy changes without precise knowledge of the rules will fail to distinguish between different policies that can have quite different effects, assuming the chosen method is even capable of analyzing the reforms at all.

Substantial additional work remains to be done in this area. Overidentification tests reject the current model, as is essentially always the case in life-cycle estimation. Understanding the sources of heterogeneity that drive otherwise similar individuals to exit the labor force at different ages remains a work in progress. In light of the results of this chapter, one important goal for future work is to construct richer datasets that contain both details of the institutional regime and information on individual characteristics. Existing work largely makes unpleasant choices between administrative data that prioritizes the former and survey data that prioritizes the latter.
References


Table 1. Joint Distribution of Annual Earnings at Age 50 (2005$) and Service at Age 50 for Pennsylvania State Employees

<table>
<thead>
<tr>
<th>Service at age 50</th>
<th>Earnings at age 50 (thousands of 2005 dollars)</th>
<th>Total</th>
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</thead>
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<tr>
<td></td>
<td>&lt; 20</td>
<td>20-39</td>
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<tr>
<td>0-4 years</td>
<td>334</td>
<td>4,486</td>
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<tr>
<td></td>
<td>0.69</td>
<td>9.29</td>
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<tr>
<td>5-9 years</td>
<td>30</td>
<td>4,001</td>
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<tr>
<td></td>
<td>0.06</td>
<td>8.29</td>
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<tr>
<td>10-14 years</td>
<td>8</td>
<td>3,248</td>
</tr>
<tr>
<td></td>
<td>0.02</td>
<td>6.73</td>
</tr>
<tr>
<td>15-19 years</td>
<td>4</td>
<td>2,671</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>5.53</td>
</tr>
<tr>
<td>20-24 years</td>
<td>4</td>
<td>1,864</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>3.86</td>
</tr>
<tr>
<td>25-29 years</td>
<td>2</td>
<td>1,677</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>3.47</td>
</tr>
<tr>
<td>30-34 years</td>
<td>1</td>
<td>844</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1.75</td>
</tr>
<tr>
<td>Total</td>
<td>383</td>
<td>18,791</td>
</tr>
<tr>
<td></td>
<td>0.79</td>
<td>38.93</td>
</tr>
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</table>

Note: Joint distribution of annual earnings at age 50 (2005$) and service at age 50 in the estimation sample. Estimation sample consists of employees who retired at or after age 50 under the institutional regime described in section two; maintained stable, full-time employment records with the state leading up to retirement; had never previously retired from state employment at the time of their retirement; and had never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania. For individuals who were already 50 by the end of 1999, earnings are projected backwards to age 50 according to the salary growth assumptions used to perform actuarial valuations of the pension plan for Pennsylvania state employees.
Table 2. Parameter Estimates

<table>
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<tr>
<th></th>
<th>(1)</th>
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<th>(3)</th>
<th></th>
<th>(4)</th>
<th></th>
<th>(5)</th>
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<tr>
<td>( \beta ): discount factor</td>
<td>0.90</td>
<td></td>
<td>0.90</td>
<td></td>
<td>0.82</td>
<td></td>
<td>0.80</td>
<td></td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(. )</td>
<td></td>
<td>(. )</td>
<td></td>
<td>(0.010)</td>
<td></td>
<td>(0.006)</td>
<td></td>
<td>(0.003)</td>
<td></td>
</tr>
<tr>
<td>( \sigma ): coeff. of relative risk aversion</td>
<td>1.00</td>
<td></td>
<td>3.65</td>
<td></td>
<td>4.95</td>
<td></td>
<td>5.28</td>
<td></td>
<td>5.23</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(. )</td>
<td></td>
<td>(0.20)</td>
<td></td>
<td>(0.71)</td>
<td></td>
<td>(0.55)</td>
<td></td>
<td>(0.13)</td>
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</tr>
<tr>
<td>( k ): disutility of labor</td>
<td>0.06</td>
<td></td>
<td>0.13</td>
<td></td>
<td>0.11</td>
<td></td>
<td>0.11</td>
<td></td>
<td>0.11</td>
<td></td>
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<tr>
<td></td>
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<td>(0.0015)</td>
<td></td>
<td>(0.0032)</td>
<td></td>
<td>(0.0019)</td>
<td></td>
<td>(0.0011)</td>
<td></td>
</tr>
<tr>
<td>( \rho ): persistence of disutility shocks</td>
<td>0.93</td>
<td></td>
<td>0.86</td>
<td></td>
<td>0.84</td>
<td></td>
<td>0.81</td>
<td></td>
<td>0.83</td>
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<tr>
<td></td>
<td>(0.0025)</td>
<td></td>
<td>(0.0037)</td>
<td></td>
<td>(0.0080)</td>
<td></td>
<td>(0.0047)</td>
<td></td>
<td>(0.0027)</td>
<td></td>
</tr>
<tr>
<td>( \sigma_\epsilon ): standard dev. of disutility shocks</td>
<td>0.16</td>
<td></td>
<td>0.11</td>
<td></td>
<td>0.11</td>
<td></td>
<td>0.10</td>
<td></td>
<td>0.11</td>
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<tr>
<td></td>
<td>(0.0005)</td>
<td></td>
<td>(0.0007)</td>
<td></td>
<td>(0.0016)</td>
<td></td>
<td>(0.0009)</td>
<td></td>
<td>(0.0005)</td>
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<tr>
<td>( \mu ): exogenous separation probability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.016</td>
<td></td>
<td>0.018</td>
<td></td>
<td>0.016</td>
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<tr>
<td></td>
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<td></td>
<td>(0.0003)</td>
<td></td>
<td>(0.0003)</td>
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</tr>
<tr>
<td>( \eta ): utility bonus for work at age 59</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>0.07</td>
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<td>(0.002)</td>
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</table>

Note: Method of simulated moments estimates of the behavioral model described in section two with standard errors in parentheses. Parameter values imposed in the estimation indicated by a standard error of (. ). Estimation sample consists of employees who retired at or after age 50 under the institutional regime described in section two; maintained stable, full-time employment records with the state leading up to retirement; had never previously retired from state employment at the time of their retirement; and had never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania.
Figure 1. Simulated and Empirical Retirement Densities by Service at Age 50 in the Baseline Specification, Service Cohorts Used in the Estimation of the Structural Model

Note: Plots show the empirical moments computed from the data and the simulated moments computed from the fitted model using specification four as shown in Table 2. Parameter estimates obtained via method of simulated moments estimation. The moments, described in more detail in section three, are empirical retirement densities with censored observations set to zero. The estimation sample consists of employees who retired at or after age 50 under the institutional regime described in section two; maintained stable, full-time employment records with the state leading up to retirement; had never previously retired from state employment at the time of their retirement; and had never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania.
Figure 2. Simulated and Empirical Retirement Densities by Service at Age 50 in the Baseline Specification, Select Service Cohorts Not Used in the Estimation of the Structural Model

Note: Plots show the empirical moments computed from the data and the simulated moments computed from the fitted model using specification four as shown in Table 2. Parameter estimates obtained via method of simulated moments estimation. The moments, described in more detail in section three, are empirical retirement densities with censored observations set to zero. The estimation sample consists of employees who retired at or after age 50 under the institutional regime described in section two; maintained stable, full-time employment records with the state leading up to retirement; had never previously retired from state employment at the time of their retirement; and had never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania.
Figure 3. Simulated and Empirical Retirement Densities by Service at Age 50 in the Specification With an Ad Hoc Bonus for Working at Age 59, Service Cohorts Used in the Estimation of the Structural Model

Note: Plots show the empirical moments computed from the data and the simulated moments computed from the fitted model using specification four as shown in Table 2. Parameter estimates obtained via method of simulated moments estimation. The moments, described in more detail in section three, are empirical retirement densities with censored observations set to zero. The estimation sample consists of employees who retired at or after age 50 under the institutional regime described in section two: maintained stable, full-time employment records with the state leading up to retirement; had never previously retired from state employment at the time of their retirement; and had never elected to determine pension benefits jointly for service as a state employee and as a public school employee in Pennsylvania.
Figure 4. Eliminate Subsidized Retiree Health Insurance Before Age 60

A. Expected Retirement Counts by Age and Service at Age 50 for a 100,000 Person Population

B. Change in Retirement Counts Relative to Current Law by Age and Service at Age 50 for a 100,000 Person Population

Note: Figure 4A presents expected counts of retirements by age and service at age 50 for a 100,000 person population under the stated policy change. Expected counts are computed using specification four of the fitted model as shown in Table 2. Figure 4B shows the change in the counts under the alternative policy relative to those for current law.
Figure 5. Reduce Initial Pension Benefit by 20 Percent

A. Expected Retirement Counts by Age and Service at Age 50 for a 100,000 Person Population

B. Change in Retirement Counts Relative to Current Law by Age and Service at Age 50 for a 100,000 Person Population

Figure 5A presents expected counts of retirements by age and service at age 50 for a 100,000 person population under the stated policy change. Expected counts are computed using specification four of the fitted model as shown in Table 2. Figure 5B shows the change in the counts under the alternative policy relative to those for current law.
Figure 6. Increase Normal Retirement Age to 62

A. Expected Retirement Counts by Age and Service at Age 50 for a 100,000 Person Population

B. Change in Retirement Counts Relative to Current Law by Age and Service at Age 50 for a 100,000 Person Population

Note: Figure 6A presents expected counts of retirements by age and service at age 50 for a 100,000 person population under the stated policy change. Expected counts are computed using specification four of the fitted model as shown in Table 2. Figure 6B shows the change in the counts under the alternative policy relative to those for current law.
Chapter 3

The Design of Public Sector Pension Benefits

Abstract

Public sector pension plans create complicated incentives in favor of continued work at some ages and in favor of retirement at others. The strength of these incentives depends on many factors, including the age of initial employment, the number of years on the job, and the rate at which earnings grow over time. Because employees differ along all of these dimensions, the value of the pension benefits earned over the course of a career varies substantially—even among retirees with the same total earnings. This chapter investigates the incentive effects and distributional consequences of four stylized plan designs: a final average salary plan, a final average salary plan with percentage reductions for early retirement, an inflation-adjusted career average salary plan, and an indexed career-average salary plan with variable accrual factors. It derives simple formulas for the accrual rate of pension wealth and the distribution of benefits under each of the four plans and uses these formulas to gain insight into the incentives and risks they create. Indexed career-average plans with variable accrual factors offer policymakers an opportunity to redesign their pension plans in a way that maintains their defined benefit nature while at the same time directly controlling the work incentives created by the plans, limiting arbitrary redistributive patterns across employees, and limiting incentives for individuals to manipulate earnings and labor supply in ways that do not advance public policy objectives.

This work builds on previous joint work with Peter Diamond, Alicia Munnell, and Jean-Pierre Aubry. See, e.g., Diamond et al. (2010). I also thank Jim Poterba and Jon Gruber for valuable feedback. This research was supported by the National Institute on Aging, Grant Number T32-AG0000186, and by the Lynde and Harry Bradley Foundation. All mistakes are my own.
3.1 Introduction

The overwhelming majority of public sector employee pension plans follow a traditional defined benefit (DB) structure. When employees retire, they receive an initial benefit equal to the product of three pieces: (1) an accrual factor specified in the plan rules, (2) some notion of average earnings, and (3) the number of years on the job. In contrast, the defined contribution plans more common in the private sector do not specify a level of benefits after retirement. Instead, they provide employees with a contribution each year during the career that employees invest in a menu of financial products determined by the plan. When employees retire, they can use whatever funds they have accumulated in their investment account to support retirement consumption. In theory, and as suggested by the two names, the essential difference between defined benefit pension plans and defined contribution pension plans is the employee's exposure to risk in asset market returns. In practice, however, existing defined benefit plans combine insurance against market risk with two additional—and inessential—features: a complicated set of incentives affecting labor supply decisions and a new source of risk in the adequacy of retirement savings arising from uncertain future labor market outcomes.

Traditional DB plan designs provide substantially larger pension benefits to those retirees whose work history follows particular patterns implicit in the plan provisions. By linking the level of pension benefits in retirement to the work history in this fashion, the plans create strong financial incentives for employees to follow these particular patterns of work and retirement. These incentives affect numerous different decision-making margins. The decision most frequently studied is that of a current employee considering whether and how long to remain on the job (Brown (2013), Chalmers et al. (2012), Friedberg (2011), Munnell et al. (2012a)). The plans also affect the decisions to work overtime, increase responsibilities, or pursue a promotion. Similarly, they affect whether potential new hires accept job offers and whether former employees attempt to return to the employer at older ages after several years elsewhere.

Whether the pension plan encourages work or discourages work at any particular age depends on numerous demographic, economic, and institutional factors, including the age at which an employee begins working for a public sector employer, the existence and duration of any gaps in the work history, and the pattern of earnings growth over the career. Be-
cause employees differ along all of these dimensions, the incentives created by the pension plan during the career, and the corresponding value of retirement benefits received after the conclusion of the career, vary substantially, even for employees with the same lifetime earnings.

By providing enhanced benefits to employees who follow particular patterns of work and retirement and thus creating incentives for certain labor supply behavior, traditional DB plans necessarily provide reduced benefits to those employees who do not follow the specified patterns. Thus, the mirror image of the labor supply incentives created by the plans is a set of risks that an employee is unable or unwilling to follow the rewarded patterns. These risks can arise for reasons beyond employee control, such as poor health events, financial shocks, government fiscal conditions, and changes in government policy. Or they may arise from learning about preferences, consumption needs, and other personal economic conditions that cause an employee to desire to follow a career path different from that which she expected. As a means of insurance against these risks individuals may accumulate additional personal savings outside the pension plan. They may also be less inclined to accept the job in the first place because of the risk.

The primary purpose of this chapter is to provide simple formulas for the work incentives and the distribution of benefits generated by four pension designs: a nominal high-three average pension with actuarial early and delayed retirement, a nominal high-three average pension with percentage reductions for early retirement, an inflation-adjusted career average pension with actuarial early retirement, and an indexed career-average pension with variable accrual factors and actuarial early and delayed retirement. The formulas both develop our intuition about how and why existing policies affect labor market behavior and employee welfare and also facilitate the construction of alternative designs that preserve the defined benefit structure but allow for complete control over the other outcomes of the plan. For example, the financial incentive for continued employment in pension plans using high-three formulas, which base the pension benefits off a simple average of the three highest-earning years of the career, depends on trend inflation rates. If trend inflation is one percent the incentive for continued employment is lower than if it is three percent. It is not clear why this dependence on inflation would be a desired feature of a pension plan. Similarly, the financial incentive for an individual with 10 years of experience to remain on the job depends on whether that individual started working for the public sector employer at age 35 or at age
Most arguments for retention incentives in pension plans suggest the use of service, not age.

A second purpose of this chapter is to provide a clear exposition of the incentives associated with different pension plans so that policymakers can choose to design plans with particular incentives. A common critique of proposals to replace existing pensions with alternatives that have more neutral work incentives (e.g. cash balance plans) is that such plans eliminate certain desired labor supply incentives, throwing out the baby with the bathwater. An oft-cited goal is to provide incentives for more experienced workers to remain on the job. The fourth class of pension plans examined in this chapter, the indexed career-average with variable accrual factors and actuarial adjustments for early and delayed retirement, can be used to construct pension plans that achieve the desired incentives without including the irrelevant incentives embedded in current designs. It maintains the defined benefit nature of the pension plans while at the same time directly controlling the work incentives created by the plans, limiting arbitrary redistributive patterns across employees, and limiting incentives for individuals to manipulate earnings and labor supply in ways that do not advance public policy objectives.

The contribution of this analysis relative to previous analyses is the focus on simple analytic formulas that provide a framework for thinking about incentives in the general class of public sector DB plans. As state and local government budget pressures continue to push in the direction of pension cuts, one way of reducing the harm of such cuts on public sector employees is to redesign the benefits so the plans use a given quantity of resources to greater effect. In such an environment, a general understanding of pension design will be crucial. Existing work has derived quantitative estimates of the pension incentives in particular plans (Costrell and Podgursky (2009), Johnson et al. (2012)), derived estimates implicitly in pursuit of some other objective (Stock and Wise (1990), Samwick (1998)), or focused on particular channels through which the pension plans affect behavior (Diamond et al. (2010) on final pay plans, Munnell et al. (2012b) on vesting).

The remainder of the chapter proceeds as follows. Section two outlines the pension plans that will be examined. Section three motivates the measures of incentives and risk that will be analyzed for each plan. Section four works through each of the incentive and risk measures in turn and section five concludes.
3.2 Four defined benefit pension plans

This section introduces the four benefit formulas considered in the present analysis. After discussing each plan, two additional sections detail the assumptions regarding other plan features, such as cost of living adjustments and death benefits, that will be common across plans and the economic and demographic assumptions underlying the illustrative numerical computations.

3.2.1 Nominal high-three with actuarial early and delayed retirement

The nominal high-three pension benefit at the normal retirement age is the product of average earnings in the three highest earning years of the career (not adjusted for inflation), the number of years of service, and an accrual factor specified by the plan. Denoting the benefit by $b$, the accrual factor by $f$, and the wage in period $t$ by $w_t$, an employee who retires at the normal retirement age at the beginning of year $t$ receives an initial benefit given by

$$b_t = f \times \text{service}_t \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}).$$

The actuarial adjustment for early or delayed retirement is computed such that the expected benefit for an employee is the same regardless of the age at which she claims it. The initial benefit is then

$$b_t = f \times \text{service}_t \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \times \frac{a_{NRA}}{a_t} \times (1 + r)^{t-NRA},$$

where $a_s$ is the cost of a $1$ annuity beginning at age $s$, $NRA$ is the normal retirement age, and $r$ is the discount rate used by the plan.\(^1\) In the numerical examples, the normal retirement age is $60$ and the accrual factor is $0.015$.

The pure nominal high-three with actuarial early and delayed retirement is not used in any plan. However, the nominal high-three formula (or the similar high-five alternative) is

\(^1\)Note that in plans with actuarial adjustments for both early and delayed retirement, the normal retirement age is a superfluous parameter. For any alternative value of the normal retirement age $NRA'$, the original level of benefits can be restored by setting the accrual factor according to the equation

$$f' = f \times a_{NRA} / a_{NRA'} \times (1 + r)^{NRA' - NRA}.$$
the core of most existing public sector plans. Thus, an examination of the simplified formula is useful in developing intuition for the role of the benefit computation in such plans. The key distinction between the basic plan analyzed here and the plans actually implemented is that the basic plan drops the strong incentive to leave government employment after the normal retirement age generated by some combination of (i) a limit on the maximum replacement rate and (ii) limited or nonexistent increases in the pension benefit for delayed retirement.

### 3.2.2 Nominal high-three with percentage early retirement

The nominal high-three formula with percentage early retirement and no adjustment for delayed retirement is widespread in the public sector. In these plans, the initial benefit is computed as under the nominal high-three of the last subsection if an employee has met the eligibility requirements for normal retirement, except no adjustment for delayed retirement is provided. In addition, for employees who choose to retire before the normal retirement age, an early retirement reduction is applied to the benefit. The initial benefit is given by

\[
b_t = \max (0, 1 - \max (0, e \times (NRA - t))) \times f \times \text{service}_t \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}),
\]

where \( e \) is the early retirement reduction rate and \( NRA \) is the normal retirement age. Note that the early retirement reduction will not be actuarially fair, regardless of the early reduction rate used by the plan, because it is computed as a constant percentage of the benefit at the normal retirement age, not a constant percentage of the benefit one year ahead. In the numerical examples, the normal retirement age is 60, the early retirement reduction is four percent, and the accrual factor is set such that the expected pension payment under this plan (net of employee contributions) is equal to the nominal high-three with actuarial early and delayed retirement (0.017).²

²The equivalence computation assumes that the age of new hires follows a uniform distribution from 18 to 55 and that there is no relationship between the age at hire and the initial wage. Separation assumptions are described in section 2.6.
3.2.3 Inflation-adjusted career average with actuarial early retirement

The inflation-adjusted career average pension replaces the short, fixed-length averaging window of the high-three pension with an average over the entire career. Plans with longer averaging periods typically also index the salary history to some measure of inflation or wage growth. The stylized plan modeled here adjusts for inflation. The initial benefit, if claimed at the normal retirement age, is therefore

\[ b = f \times \text{service}_t \times \left( \frac{1}{\text{service}_t} \times \sum_{s=t_0}^{t-1} (1 + \pi)^{NRA-s} w_s \right) \]

\[ = f \times \sum_{s=t_0}^{t-1} (1 + \pi)^{NRA-s} w_s, \]

where \( t_0 \) is the age at which the employee begins covered employment, \( \pi \) is the inflation rate, and \((1 + \pi)^{NRA-s}\) serves to index the wage history for inflation. Note that, in a career average pension plan, the service term appearing in the benefit formula cancels with the service term in the computation of average earnings. The stylized plan provides an actuarial adjustment for early retirement and no adjustment for delayed retirement. The complete formula is then

\[ b_t = f \times \text{service}_t \times \left( \frac{1}{\text{service}_t} \times \sum_{s=t_0}^{t-1} (1 + \pi)^{t-s} w_s \right) \times \min \left( 1, \frac{a_{NRA}}{a_t} \times \left( 1 + \frac{\tau}{1 + \pi} \right)^{t-NRA} \right). \]

In the numerical examples, the normal retirement age is 60 and the accrual factor is set such that the expected pension payment under this plan (net of employee contributions) is equal to the nominal high-three with actuarial early and delayed retirement (0.021).

Recent public sector pension legislation has tended to lengthen the averaging period for earnings used to compute the initial benefit. While the economics of plans using a high-three, high-five, or high-ten measure of earnings are broadly similar, plans that match the averaging window to the full career behave quite differently. There is also a close relationship between career-average plans and cash balance plans, which have attracted increasing attention.\(^3\)

\(^3\)An inflation-adjusted career average plan using accrual factor \( f \) and index \( x(t) \) is identical to a cash balance plan with annual contribution \( f \) and interest rate \( x(t+1)/x(t) \) in period \( t \).
3.2.4 Indexed career-average with variable accrual factors and actuarial early and delayed retirement

The indexed career-average pension with variable accrual factors is a flexible design that uses a indexed salary history computed over the full career and, in addition, allows the accrual factor to vary with age and service. The initial benefit, if claimed at the normal retirement age, is

\[ b_t = \sum_{s=t_0}^{t-1} f(a(s), s) \times w_s \times \frac{x(NRA)}{x(s)}, \]

where \( f(a, s) \) is the accrual factor for age and service combination \((a, s)\) and \( x(t) \) is the value of an arbitrary index used to adjust the wage history at time \( t \). Writing \( a(s) \) serves to emphasize that for an individual employee age and service have a fixed relationship conditional on the starting date. The stylized plan offers actuarial adjustments for early and delayed retirement though, given the plan designer’s ability to select \( f(a, s) \), this additional structure actually imposes few restrictions on the benefit. The initial benefit at any age is therefore

\[ b_t = \sum_{s=t_0}^{t-1} f(a(s), s) \times w_s \times \frac{x(NRA)}{x(s)} \times \frac{a_{NRA}}{a_t} \times (1 + r)^{t-NRA}. \]

In the numerical examples, the normal retirement age is 60, the annual change in the index will be set equal to the nominal interest rate, and the accrual factor will be given by the logistic function in service \( f(a, s) = 0.012 + 0.097 / (1 + \exp(-(s - 20))) \). This specification of the index and the accrual factors is selected to highlight the potential for pension plans with variable accrual factors to maintain the essential advantages of defined benefit pensions while inducing labor supply incentives only as desired. One commonly-stated objective is to encourage retention of experienced employees. An accrual factor that is constant in age and increases with service could do so. The logistic function is a simple way of modeling a set of accrual factors which begin at a base level, increase as an employee accumulates additional service, and eventually level out for long-tenure employees. As before, the level is set such

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4 For a wide variety of reasons, e.g. heterogeneity in risk aversion, financial sophistication, etc., individuals may behave as if they have different discount rates. The current analysis will abstract from this consideration, but in thinking about the application of the results of this analysis to real-world policies, this limitation should be kept in mind.

5 Note that the pension formula does not integrate the product of the accrual factor and indexed wages over the career, it simply sums the values evaluated at integer combinations of age and service. Since the legislation governing pension benefits often specifies different plan features in the form of a tables of values,
that the expected pension payment under this plan (net of employee contributions) is equal to the nominal high-three with actuarial early and delayed retirement.

The indexed wage history is familiar in the U.S. context from Social Security, in which the benefit formula adjusts the wage history for aggregate growth in wages. Variable accrual factors are used in some defined benefit plans; however, in such cases, the initial benefit is typically the product of the sum of the accrual factors and the average wage, i.e. \( b = (\sum f)(\sum w) \), rather than the sum of the product, \( b = \sum f w \), as specified above. This choice will facilitate the direct control of labor supply incentives under this plan by eliminating the link between the financial incentive for work in the current period and the wages earned in prior periods.

3.2.5 Features common to all plan designs

Pension plans typically include an array of ancillary benefits in addition to the standard retirement benefit. The most significant of these are the death and disability benefits. Because these benefits are claimed by relatively few individuals and are not the focus of this chapter, they are assumed to take a very simple form. If an individual dies or becomes disabled while covered by the plan, the plan pays out a death or disability benefit equal to the present value of the retirement benefit to which the employee would be entitled in the next period. This assumption simplifies the current analysis by eliminating the need to specify formulas for each of the alternative benefits and incorporate them into the computations. However, it is an obvious simplification as, especially in cases where death or disability results from on-the-job activities, the death and disability benefits can be much more generous. In addition, such a simplification prevents discussion of the incentive effects associated with the abuse of disability benefits.

A key determinant of the level of benefits and the riskiness of those benefits is the extent of inflation protection provided by the plan. The plans described here are assumed to have a constant percentage cost of living adjustment. In the numerical examples, the percentage will equal to the inflation rate. This full, automatic COLA is one of several forms used in existing plans. It is not without loss of generality. The presence of a full COLA in a nominal plan decreases the incentive to continue working late in the career as, once the employee

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using this logistic specification would not be difficult to implement and would not require any reference to the underlying functional form.
retires, the benefit will increase in line with inflation. In plans without a COLA, or in which the COLA is not automatic but applied (or not) on an ad hoc basis by legislative action every few years, an additional year of work increases the pension benefit through both nominal and real wage growth.

Most plans offer a variety of payment options which may include a single life annuity, a joint and survivor annuity, a partial lump sum, and various combinations of these options. In most plans, these options are constructed such that the individual receives a benefit of equal actuarial value. However, because individuals may have private information about their mortality risk, they can exploit the presence of these options to increase the value of their benefits.⁶ If employees plan their claiming strategies in advance, these options will simply scale the incentive and distributional measures considered and introduce heterogeneity across individuals. For simplicity, this analysis assumes a single life annuity for the average individual.

Public sector employees covered by DB plans typically make mandatory contributions to the pension plan. In most cases, these contributions are computed as a constant fraction of covered earnings. For simplicity, all four plans will be assumed to follow this practice in this analysis. In the numerical computations, the contribution rate will be set to five percent.

### 3.2.6 Economic and demographic assumptions

This chapter derives analytic formulas for select financial incentives created by defined benefit pension plans and provides illustrative numerical examples. This section spells out the details necessary for such calculations.

While all formulas can be derived for general wage processes, the essential insights can be most clearly obtained assuming a constant rate of wage growth. Therefore the baseline analysis will assume that wage growth occurs at a constant rate, \( g \).⁷ However, as pension plans can create incentives for spiking, that is, for individuals to dramatically increase their

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⁶At the same time, individuals may choose period certain options that appear to reduce the value of their benefit.

⁷In reality, wage growth among employees covered by public sector plans tends to be high and sharply decreasing in the first few years of the career before then decreasing at a slower rate over the remaining years of the career. Incorporating non-constant wage growth into the formulas derived in section four merely obscures the underlying economics of the pension plans. Longitudinal variation in the rate of wage growth does not drive much interesting behavior in the financial incentives beyond that which is considered in the spiking analysis discussed next.
wages at particular points in time, additional analyses will also investigate the importance of such behavior directly. In the numerical exercises, the nominal rate of salary growth will be set to four percent.

Present value computations require assumptions about mortality and interest rates. All computations are performed for a 50-50 gender mix of the RP-2000 mortality tables projected according to the Scale BB mortality improvement factors for an individual born in 1980.8 The results are not sensitive to these assumptions. Shifting the assumed date of birth earlier in time decreases the value of benefits overall and shifts the relative value of benefits provided at different ages but the differential shift is quite modest. Alternative assumptions about mortality have only a modest effect on the incentive and distributional measures considered and do not drive interesting variation in those measures within the career or across different careers.

The choice of interest rate has an important effect on both the level of the incentive and risk measures and the shape of those measures over the career. The proper selection of discount rate has been discussed extensively in other work and is beyond the scope of this chapter (see, e.g., Novy-Marx and Rauh (2009) and Novy-Marx and Rauh (2011)). This chapter assumes an inflation rate of two percent and a real discount rate of 2.5 percent. However, one advantage of the derivation of general formulas for each pension plan is that alternative assumptions can be readily substituted into the formulas presented.

Computing the incentive for job acceptance and the riskiness of pension benefits requires assumptions about separation patterns. Since two of the plans do not exist and the other two are merely stylized representations of plans that do exist, it is not possible to select separation assumptions directly from data on current behavior. For transparency, a very simple set of separation assumptions is used. The separation rate at age and service combination \((a, s)\) under the nominal high-three with actuarial adjustment for early and delayed retirement is max \((0.22 - 0.04s, 0.02 + 0.28/(1 + \exp(- (a - 60)/2)))\). Under the nominal high-three with percentage early retirement separation rates at older ages jump from 0.02 to 0.30 at 60, and under the inflation-adjusted career-average with actuarial early retirement separation rates increase according to the smooth function through 59 but jump to 0.30 at 60. Separation rates under the indexed career-average with variable accrual factors are set equal to the separation rates under the high-three with actuarial adjustment for early and

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8Mortality improvements are set to zero for ages 1-14.
delayed retirement.

3.3 Quantifying financial incentives and risks

Pension plans link retirement income streams to labor market behavior over an individual's entire career. Because the pension is a function not only of how much an employee works but when that work was performed, direct specification of the budget constraints yields few clear insights. As an alternative, this section develops a series of implicit subsidy rates as they affect particular decision margins. A corresponding measure of risk reflects the probabilities that an individual follows any particular path. The decisions considered are (i) whether to continue employment, (ii) whether to seek additional earnings (e.g. by working overtime or pursuing a promotion), and (iii) whether to accept a job.

3.3.1 Continued employment

The accrual rate of pension wealth over a one-year period is a widely used summary measure of pension incentives. The accrual rate measures the increase in the present value of the pension benefits to which an employee would be entitled if she were to work an additional year as a percentage of salary. In most DB plan designs, the accrual rate is constant or nearly constant as salary varies. Because continued work typically requires additional employee contributions to the pension fund, net measures are often used. This chapter adopts the convention that accrual rates reflect the deviation between total compensation and quoted salary.\footnote{The accrual rate could also be measured relative to salary less pension contributions, total compensation, or salary less contributions plus normal cost. The ideal benchmark would perhaps be productivity or an employee's outside employment opportunities, but such quantities are generally unobserved.}

Denoting the one-year accrual rate by $i_{1yr}(t)$, the probability of survival from period $t$ to the beginning of period $s$ by $p(s \mid t)$, the COLA by $i$, the interest rate by $r$, the benefit claimed at time $s$ by $b_s$, contributions made in period $s$ by $c_s$, and the wage in period $s$ by...
the one-year accrual rate is defined as

\[ i_{1\text{yr}} (t) = \frac{\Delta \text{PV of pension benefits} - \text{contributions}}{\text{wages}} \]

\[ = \frac{1}{w_t} \left( \sum_{s=t+1}^{T} p(s \mid t+1) \left( \frac{1+i}{1+r} \right)^{s-t} b_{t+1} - \sum_{s=t}^{T} p(s \mid t) \left( \frac{1+i}{1+r} \right)^{s-t} b_t - c_t \right). \]

While the one-year accrual rate provides a concise summary measure of the institutional features of the pension plan, it is rarely the correct measure for thinking about the impact of the plan on employee behavior.\(^{10}\) It is relevant only when employees face a choice between one additional year of work and leaving the job now. Otherwise, workers trade off the increase in the value of the pension benefit over all years until the intended departure.

Two alternative measures more directly capture these longer-horizon incentives. First, the \( k \)-year accrual measures the increase in the value of the pension benefit less contributions over the next \( k \) years. This longer-horizon accrual rate is given by

\[ i_{k\text{yr}} (t) = \mathbb{E}_{\text{able}} \left[ \frac{\Delta \text{PV of pension benefits} - \text{PV of contributions}}{\text{PV of wages}} \right] \]

\[ = \sum_{s=t+1}^{t+k-1} a(s-1 \mid t) \eta(s-1) \]

\[ \times \left[ \frac{\sum_{u=s}^{T} p(u \mid t) \left( \frac{1+i}{1+r} \right)^{u-s} b_u - \sum_{u=t}^{T} p(u \mid t) \left( \frac{1+i}{1+r} \right)^{u-t} b_t - \sum_{u=t}^{s-1} (1+r)^{t-u} c_u \sum_{u=t}^{s-1} (1+r)^{t-u} w_u}{\sum_{u=t}^{s-1} (1+r)^{t-u} w_u} \right], \]

where all notation is as before with the addition of \( a(s \mid t) \) to denote the probability that an individual alive and able at time \( t \) remains alive and able at time \( s \) and \( \eta(s) \) to denote the probability that an alive and able individual dies or becomes disabled at time \( s \). In an abuse of notation, for purposes of the \( k \)-year accrual, set \( \eta(t+k-1) = 1 \). This on-the-fly redefinition allows the definition of the accrual measure to be written as a single sum. In contrast to the one-year accrual, where the assumption that death or disability during the current period

\(^{10}\)The definition of the accrual rate stated here implicitly assumes immediate claiming of the pension benefit upon leaving a job. While this will be optimal in most cases, under the nominal high-three pension with percentage early retirement employees who leave public sector employment at sufficiently young ages should defer their claim. The analysis will assume that individuals claim optimally (defined as claiming to maximize the present value of the pension benefit).
leads to benefits equal to the retirement benefit in the next period eliminates death and
disability from the equation, death and disability do affect the $k$-year accrual. An individual
considering whether to work for the next $k$ years knows that with some probability she will
be forced to stop working at each intervening year due to death or the onset of disability.
Because the death and disability hazard is small at most ages of interest, the inclusion of
this term will be relatively unimportant for the results.

One horizon of particular interest is the accrual through the normal retirement age, where
$k$ is simply the difference between the normal retirement age and the current age. Because
the level of benefits is often highest at this age, many individuals will choose between leaving
the job in the current period for retirement or another opportunity and remaining on the job
until the normal retirement age. The $k$-year accrual is the appropriate wedge for individuals
considering this decision.

However, in general there is no reason to privilege the normal retirement age over all other
ages at which an employee might quit. A more general measure that captures incentives for
employees who may have more flexibility in determining their retirement age is the maximum
accrual rate. This measure is defined as

$$i_{\text{max}} (t) = \max_k \{i_{\text{kyr}} (t)\}.$$  

The maximum accrual is the maximum percentage deviation between total compensation
and the quoted compensation, where the maximum is taken over all possible departure
dates. For an employee with a fixed reservation value at which she would depart from the
public sector workforce, this will identify the first age at which the total future value of
compensation fails to surpass it. It will more richly capture the incentives when employees
cross a series of staggered eligibility thresholds. However, for purposes of the current chapter
this measure is of relatively little interest. As a result of the relative simplicity of the plans
considered here, the maximum accrual will largely coincide with the accrual through the
normal retirement age. When the one-year accrual schedule has multiple peaks, when the
interaction of age and service requirements for eligibility leads to variation in the age at
which individuals achieve their maximum benefit, or when caps on replacement rates lead
to sharp reductions in accrual rates before the normal retirement age, the maximum accrual
emerges as an informative measure.
To develop intuition for the longer-horizon measures, it is useful to observe that the accrual rate over any $k$-year period can be written as

$$i_{kyr}(t) = \sum_{s=t+1}^{t+k-1} a(s-1|t) \eta(s-1) \left( \sum_{u=t}^{s-1} (1 + r)^{t-u} w_u i_{1yr}(u) \right) \left( \sum_{u=t}^{s-1} (1 + r)^{t-u} w_u \right)^{-1}.$$

That is, the accrual over the next $k$ years is a weighted average of the one-year accrual rates. The accrual rates are first averaged across the years of each potential career, where the weights reflect the importance of each year's wage in the present value of the stream of wage payments over the potential career. They are then averaged over the potential careers weighted by the probability that death or disability forces individuals to exit from the labor force early and thus follow one of these alternative careers. This averaging interpretation allows for a quick mental construction of normal retirement age accruals and maximum accruals from figures that show only the 1-year accrual rate. For this reason, the derivation of formulas will focus on the single-year accrual rates.

Alternative measures of the incentives for continued work created by the pension system have been proposed in the literature for a variety of different purposes, including the option value (Stock and Wise (1990) and Samwick (1998) using a special case), the premium value (Gustman and Steinmeier (2001/2002)), and the peak value (Coile and Gruber (2007)). The key conceptual distinctions between the measures of future pension benefits used in this chapter and those established in the literature are that the Stock and Wise option value measure includes the value of future wages and does not normalize by earnings, the Samwick option value measure includes the value of future wages and does not normalize by earnings or the number of years of work required to claim the pension benefit, and the peak value does not normalize by earnings or the years of work required to claim the pension benefit. Of course it is simple to define analogs of each measure that make each of these adjustments. The different measures should be viewed as broadly similar.

### 3.3.2 Additional earnings

Employees may have opportunities to increase earnings at different times in their careers, whether by working over time, applying for a promotion, or otherwise attempting to increase
their salary. Since average earnings are a key input into the computation of initial pension benefits, the pension plan has an important effect on the financial return to such a decision. The importance of the pension plan for this margin can be measured in the form of an implicit subsidy for each dollar of additional earnings at different points in the career. This analysis considers the implicit subsidy for earnings for an employee at time \( t \) who intends to retire at \( t' \). For purposes of this computation, survival until age \( t' \) is assumed. The measure is defined as

\[ i_c(t, t') = \frac{\partial}{\partial w_t} \left[ \sum_{s=t'}^{T} \frac{p(s | t')}{(1 + r)^{t'-s}} \left( \frac{1 + i}{1 + r} \right)^{s-t'} b_w - \sum_{s=t_0}^{t'-1} (1 + r)^{t'-s} c_s \right] \]

\[ = \sum_{s=t'}^{T} \frac{p(s | t')}{(1 + r)^{t'-s}} \left( \frac{1 + i}{1 + r} \right)^{s-t'} \left( \frac{\partial b_w}{\partial w_t} - \sum_{s=t_0}^{t'-1} (1 + r)^{t'-s} \left( \frac{\partial c_s}{\partial w_t} \right) \right). \]

where the notation is as above. Assuming mortality probabilities, interest rates, and COLAs are unaffected by additional earnings, the financial incentive is the difference between the impact of additional earnings on the initial benefit scaled by the value of a $1 annuity with COLA at rate \( i \) and the impact of additional earnings on contributions.

Because individuals may manipulate earnings in ways other than simply attempting to increase earnings today, the analysis considers two other thought experiments. The first investigates the impact of different rates of sustained earnings growth on the level of pension benefits and the second the impact of receiving a promotion accompanied by a 35 percent pay increase at different ages. The outcome measure examined under each experiment is the ratio of the present value of pension benefits less the present value of contributions relative to the present value of salary as described in the next subsection.

### 3.3.3 Job acceptance

Individuals choose jobs based in part on the compensation. Because pensions provide a valuable source of retirement consumption, they affect individuals decisions as to whether to take the job. The impact on the decision to accept a job can be thought of in two pieces. The first is the effect of the pension plan on the expected level of total compensation. For this purpose, the value of the pension is measured as the ratio of the present value of the pension
benefit less the present value of contributions to the present value of the salary. Consider an employee who began employment at $t$ and separates at age $t'$. The realized increase in compensation relative to quoted salary as a percentage of quoted salary is

$$P(t, t') = \frac{PV \text{ of pension benefits} - PV \text{ of contributions}}{PV \text{ of salary}}$$

$$= \sum_{s=t}^{t'} p(s \mid t') \left( \frac{1 + i}{1 + r} \right)^{s-t'} b_s - \sum_{s=t}^{t'-1} (1 + r)^{t'-s} c_s$$

Note that because the net value of pension benefits is normalized by total earnings, a long-tenure individual with a lower payoff according to this measure may well still receive a larger pension benefit than a short-service individual with a higher payoff. The benefit in such cases is smaller only relative to the earnings over the carer.

In general, the pension does not provide the same benefit for employees who follow different careers. Denoting the probability of employment at the beginning of period $s$ for an individual whose employment spell begins in period $t$ by $e(s \mid t)$ and the probability that an employee separates at age and service combination $(a, s)$ by $\lambda(a, s)$, the ex ante expected benefit from the pension system is defined as\footnote{An important complication is that individuals may have private information about their expected future career path. While this is beyond the scope of the current analysis, to the extent that individuals have information of this nature it would generate heterogeneity in the expected markup across individuals and heterogeneity in the riskiness of that markup. The private information could increase or decrease both measures. An important issue in evaluating the effect of these plans on individual behavior is the extent to which individuals have private information about their expected future career path and how accurate their perceptions of the future employment probabilities are.}

$$i_{\text{accept}}(t) = E_{\text{career}} \left[ \frac{PV \text{ of pension benefits} - PV \text{ of contributions}}{PV \text{ of salary}} \right]$$

$$= \sum_{s=t}^{T} e(s \mid t) \lambda(a, s) \left( \sum_{u=s}^{T} p(u \mid s) \left( \frac{1+i}{1+r} \right)^{u-s} b_s - \sum_{u=t}^{s-1} (1 + r)^{t-u} c_u \right)$$

$$\sum_{s=t}^{T} (1 + r)^{t-u} w_u$$

An immediate relationship with normal cost computations is apparent. The effect of the pension plan on expected lifetime compensation would be the normal cost assuming an
entry-age level percent formula if the employee were the only individual in the workforce. Like the $k$-year accrual, the ratio of pension value less contributions to quoted salary can be expressed in terms of the one-year accrual rates:

$$P(t, t') = \frac{\sum_{s=t}^{t'-1} (1 + r)^{t'-s} w_s \tilde{i}_{1yr}(s)}{\sum_{s=t}^{t'-1} (1 + r)^{t'-s} w_s}.$$  

This will again facilitate intuitive construction of the payoff functions using only information on the single-year accrual rates.

The second important impact of the pension plan on the decision to accept a job is the risk that the potential employee will not actually receive the expected benefit. An individual may take the job thinking she will make it to the normal retirement age or an age that otherwise maximizes the benefits, but with some probability, she will fail to do so. The expected benefit does not distinguish between two plans, one that guarantees the markup by providing the same benefit in all years and another that gives a higher benefit only to those employees who work for the employer for 20 years or more and no benefit for short-service employees. The second plan is substantially riskier. A simple measure of this risk is the standard deviation of the markup:

$$r_{accept} = \left( \text{Var} \left( \frac{\text{PV of pension benefits} - \text{PV of contributions}}{\text{PV of salary}} \right) \right)^{\frac{1}{2}}.$$  

While this analysis will focus on the risk created by different potential exit dates, other sources of risk can affect benefits as well. An important risk in nominal final average salary plans, for example, is the possibility that the employer will institute a wage freeze a few years before an employee’s intended date of retirement. A wage freeze can result in a substantial reduction in nominal salary at the end of the career and, because many plans provide benefits based on final salary, in the level of pension benefits as well.
3.4 Analytic pension formulas

The analysis in this section works through the different incentive and risk measures for each of the four plan designs.

3.4.1 The financial incentive for continued work

Nominal high-three with actuarial early and delayed retirement

The financial incentive for continued work under the nominal high-three formula increases dramatically with age and modestly with tenure. The end result is a system which encourages employment by older workers but does little to achieve retention goals for younger workers regardless of experience. The one-year accrual rate is

\[
i_{yr} = \frac{a_{NRA} \times f \times G}{3(1+r)^{NRA-1}} \times (1 + g \times \text{service}_{t+1}) - c,
\]

where \(a_{NRA}\) is the cost of a $1 annuity beginning at the normal retirement age (including COLAs), \(f\) is the plan’s accrual factor, \(G = (1+g)^{-1} + (1+g)^{-2} + (1+g)^{-3}\) and \(g\) is the growth rate of earnings, \(r\) is the interest rate, and \(c\) is the contribution rate. The financial incentive for an additional year of work depends on age, service, and the rate of earnings growth. Because one dollar of earnings today increases average earnings at the normal retirement age by one dollar, the financial incentive for work is discounted by the interest rate for each year between the current age and the normal retirement age. Since the current year’s earnings will increase the pension benefit associated with each prior year of service, the financial incentive increases with the product of nominal earnings growth and service.

The cost of a $1 annuity is obviously a relevant scaling factor because the pension plan provides an annuity. The accrual factor and the contribution rate are specified in the plan rules and under the direct control of the relevant policymakers. However, \(g\), \(G\), and \(r\) are economic variables outside their control.\(^\scriptscriptstyle{12}\) Thus the choice to use a nominal high-three pension plan is a choice not only to create financial incentives according to the general structure imposed by equation (3.1), but also to make them depend on general economic conditions in a particular way.

\(^{12}\)The public sector employer has some control over \(g\) and \(G\) though this is limited by labor market equilibrium. This complexity does not affect the central point.
To illustrate the behavior of this incentive, the accrual rates for three hypothetical careers differing based on the age of initial employment are shown in Figure 1. The three hypothetical careers represent individuals whose employment begins at ages 25, 35, and 45. The accrual rate increases markedly throughout the career. Consider a worker who begins working for the government at age 25 with a salary of $30,000. At 35 she earns a gross salary of $44,407. An additional year of work increases the value of her future pension benefits by $8,180, but contributions of $2,220 are deducted from her paycheck. Thus, on net, the pension system increases total compensation above quoted salary by $5,959, or 13.4 percent. In contrast, at age 55 her salary is $97,301 and the value of the pension accrual $54,322. Net of contributions, the pension system increases compensation by $49,457, or 50.8 percent. Thus, as the individual advances through her career, the pension adds an increasing amount of compensation relative to the wage and the differences are quite large.

The curves in Figure 1 combine the effects of both age and tenure as movement along a curve represents progression through the career. An alternative presentation of the same information compares across individuals holding one variable constant and letting the other vary. Figures 2 and 3 provide this perspective for the basic high-three formula. Figure 2 shows the one-year accrual rate by age holding service constant. Each line represents a different fixed number of years of service. Figure 3 shows the pension compensation relative to gross wage by service holding age constant. In this figure, each series represents a different fixed age. As inspection of either equation (3.1) or the figures reveals, the accrual rate increases exponentially in age but only linearly in service. For older individuals, accruing pension benefits are worth more because they are provided fewer years into the future. For long-tenure individuals, the higher wage used in the computation of average earnings applies to a much larger pension. At 10 years of service, the accrual rate increases from 10.7 percent at age 30 to 16.8 percent at 40 to 40.8 percent at 60. In contrast, at age 40, the accrual rate increases from 16.7 percent at 10 years of service to 21.4 percent at 20 years to 26.1 percent at 30 years.\(^\text{13}\)

In addition to its dependence on economic variables outside the control of policymakers, the choice of the high-three formula also commits the employer to providing different benefits to individuals who join the public sector workforce at different ages. Since wage schedules are

\(^{13}\text{Admittedly, the practical import of the accrual rate for a 40 year-old with 30 years of service is limited, but considering such a hypothetical employee helps develop intuition for the behavior of the underlying formula. Throughout the analysis, formulas that can be evaluated in such scenarios often will be.}
not conditioned on age, this means that total compensation will differ across these individuals as well. One possible way of relaxing this constraint would be to develop contribution rates that depend on the age of initial employment. As with all such choices, the central question is whether the design of the plan is facilitating the achievement of important goals or whether it is creating undesirable side effects.

As previewed in the last section, an employee at age 40 is unlikely to be choosing between departure and only one additional year of work. She is more likely to be comparing a longer period of continued work in the current job against a period of work in an alternative occupation. This longer horizon smooths the incentives created by the one-year accrual according to the averaging formula derived in section three. Figure 4 presents the accrual rates through the normal retirement age for the nominal high-three pension with actuarial early and delayed retirement. Since the basic formula is already a smooth function, the smoothing does not change the qualitative nature of the incentives. However, by incorporating the value of working until the normal retirement age for younger workers, it reflects the stronger incentive for young individuals to remain on the job created by the plan than that suggested by the single year accrual rate. For an employee joining the public sector workforce at 25, the one-year accrual rate is only 6.2 percent, but the accrual rate through the normal retirement age is 23.5 percent. And while the one-year accrual rate increases by 720 percent between 25 and 55, the accrual rate through the normal retirement age increases by only 140 percent.

The maximum accrual rate for the nominal high-three with actuarial early and delayed retirement is dictated by the mortality assumptions and therefore relatively uninteresting. As individuals age, the one-year accrual rate increases without bound. This explosive behavior arises because the pension plan provides a benefit actuarially equivalent to an annuity paying a fixed percentage of salary beginning at the normal retirement age. For each year by which an employee’s age exceeds the normal retirement age, the size of the actuarial adjustment increases. Were an arbitrarily old employee to exist, the adjustment would be arbitrarily large. The $k$-year accrual will therefore always reflect the accrual rate through the age at which any individuals still alive are assumed to die with certainty (120 in this analysis). Abstracting from mortality, the maximum accrual rate would be undefined as the $k$-year accruals would increase indefinitely.
Nominal high-three with percentage early retirement

Introducing non-actuarial adjustments for early and delayed retirement leads to much more complicated expressions for the accrual rate. The one-year accrual for a nominal high-three pension with percentage early retirement (and no credit for delayed retirement) is

\[
\begin{align*}
& \frac{1}{3} \times f \times \left\{ \sum_{s=t+1}^{t^*} \frac{p(s-1|t)\mu(s-1)}{(1+r)^{s-t}} \times a_s \times \max\left(0, 1 - \max\left(0, e \times (NRA - s)\right)\right) \right\} \\
& \times \max\left(0, 1 - \max\left(0, e \times (NRA - s)\right)\right) \\
& \times G \times (1 + g \times service_{t+1}) - c.
\end{align*}
\]

where \( t^* \) solves the problem

\[
\max_{t} \left\{ \sum_{s=1}^{t} p(s-1|t)\mu(s-1) \times a_s \times \max\left(0, 1 - \max\left(0, e \times (NRA - s)\right)\right) \right\}.
\]

As before, \( p(s|t) \) is the probability that an individual alive in period \( t \) survives to period \( s \), \( a_s \) is the cost of a $1 annuity beginning at age \( s \), \( g \) is the rate of earnings growth, \( G \) collects terms in \( g \), \( NRA \) is the normal retirement age, and \( c \) is the contribution rate. Relevant for this pension but not the nominal high-three with actuarial adjustments for the timing of retirement are \( p(s) \), the mortality probability at age \( s \), \( e \), the early retirement reduction rate, and \( i \), the COLA rate.

With a non-actuarial adjustment for early retirement, the decision of when to claim benefits—ignored in the last section—becomes an important one. This formula assumes optimal claiming, defined as claiming at the age that maximizes the present value of the pension benefit. The decision rule takes the form of deferring claiming until a threshold age \( t^* \) if separating before that age and claiming immediately if separating at or after that age. This rule is feasible to implement in practice, provided individuals retiring early are
not liquidity constrained.\textsuperscript{14}

The accrual rate prior to the optimal claiming age is identical to that for the pension of the prior subsection, except that the cost of a $1 annuity at the normal retirement age is replaced with the expected value of an attempt to claim at the optimal age $t^\ast$. This expected value is the value of a $1 annuity claimed at each age before $t^\ast$ weighted by the probability of death at that age (which results in immediate payment of the death benefit) plus the value of a $1 annuity claimed at $t^\ast$ weighted by the probability of survival until $t^\ast$. In years before the optimal claiming age, the accrual rate will behave in the same way as that for the nominal high-three with actuarial adjustments: exponential growth in age and linear growth in service.\textsuperscript{15}

The accrual rate at and after the optimal claiming age generalizes the basic formula. Whereas additional service in the simple plan affects the accrual rate only through $g$, under the more complex plan its effect is determined by four interacting pieces: (1) the probability of death, (2) the relative magnitudes of wage growth and the COLA, (3) the value of a $1 annuity at the current age, and (4) the early retirement reduction rate. Because there is no adjustment for delayed retirement, a large probability of death increases the value of work as it leads to a guaranteed higher payout in the next period rather than an annuity that stops after only one period. The second term reflects the fact that an additional year of work increases the earnings used to compute the initial benefit but sacrifices one year of the COLA. The third term measures the value of sacrificing the current year’s pension benefit in order to remain on the job and the fourth term measures the value of reducing the early retirement reduction by one year. (Of course, this fourth term only matters if retiring before the normal retirement age.)

As with the basic high-three plan, the financial incentive for continued work combines parameters under the direct control of policymakers (e.g. $f$ and $e$) with economic variables outside their control ($g$ and $\pi$). Thus, when choosing a high-three plan with percentage early retirement, policymakers have only limited ability to construct the financial incentives for continued work of their choosing.

Figure 5 illustrates the one-year accrual rate for the same three hypothetical careers

\textsuperscript{14}Since the threshold age is typically sufficiently early that individuals must seek an alternative source of income (i.e. a spouse or another job) if separating before that age, this seems like a reasonable assumption.

\textsuperscript{15}This description ignores the effect of age on the expected value of a $1 annuity under the optimal claiming strategy. However, this effect is not quantitatively significant as mortality probabilities are extremely low at young ages.
considered in the previous subsection. The accrual rate increases smoothly until the optimal claiming age, roughly levels out between the optimal claiming age and the normal retirement age, and then drops sharply at the normal retirement age. After the normal retirement age, the accrual rate continues to decrease. For an employee whose employment begins at age 25, the accrual rate increases from 2.9 percent in the first year to 12.1 percent at age 35 to 47.6 percent at 55. However, unlike the basic high-three, the accrual rate is approximately constant between 51 and 59.

Figure 6 shows the one-year accrual rates by age holding service constant and Figure 7 shows the one-year accrual rates by service holding age constant. As with the basic plan, most of the variation and the overall shape of the accrual schedule is determined by age. Different levels of service have a more modest linear effect on the accrual rate. Unlike the basic plan, increasing service can decrease the accrual rate since service merely scales up the combined effect of the four terms discussed previously. At or after the normal retirement age, additional work no longer reduces the early retirement reduction. Thus giving up a year’s payment becomes the driving force behind the accrual rate. Greater service increases the size of the pension and therefore the cost of giving up a year’s payment relative to the additional pension resulting from an additional year of work. Thus, at these older ages, increasing service decreases the accrual rate and eventually drives it negative.

Figure 8 presents the accrual rate through the normal retirement age. As expected, the extended horizon smoothes the financial incentive for continued work. The normal retirement age accrual again indicates that the financial incentive for continued work created by the plan is much stronger at younger ages than is reflected by the one-year accrual rate. The maximum accrual (not shown) peaks for longer service employees before the normal retirement age. For employees with large pensions, the non-actuarial adjustment for early retirement leads to modestly declining single-year accruals in the late 50s. Thus, while the absolute financial incentive for continued work provided by the pension remains quite large, the fact that it decreases suggests that some marginal individuals may begin considering departure in their late 50s.
Inflation-adjusted career average with actuarial early retirement

The accrual rate of pension wealth under the inflation-adjusted career average with actuarial early retirement is given by

\[
i_{1yr}(t) = \begin{cases} 
  f \times a_{NRA} \times \left( \frac{1 + \pi}{1 + r} \right)^{NRA - t} - c & t < NRA \\
  f \times a_t \times \left\{ 1 + \left( \frac{1}{1 - \mu(t)} \right) \left( \frac{1 + \pi}{1 + r} \right) \left( \frac{a_t - 1}{a_t} \right) - 1 \right\} \times \sum_{s=t_0}^{t} (1 + \pi)^{s-t} - c & t \geq NRA.
\end{cases}
\]

(3.3)

All variables retain their previous meaning. For clarity, the formula is broken into two pieces: one applicable in the years before the normal retirement age and the other applicable in the years at or after. In the years prior to the normal retirement age, the formula depends only on the accrual factor, the value of a $1 annuity at the normal retirement age, the real interest rate, the age, and the contribution rate. As under the nominal high-three plans, the accrual factor increases exponentially with age, but the growth rate is reduced from the nominal interest rate to the real interest rate. The earnings growth rate disappears from the formula entirely. Because the computation of average earnings now depends on the full career, an additional year of work at a higher wage does not replace any previous earnings in the earnings history, it merely increases the total earnings. Relatively fewer variables not under the control of the policymakers appear in the equation, only the real discount rate and the value of a $1 annuity.

After the normal retirement age, the formula in equation (3.3) parallels that of equation (3.2). The accrual factor depends on mortality, the relationship of the inflation rate to the COLA, and the cost of giving up one year’s pension benefit. In the career-average plan, the appropriate scaling factor is not service itself but a term reflecting the accumulated earnings in all years relative to the current year.\(^{16}\)

The one-year accrual rates for each of the three hypothetical careers examined previously are shown in Figure 9, the accrual rates by age holding service constant in Figure 10, and the accrual rates by service holding age constant in Figure 11. Prior to the normal retirement age, the increase in the accrual rate associated with age is dramatically reduced and the variation in the accrual rate associated with service is eliminated. After the normal retirement age, the accrual rates drop sharply. This drop is even larger than that in the nominal high-

\(^{16}\)If salary growth were equal to inflation, this scaling factor would be equal to service.
three because the salary history is adjusted for inflation. As a result, wage increases are less valuable. (Only the real increase in wages increases the benefit rather than the entire nominal increase.) Because the relative value of the increase in the pension benefit resulting from an additional year of service and the loss of one year’s payment resulting from continued work depends on service, the three accrual rates diverge after the normal retirement age. The accrual rates for long-tenure employees drop most sharply because long-tenure employees have the largest pensions. Additional work results in only a small percentage increase in the value of the initial benefit, while giving up a year’s payment represents a substantial loss. For an employee joining the public sector workforce at 25, the accrual rate increases from 13.3 percent at 25 to 18.5 percent at 25 to 33.5 percent at 55. The accrual rate at age 30, regardless of service, is 15.7 percent and the accrual rate at age 40, regardless of service, is 21.6 percent. However, at age 60 the accrual rate is sharply decreasing in service, from 15.3 percent at 10 years of service to -42.1 percent at 30 years of service.

Figure 12 presents the accrual rate through the the normal retirement age. As would be implied by the previous results, the accrual rate is solely a function of age and does not depend on service, and, because the plan provides actuarial adjustments for early retirement, it is a single, smoothly increasing function. Since the one-year accrual rate is increasing until the normal retirement age and drops sharply at that age, the maximum accrual at all ages before the normal retirement age will be equal to the accrual through the normal retirement age.

Indexed career-average with variable accrual factors and actuarial early and delayed retirement

The one-year accrual rate for an indexed career-average pension with variable accrual factors and actuarial adjustments for early and delayed retirement is given by

\[ i_{1yr} (t) = \frac{a_{NRA}}{(1 + r)^{NRA-t}} \times \frac{x(NRA)}{x(t)} \times f(a(t), t) - c, \]

where \( x(s) \) is introduced to reflect the value of an arbitrary index at time \( t \) and the constant accrual factor \( f \) used in the previous plan designs is generalized to be a function of age and service. The analysis will focus on the special case in which the change in the index \( x \) is set equal to the interest rate \( 1 + r \). This then means \( \frac{x(NRA)}{x(t)} = (1 + r)^{NRA-t} \) and the one-year
accrual rate of equation (3.4) becomes

\[ i^{19}r(t) = a_{NRA} \times f(a(t), t) - c. \] (3.5)

The accrual rate under this plan takes a very simple form, and, more importantly, is under the direct control of the policymakers. Other than the cost of a $1 annuity at the normal retirement age, which simply serves as a scaling factor, the only two terms in this formula, \( f(a, s) \) and \( c \), are specified in the plan rules. By using an indexed career-average pension with variable accrual factors, policymakers can construct whatever financial incentives for continued work they so desire. In the numerical computations, a simple s-shaped function of service, independent of age, is used for the accrual factors so as to model a plan along the lines of the oft-stated retention goals of defined benefit pension plans.

Figure 13 illustrates the accrual rates for the three hypothetical careers. In each case, the accrual rate starts out relatively flat, increases in the middle of the career, and then levels out late in the career. Figures 14 and 15 show these features most clearly. Accrual rates are constant as age varies conditional on a level of service: 19.7 percent for 10 years, 22.7 for 20 years, and 25.7 for 30 years. In contrast, regardless of age, accrual rates follow the same s-shaped pattern in service. Figure 16 plots the accrual rate through the normal retirement age. As the one-year accrual rates are smooth, the qualitative shape of the curves is very similar. In addition, since the variation in the accrual rates through the career is relatively modest, the normal retirement age accrual rates are relatively flat. Because the accrual rate limits to an upper bound in service, the maximum accrual (not shown) will follow a very similar pattern to the normal retirement age accrual for the youngest cohort re-expressed as a function of service for any starting age.

3.4.2 The financial incentive for additional earnings

Nominal high-three with actuarial early and delayed retirement

The implicit subsidy for additional earnings at age \( t \) conditional on survival until and retirement at \( t' \) under a nominal high-three pension with actuarial early and delayed retirement
where $f$ is the accrual factor, $a_{NRA}$ the value of a $1$ annuity beginning at the normal retirement age, $r$ the real interest rate, $NRA$ the normal retirement age, and $c$ the contribution rate. Since additional earnings in any year require additional contributions to the plan, a negative subsidy (i.e. a tax) is applied to earnings in all years. However, in the final three years of the career, that is, the years used in the computation of average earnings for the initial pension benefit, there is a large subsidy for additional earnings. This subsidy scales with the accrual factor and service and is discounted by the real interest rate for each year between the current age and the normal retirement age.

Figure 17 presents the implicit subsidy for four hypothetical careers. A modest tax equal to the contribution rate (five percent) applies in most years, but in the final years of the career the plan creates a massive subsidy for additional earnings. For an employee who starts at age 20 this subsidy reaches 386 percent at age 59. For shorter-service employees, the subsidy is reduced: 288 percent for an employee who starts at 30, 190 percent for an employee who starts at 40, and 93 percent for an employee who starts at 50.

An alternative perspective on the relationship between pension benefits and earnings is provided by figures 18 and 19. Figure 18 shows the ratio of pension value less contributions to lifetime earnings for employees retiring with 20 years of service at age 60. For an employee with zero nominal earnings growth, this ratio would be only 13.6 percent while for an employee with five percent nominal earnings growth it would be 24.1 percent. Since the short averaging window relies on earnings in only the final three years of the career, employees whose earnings increase at a faster rate will receive a much larger pension payout relative to earnings than those whose earnings increase at a slower rate. Similarly, Figure 19 presents the same ratio by the age at which an employee receives a promotion with a 35 percent pay increase. Because the pension determines benefits based solely on late career earnings, the relative benefit provided by the pension plan increases with the age of promotion. The largest difference in payout is between those individuals who receive the promotion exactly three years before retirement and those who would have been promoted if they stayed just one more year (i.e. were offered the promotion at age 60). However, these individuals are
much more similar in their work history than those who were promoted at younger ages.

**Nominal high-three with percentage early retirement**

The implicit subsidy under the nominal high-three with percentage early retirement is qualitatively very similar to that for the nominal high-three with actuarial early retirement. This similarity arises because the key driver of the implicit subsidy is the structure of the average earnings computation, and this is identical in the two plans. The subsidy for this plan is given by

\[
i_e(t, t') = \frac{f \times a_r \times \max\left(0, 1 - \max\left(0, e \times (NRA - t')\right)\right) \times service_r}{3 \left(1 + r\right)^{t - t'}} \\
\times 1\left(t \in \{t' - 1, t' - 2, t' - 3\}\right) - c,
\]

where all terms are as before with the addition of \(e\) to denote the early retirement reduction rate. While the magnitude of the implicit subsidy for additional earnings is scaled by the accrual factor \(f\) specified by the plan rules, the overall shape of the implicit subsidy is fixed by the decision to use a high-three formula. Without changing the formula, policymakers have little ability to eliminate these subsidies.\(^{17}\)

Figure 20 illustrates the implicit subsidy for four hypothetical careers assuming survival until and retirement at age 60. In each case, the implicit tax on earnings before age 57 is 5 percent. The maximum subsidy at age 59 is 445 percent for an employee who starts at age 20, 333 percent for an employee who starts at age 30, and 108 percent for an employee who starts at age 50. These numbers differ from those in section 4.2.1 only because the accrual rate for the two plans differs. Were they the same, the values would be identical. Figures 21 and 22 present the ratio of pension value less contributions to lifetime earnings for employees with different rates of nominal earnings growth and obtaining a promotion with a 35 percent pay increase at different ages, respectively. As with the basic high-three plan, the ratio increases dramatically as the rate of earnings growth increases and as the age of promotion increases, provided the promotion occurs before age 57.

\(^{17}\)For this reason, many final average salary plans have introduced anti-spiking provisions. These rules do not reduce the subsidy for the first dollar of additional earnings, but attempt to limit the total increase in pension value that can be obtained in this fashion by establishing limits on late-career wage increases. For example, an anti-spiking provision might state that only earnings that do not exceed the previous year's earnings by more than 20 percent will be used in the determination of an employee's initial pension benefit.
Inflation-adjusted career average with actuarial early retirement

Pension plans that use a career-average formula for the initial benefit eliminate the massive implicit subsidy for earnings in the final years of the career. If an employee receives a raise, her pension still increases, but only in proportion to the effect of the raise on the employee’s lifetime earnings. The implicit subsidy for earnings in period $t$ conditional on survival until and retirement at $t'$ is

$$i_e (t, t') = f \times \left( \frac{1 + \pi}{1 + r} \right)^{t'-t} \times \min \left( a_{t'}, a_{NRA} \times \left( \frac{1 + \pi}{1 + r} \right)^{NRA-t'} \right) - c,$$

(3.8)

where the variables retain their previous meanings and $\pi$ is introduced for the inflation rate. Because increased earnings today result in increased pension benefits in the future regardless of the current age, a positive implicit subsidy no longer requires that the current period fall in one of a small number of late-career periods. Because earnings are indexed only for inflation and the value of the increased pension benefit is always benchmarked by the normal retirement age, the implicit subsidy increases with age at a rate equal to the real discount rate. Since there is no adjustment for delayed retirement, the implicit subsidy decreases after the normal retirement age as individuals forgo years of benefits and thus the value of the pension decreases. As with the accrual rate for this inflation-adjusted career average pension, service has no effect on the implicit subsidy for earnings.

Figure 23 plots the implicit subsidy as a function of age for four hypothetical careers. However, because it does not depend on service, there is no difference in the subsidy across the four careers. The subsidy at age 30 is 15.7 percent, at age 40 is 21.6 percent, and at age 50 is 29.0 percent. The subsidy at age 57 is only modestly higher at 35.4 percent.

Figures 24 and 25 similarly emphasize the much weaker link between the allocation of earnings across the different years of the career and the value of the eventual pension benefit in inflation-adjusted career average plans. The ratio of pension value less contributions to lifetime earnings only increases from 27.7 percent to 29.0 percent as the rate of nominal earnings growth increases from zero to five percent. The relationship between earnings growth and pension value remains positive because the increasing accrual rate over the career means the pension still places greater weight on the years nearest the normal retirement age and a higher rate of salary growth means a greater share of total earnings will fall in these years. However, the longer averaging period relative to the high-three plans means the
quantitative significance of this link is substantially reduced.

The ratio of pension value less contributions to lifetime earnings has a non-monotone relationship with the timing of a major promotion. The ratio increases from 23.7 percent for an individual who is promoted at age 30 to 24.2 percent for an individual who is promoted at age 45 and then decreases to 23.4 percent for an individual who just misses the promotion. The non-monotone relationship arises from a simple tension: the discounting applied to future pension benefits increases the ratio when earnings are clustered at the end of the career, but the longer averaging window means that clustering earnings at the end of the career reduces average earnings. More important than the hump-shaped profile, however, is the fact that the ratio is approximately constant. Large changes in the timing of earnings generate only very modest changes in the ratio of pension benefits to earnings. Of course, individuals with higher earnings will receive higher pension benefits, but the ratio is approximately constant as the timing of earnings varies and thus there is little incentive to shift the timing of earnings in order to maximize the pension benefit.

Indexed career-average with variable accrual factors and actuarial early and delayed retirement

The implicit subsidy for additional earnings in the indexed career-average with variable accrual factors is

$$i_e(t, t') = \frac{a_{NRA}}{(1 + r)^{NRA-t}} \times \frac{x(NRA)}{x(t)} \times f(a(t), t) - c,$$

(3.9)

where $x(t)$ is the index used to adjust the wage history. In the special case where the index matches the discount rate the subsidy takes the form

$$i_e(t, t') = a_{NRA} \times f(a(t), t) - c.$$

(3.10)

As with the accrual rate, policymakers have direct control over the subsidy through the choice of the accrual factor and can achieve whatever implicit subsidy schedule they desire. One key constraint remains, however, in that the accrual factor determines both the implicit subsidy for additional earnings and the accrual rate of pension wealth. Thus, it is not possible to independently control the financial incentive for continued work and the financial

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incentive for additional earnings. Achieving such a goal would require an even richer set of policy instruments.\footnote{One way to do this would be to specify a formula for the initial benefit which is the sum of two pieces, the first based on service and the second based on earnings.} As with the accrual rate, indexing the wage history to the real interest rate eliminates the growth in the implicit subsidy associated with age.

Figure 26 plots the implicit subsidy for four hypothetical careers using the example schedule of accrual factors. For each career the implicit subsidy increases modestly with service from 19.7 percent at 10 years to 22.7 percent at 20 years to 25.7 percent at 30 years. Age has no effect on the implicit subsidy if service is held constant. For long-tenure individuals near the end of the career, the implicit subsidy for additional earnings is approximately constant. For example, for an employee whose career began at 20 it increases from 26.4 percent at 57 to 26.5 percent at 59. However, for employees whose service falls within the range over which the accrual factor increases, the implicit subsidy also increases modestly late in the career. For an employee whose career began at 40, it increases from 21.5 percent at 57 to 22.3 percent.

Figures 27 and 28 present the ratio of pension value less contributions to lifetime earnings as a function of the rate of nominal earnings growth and the timing of a promotion. In both cases the ratio is almost completely constant across a wide range of variation. A small effect is present because changes in the timing of earnings can change the accrual rate applied to a particular dollar of earnings. That is, an employee with a higher rate of earnings growth would earn a larger share of total compensation late in the career when service is higher and therefore the accrual factor is higher. However, this effect generates a very modest effect on the ratio. The same channel is operative, again with a small effect, as the timing of a promotion varies.

### 3.4.3 The financial incentive for job acceptance

**Nominal high-three with actuarial early and delayed retirement**

The financial incentive for job acceptance depends on the expected level of benefits provided by the pension plan. A first step in the computation of the expected level of benefits is the determination of the benefits provided under each possible career path. The realized pension contribution to compensation under the nominal high-three with actuarial early and delayed...
retirement for a career from \( t \) to \( t' - 1 \) is

\[
P(t, t') = \frac{1}{3} \times f \times \alpha_{NRA} \times G \times (1 + r)^{t' - t} - \frac{\text{service}_{t'}}{\sum_{s=t}^{t'-1} \left( \frac{1 + g}{1 + r} \right)^{s-t}} \times \left( \frac{1 + g}{1 + r} \right)^{t'-t} - c, \tag{3.11}
\]

where \( f \) is the accrual factor, \( \alpha \) the cost of a $1 annuity beginning at age \( s \), \( g \) the earnings growth rate, \( G \) collects terms in \( g \), \( r \) the real discount rate, \( NRA \) the normal retirement age, and \( c \) the contribution rate. Inspecting equation (3.11) indicates that this will increase exponentially with age and vary modestly with service. (If \( r < g \) it will increase with service and if \( r > g \) it will decrease with service. If \( r = g \) it will be independent of service.) With only modest differences between \( r \) and \( g \), the key determinant of the pension payoff is age. This is unsurprising, since the accrual rates examined previously for this pension varied dramatically with age and more modestly with service. As with the accrual rates, some elements of this formula are under the control of the policymakers, but others are not. Thus choosing a high-three plan generates an allocation of benefits that will only be partially designed to achieve the retention, recruitment, and retirement security goals and will be partially subject to the whims of economic fortune.

Figure 29 plots the ratio of net pension value to earnings as a function of retirement age for select service levels. The light gray line indicates the ratio holding service constant at 10 years, the dashed black line the ratio for an employee who begins work at age 20, and the solid black line the ratio holding service constant at 40 years. The difference between the ratio for different levels of service at any age is quite modest, but the difference across ages is dramatic. Holding service constant at 10 years, the ratio increases from 2.3 percent at age 30 to 6.5 percent at age 40 to 12.9 percent at age 50 to 22.9 percent at age 60. Under the basic high-three plan, the generosity of a retiree’s pension benefit relative to her earnings is primarily an indication of the age at which she retired and has little relation to service. Table 1 presents the ratio by age and service for multiples of five years and confirms the facts presented in the figure.

The distribution of benefits matters for ex post welfare, but ex ante individuals likely do not know exactly when they will retire. Thus the expected level of benefits and the variance in those outcomes are crucial inputs into the initial job acceptance decision. Figure 30 shows the expected compensation markup provided by the pension system as a function
of the initial age of employment. The value increases with age as individuals who start at older ages are more likely to work until older ages, when the benefits provided are more generous. At younger ages, the rate of increase in the expected benefit is slower than the rate of increase in the realized benefit as individuals are assumed to cluster at traditional retirement ages and thus a one-year delay in the start date of employment results in a less than one year delay in the expected retirement age. The high expected payoff to joining the public sector workforce at older ages under the high-three plan should make public sector employment extremely attractive to older individuals. In contrast, younger individuals who know that with some probability they will not actually remain on the job until the older ages at which the pension pays a generous benefit will find public sector employment much less attractive. That is, the high-three plan will change the relative attractiveness of the covered jobs for individuals of different ages. 19

Individuals may also be sensitive to the riskiness of the pension compensation. A guarantee that a pension plan will increase quoted compensation by 10 percent is more valuable to a risk-averse employee than a chance at an even higher pension benefit and otherwise nothing assuming the expected benefit remains the same. Figure 31 plots the standard deviation of the benefit as a function of the age of initial employment. The standard deviation is high at young ages and then decreases as individuals approach traditional retirement ages. Employees who join when young have some probability of leaving quickly if the job is a poor match—and thus getting very little in the way of benefits relative to their earnings—and some probability of making it to traditional retirement ages when benefits are more generous. As the employee ages, both the probability of making it to traditional retirement ages and the benefit ratio associated with an early exit increase. Thus the variance of the pension payoff falls. (The uptick in the variance after the traditional retirement ages reflects the assumed constant hazard after traditional retirement ages and the increasing slope of the ratio shown in Figure 29. It is neither particularly interesting nor robust to alternative separation assumptions.)

19 This differential selection could be undone if contribution rates varied with the age of initial employment.
Nominal high-three with percentage early retirement

The realized pension payoff under the nominal high-three with percentage early retirement is given by

\[
P(t, t') = \frac{1}{3} \times f \times G \times \frac{\text{service}_t}{t'} \times \left( \frac{1 + g}{1 + r} \right)^{t'-t} - c
\]

\[
\times \max_{i > t'} \left\{ \sum_{s=t}^{i} \frac{p(s - 1 | t') \mu(s - 1)}{(1 + r)^{s-t'}} \times a_s \times \max(0, 1 - \max(0, e \times (\text{NRA} - s))) \right\},
\]

where the notation is as above with the addition of \(e\) for the early retirement reduction rate.

Because the accrual rate drops dramatically after the normal retirement age under this plan, the markup in compensation over quoted salary is maximized at the normal retirement age and then declines afterward. The qualitative nature of the payoff as expressed in equation (3.12) is similar to that for the basic high-three in equation (3.11). The only change is that rather than the cost of a $1 annuity at the normal retirement age, the key scaling factor is the maximizing choice of the expected value of a claiming strategy that defers claiming until age \(t\) and claims immediately if retiring after that age.\(^{20}\) Like the implicit subsidy for additional earnings under the high-three pension with percentage early retirement, the dependence of the relative pension generosity on the characteristics of an employee's work history and economic conditions is almost entirely determined by the structure of the pension plan. Policymakers have relatively little ability to modify it. They can scale the entire payoff up or down by changing the accrual factor \(f\) and, through judicious choice of the early retirement reduction rate \(e\), could modify somewhat the payoffs at different ages, but the overall generosity will be largely pinned down by age. This finding is not surprising as the generosity of any plan can be expressed as a weighted average of the accrual rates and the accrual rates derived in section 4.1.2 were primarily a function of age and the real interest rate.

As with the basic high-three, the key determinant of the pension payoff is the age at which the individual retires. The payoff first increases dramatically with age as individuals move in the direction of the normal retirement age and then decreases once individuals pass

\[^{20}\text{The optimal value of } t \text{ in this expression is the same } t^* \text{ from the computation of the accrual rate.}\]
the normal retirement age. Figure 32 plots the realized payoff as a function of the retirement age for select service levels. At a single age, the difference in the payoff across service levels is modest, but the effect of age is dramatic. With 10 years of service the payoff increases from 4.4 percent at 30 to 9.7 percent at 40 to 17.9 percent at 50 to 27.1 percent at 60 before falling to 20.2 percent at 70. Table 2 presents the realized markup for a range of ages and service levels at retirement.

Figures 33 and 34 present the expected pension payoff and the standard deviation of the pension payoff by the age of initial employment. The expected payoff broadly follows the pattern set out by the realized payoff. It increases with age until the normal retirement age and declines thereafter. Older individuals are more likely to make it to the normal retirement age at which the largest payoffs are received. However, individuals who do not join the public sector workforce until after the normal retirement age will necessarily get pension benefits worth less and so the expected value declines. The expected markup increases from 10.0 percent for employees beginning work at age 25 to 14.0 percent for those beginning work at 35 to 24.9 percent for those starting work at 55. As with the basic high-three, the standard deviation of the payoff decreases with age as the relative generosity of benefits increases and the gap between the benefit ratio early in the career and benefit ratio at traditional retirement ages declines. However, in the late 50s the variance begins to increase as the odds that an employee will remain on the job after the normal retirement age (pursuing a larger absolute benefit) increases.
Inflation-adjusted career average with actuarial early retirement

The relative payoff for the inflation-adjusted career average with actuarial early retirement is given by

\[
P(t, t') = \begin{cases} 
  f \times a_{NRA} \times \left(\frac{1+\pi}{1+\pi}\right)^{NRA-t} \times \frac{\sum_{s=t}^{t'-1} \left(\frac{1+g}{1+\pi}\right)^{s-t}}{\sum_{s=t}^{t'-1} \left(\frac{1+g}{1+\pi}\right)^{s-t}} - c & t < NRA \\
  f \times a_{t'} \times \left(\frac{1+\pi}{1+\pi}\right)^{t'-t} \times \frac{\sum_{s=t}^{t'-1} \left(\frac{1+g}{1+\pi}\right)^{s-t}}{\sum_{s=t}^{t'-1} \left(\frac{1+g}{1+\pi}\right)^{s-t}} - c & t \geq NRA,
\end{cases}
\]

where all terms are defined as before. Prior to the normal retirement age, the formula is similar to those for the two high-three variants, except the inflation adjustment in the earnings history reduces the discounting applied from the nominal interest rate to the real interest rate and service is replaced by the sum \( \sum_{s=t}^{t'-1} \left(\frac{1+g}{1+\pi}\right)^{s-t} \), which measures total inflation-adjusted career earnings relative to the current year’s earnings. After the normal retirement age, the ratio decreases as there is no credit for delayed retirement. Crucially, as long as there is real salary growth over the career, both age and service will have important effects on the measured ratio. That is, the inflation-adjustment simultaneously reduces the importance of age through its effect on the discounting term and increases the role of service as a result of the accumulated earnings term.

As with the high-three pension with percentage early retirement, policymakers have relatively little control over the distribution of benefits under the inflation-adjusted career average pension. The payoff will increase with age as a function of the real discount rate and the payoff will vary with service based on real salary growth. Policymakers can merely scale up or down the level of benefits provided through their choice of the accrual factor \( f \).

Figure 35 illustrates the ratio for select service levels. The payoff increases smoothly with age until the normal retirement age, but does so much more modestly than under a nominal high-three plan. After the normal retirement age, the payoff decreases with age as benefits are forfeited while the employee remains on the job. The effect of service is also clearly
visible in the figure. Increased service reduces the relative payoff significantly at all ages. This behavior results from the use of the career averaging window. In the early years of the career, employees receive lower wages than in the years approaching retirement. Because they are adjusted in the earnings history only for inflation but not for the real discount rate, the benefits provided have less weight than the accumulated earnings themselves. Holding service constant at 10 years, the pension payoff increases from 14.3 percent at 30 to 19.7 percent at 40 to 35.4 percent at 60. Holding age constant at 60, the payoff decreases from 35.4 percent with 10 years of service to 30.8 percent with 20 years of service to 28.8 percent with 30 years of service.

Figures 36 and 37 present the expected payoff and the standard deviation of the payoff by the age of initial employment. Both follow the same qualitative patterns as those for the high-three plans, with the expected payoff increasing with age until the normal retirement age and then decreasing thereafter and the standard deviation of the payoff decreasing with age until the early 50s, before increasing thereafter. However, the magnitudes are notably different. The expected payoff increases from 16.5 percent at 25 to 21.2 percent at 35 to 33.2 percent at 55. These increases are much more modest than those for the high-three plans. Correspondingly, the standard deviation of the payoff is much smaller; it decreases from 3.8 percent at 25 to a minimum of 2.1 percent at 50 before increasing modestly to 2.4 percent at 55. That is, the indexed career average provides a much larger benefit to employees who enter employment at younger ages and the benefit offered is much less risky.

Indexed career-average with variable accrual factors and actuarial early and delayed retirement

The payoff for the indexed career-average with variable accrual factors is given by

\[
P(t, t') = \frac{a_{NRA} \times \sum_{s=t}^{t'-1} \left\{ f(a(s), s) \times \left( \frac{1+g}{1+r} \right)^{s-t} \times \frac{x(NRA)}{x(s)} \times \frac{(1+r)^s}{(1+r)^{NRA}} \right\}}{\sum_{s=t}^{t'-1} \left( \frac{1+g}{1+r} \right)^{s-t}} - c_r.
\]

(3.14)
and, in the special case where the index is equal to the real interest rate,

\[
P(t, t') = a_{NRA} \times \sum_{s=t}^{t'-1} \left\{ f(a(s), s) \times \left( \frac{1 + g}{1 + r} \right)^{s-t} \right\} - c.
\]

(3.15)

In contrast with the previous formulas, the payoff is under the (nearly) complete control of the policymakers. By selecting the schedule of accrual factors appropriately, the employer can achieve the desired payoffs for each potential career. However, control is not quite complete, because the average of the accrual factors used in the computation of benefits will depend on the rate of earnings growth relative to the real interest rate. Thus, two individuals who join the public sector workforce at the same age and retire at the same age but whose rates of earnings growth differ will receive modestly different benefits. In the relatively simple cases where one individual’s earnings grow at a faster rate than the other, that individual’s pension payoff will be more heavily influenced by the accrual factors at the older ages and higher levels of service associated with the end of the career while the other individual’s will depend more on those from early in the career. In the special case where the accrual factor is constant, this complication is of no importance.

Figure 38 plots the realized pension payoff as a function of the retirement age for select service levels using the s-shaped accrual schedule discussed previously. Holding service constant, the realized payoff is is the same for all ages and modestly higher for individuals with more service. As individuals progress through their career, the realized payoff increases. Regardless of age, the payoff is 18.9 percent for individuals with 10 years of service, 19.4 percent for individuals with 20 years of service, and 20.6 percent for individuals with 30 years of service. Table 4 shows the realized payoff for a wide range of age and service combinations, confirming the basic result.

Figures 39 and 40 show the expected payoff and the standard deviation of that payoff by the age of initial employment. The expected payoff decreases with age as individuals who join the public sector workforce at older ages are less likely to work until the higher service levels that result in an increased accrual factor. The standard deviation decreases with the starting age as individuals who start young have a chance at reaching the higher levels of service and receiving a greater relative benefit while individuals who start work at older
ages do not. Even more importantly, the standard deviation of the payoff is much reduced at all starting ages and for the older ages is very close to zero. Under this plan, the only variation in the payoff is that necessitated by the policymakers' decision to create incentives for long-tenure employees to remain on the job.

3.5 Conclusion

This analysis has investigated the financial incentives for continued employment, additional earnings, and job acceptance associated with four pension plan designs. Under existing plan designs, which are broadly similar to the high-three pension plan with percentage early retirement, an important role in the determination of the financial incentives is given to economic variables outside the control of the policymakers, such as trend inflation and the real interest rate. In addition, the choice of the benefit formula imposes an arbitrary structure on the incentives that is at odds with many of the stated goals for recruitment, retention, and retirement security. These include dramatically increasing incentives for continued work and job acceptance as individuals age, relatively little in the way of incentives for experienced employees to remain on the job, and substantial risk in the ultimate pension benefits workers receive.

The inflation-adjusted career-average pension and the indexed career-average pension with variable accrual factors considered here represent two alternative pension designs that allow policymakers more direct control over the financial incentives their plans create. In particular, under the indexed career-average pension with variable accrual factors—when the index is set equal to the real interest rate—policymakers have nearly complete control over the financial incentives for continued employment, additional earnings, and job acceptance. Furthermore, the risk associated with future pension benefits can be reduced to only that necessarily associated with failure to respond to the financial incentives as desired. Risk associated with elements of the pension plan that do not facilitate any recruitment or retention goals can be eliminated.

The essential difference between defined benefit and defined contribution plans is the treatment of asset-market risk. The sharp incentives that existing DB plans create for particular patterns of work and retirement are unnecessary. By selecting alternative accrual factors for use within the broad class of indexed career-average plans, policymakers can sever
the link between defined benefit plans and arbitrary financial incentives. Having done so, the choice between defined benefit and defined contribution plans can be based on their relative sensitivity to risky asset market returns. Policymakers can then design plans that generate reasonable financial incentives for continued work, moderate the incentives for manipulation of earnings in existing plans, and reduce the riskiness of benefits for employees arising from the arbitrary distribution of benefits across employees who follow different career paths.
References


Note: The one-year accrual rate is the increase in the present value of the pension benefit to which an employee is entitled as a result of working in the current year less the value of contributions to the pension plan made during the year divided by the wage. A nominal high-three pension with actuarial adjustment for early/delayed retirement provides benefits according to the formula

\[ b_t = f \times \text{service}_t \times \frac{1}{2} \left( w_{t-1} + w_{t-2} + w_{t-3} \right) \times \frac{\delta t}{a_s} \times (1 + r)^{-NRA}, \]

where \( f \) is an accrual factor specified by the plan, \( a_s \) the cost of a $1 annuity beginning at age \( s \), and \( r \) the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 1. One-Year Accrual Rate by Age for Three Careers, Nominal High-Three With Actuarial Early/Delayed Retirement

Figure 2. One-Year Accrual Rate by Age at Constant Service, Nominal High-Three With Actuarial Early/Delayed Retirement
Figure 3. One-Year Accrual Rate by Service at Constant Age, Nominal High-Three With Actuarial Early/Delayed Retirement

Note: The one-year accrual rate is the increase in the present value of the pension benefit to which an employee is entitled as a result of working in the current year less the value of contributions to the pension plan made during the year divided by the wage. A nominal high-three pension with actuarial adjustment for early/delayed retirement provides benefits according to the formula $b_t = f \times \text{service} \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \times \frac{\Delta u_{i}}{a_s} \times (1 + r)^{t-NRA}$, where $f$ is an accrual factor specified by the plan, $a_s$ the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 4. Accrual Rate Through Normal Retirement Age for Three Careers, Nominal High-Three With Actuarial Early/Delayed Retirement

Note: The accrual rate through the normal retirement age is the increase in the present value of the pension benefit to which an employee is entitled as a result of working until the normal retirement age less the present value of contributions to the pension plan made during the period divided by the wage (accounting for the probability of death/disability prior to the NRA). A nominal high-three pension with actuarial adjustment for early/delayed retirement provides benefits according to the formula $b_t = f \times \text{service} \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \times \frac{\Delta u_{i}}{a_s} \times (1 + r)^{t-NRA}$, where $f$ is an accrual factor specified by the plan, $a_s$ the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 5. One-Year Accrual Rate by Age for Three Careers, Nominal High-Three With Percentage Reduction for Early Retirement

Note: The one-year accrual rate is the increase in the present value of the pension benefit to which an employee is entitled as a result of working in the current year less the value of contributions to the pension plan made during the year divided by the wage. A nominal high-three pension with percentage reduction for early retirement provides benefits according to the formula

\[ b_t = (1 - \max(0, e \times (NRA - t))) \times f \times \text{service}_t \times \frac{1}{2} (w_{t-1} + w_{t-2} + w_{t-3}) \]

where \( f \) is an accrual factor specified by the plan and \( e \) the early retirement reduction rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 6. One-Year Accrual Rate by Age at Constant Service, Nominal High-Three With Percentage Reduction for Early Retirement

Note: The one-year accrual rate is the increase in the present value of the pension benefit to which an employee is entitled as a result of working in the current year less the value of contributions to the pension plan made during the year divided by the wage. A nominal high-three pension with percentage reduction for early retirement provides benefits according to the formula

\[ b_t = (1 - \max(0, e \times (NRA - t))) \times f \times \text{service}_t \times \frac{1}{2} (w_{t-1} + w_{t-2} + w_{t-3}) \]

where \( f \) is an accrual factor specified by the plan and \( e \) the early retirement reduction rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 7. One-Year Accrual Rate by Service at Constant Age, Nominal High-Three With Percentage Reduction for Early Retirement

Note: The one-year accrual rate is the increase in the present value of the pension benefit to which an employee is entitled as a result of working in the current year less the value of contributions to the pension plan made during the year divided by the wage. A nominal high-three pension with percentage reduction for early retirement provides benefits according to the formula $b_t = (1 - \max(0, e \times (NRA - t))) \times f \times \text{service} \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3})$, where $f$ is an accrual factor specified by the plan and $e$ the early retirement reduction rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 8. Accrual Rate Through Normal Retirement Age for Three Careers, Nominal High-Three With Percentage Reduction for Early Retirement

Note: The accrual rate through the normal retirement age is the increase in the present value of the pension benefit to which an employee is entitled as a result of working until the normal retirement age less the present value of contributions to the pension plan made during the period divided by the wage (accounting for the probability of death/disability prior to the NRA). A nominal high-three pension with percentage reduction for early retirement provides benefits according to the formula $b_t = (1 - \max(0, e \times (NRA - t))) \times f \times \text{service} \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3})$, where $f$ is an accrual factor specified by the plan and $e$ the early retirement reduction rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 9. One-Year Accrual Rate by Age for Three Careers, Inflation-Adjusted Career Average With Actuarial Early Retirement

Note: The one-year accrual rate is the increase in the present value of the pension benefit to which an employee is entitled as a result of working in the current year less the value of contributions to the pension plan made during the year divided by the wage. An inflation-adjusted career average pension with actuarial adjustment for early retirement provides benefits according to the formula $b_t = f \times \text{service}_t \times \sum_{s=0}^{t-1} (1 + \pi)^{t-s} w_s \times \min \left( 1, \frac{\text{NRA}}{\text{trans}} \times \left( \frac{1+\pi}{1+r} \right)^{t-\text{NRA}} \right)$, where $f$ is an accrual factor specified by the plan, $\pi$ the inflation rate, $\alpha_s$ the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 10. One-Year Accrual Rate by Age at Constant Service, Inflation-Adjusted Career Average With Actuarial Early Retirement

Note: The one-year accrual rate is the increase in the present value of the pension benefit to which an employee is entitled as a result of working in the current year less the value of contributions to the pension plan made during the year divided by the wage. An inflation-adjusted career average pension with actuarial adjustment for early retirement provides benefits according to the formula $b_t = f \times \text{service}_t \times \sum_{s=0}^{t-1} (1 + \pi)^{t-s} w_s \times \min \left( 1, \frac{\text{NRA}}{\text{trans}} \times \left( \frac{1+\pi}{1+r} \right)^{t-\text{NRA}} \right)$, where $f$ is an accrual factor specified by the plan, $\pi$ the inflation rate, $\alpha_s$ the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 11. One-Year Accrual Rate by Service at Constant Age, Inflation-Adjusted Career Average With Actuarial Early Retirement

Note: The one-year accrual rate is the increase in the present value of the pension benefit to which an employee is entitled as a result of working in the current year less the value of contributions to the pension plan made during the year divided by the wage. An inflation-adjusted career average pension with actuarial adjustment for early retirement provides benefits according to the formula $b_t = f \times \text{service}_t \times \left( \frac{1}{\text{service}_0} \times \sum_{s=t_0}^{t-1} (1 + \pi)^{t-s} w_s \right) \times \min \left( 1, \frac{a_{NRA}}{a_s} \times \left( \frac{1+r}{1+\pi} \right)^{t-NRA} \right)$, where $f$ is an accrual factor specified by the plan, $\pi$ the inflation rate, $a_s$ the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 12. Accrual Rate Through Normal Retirement Age for Three Careers, Inflation-Adjusted Career Average With Actuarial Early Retirement

Note: The accrual rate through the normal retirement age is the increase in the present value of the pension benefit to which an employee is entitled as a result of working until the normal retirement age less the present value of contributions to the pension plan made during the period divided by the wage (accounting for the probability of death/disability prior to the NRA). An inflation-adjusted career average pension with actuarial adjustment for early retirement provides benefits according to the formula $b_t = f \times \text{service}_t \times \left( \frac{1}{\text{service}_0} \times \sum_{s=t_0}^{t-1} (1 + \pi)^{t-s} w_s \right) \times \min \left( 1, \frac{a_{NRA}}{a_s} \times \left( \frac{1+r}{1+\pi} \right)^{t-NRA} \right)$, where $f$ is an accrual factor specified by the plan, $\pi$ the inflation rate, $a_s$ the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 13. One-Year Accrual Rate by Age for Three Careers, Indexed Career-Average With Variable Accrual Factors and Actuarial Early/Delayed Retirement

Note: The one-year accrual rate is the increase in the present value of the pension benefit to which an employee is entitled as a result of working in the current year less the value of contributions to the pension plan made during the year divided by the wage. An indexed career-average pension with variable accrual factors and actuarial adjustment for early/delayed retirement provides benefits according to the formula

$$b_t = \sum_{s=a}^{s+b} f(a(s), s) \times w_s \times x(NRA) \times \alpha_{a(s)} \times (1 + r)^{t-NRA}$$

where \(f(a, s)\) is the accrual factor as a function of age and service specified by the plan, \(x\) is an index used to adjust the wage history, \(a_s\) the cost of a $1 annuity beginning at age \(s\), and \(r\) the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 14. One-Year Accrual Rate by Age at Constant Service, Indexed Career-Average with Variable Accrual Factors and Actuarial Early/Delayed Retirement

Note: The one-year accrual rate is the increase in the present value of the pension benefit to which an employee is entitled as a result of working in the current year less the value of contributions to the pension plan made during the year divided by the wage. An indexed career-average pension with variable accrual factors and actuarial adjustment for early/delayed retirement provides benefits according to the formula

$$b_t = \sum_{s=a}^{s+b} f(a(s), s) \times w_s \times x(NRA) \times \alpha_{a(s)} \times (1 + r)^{t-NRA}$$

where \(f(a, s)\) is the accrual factor as a function of age and service specified by the plan, \(x\) is an index used to adjust the wage history, \(a_s\) the cost of a $1 annuity beginning at age \(s\), and \(r\) the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 15. One-Year Accrual Rate by Service at Constant Age, Indexed Career-Average With Variable Accrual Factors and Actuarial Early/Delayed Retirement

Note: The one-year accrual rate is the increase in the present value of the pension benefit to which an employee is entitled as a result of working in the current year less the value of contributions to the pension plan made during the year divided by the wage. An indexed career-average pension with variable accrual factors and actuarial adjustment for early/delayed retirement provides benefits according to the formula

$$b_t = \sum_{s=s_0}^{s_{t-1}} f(a(s), s) \times w_s \times \frac{(NRA)}{x(s)} \times a_{s} \times (1 + r)^{t-NRA},$$

where $$f(a, s)$$ is the accrual factor as a function of age and service specified by the plan, $$x$$ is an index used to adjust the wage history, $$a_s$$ the cost of a $1 annuity beginning at age $$s$$, and $$r$$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 16. Accrual Rate Through Normal Retirement Age for Three Careers, Indexed Career-Average With Variable Accrual Factors and Actuarial Early/Delayed Retirement

Note: The accrual rate through the normal retirement age is the increase in the present value of the pension benefit to which an employee is entitled as a result of working until the normal retirement age less the present value of contributions to the pension plan made during the period divided by the wage (accounting for the probability of death/disability prior to the NRA). An indexed career-average pension with variable accrual factors and actuarial adjustment for early/delayed retirement provides benefits according to the formula

$$b_t = \sum_{s=s_0}^{s_{t-1}} f(a(s), s) \times w_s \times \frac{(NRA)}{x(s)} \times a_{s} \times (1 + r)^{t-NRA},$$

where $$f(a, s)$$ is the accrual factor as a function of age and service specified by the plan, $$x$$ is an index used to adjust the wage history, $$a_s$$ the cost of a $1 annuity beginning at age $$s$$, and $$r$$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 17. Implicit Subsidy for Earnings by Start Age, Employees Intending to Retire at 60, Nominal High-Three With Actuarial Early/Delayed Retirement

Note: The implicit subsidy for earnings is the derivative of the difference between the present value of the pension benefit and the lifetime contributions with respect to current-year earnings. A nominal high-three pension with actuarial adjustment for early/delayed retirement provides benefits according to the formula $b_t = f \times \text{service}_t \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \times \frac{\Delta_\text{act}}{a_s} \times (1 + r)^{-NRA}$, where $f$ is an accrual factor specified by the plan, $a_s$ the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 18. Ratio of Pension Value Less Contributions to Lifetime Earnings by Nominal Earnings Growth Rate, Employees Retiring at 60 With 20 Years of Service, Nominal High-Three With Actuarial Early/Delayed Retirement

Note: A nominal high-three pension with actuarial adjustment for early/delayed retirement provides benefits according to the formula $b_t = f \times \text{service}_t \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \times \frac{\Delta_\text{act}}{a_s} \times (1 + r)^{-NRA}$, where $f$ is an accrual factor specified by the plan, $a_s$ the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 19. Ratio of Pension Value Less Contributions to Lifetime Earnings by Age of Promotion With 35% Pay Increase, Employees Retiring at 60 With 35 Years of Service, Nominal High-Three With Actuarial Early/Delayed Retirement

Note: A nominal high-three pension with actuarial adjustment for early/delayed retirement provides benefits according to the formula $b_t = f \times \text{service}_t \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \times \frac{\Delta A}{\Delta a} \times (1 + r)^{-NRA}$, where $f$ is an accrual factor specified by the plan, $a_s$ the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 20. Implicit Subsidy for Earnings for Four Careers, Employees Intending to Retire at 60, Nominal High-Three With Percentage Reduction for Early Retirement

Note: The implicit subsidy for earnings is the derivative of the difference between the present value of the pension benefit and the lifetime contributions with respect to current-year earnings. A nominal high-three pension with percentage reduction for early retirement provides benefits according to the formula $b_t = (1 - \max(0, e \times (NRA - t))) \times f \times \text{service}_t \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3})$, where $f$ is an accrual factor specified by the plan and $e$ the early retirement reduction rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 21. Ratio of Pension Value Less Contributions to Lifetime Earnings by Nominal Earnings Growth Rate, Employees Retiring at 60 With 20 Years of Service, Nominal High-Three With Percentage Reduction for Early Retirement

![Graph showing ratio of pension value less contributions to lifetime earnings by nominal earnings growth rate.](image)

Note: A nominal high-three pension with percentage reduction for early retirement provides benefits according to the formula \( b_t = (1 - \max(0, e \times (NRA - t))) \times f \times \text{service} \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \), where \( f \) is an accrual factor specified by the plan and \( e \) the early retirement reduction rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 22. Ratio of Pension Value Less Contributions to Lifetime Earnings by Age of Promotion With 35% Pay Increase, Employees Retiring at 60 With 35 Years of Service, Nominal High-Three With Percentage Reduction for Early Retirement

![Graph showing ratio of pension value less contributions to lifetime earnings by age of promotion.](image)

Note: A nominal high-three pension with percentage reduction for early retirement provides benefits according to the formula \( b_t = (1 - \max(0, e \times (NRA - t))) \times f \times \text{service} \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \), where \( f \) is an accrual factor specified by the plan and \( e \) the early retirement reduction rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 23. Implicit Subsidy for Earnings for Four Careers, Employees Intending to Retire at 60, Inflation-Adjusted Career Average With Actuarial Early Retirement

Note: The implicit subsidy for earnings is the derivative of the difference between the present value of the pension benefit and the lifetime contributions with respect to current-year earnings. An inflation-adjusted career average pension with actuarial adjustment for early retirement provides benefits according to the formula:

\[ b_t = \frac{f \times \text{service}_t \times \sum_{s=t}^{t-1} (1 + \pi)^{t-s} w_s}{\text{service}_t} \times \min\left(1, \frac{\text{a}}{\text{a}} \times \left(\frac{1 + \pi}{1 + \pi}\right)^{t-NRA}\right) \],

where \( f \) is an accrual factor specified by the plan, \( \pi \) the inflation rate, \( a \) the cost of a $1 annuity beginning at age \( s \), and \( r \) the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 24. Ratio of Pension Value Less Contributions to Lifetime Earnings by Nominal Earnings Growth Rate, Employees Retiring at 60 With 20 Years of Service, Inflation-Adjusted Career Average With Actuarial Early Retirement

Note: An inflation-adjusted career average pension with actuarial adjustment for early retirement provides benefits according to the formula:

\[ b_t = \frac{f \times \text{service}_t \times \sum_{s=t}^{t-1} (1 + \pi)^{t-s} w_s}{\text{service}_t} \times \min\left(1, \frac{\text{a}}{\text{a}} \times \left(\frac{1 + \pi}{1 + \pi}\right)^{t-NRA}\right) \],

where \( f \) is an accrual factor specified by the plan, \( \pi \) the inflation rate, \( a \) the cost of a $1 annuity beginning at age \( s \), and \( r \) the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 25. Ratio of Pension Value Less Contributions to Lifetime Earnings by Age of Promotion With 35% Pay Increase, Employees Retiring at 60 With 35 Years of Service, Inflation-Adjusted Career Average With Actuarial Early Retirement

Note: An inflation-adjusted career average pension with actuarial adjustment for early retirement provides benefits according to the formula $b_t = f \times \text{service}_t \times \left( \frac{1}{\text{service}_t} \times \sum_{s=1}^{t-1} (1 + \pi)^{t-s} \text{w}_s \right) \times \min \left( \frac{\alpha \Delta R \Delta}{\alpha} \times \left( \frac{1 + \pi}{1 + \pi} \right)^{t-NRA} \right)$, where $f$ is an accrual factor specified by the plan, $\pi$ the inflation rate, $\alpha$, the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 26. Implicit Subsidy for Earnings for Four Careers, Employees Intending to Retire at 60, Indexed Career-Average With Variable Accrual Factors and Actuarial Early/Delayed Retirement

Note: The implicit subsidy for earnings is the derivative of the difference between the present value of the pension benefit and the lifetime contributions with respect to current-year earnings. An indexed career-average pension with variable accrual factors and actuarial adjustment for early/delayed retirement provides benefits according to the formula $b_t = \sum_{s=0}^{t-1} f(a,s) \times \text{w}_s \times \pi(NRA) \times \alpha \Delta R \Delta \times (1 + r)^{t-NRA}$, where $f(a,s)$ is the accrual factor as a function of age and service specified by the plan, $z$ is an index used to adjust the wage history, $\alpha$, the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 27. Ratio of Pension Value Less Contributions to Lifetime Earnings by Nominal Earnings Growth Rate, Employees Retiring at 60 With 20 Years of Service, Indexed Career-Average With Variable Accrual Factors and Actuarial Early/Delayed Retirement

Note: An indexed career-average pension with variable accrual factors and actuarial adjustment for early/delayed retirement provides benefits according to the formula \( b_t = \sum_{s=t_0}^{t-1} f(a(s), s) \times w_{x} \times \frac{x(NRA)}{x(s)} \times \frac{a_{1+s}}{a_{t}} \times (1 + r)^{-NRA} \), where \( f(a, s) \) is the accrual factor as a function of age and service specified by the plan, \( x \) is an index used to adjust the wage history, \( a_{t} \) the cost of a $1 annuity beginning at age \( s \), and \( r \) the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 28. Ratio of Pension Value Less Contributions to Lifetime Earnings by Age of Promotion With 35% Pay Increase, Employees Retiring at 60 With 35 Years of Service, Indexed Career-Average With Variable Accrual Factors and Actuarial Early/Delayed Retirement

Note: An indexed career-average pension with variable accrual factors and actuarial adjustment for early/delayed retirement provides benefits according to the formula \( b_t = \sum_{s=t_0}^{t-1} f(a(s), s) \times w_{x} \times \frac{x(NRA)}{x(s)} \times \frac{a_{1+s}}{a_{t}} \times (1 + r)^{-NRA} \), where \( f(a, s) \) is the accrual factor as a function of age and service specified by the plan, \( x \) is an index used to adjust the wage history, \( a_{t} \) the cost of a $1 annuity beginning at age \( s \), and \( r \) the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 29. Ratio of Pension Value Less Contributions to Lifetime Earnings by Retirement Age for Select Service Levels, Nominal High-Three With Actuarial Early/Delayed Retirement

Note: A nominal high-three pension with actuarial adjustment for early/delayed retirement provides benefits according to the formula $b_t = f \times \text{service} \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \times \frac{\Delta NTA}{a_r} \times (1 + r)^{t-\text{NRA}}$, where $f$ is an accrual factor specified by the plan, $a_r$ the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 30. Expected Ratio of Pension Value Less Contributions to Lifetime Earnings by Age of Initial Employment, Nominal High-Three With Actuarial Early/Delayed Retirement

Note: A nominal high-three pension with actuarial adjustment for early/delayed retirement provides benefits according to the formula $b_t = f \times \text{service} \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \times \frac{\Delta NTA}{a_r} \times (1 + r)^{t-\text{NRA}}$, where $f$ is an accrual factor specified by the plan, $a_r$ the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 31. Standard Deviation of Ratio of Pension Value Less Contributions to Lifetime Earnings by Age of Initial Employment, Nominal High-Three With Actuarial Early/Delayed Retirement

Note: A nominal high-three pension with actuarial adjustment for early/delayed retirement provides benefits according to the formula \( b_t = f \times \text{service} \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \times \frac{e^{NRA}}{a} \times (1 + r)^{-NRA} \), where \( f \) is an accrual factor specified by the plan, \( a \) the cost of a $1 annuity beginning at age \( s \), and \( r \) the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 32. Ratio of Pension Value Less Contributions to Lifetime Earnings by Retirement Age for Select Service Levels, Nominal High-Three With Percentage Reduction for Early Retirement

Note: A nominal high-three pension with percentage reduction for early retirement provides benefits according to the formula \( b_t = (1 - \max(0, e \times (NRA - t))) \times f \times \text{service} \times \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \), where \( f \) is an accrual factor specified by the plan and \( e \) the early retirement reduction rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 33. Expected Ratio of Pension Value Less Contributions to Lifetime Earnings by Age of Initial Employment, Nominal High-Three With Percentage Reduction for Early Retirement

![Graph of Figure 33]

Note: A nominal high-three pension with percentage reduction for early retirement provides benefits according to the formula $b_t = (1 - \max(0, e \times (NRA - t))) \times f \times service_t \times \frac{1}{3} (w_t - 1 + w_t - 2 + w_t - 3)$, where $f$ is an accrual factor specified by the plan and $e$ the early retirement reduction rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 34. Standard Deviation of Ratio of Pension Value Less Contributions to Lifetime Earnings by Age of Initial Employment, Nominal High-Three With Percentage Reduction for Early Retirement

![Graph of Figure 34]

Note: A nominal high-three pension with percentage reduction for early retirement provides benefits according to the formula $b_t = (1 - \max(0, e \times (NRA - t))) \times f \times service_t \times \frac{1}{3} (w_t - 1 + w_t - 2 + w_t - 3)$, where $f$ is an accrual factor specified by the plan and $e$ the early retirement reduction rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 35. Ratio of Pension Value Less Contributions to Lifetime Earnings by Retirement Age for Select Service Levels, Inflation-Adjusted Career Average With Actuarial Early Retirement

Note: An inflation-adjusted career average pension with actuarial adjustment for early retirement provides benefits according to the formula $b_t = f \times \text{service}_t \times \left( \frac{1}{\text{service}_t} \times \sum_{s=1}^{t-1} (1 + \pi)^{t-s} a_s \right) \times \min \left( 1, \frac{0.9 \times 1.06}{1.06} \times \left( \frac{1+\tau}{1+\pi} \right)^{1-NRA} \right)$, where $f$ is an accrual factor specified by the plan, $\pi$ the inflation rate, $a_s$ the cost of a $1$ annuity beginning at age $s$, and $\tau$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 36. Expected Ratio of Pension Value Less Contributions to Lifetime Earnings by Age of Initial Employment, Inflation-Adjusted Career Average With Actuarial Early Retirement

Note: An inflation-adjusted career average pension with actuarial adjustment for early retirement provides benefits according to the formula $b_t = f \times \text{service}_t \times \left( \frac{1}{\text{service}_t} \times \sum_{s=1}^{t-1} (1 + \pi)^{t-s} a_s \right) \times \min \left( 1, \frac{0.9 \times 1.06}{1.06} \times \left( \frac{1+\tau}{1+\pi} \right)^{1-NRA} \right)$, where $f$ is an accrual factor specified by the plan, $\pi$ the inflation rate, $a_s$ the cost of a $1$ annuity beginning at age $s$, and $\tau$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 37. Standard Deviation of Ratio of Pension Value Less Contributions to Lifetime Earnings by Age of Initial Employment, Inflation-Adjusted Career Average With Actuarial Early Retirement

Note: An inflation-adjusted career average pension with actuarial adjustment for early retirement provides benefits according to the formula
\[ b_t = f \times \text{service} \times \left( \frac{1}{\text{service}} \times \sum_{s=1}^{t} (1 + \pi)^{t-s} w_s \right) \times \min \left( \frac{NRA}{\text{.any}} \times \left( \frac{1 + r}{1 + \pi} \right)^{t-NRA} \right), \]
where \( f \) is an accrual factor specified by the plan, \( \pi \) the inflation rate, \( a_s \) the cost of a $1 annuity beginning at age \( s \), and \( r \) the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 38. Ratio of Pension Value Less Contributions to Lifetime Earnings by Retirement Age for Select Service Levels, Indexed Career-Average With Variable Accrual Factors and Actuarial Early/Delayed Retirement

Note: An indexed career-average pension with variable accrual factors and actuarial adjustment for early/delayed retirement provides benefits according to the formula
\[ b_t = \sum_{s=1}^{t} f(a(s), s) \times w_s \times \frac{x(NRA)}{x(s)} \times \frac{a_s}{w_s} \times (1 + r)^{t-NRA}, \]
where \( f(a, s) \) is the accrual factor as a function of age and service specified by the plan, \( x \) is an index used to adjust the wage history, \( a_s \) the cost of a $1 annuity beginning at age \( s \), and \( r \) the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Figure 39. Expected Ratio of Pension Value Less Contributions to Lifetime Earnings by Age of Initial Employment, Indexed Career-Average With Variable Accrual Factors and Actuarial Early/Delayed Retirement

Note: An indexed career-average pension with variable accrual factors and actuarial adjustment for early/delayed retirement provides benefits according to the formula $b_t = \sum_{s=t}^{t-1} f(a(s), s) \times w_s \times \frac{x(NRA)}{x(s)} \times \frac{a(s)}{a_t} \times (1 + r)^{t-NRA}$, where $f(a, s)$ is the accrual factor as a function of age and service specified by the plan, $x$ is an index used to adjust the wage history, $a_s$ the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Figure 40. Standard Deviation of Ratio of Pension Value Less Contributions to Lifetime Earnings by Age of Initial Employment, Indexed Career-Average With Variable Accrual Factors and Actuarial Early/Delayed Retirement

Note: An indexed career-average pension with variable accrual factors and actuarial adjustment for early/delayed retirement provides benefits according to the formula $b_t = \sum_{s=t}^{t-1} f(a(s), s) \times w_s \times \frac{x(NRA)}{x(s)} \times \frac{a(s)}{a_t} \times (1 + r)^{t-NRA}$, where $f(a, s)$ is the accrual factor as a function of age and service specified by the plan, $x$ is an index used to adjust the wage history, $a_s$ the cost of a $1$ annuity beginning at age $s$, and $r$ the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Table 1. Ratio of Pension Value Less Contributions to Lifetime Earnings by Age and Service, Nominal High-Three With Actuarial Early/Delayed Retirement

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Note: A nominal high-three pension with actuarial adjustment for early/delayed retirement provides benefits according to the formula \( b_t = f \times \text{service} \times \left( \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \times \frac{\text{NRA}}{a_t} \times (1 + r)^{t-NRA} \right) \), where \( f \) is an accrual factor specified by the plan, \( a_t \) the cost of a $1 annuity beginning at age \( s \), and \( r \) the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Table 2. Ratio of Pension Value Less Contributions to Lifetime Earnings by Age and Service, Nominal High-Three With Percentage Reduction for Early Retirement

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Note: A nominal high-three pension with percentage reduction for early retirement provides benefits according to the formula \( b_t = (1 - \max(0, e \times (NRA - t))) \times f \times \text{service} \times \left( \frac{1}{3} (w_{t-1} + w_{t-2} + w_{t-3}) \right) \), where \( f \) is an accrual factor specified by the plan and \( e \) the early retirement reduction rate. Plan parameters as well as economic and demographic assumptions are described in the text.
Table 3. Ratio of Pension Value Less Contributions to Lifetime Earnings by Age and Service, Inflation-Adjusted Career Average With Actuarial Early Retirement

| Age | Years of Service | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|-----|------------------|---|----|----|----|----|----|----|----|----|
| 25  |                  | 13.3|   |    |    |    |    |    |    |    |
| 30  |                  | 15.7|   |    |    |    |    |    |    |    |
| 35  |                  | 18.5| 16.8| 15.5|    |    |    |    |    |    |
| 40  |                  | 21.6| 19.7| 18.2| 16.9|    |    |    |    |    |
| 45  |                  | 25.0| 22.9| 21.3| 19.7| 18.3|    |    |    |    |
| 50  |                  | 29.0| 26.6| 24.7| 23.0| 21.4| 19.9|    |    |    |
| 55  |                  | 33.5| 30.7| 28.6| 26.7| 24.9| 23.2| 21.6|    |    |
| 60  |                  | 38.5| 35.4| 33.0| 30.8| 28.8| 26.9| 25.1| 23.4|    |
| 65  |                  | 34.0| 31.2| 29.1| 27.1| 25.3| 23.5| 21.9| 20.4|    |
| 70  |                  | 29.1| 26.7| 24.8| 23.1| 21.5| 20.0| 18.6| 17.3|    |

Note: An inflation-adjusted career average pension with actuarial adjustment for early retirement provides benefits according to the formula \( b_t = f \times \text{service} \times \left( \frac{1}{\text{service}} \times \sum_{t=0}^{t-1} (1 + \pi)^{t-s} w_s \right) \times \min \left( 1, \frac{a_s \times A}{a_r} \times \left( \frac{1+r}{1+r} \right)^{t-NRA} \right) \), where \( f \) is an accrual factor specified by the plan, \( \pi \) the inflation rate, \( a_s \) the cost of a $1 annuity beginning at age \( s \), and \( r \) the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.

Table 4. Ratio of Pension Value Less Contributions to Lifetime Earnings by Age and Service, Indexed Career-Average With Variable Accrual Factors and Actuarial Early/Delayed Retirement

| Age | Years of Service | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|-----|------------------|---|----|----|----|----|----|----|----|----|
| 25  |                  | 18.9|   |    |    |    |    |    |    |    |
| 30  |                  | 18.9|   |    |    |    |    |    |    |    |
| 35  |                  | 18.9| 18.9| 19.1|    |    |    |    |    |    |
| 40  |                  | 18.9| 18.9| 19.1| 19.4|    |    |    |    |    |
| 45  |                  | 18.9| 18.9| 19.1| 19.4| 19.9|    |    |    |    |
| 50  |                  | 18.9| 18.9| 19.1| 19.4| 19.9| 20.6|    |    |    |
| 55  |                  | 18.9| 18.9| 19.1| 19.4| 19.9| 20.6| 21.3|    |    |
| 60  |                  | 18.9| 18.9| 19.1| 19.4| 19.9| 20.6| 21.3| 21.9|    |
| 65  |                  | 18.9| 18.9| 19.1| 19.4| 19.9| 20.6| 21.3| 21.9|    |
| 70  |                  | 18.9| 18.9| 19.1| 19.4| 19.9| 20.6| 21.3| 21.9|    |

Note: An indexed career-average pension with variable accrual factors and actuarial adjustment for early/delayed retirement provides benefits according to the formula \( b_t = \sum_{s=0}^{t-1} f(a(s), s) \times w_s \times \frac{z(NRA)}{z(s)} \times \frac{a_s \times A}{a_r} \times \left( \frac{1+r}{1+r} \right)^{t-NRA} \), where \( f(a,s) \) is the accrual factor as a function of age and service specified by the plan, \( x \) is an index used to adjust the wage history, \( a_s \) the cost of a $1 annuity beginning at age \( s \), and \( r \) the nominal discount rate. Plan parameters as well as economic and demographic assumptions are described in the text.