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ABSTRACT

The Oregon Public Employees Retirement System (PERS) is a hybrid pension plan that provides employees the security of a defined benefit (DB) pension plus the option to receive instead retirement benefits based on a defined contribution-style (DC) retirement account. We use PERS administrative data for 1990 to 2003 to study the effect of this hybrid design on employers' costs and employees' retirement-timing decisions. We have four findings. First, the option built into PERS is costly for employers to provide. Ex post, average retirement benefits are 49% higher in the hybrid plan than they would have been in a traditional DB plan. For the typical retiree, simulations show that our ex post estimate lies between the 50th and 75th percentiles of the ex ante distribution. Second, the hybrid plan distorts employees' retirement timing decisions relative to a traditional DB plan. Looking across benefit formulas, we find that as an employee's DC benefit increases above her DB benefit, so does the probability that she retires before the normal retirement age. Third, we find that retirement timing decisions respond to two sources of exogenous variation in the level of the DC benefit. Finally, we find evidence of peer effects in that employees respond more strongly to their own retirement incentives when more of their coworkers face similar incentives. The retirement waves that result from employees seeking to avoid declines in pension benefits are likely to impose significant administrative costs on employers.

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1. Introduction

Employers must weigh the expected benefits of the pension plans they offer to employees against the expected costs. From an employer's perspective, offering a more generous pension plan has two potential benefits. First, it may allow the employer to attract higher quality employees. Second, it may reduce employee turnover. Governor Tom McCall emphasized both of these potential benefits in 1967, when arguing to reform Oregon's Public Employees Retirement System (PERS):[1]

> "We are in a time of inflation and high employment. I have personal experience with the difficulty of recruiting top quality people at the available salaries and personal knowledge of the real sacrifices made by some who have accepted positions in my administration…. At all levels our state employment has shown heavy turnover. This requires extensive recruiting and training programs and threatens a real loss of competency if not checked…."

The implication was that a more generous pension plan would improve the quality of the services provided by state and local employers and reduce the administrative costs associated with employee turnover. On the other hand, increasing the expected retirement benefit payments imposes a direct cost on employers who must cover the larger pension payments. It may also impose indirect costs insofar as the changes to plan generosity affect employee behavior.

PERS was created in 1946 as a simple "money-purchase system," with benefits capped at $125 per month. Between 1946 and 1990, PERS evolved into a pension plan with both defined benefit (DB) and defined contribution (DC) elements.[2] The DB half of the plan offers a monthly life annuity payment based on the employee's salary and years of service. The DC half consists of a limited DC-style retirement account that can be partially or completely annuitized at retirement. To be clear, the DC elements in PERS differ significantly from those in a traditional 401(k) plan. Oregon manages the investments, provides a guaranteed rate of return to employees with the longest tenure of at least 8%, and, as shown in Chalmers and Reuter (2012), calculates annuity payouts using annuity factors that are better than actuarially fair. At retirement, PERS automatically pays each employee the *maximum* retirement benefits for which she is eligible. The fact that employees can expect to receive higher retirement benefits when equity market returns have been high makes the pension more generous to employees—and more expensive to employers—than if PERS only used the DB benefit formula. Similarly, the fact that employees are insured against downside market risk makes the pension more generous to employees—and

[1] The quote comes from page 12 of "The Oregon Public Employees Retirement System History, the First 60 Years," published by PERS on July 6, 2010.

[2] See Snell (2012) and the following link for a listing of state and local plans that provide hybrid benefits plans that share some common characteristics with the Oregon plan. http://www.nasra.org/resources/HybridBrief.pdf.

more expensive to employers—than if PERS only offered a collective DC benefit.

In this paper, we study the effect of PERS' hybrid structure on both employers' pension costs and employees' retirement-timing decisions. We begin by comparing the actual retirement benefits of PERS retirees to the hypothetical benefits they would have received if PERS were a traditional DB plan. We find that the incremental costs of the hybrid pension plan are economically significant. One way to measure these costs is as the expected present values of the retirement benefits owed to employees who retire during our sample period, 1990 to 2003. We find that retirement benefits are 57.3% higher under the hybrid pension plan than they would have been under the DB benefit formula in PERS, increasing employers' costs by $7 billion. We also find that more than half of the additional costs are due to the use of annuity factors that are better than actuarially fair.

Another way to measure the incremental employer costs is to calculate the replacement rate employers pay per year of service. Under its DB benefit formula, the average employee would have received 1.63% of her final average monthly salary per year of service.[3] To match the actual benefit payments we observe under the hybrid plan, the average payout factor would need to be 2.43%, which is 49.2% higher. When we simulate the distribution of retirement benefits using PERS plan features as of January 1990 and historical return data from 1957 to 1989, we obtain distributions of this ratio for different employees. For a typical employee, who retirees at age 60 with 20 years of service, we observe DC benefits that are 30% higher than DB at the 25th percentile, 40% higher at the median, and 53% higher at the 75th percentile. In this case, our *ex post* estimate falls between the 50th and 75th percentiles of the *ex ante* distribution.

While our data do not allow us to document the effectiveness of PERS in attracting, retaining, or reducing the costs of employee turnover *per se*, we are able to document strong evidence that the hybrid pension plan distorts employee retirement behavior. The simplest way to demonstrate these distortions is to note that as average retirement benefits increase above the levels they would be in a traditional DB plan, the probability of retiring before the normal retirement age increases. In part, this pattern reflects the fact the high market returns of the 1990s allowed some retirees to earn more in retirement benefits than they earned in salary. To the extent that the hybrid pension allows employees to fund their retirement after fewer years of service, it will increase employee turnover rates, which will, in turn, increase administrative costs as

[3] The actual payout factor in the DB formula is 1.67% for general service employees and 2.00% for police and fire officers. The average realized payout factor of 1.63% reflects the relatively small number of police and fire officers and the impact of the early retirement penalties associated with retirements before the normal retirement age.

employers must hire and train more employees.[4]

To provide more direct evidence on the link between pension design and retirement-timing decisions, we exploit two sources of exogenous variation in the level of the DC benefit. The first arises from the fact that, until January 2000, PERS calculated returns earned by the DC-style accounts only once per year, in March. For employees retiring in other months, DC account balances were determined by extending last year's return forward, providing them with the option to exploit "stale returns" (in the spirit of Stanton (2000)). Consider an employee trying to decide whether to retire in February 1993 or March 1993. When she retires in February 1993, PERS uses the 15% annual return from 1991 to determine the return in 1992 and the first two months of 1993. When she retires in March 1993, PERS instead uses the "finalized" rate of 8%, resulting in significantly lower retirement benefits. We find evidence that retirement timing decisions respond to retirement incentives due to stale returns. This is true both in regressions predicting individual retirement decisions and in graphs showing how the number of retirements in January and February (when employees are best able to estimate the retirement incentive due to stale returns) falls sharply after PERS eliminates the use of stale returns in January 2000. However, we also find that several hundred of the employees who retired in February, and therefore had DC benefits calculated using estimated prior-year returns, would have been better off retiring in March, when prior-year returns were finalized.

The second source of exogenous variation arises from a change that PERS made in July 2003 to the annuity factors used to convert an employee's retirement account balance into an initial monthly retirement benefit. Because life expectancies had increased significantly since 1978, when the factors were last updated, the new factors were between 1.4% and 17.8% lower than the old factors. This well-publicized change gave employees who expected to receive retirement benefits calculated using the DC benefit formula a strong incentive to retire before July 2003. As suggested by the large number of retirements that we observe in the first six months of 2003, we find strong evidence in our regressions that employees are willing to retire to prevent a reduction in their retirement benefits. This finding is important because it implies that attempts to lower future pension obligations by reducing plan generosity are likely to trigger large numbers of retirements, which are likely to increase administrative costs and potentially disrupt the provision of public services.

Finally, we exploit the fact that our employees work for hundreds of different employers

[4] Goda, Shoven, and Slavov (2009) discuss similar policy issues that arise from the retirement incentives built into the U.S. Social Security system.

to test for peer effects in the retirement decision. Our motivation is the idea that employees are likely to learn about retirement incentives related to stale returns or upcoming changes in benefits from their coworkers. We find strong evidence of peer effects across a variety of different specifications. Namely, employees respond more strongly to their own retirement incentives when more of their coworkers face the same retirement incentives. To the extent that peer effects amplify the reactions to retirement incentives, including those that might not have otherwise been salient to the typical retiree, they are likely to increase the administrative costs associated with replacing retirees.

Our paper is organized as follows. In Section 2, we compare and contrast the PERS hybrid pension plan with a traditional defined benefit retirement plan, with an emphasis on the different retirement incentives they create for employees. In Section 3, we describe our sample of retirement-eligible employees and retirees. In Section 4, we calculate the *ex post* cost of the hybrid pension plan to PERS employers. We also simulate the *ex ante* costs under alternative assumptions about market returns. In Section 5, we use individual-level data to study the effect of retirement incentives, employee characteristics, and peer effects on the retirement timing decision. In Section 6, we conclude.

2. Institutional Details

The Oregon Public Employees Retirement System uses benefit formulas drawn from both defined benefit (DB) and defined contribution (DC) pension plans. Before describing how retirement benefits are calculated in this hybrid pension plan, we describe how benefits are calculated in traditional pension plans, which serve as useful benchmarks.

2.1. Calculating Retirement Benefits in a Traditional Defined Benefit (DB) Pension Plan

In a traditional defined benefit plan, the employee and employer both contribute into an account intended to cover the employee's future retirement benefits. PERS shares this basic structure. The employee's contribution rate is 6.0% of her salary, while the employer's contribution rate varies with the level of funding. Importantly, because DB retirement benefits are independent of the returns earned on the employee and employer contributions, the employee is fully insured against financial market risk. PERS offers a typical DB retirement benefit. The payment in month t is the product of five inputs:

$$\boldsymbol{DB_t} = \textit{Final Salary} \times \textit{Years of Service} \times (100\% - \textit{Early Retirement Penalty}) \times \text{Payout Factor} \times \text{COLA}_t$$

An employee can affect the first three inputs through her choice of retirement date.[5] The monthly payment is increasing in both the employee's monthly salary before retirement and the number of years of service. *Final Salary* is typically the employee's average monthly salary over the past 36 months, and *Years of Service* is the number of months that the employee contributed into PERS divided by 12. For an employee who chooses to retire before the plan's stipulated "normal" retirement age, the monthly retirement benefit is decreasing in the number of years until the employee reaches the normal retirement age. *Early Retirement Penalty* equals 100% until the employee reaches the early retirement age. Thereafter, *Early Retirement Penalty* reduces retirement benefits by 8% per year between the employee's current age and her normal retirement age. For police and fire officers, the early retirement age is age 50 and the normal retirement age is 55 (or 50 with 25 years of service). For all of the other retirement-eligible employees during our sample, the early retirement is age 55. However, the normal retirement age for "normal" employees depends on when they were hired. It is 58 (or 55 with 30 years of service) for "Tier 1" employees hired before January 1, 1996, and 60 (or 55 with 30 years of service) for "Tier 2" employees hired between January 1, 1996 and August 28, 2003. (Employees hired after August 28, 2003 face higher normal retirement ages and lower payout factors, but are not eligible to retire before our sample ends on December 31, 2003. We discuss the design of their pension plan in the web appendix.)

From the employer's perspective, the cost of the DB plan is the difference between the current plan assets and the expected present value of the DB retirement payments owed to current and future retirees. It is worth noting that the expected present value of the DB pension is lower for an older worker, everything else equal, because she can expect to receive fewer retirement payments before death. This differential incentive to retire is not present for those who expect to retire under the DC benefit formula, which annuitizes the value of the worker's retirement account balance based on her age at retirement.

2.2. Calculating Retirement Benefits in a Traditional Defined Contribution (DC) Pension Plan

In a traditional defined contribution pension plan, such as a 401(k) plan, employers and employees contribute into individual accounts that the employee manages herself. The employee's retirement account balance depends on the size of these contributions and on the returns

[5] This formula applies to a single life annuity, which stops making retirement benefit payments when the retiree dies. We are abstracting from the choice between a single life annuity and a joint life annuity because this choice is available in both PERS and traditional defined benefit plans.

earned within the individual account. In contrast, to a typical DB plan, the employee bears all financial market risk. To the extent that retirement account balances can be used to purchase life annuities, the retiree typically faces the life annuity prices available in the private market, which depend on the retiree's expected life expectancy and the prevailing risk-free rate of return. Therefore, from the employer's perspective, the cost of the DC plan is limited to the employer's contributions and any administrative costs.

2.3. Calculating Retirement Benefits in PERS' Hybrid Pension Plan

We describe PERS as a hybrid pension plan because it offers DC-style retirement benefits in addition to the DB-style retirement benefits described above. For employees who contributed into PERS before August 21, 1981, initial monthly retirement benefits, when taken as a life annuity, are the maximum of those implied by three benefit formulas:

(1) $\boldsymbol{DB} = \textit{Final Salary} \times \textit{Years of Service} \times \textit{Early Retirement Factor} \times 1.67\%$,

(2) $\boldsymbol{DC} = \textit{PERS Account Balance} \times \textit{Actuarial Equivalency Factor} \times 2$,

(3) $\boldsymbol{DCDB} = \textit{Final Salary} \times \textit{Years of Service} \times \textit{Early Retirement Factor} \times 1.00\%$

$+ \textit{PERS Account Balance} \times \textit{Actuarial Equivalency Factor} \times 1$

$= 0.600 \times \boldsymbol{DB} + 0.500 \times \boldsymbol{DC};$

where equations (2) and (3) depend on two DC-style inputs. *PERS Account Balance* is the employee's account balance within PERS' defined contribution plan. It depends on how the employee's contributions into PERS are allocated across the "regular" and "variable" investment accounts, and on the annual returns credited to each account. Tier 1 employees receive a minimum annual return of 8% in the regular account but market returns in the variable account. Tier 2 employees receive market returns in both accounts. Note that while the employee nominally contributes 6% of her salary into PERS, the employer almost always makes this contribution on behalf of the employee. Since the *PERS Account Balance* is doubled in equation (2), the employer's contribution rate is effectively 12%. Note also that when the employee retires under the DB benefit formula, her *PERS Account Balance* reverts to PERS.

The *Actuarial Equivalency Factor* (AEF) is an age-based, gender-neutral annuity factor that is set by PERS actuaries.[6] In their study of the choice between life annuity payments and lump sum payments, Chalmers and Reuter (2012) show that the life annuity payments available from PERS under the DC benefit formula are better than actuarially fair. There are two sources

[6] The formulas that we report are for general service employees, which exclude police and fire officers as well as certain other employees. The payout factors in the *DB* and *DCDB* benefit formulas are higher for police and fire officers (2.00% versus 1.35% in equation (1) and 1.35% versus 1.00% in equation (2)).

of this generosity. First, during most of our sample period, PERS bases its AEFs on life expectancy forecasts from the late 1970s. In contrast, the AEFs available from TIAA (and other life insurance companies) are updated each year to reflect prevailing forecasts of retiree life expectancy. Second, PERS' AEFs use an "assumed rate" of 8 percent (excluding the COLA) whereas TIAA's AEFs are updated each year to reflect the prevailing yield on 10-year U.S. Treasury notes. Because the yield on 10-year U.S. Treasury notes trends down from 8.43% in January 1990 to 4.26% in December 2003, and because the annual COLA on PERS retirement benefits is 2.00%, the life annuity payments PERS pays are significantly higher than the life annuity payments that could be purchased in the private market.

For employees who first contributed into PERS after August 21, 1981, monthly retirement benefits are the maximum of those calculated under the DB and DC benefit formulas (equations (1) and (2)). Therefore, while eliminating the DCDB formula reduces the expected generosity of the PERS retirement benefits (because there are parameter values under which these newer employees would have earned higher benefits under DCDB), it does not change the fact that PERS offers employees the option to receive better-than-actuarially fair life annuities with the *PERS Account Balance* when equity market returns have been high.[7] It is this option that increases the expected generosity of the PERS pension plan relative to a traditional DB pension plan based solely on formula (1). To see this, note that any actual retirement benefit can be mapped back into the DB benefit formula by changing the payout factor,

$$(4)\quad \textbf{\textit{Actual}} = \textit{Final Salary} \times \textit{Years of Service} \times \textit{Early Retirement Factor} \times \textit{Implicit Payout Factor}$$

Because *Actual* is greater than or equal to *DB* by construction, the *Implicit Payout Factor* is greater than or equal to the payout factor used in equation (1). The larger the *Implicit Payout Factor* we calculate for retiree *i*, the more generous her retirement benefit. Of course, because different retirees receive payments calculated using different benefit formulas, the *Implicit Payout Factor* will vary across retirees in a way that it would not in a traditional DB pension plan.

2.4. Retirement Incentives Differ Across the DB and DC Benefit Formulas

In their seminal paper, Stock and Wise (1990) contrast the retirement incentives embedded in traditional DB and DC retirement plans. They demonstrate that the DB retirement plan gives an employee a stronger incentive to work until she is eligible for normal retirement benefits, but a weaker incentive to continue working thereafter. The intuition for their finding is that once an employee with a DB retirement plan is eligible for normal retirement benefits, increases

[7] In their study of retirement payout choices, Chalmers and Reuter (2012) find that 10.1% of the PERS retirees in their sample receive lower retirement benefits because they are ineligible for *DCDB.*

in the expected present value of retirement benefits from an additional year of service are typically dominated by the prospect of receiving one less year of retirement benefits. This is because the DB benefit does not adjust for the employee's life expectancy. In contrast, for an employee with a DC retirement plan, there is no explicit early retirement penalty to avoid through an additional year of labor, but the factors used to convert the DC account balance into life annuity income increases monotonically with the employee's age. For these same reasons, we expect PERS retirements under the DB benefit formula will be more closely related to the early retirement penalty and normal retirement age than PERS retirements under the DC benefit formula.

Consider an employee who will retire under the DB benefit formula and who is eligible for early retirement benefits in month *t* (at age 55, with 27 years of service) and normal retirement benefits in month *t+36* (at age 58, with 30 years of service). To determine the effect of each additional year of employment on the employee's retirement benefits, we can compare the initial retirement benefits in months *t-1, t, t+12, t+24, t+36,* and *t+48*. We state the initial monthly retirement benefit as a replacement rate, which measures the monthly benefit as a fraction of the employee's final average monthly salary.

Month	**Retirement Eligibility**	**Years of Service**		**Early Retirement Adjustment**		**DB Payout Factor**		**Replacement Rate**
t-1	Ineligible	26.92	×	(100% - 100%)	×	1.67%	=	0.00%
t	Early	27.00	×	(100% - 24%)	×	1.67%	=	34.27%
t+12	Early	28.00	×	(100% - 16%)	×	1.67%	=	39.28%
t+24	Early	29.00	×	(100% - 8%)	×	1.67%	=	44.56%
t+36	Normal	30.00	×	(100%)	×	1.67%	=	50.10%
t+48	Normal	31.00	×	(100%)	×	1.67%	=	51.77%

The replacement rate jumps from 0% to 34.27% in month *t*, when the employee becomes eligible to receive retirement benefits, and it rises rapidly thereafter as the employee moves from early retirement to normal retirement. Once the employee is eligible for normal retirement benefits, however, the replacement rate only increases by 1.67 percentage points with each additional year of service. Unless the final average salary increases significantly with each additional year of service, or the disutility of labor is low, this employee would be better off retiring and claiming normal retirement benefits (which include a cost-of-living adjustment) rather than continuing to work.[8] The caveat is that if the employee's benefits under the DB formula are insufficient to finance her consumption in retirement, she may delay retirement until she is also eligible to collect

[8] Employees who no longer work at the firm have an even stronger incentive to claim DB retirement benefits at the normal retirement age because they lack the ability to increase their final average salary by working another year.

benefits from the Social Security Administration. (Oregon public employees pay into Social Security.) For an employee who will retire under the DC benefit formula, the early retirement penalty does not play a role in determining her retirement benefits. What matters instead is the ability of the employee's annuitized *PERS Account Balance* to finance her consumption in retirement.

The hybrid plan design has several implications for employers. As the fraction of employees receiving DC benefit increases, so does the cost of providing the hybrid pension plan. In addition, as the fraction of employees receiving DC benefits increases, retirement timing decisions will depend more on market returns, which are highly correlated across employees, and less on employee ages and years of service. This makes lumpy retirements more likely. To the extent that lumpy retirements impose greater administrative costs on employers—or have a greater impact on the provision of local services—these follow directly from the hybrid plan design.

2.5. Retirement Incentives Embedded in the PERS Hybrid Pension Plan

In the section above, we focus on variation in retirement incentives across the DB and DC benefit formulas. In this section, we focus on one source of exogenous variation in the level of the DB benefits and three sources of exogenous variation in the level of the DC benefits. We use these sources of variation to test the sensitivity of the retirement timing decision to retirement incentives. We also use them to ask both how many employees appear to be timing their retirements to exploit these incentives and how many employees would have benefited from more carefully considering the precise month in which they chose to retire.

2.5.1. Early Retirement Penalty for DB Benefits

The first source of exogenous variation arises because prior to January 1, 1997 the early retirement penalty is updated only in the employee's birth month, while subsequent to January 1, 1997 the early retirement penalty is updated monthly. Consequently, between 1990 and 1996, an employee who retires one month before her birth month receives DB benefits that are 92% of the DB benefits she would receive if she waited to retire in her birth month. Beginning in 1997, the 8% percent penalty is spread evenly over 12 months, so that the corresponding number is 99.3%. Primarily, this change eliminates the possibility that an employee retiring under the DB benefit formula could earn a significantly higher benefit by delaying retirement one month. However, by reducing the disincentive to retire in the months immediately before the normal retirement age, this change has the potential to increase early retirements under the DB benefit formula between 1997 and 2003.

2.5.2. Stale Returns for DC Benefits

The second source of exogenous variation in retirement incentives arises from the calculation of the *PERS Account Balance*, which is one important determinant of the DC (and DCDB) retirement benefit. Every April, PERS provides employees with a statement that reports the retirement contributions and investment returns credited to the employee over the prior calendar year, and the current account balance. Prior to January 1, 2000, the timing of this report reflected the fact that PERS did not finalize annual returns for the regular and variable accounts in year *y* until the end of February in year *y+1*. Moreover, PERS did not utilize estimated year-to-date returns. Consequently, the PERS Account Balances of employees retiring prior to January 1, 2000 were based, at least in part, on stale returns.[9] Consider a member who retires in February 1998, which is before PERS finalizes the annual returns for 1997 and 1998. His retirement account balance for 1997 and the first two months of 1998 will be credited with the "finalized" 1996 return of 21.0% despite the fact that the 1997 returns were 18.7% (finalized on March 1, 1998) and the 1998 returns were 14.1% (finalized on March 1, 1999). In this example, the member benefits from the use of stale returns. Moreover, to the extent that employees understood how PERS calculated account balances, the incentive to retire in February 1998 (rather than March 1998) was apparent at the time because employees could easily observe market returns in 1997. Effective January 1, 2000, PERS began calculating account returns each month, thereby eliminating retirement incentives due to stale returns.

We define *DC_delta* as the monthly return that the employee receives from retiring in month *t* instead of in the month that PERS next finalizes returns for the regular and variable accounts (i.e., March 1990, March 1991, …, March 1999, and January 2000). For example, in February 1998, this is the percentage change in the *PERS Account Balance* from retiring under the stale returns available in February versus retiring under the finalized returns in March. In Figure 1a, we plot the average, minimum, and maximum fluctuations in retirement benefits due to stale returns (*DC_delta*) available to employees who would retire under the DC benefit formula. The fact that *DC_delta* ranges from -9.3% to 6.0% in February 1998 reflects the fact that PERS relied in stale returns in the regular and variable accounts and different employees have different amounts invested in these two accounts.

2.5.3. Actuarial Equivalency Factors for DC Benefits

The final two source of variation in retirement incentives comes from changes to the *Ac-*

[9] Stanton (2000) studies the option value of exploiting stale returns within 401(k) plans.

tuarial Equivalency Factors (AEFs), which is the other important determinant of the DC (and DCDB) retirement benefit. The AEFs in use by PERS at the beginning of our sample period are gender-neutral factors, introduced on July 1, 1978.[10] As discussed above (and in Chalmers and Reuter (2012)), these AEFs are significantly more generous that the AEFs available in the market for voluntary life annuities because they underestimate retiree life expectancies and assume a constant annual risk-free rate of return of 8%.

Before January 1, 1997, PERS only changed the AEF used in an employee's benefit calculations once a year, in her birth month. During this regime, DC benefits could be as much as 4.10% lower if the employee retired in the month immediately before her birth month rather than in her birth month (1.75% lower at the median). On January 1, 1997, monthly factors were added to the Actuarial Equivalency Factor tables. As with the change from annual to monthly early retirement penalties, this change greatly reduced the incentive for an employee to delay retirement until her birth month.

The larger and more salient source of variation comes from the fact that, effective July 1, 2003, PERS updated its table of AEFs to reflect then-current forecasts of retiree life expectancies. The new AEFs were between 1.4% and 17.8% lower than the old AEFs, with the largest decreases for older retirees.[11] For employees between the ages of 58 and 65, AEFs decreased between 5.8% and 10.2%. These changes, which were well publicized, created strong incentives for employees who expected to receive DC (and, to a lesser extent, DCDB) benefits to retire before the new AEFs took effect on July 1, 2003. (It is worth noting, however, that because the new AEFs continued to assume a constant annual risk-free rate of return of 8%, they remained significantly more generous than the AEFs available from TIAA.)

We define *AEF_delta* as the change in DC retirement benefits that an employee (eligible for DC benefits) would receive if she retired now rather than waiting for the next known change to her AEF. It is measured as a monthly return, from the date of the possible retirement to the date of the change. Between January 1990 and December 1996, the next known change occurs in the employee's birth month or in January 1997, whichever comes first. In Figure 1b, we plot the average, minimum, and maximum fluctuations in retirement benefits due to these predictable

[10] The decision to use gender-neutral Actuarial Equivalency Factors grew out of a 1974 lawsuit filed by four female PERS members, which alleged that the use of gender-based mortality tables violated Title VII of the Civil Rights Act of 1964. The resulting consent decree also formed the basis for subsequent lawsuits that challenged the legality of updating the PERS Actuarial Equivalency Factors to reflect the subsequent secular change in mortality risk.

[11] On June 10, 2003 PERS adopted the new Actuarial Equivalency Factor tables based on the mortality assumptions it adopted on September 10, 2002 in order to comply with the PERS Reform and Stabilization Act of 2003, which was signed by Oregon Governor Kulongoski on May 9, 2003.

changes in AEFs (*AEF_delta*). The negative returns during the 1990 to 1996 period measure the cost to employees eligible for DC benefits of retiring in the months leading up to her birth month. In contrast, the large positive returns leading up to June 2003 measure the growing incentive for employees retiring under DC to retire before the change to the new AEFs on July 1, 2003. For the median employee eligible to retire under DC, average monthly life annuity payments are 5.3% higher if she retires in June 2003 instead of July 2003. However, the incentive to retire in June 2003 ranges from 2.7% to 21.1%, with the strongest incentives for the oldest employees.

3. Data

In 2006, PERS held nearly $56 billion in assets, making it the 22nd largest public or private pension fund in the country. PERS covers approximately 95% of all non-federal public employees in Oregon. Participating employers include all state agencies, universities, and school districts; and almost all cities, counties, and other local government units. Administrative data obtained from PERS allow us to calculate PERS participant *i*'s retirement benefits under the DB, DCDB, and DC benefit formulas if she chooses to retire in month *t*.[12] These data also allow us to determine when employee *i* becomes eligible to receive PERS retirement benefits and, when employee *i* is currently employed, the PERS employer code.

Our main sample includes 62,953 unique employees who are either eligible to retire on January 1990 or become eligible to retire between January 1990 and December 2003.[13] Panel A of Table 1 provides annual summary statistics for all retirement-eligible employees. The average nominal monthly final average salary ranges from $2,319 in 1990 to $3,667 in 2003. The average replacement rate, calculated as the monthly benefit that the employee would receive upon retirement divided by the employee's salary over the prior 12 months, increases from 27% in 1990 to 39% in 1998, and then decreases to 33% in 2003. Among retirement-eligible employees, the fraction of female employees increases from 54.7% in 1990 to 60.5% in 2003; the fraction working as police and fire fighters ranges from 5.7% to 8.1%. A useful benchmark not reported in Table 1, is that the unconditional probability of retirement in any given month among the individuals represented in Panel A is 1.46%.

[12] Our analysis includes all PERS participants except for legislators, judges, and employees of the Oregon University System. The first two groups are excluded because PERS declined to provide data for them, and the third group is excluded because OUS permits its employees to opt out of PERS and into a portable defined contribution retirement plan and because the PERS employer code does not differentiate between the seven OUS universities..

[13] The administrative data that we use to estimate employee retirement benefits come from the computer system that PERS used between 1990 and 2003.

Panel B provides annual summary statistics for the 35,128 employees who choose to begin collecting their retirement benefits between January 1990 and December 2003. Comparing Panels A and B, we see that retirees have monthly salaries that are 17-26% higher, replacement rates than are 24-68% higher, and three to seven more years of service than their non-retiring peers. The average retirement age falls from 60.6 years at retirement in 1990 to 58.5 years old in 2003 while, over the same period, average years of service increases from 18.9 to 21.2 years. The time-series correlation between the average replacement rate and the average retirement age is -0.95, suggesting that higher retirement benefits allow for earlier retirements.

We graph the fraction of retirement eligible employees who retire each month in Figure 2. Retirements by teachers at the end of the school year help to explain the retirement spikes in June. However, the spikes at the beginning and end of 1999 are likely due to the last known rate, and the spikes in the first six months of 2003 are likely due to the reduction in the actuarial equivalency factor tables that took effect on July 1, 2003.

We also study a second sample of prospective retirees that includes former employees. Because the summary statistics for this sample of 41,940 retirees are similar to those in Panel B, we do not report them. However, the larger sample is helpful for measuring the total cost of the hybrid pension plan to employers, which is our goal in the next section.

4. Estimating the Incremental Costs of the Hybrid Pension Plan to Employers

PERS guarantees that employees will receive retirement benefits no lower than those offered by a traditional defined benefit pension plan, but it also provides them with the option to receive retirement benefits based instead on equity market returns realized over their careers. In Table 2, we estimate the *ex post* value of this embedded option. To do so, we benchmark retiree's actual benefits against the benefits that they would have received under the *DB* benefit formula. To be clear, we are benchmarking the pension plan that employees were offered at the time of employment against a mechanically less generous alternative with the goal of measuring the *ex post* benefit to employees and associated *ex post* cost to employers arising from the embedded option.[14] Any discussion of efficiency must focus on distortions in the behavior of employees and employers resulting from this option, rather than on the promised "transfer" from employers to employees.

During our sample period, we observe retirements by 41,940 current and former employ-

[14] Note that we are measuring the net effect of the particular way that the PERS pension plan combines elements from DB and DC plans, including the net effect of the changes they made during our sample period. Our specific estimates are unlikely to generalize to other pension plans.

ees. While 5,188 (12.4%) receive their retirement benefits under the *DB* benefit formula, the other 36,572 (87.6%) receive larger benefits due to the availability of the DCDB and DC benefit formulas. We measure these additional benefits in three ways, in each case assuming that retirement dates are exogenous and that employees choose to receive all of their retirement benefits as life annuity payments.[15] First, we focus on replacement rates. We find that employee's actual replacement rates are 18.3 percentage points higher, on average, than they would have been under a traditional DB plan (52.1% versus 33.8%). Under this *ex post* measure, benefits are 54.1% higher because of the embedded option. Second, we focus on the payout factor, which is the replacement rate that employers pay per year of service. Under the DB formula, PERS pays the typical employee 1.67% of her final average monthly salary per year of service. (The payout factor for police and fire officers is 2.00%.) When we hold retirement dates constant and recompute benefits for all 41,940 retirees using the DB formula, the average payout factor is 1.63% (which reflects the fact that some of the retirement ages observed under the DC formula trigger early retirement penalties under the DB formula). To match the actual benefit payments that we observe, the average payout factor would need to be 2.43%, which is 49.2% higher.

Finally, following Novy-Marx and Rauh (2011), we focus on the expected present value of the retirement benefits owed to new retirees.[16] For our subset of PERS retirees, we estimate that pension obligations are 57.3% higher under the hybrid pension plan than they would have been under the DB benefit formula in PERS, increasing employers' costs by approximately $7 billion (measured in constant 2003 dollars). By way of comparison, PERS estimates the difference between pension liabilities and pension assets is approximately $17 billion in 2003 and $15 billion in 2009, and Novy-Marx and Rauh (2011) estimate the Oregon underfunding to be approximately $38 billion in 2009. Therefore, while we likely would have observed underfunding even if PERS benefits were capped at defined benefit levels, the estimated effect of the embedded option on the level of PERS underfunding is economically significant.

Note that providing retirees with the maximum retirement benefits for which they are eligible also increases dispersion in realized retirement benefits (holding inputs like salary and years of service constant). The average implied payout factor ranges from 1.99% in 1992 to

[15] Chalmers and Reuter (2012) show that within this sample approximately 85% of retires choose to receive all of their retirement benefits in the form of life annuity payments. We discuss the impact of retirement benefit payout choices on our present value calculations in section 4.1.

[16] For this calculation, we use retiree i's gender and age at retirement and life tables from the Social Security Administration for 2004 to determine the probability that she receives each future monthly payment, we assume an constant annual cost of living adjustment of 2.00%, and we use the prevailing yield on 10-year U.S. Treasury notes as our discount rate.

2.74% in 1999. This dispersion is likely to increase uncertainty about the ultimate cost of providing retirement benefits to new and existing employees. And, because PERS employers must pursue relatively safe investments to satisfy their obligations under the DB benefit formula when equity market returns are high, returns in the employee's retirement accounts are likely to exceed those in the employer's retirement accounts, resulting in increased underfunding. Thus, employers face considerable market risk due to the hybrid features of PERS.

4.1. Underfunding Due to Life Annuity Pricing

Our estimate of the present value of retirement benefits owed to new retirees in Panel A assumes that all retirement benefits are fully annuitized. However, between 1990 and 2002, retirees have the option to receive some of their retirement benefits in the form of a lump sum payment. And, in 2003, retirees have the option to receive all of their retirement benefits in the form of a lump sum payment. Within our sample, 15.3% of PERS retirees choose to receive a (partial or full) lump sum payment. When we use data on actual retirement payout choices to adjust our present value estimate, it falls from $19.258B to $18.737B. While the decrease of $0.521B is small in comparison to the total cost of $19.258B, it is borne entirely by the 15.3% of retirees who choose to receive a lump sum payment. Among these retirees, the total present value owed to new retirees is $2.500B when we factor in the impact of the lump sum payment versus $3.021B when we assume the full annuitization of retirement benefits. Among the subset of retirees who choose the full lump sum payment in 2003, the corresponding numbers are $0.112B and $0.212B. This difference of $0.100B is driven by the fact that the annual rate of return of 8% embedded in PERS' AEFs was almost double the prevailing yield on U.S. Treasury notes in 2003.

One implication of this discussion is that employer costs would have been significantly smaller if PERS had used AEFs from the private life annuity market to determine DC and DCDB benefits. In Panel B of Table 2, we re-estimate employer costs under the counterfactual assumption that PERS used the same AEFs as TIAA. This calculation holds constant PERS' hybrid structure, the market returns credited to PERS retirement accounts, and employees' retirement timing decisions. However, it recalculates each employee's maximal retirement benefit using TIAA's AEFs. The fraction of the 41,940 retirees who receive benefits in excess of the DB benefit falls from 87.6% to 71.0%. Furthermore, the PV of retirement benefits owed to new retirees arising from the hybrid plan design falls from $7.016B to $3.104B. In other words, even conditioning on the unusual equity market returns of the 1990s, we find that more than half of the $7B in *ex post* underfunding is due to the pricing of life annuities in the DC and DCDB benefit formulas.

4.2. Underfunding Due to Market Returns

In this subsection, we simulate the expected costs to PERS employers of offering both DB and DC benefits. Our Monte Carlo simulations follow the PERS policies that were in effect at the start of our sample period. To measure expected employer costs, we focus on the ratio of simulated DC benefits to simulated DB benefits. For a sample employee who joins PERS at each age between 20 and 58, we generate 50,000 trials of the DC and DB benefits at the modeled retirement date. We report the statistics describing the *ex ante* distribution of the DC/DB ratio for each age cohort.

We make a number of assumptions in our simulations. First, we assume that employers contribute 12% of the employee's annual salary into the DC account at the start of each year. Second, to match PERS, we incorporate both the guaranteed annual return of 8% and the fact that employees and employers share the gains when market returns are greater than 8%. Specifically, we randomly draw from the historical distribution of S&P 500 annual returns between 1957 and 1989 for each employee-year, and we set the portfolio return equal to MAX(8%, 8% + 0.5*(SP500 – 8%)). Third, we assume that wages grow by 2% each year. Finally, we assume that employees use the following rule to determine when to retire. For each year between the early retirement age and the normal retirement age, the member compares the annuitized DC benefit with the DB benefit at the normal retirement age. If the DC benefit is larger, the employee retires immediately. Otherwise, the employee waits one year and re-evaluates the two alternatives until mandatory retirement at the normal retirement age.

We present our simulation results in Figure 3. The horizontal axis depicts the age cohort, and the vertical axis depicts the ratio of DC to DB benefits at the simulated retirement date. For each age cohort, we consider the impact of 50,000 randomly drawn return histories on DC benefits. . The figure plots the mean, 25th percentile, 50th percentile, and 75th percentile of that distribution of the DC/DB ratio. For example, the average ratio for members who join PERS when they are 40 years old is 1.42. This implies that members who were 40 years old when they joined PERS in 1990 can expect DC benefits that are 1.42 times the value of DB benefits. The ratio is 1.30 at the 25th percentile; it is 1.40 at the 50th percentile; and it is 1.53 at the 75th percentile. On the secondary vertical axis (the right hand side), the fraction of simulated members whose DC benefits exceed their DB benefits is plotted. For age cohorts 20 through 39, all simulated members retiree with DC benefits. For age cohorts 40 through 51, over 97% of simulated members retire with DC benefits. After the 51 year old cohort, an increasing fraction of simulated members take the DB benefits. At age 58, all simulated members retire with one year of service and take the DB benefit. The intuition for these results is that for employees with long careers ahead of them, 12% retirement contributions, guaranteed annual returns of at least 8%, and better-than-actuarially-fair annuity factors combine to generate large expected DC benefits. For employees who begin work at later ages, there is a lower probability that returns grow beyond the DB benefit, which is primarily driven by wage growth and years of service. We conclude from our simulations that the *ex post* realizations for PERS underfunding that we document above are consistent with what could have been modeled using *ex ante* data in 1990.

5. Analysis of Employees' Retirement Timing Decisions

Our analysis of the employee retirement timing decision proceeds in five steps. First, motivated by the predictions in Stock and Wise (1990), we present evidence on the retirement ages of employees receiving retirement benefits under the three different benefit formulas. Second, we use variation in the level of retirement benefits within the DB and DC benefit formulas from one month to the next to identify the numbers of employees who appear to have successfully and unsuccessfully exploited this variation. Third, we estimate a baseline model to predict whether a retirement-eligible individual will choose to retire in month t. We use individual-specific information such as age, gender, job type, projected retirement benefit, and *ex post* mortality measures, as well as exogenous variation in retirement incentives. The baseline model allows us to test whether employees respond to the different retirement incentives generated by the hybrid structure, and it allows us to quantify the effects of those incentives.

Fourth, to test for peer effects in the retirement decision, we add the actual retirement decisions of an individual's coworkers to the baseline model. To help distinguish peer effects from alternative explanations such as unobserved heterogeneity among employers, we include controls that vary at the employer-date level, such as the fraction of non-retirement eligible employees leaving the employer in month t. In addition, we instrument coworker retirements with several sources of exogenous variation in coworker retirement incentives. Fifth, to test whether peer effects reflect the diffusion of information about retirement incentives, we test whether employees are disproportionately more likely to respond to retirement incentives when more of their coworkers face the same incentives. Finally, to shed light on whether the peer-induced retirements that we observe are harmful, we estimate reduced-form regressions for different samples of retirement-eligible employees.

5.1. Retirement Ages and Retirement Benefit Formulas

Following Stock and Wise (1990), we predict that retirements under the DB benefit formula will be more sensitive to the size of the early retirement penalty and attainment of the normal retirement age than retirements under the DC benefit formula. In Table 3, we find strong support for this prediction. In Panel A, we report the distribution of retirement ages for employees who receive benefits under the DB, DCDB, and DC formulas. To facilitate comparisons across benefit formulas, we focus on 29,554 retirees for whom the early retirement age is 55 and the normal retirement age is 58. (We begin with the sample of retirees described in Panel B of Table 1, but then exclude 2,385 police and fire officers, 632 retirees for whom the normal retirement age is 60, and 2,568 retirees for whom the normal retirement age is 58 but who qualify for normal retirement benefits based on their years of service rather than their age.)

We find that retirees receiving DB and DCDB benefits are five to seven times more likely to retire at age 58 than they are at age 55. In contrast, retirees receiving DC benefits are more likely to retire at age 55, when they first become eligible to collect retirement benefits, than at age 58. At age 55, we observe 17.2% of the retirements under DC versus only 3.1% under DB. By age 58, we observe 50.6% of the retirements under DC versus only 29.1% under DB. These patterns suggest that the higher benefits made possible by the DC benefit formula are allowing employees to retire at earlier than normal ages. Another interesting pattern is that retirements under DB are almost twice as likely to happen at age 62 as retirements under DC. One interpretation is that receiving a higher-than-DB benefit via the DC benefit formula makes it easier for an employee to finance her retirement before she is eligible to collect benefits from Social Security. Overall, the patterns in Panel A suggest that the hybrid pension plan increases early retirements, both by increasing expected retirement benefits and by eliminating the penalty associated with early retirements.

In Panel B of Table 3, we explicitly classify each of the retirees described in Panel B of Table 1 as "retiring early" if she would have been be subject to an early retirement penalty under the DB benefit formula. We then calculate the fraction of early retirements for each of the three benefit formulas. As predicted, early retirements are much less common under the DB benefit formula than under the DC benefit formula. This is true both overall (14.0% versus 33.8%) and within the 1990-1996 and 1997-2003 subsamples. As expected, between 1996 and 1997, when early retirement penalty calculations change from annual to monthly updates, there is a modest increase in early retirements under the DB benefit formula, from 8.1% to 13.7%, a difference which is statistically significant at the 10-percent level.

5.2 How many retirees respond to exogenous variation in their retirement incentives?

In this section, we use discrete, predictable changes in the level of retirement benefits between months *t* and *t+1* to ask what fraction of retirees appear to be responding to this high-frequency variation in their retirement incentives. Using a narrow but operational definition of what constitutes a mistake, we also ask how many employees would have been better off if they had retired one month earlier or one month later than their chosen retirement date.

5.2.1. Early retirement penalty update frequency changed from annual to monthly

Between 1990 and 1996, the early retirement penalty is updated once per year, in the employee's birth month. This creates a disincentive for an employee whose retirement benefit will be reduced by the early retirement penalty to retire in the month immediately before her birth month. Obvious mistakes involving the early retirement penalty are rare. We only observe 197 retirements during this period where the value of the DB benefit is reduced by an early retirement penalty, and only 19 of these occur in the month immediately before the employee's birth month.

5.2.2. Actuarial equivalency factor update frequency changed from annual to monthly

Between 1990 and 1996, the actuarial equivalency factor is also updated once per year, in the employee's birth month. This creates a disincentive for an employee whose retirement benefit depends on the AEF to retire in the month before her birth month. Mistakes involving the AEF are significantly more common. We observe 5,323 retirements during this period in which benefits are determined using the DC benefit formula. We find that 398 (7.5%) employees retire in the month immediately below their birth month, and that their retirement benefits are 2.2% lower, on average, than they would have been if the employees had retired one month later. On the other hand, we find that the fraction of employees retiring in their birth month falls from 18.4%, when AEFs are updated annually, to 14.0%, when they are updated monthly. This suggests that, between 1990 and 1996, some employees delayed retirement until their birth month to receive a higher AEF.

5.2.3. Using stale returns to determine the PERS account balance

Through December 1999, PERS relied on stale returns when determining the value of the PERS account balance, which helped to determine the values of the DC and DCDB retirement benefits. As we discuss in section 2.5.2, the use of stale returns caused retirement benefits calculated under the DC formula to change discretely—and predictably—between February and March. In Panel A of Table 4, we report the number of retirements by month for the ten-year period during which PERS relied on stale returns and the three-year period during which PERS relied on actual monthly returns (but before it was known that PERS would be adjusting its AEF tables on July 1, 2003). We find that the fraction of retirements occurring in February is five times higher during the stale return regime (31.3% versus 6.1%). This is strong evidence that employees shifted their retirements to February to lock in the stale returns.

In Panel B, we divide the 4,100 employees who retired in February into two groups. The first group benefited from retiring in February rather than March. Among these 3,436 retirees, the average value of *DC_delta* is 1.9% and the maximum is 28.9%. (Recall that *DC_delta* measures how much higher the PERS account balance will be in February than in March because of the use of stale returns.) The other 664 retirees did not benefit from the stale returns. For this second group, the average value of *DC_delta* is -4.0% and the minimum is -27.1%. The fact that approximately 16% of the employees who retired in February between 1990 and 1999 were made worse off by stale returns helps to explain the relatively low coefficient on *DC_delta* that we estimate below in Table 5.

We also consider the 232 employees who were eligible to retire in February but chose instead to retire in March. Within this sample, 140 earned higher average DC benefits because of this one month delay. Because we continue to measure *DC_delta* in February, the average value of -8.0% implies that these 140 retirees' DC benefits would have been, on average, 8.0% lower if they had retired in February. On the other hand, the 92 employees who retired in March would have earned DC benefits that were 7.1% higher if they had retired one month earlier. This is a costly mistake; albeit one that impacts few retirees.

In Panel C, we compare the characteristics of the 3,576 employees who benefited from stale returns and the 756 who do not. Based on existing evidence that levels of financial literacy are lower among women (e.g., Lusardi and Mitchell (2007) and Lusardi and Tufano (2008)) and those with lower incomes (e.g., Campbell (2006) and Levy and Seefeldt (2008)), we expect the likelihood of a mistake to be higher for women and lower for those with higher incomes. Instead, we find fewer mistakes by women and no differences in final average salary. The only other meaningful difference we find is in the fraction of retirees who invested their retirement contributions in the variable account. Because employees are required to direct at least 25% of each retirement contribution to the regular account, employees who invest in the variable account have two sets of stale returns to consider, making the net impact of stale returns on the PERS account balance more difficult to determine.

5.2.4. Updating actuarial equivalency factors in July 2003

In July 2003, PERS updated its actuarial equivalency factors to reflect prevailing life expectancies. As Figure 2 shows, a significant fraction of retirement-eligible employees retired each month between January 2003 and June 2003. If these retirements were in response to the changes in AEFs, then they should have been concentrated among employees facing the DC and DCDB benefit formulas. Indeed, we find that 26.6% of the 13,864 employees eligible for DC benefits and 33.2% of the 642 employees eligible for DCDB benefits retire during this six month period, compared to only 6.7% of the 7,982 employees eligible for DB benefits. Between July 2003 and December 2003, when the new AEFS are in effect, all three fractions fall, to 6.4%, 7.7%, and 1.8%.

Focusing on retirements under the DC benefit formula in the two months surrounding the change in AEFs, we observe 728 in June but only 30 in July. We find that those retiring in June earned DC benefits between 2.8% and 21.1% higher than they would have been under the new AEFs; the average increase was 6.6%. The small number of employees retiring in July would have earned DC benefits between 2.9% and 14.0% higher if they had retired under the old AEFs.

5.3. Baseline Retirement Timing Model

In Table 5, we use linear probability models to explain the retirement timing decisions of retirement-eligible employees. Because PERS retirement incentives can vary significantly from coworker to coworker and from month to month, the dependent variable equals one if employee *i* retires from employer *j* in month *t*, and zero otherwise. (In contrast, virtually all existing studies focus on predicting the year (or age) of retirement.) In column (1), we focus on the full sample of retirement-eligible employees. In columns (2) through (5), we restrict the sample to: female employees, active police and fire officers, and employees whose birth month is month *t*. We multiply coefficient estimates by 100, so that 1.00 represents 1 percentage point. To allow for correlated behavior within employers, standard errors are clustered on employers.

In addition to the employee characteristics and retirement incentives variables described below, we include fixed effects for each of the 34 ages (measured in years) between 46 and 79.[17] We also include a separate fixed effect for each of the 168 months in our sample period (January 1990 through December 2003). However, because our sample combines school districts that operate on a nine-month schedule with employers that operate on a year-round schedule, we interact each date fixed effect with a dummy variable that indicates whether employer *j* operates on a nine-month schedule. These date-by-employer-type fixed effects allow us to control for the fact that school district employees are more likely to retire in June at the end of the school year.

[17] Although we limit our sample to ages between 46 and 79, doing so throws out few observations. We only have 4 observations before age 46 and 554 observations after age 79.

More generally, by including date-by-employer-type fixed effects, we "remove" the average retirement effects due to PERS plan changes and any other time-specific event within our sample period. In other words, we use within-period, within-employer-type, within-age variation to estimate the coefficients in Table 5.

Because we predict that employee *i* will be more likely to retire when her expected retirement benefits are more generous, we include two measures of generosity. The first is the fraction of employee i's current monthly income that she would receive each month from PERS in retirement.[18] Consistent with our prediction, the coefficient on the replacement rate is positive and statistically significant at the 1-percent level. The estimated coefficient of 3.451 implies that a one-standard deviation increase in the replacement rate (0.245) increases the probability of retirement by 0.85 percentage points. This effect is economically large; the unconditional probability of retiring in a given month is only 1.46%.

Our second measure of generosity is the "optional value" introduced by Stock and Wise (1990), which is a forward-looking measure that estimates the utility gain from deferring retirement until the optimal retirement time. The more that a worker gains from delaying retirement the less likely she is to retire today. We implement the Stock and Wise (1990) model by calculating the present value of a member's dollar wealth when retiring on the optimal date (including both labor and pension income) and subtracting the present value of a member's dollar wealth when retiring today.[19] When the optimal retirement date is today, the difference between these numbers is zero. When the optimal retirement date is in the future, the difference between these numbers is strictly positive, and it measures the present value of the benefit of deferring retirement.[20] The measure that we include in our regressions is divided by employee i's average annual salary over the past 12 months. The predicted sign is negative. The coefficient on the scaled option value of retirement measure is negative in three of the five specifications, but only statistically significant from zero in the sample of employees age 62 or older. However, it is not

[18] This is defined as the expected monthly retirement income that employee *i* would receive if she retired in month *t* scaled by her average monthly salary over the past 12 months

[19] Variations of the Stock and Wise measure have been used by Samwick (1998), Chan and Stevens (2004), Chan and Stevens (2008), Coile and Gruber (2007), and others.

[20] Our estimation requires several assumptions. We assume that annual wage growth is 2% and that the annual discount rate is 3%. PERS makes COLA adjustments to the benefit each August that is set at the smaller of Portland's CPI and 2%. Since Portland's CPI was rarely under 2%, we assume the annual adjustments would always be 2%. Consistent with prior research, we assume that members are risk averse and that members value retirement income more than labor income (i.e., members would rather not work). We pick the same parameter values as Samwick (1998). Specifically, we set gamma=0.75 for risk aversion and k=1.5 for the preference for retiring. When k=1.5, members are indifferent between working to earn $3 and retiring to collect $2. Last, we forced members to retire by age 80 because PERS does not calculate the *Actuarial Equivalency Factors* beyond age 80. Given the very small number of members who actually choose to retire beyond age 80, this last assumption does not seem unreasonable.

economically significant. Even the estimated coefficient of -0.021 in column (4) implies that a one-standard deviation increase (7.793) only decreases the probability of retirement by 0.16 percentage points.

Of more interest to us are four variables that isolate the short-run retirement incentives (or disincentives) generated by the use of stale returns in the PERS account balance calculation (*DC_delta*) and by changes in annuity factors *(AEF_delta)*. Each variable measures the change in retirement benefits (as a monthly return) from retiring in month *t* relative to waiting for the updated annual returns or annuity factors to take effect. Therefore, the predicted sign on each variable is positive.

Our stale return variable takes on non-zero values between January 1990 and December 1999. We interact it with two dummy variables, one indicating whether month *t* is January or February and another indicating whether it is March through December. This is because the incentives (or disincentives) of having retirement benefits calculated using stale returns should be clearest in January or February, after the prior year's equity market returns have been fully realized. (Consistent with this intuition, in Table 4, we observe a sharp drop in the fraction of February retirements when PERS eliminates the use of stale returns.) The coefficient on the variable measuring retirement incentives in January and February is statistically significant at the 1-percent level, but its economic significance is modest. A one standard deviation increase is associated with a 0.30 percentage point increase in the probability of retirement.

To measure the impact of PERS only updating an employee's actuarial equivalency factor in her birth month, we interact *AEF_delta* with a dummy variable indicating whether month *t* is between January 1990 and December 1996. The coefficient on this variable is statistically significant at the 5-percent level, but economically insignificant. A one-standard deviation increase in *AEF_delta* during this period increases the probability of retirement by 0.04 percentage points. To measure the impact of the new AEFs in July 2003, we interact AEF_delta with a dummy variable that indicates whether month t is between January 2003 and June 2003. The coefficient on this variable is both statistically significant at the 1-percent level and economically significant. Here, a one standard deviation increase is associated with a 1.83 percentage point increase the probability of retirement. Note that since 1-percentage point increases in *DC_delta* and *AEF_delta* have the same effect on DC benefits, the fact that coefficients differ across these two measures suggests that the retirement incentives due to stale returns were less well known than the retirement incentives due to the changing actuarial equivalency factors. The fact that 16% of the employees who retire in February have negative values of *DC_delta* also helps to explain the difference in magnitudes.

To study whether employee retirement decisions are constrained by retirement eligibility rules, we introduce dummy variables to indicate whether employee *i* became eligible for early retirement benefits in month *t*, in months *t-1* through *t-11*, or prior to month *t-11*, and to indicate whether employee *i* became eligible for normal retirement benefits in months *t* or in months *t-1* through *t-11*. (The omitted category is being eligible for normal retirement for twelve or more months.) Similarly, to control for the possibility that members are more likely to retire in their birth month, we introduce a dummy variable that indicates whether month *t* is employee *i*'s birth month.[21] We find that individuals are much more likely to retire in a birth month (0.998 percentage points) and in the first month that they are eligible for normal PERS retirement benefits (3.021 percentage points).

As *ex post* measures of health, we introduce a dummy variable that indicates whether the member dies over the next 12 months and another that indicates whether she dies over the next 48 months. Since we possess information on employee deaths through the end of 2007, we are able to define these dummy variables for every retirement-eligible employee in every year of our sample. To the extent that these future deaths are good proxies for relatively poor health today, the predicted signs on both coefficients are positive. Consistent with this prediction, both *ex post* mortality measures are economically significant predictors of retirement. An individual who dies within the next 12 months is 1.029 percentage points more likely to retire today.[22]

Other continuous variables include years of service, which is positively correlated with the retirement decision, and the unemployment rate within the county in month *t*, which is negatively correlated with the retirement decision in some specifications. For completeness, we also include dummy variables indicating whether employee *i* is female; actively employed as a police or fire officer, eligible for Tier 2 pension benefits; or would receive benefits calculated under DC, DB, or DCDB (the omitted category).

When we restrict our sample to the subset of employees who are female (column (2)) or active police and fire (column (3)), the estimated coefficients on the variables of interest are qualitatively similar to those found in the earlier specifications. Perhaps the most interesting difference is that police and fire officers are more likely than the other participants to retire in the first month in which they are eligible for normal PERS retirement benefits (10.243 percentage

[21] This variation drops out of the regression in column (5) that restricts the sample to each employee's birth month.
[22] Equal to the sum of 0.819 and 0.210, since the variable "dies within 48 months" excludes the subset of employees that die within twelve months.

points versus an unconditional probability of 1.25 percent). When we restrict the sample to employees who have a birthday in month t, we find greater sensitivity to the replacement rate and similar or slightly greater sensitivity to variation in the level of the DC benefit.

5.4. Testing for Peer Effects

PERS employees may have many peers, each important in a different context. Because we are interested in testing whether employees learn about their retirement incentives from coworkers, we define peers as those people who work for the same employer and are eligible for retirement in the same month.[23] In many cases, this gives relatively fine peer groups. For example, employers include individual school districts (e.g., Jackson County School District #1 and Jackson County School District #10), city employers (e.g., City of Madras and City of Klamath Falls), and fire districts (e.g., Rainier Fire Department and Keizer Fire Department). Many of our employers are quite small and have only a few employees (e.g., the Oregon Hazelnut Commission) while a few are quite large and have thousands of employees (the largest is the Portland School District). In our empirical work, we exclude employers in months where the employer has fewer than two retirement-eligible employees because peer effects are not defined when the PERS member has no retirement-eligible coworkers.

In Table 6, we extend our empirical specification to test for peer effects. With the notable exception of Brown and Laschever (2012), the existing retirement literature does not allow for peer effects. Our measure of peer retirements, *frac_retire*, is the fraction of a member's retirement-eligible coworkers (excluding herself) that retire from employer *j* in month *t*. Our test for peer effects is whether the probability that employee *i* retires in month *t* is increasing in *frac_retire*. The decision to focus on retirements in month *t* (instead of in year *y* or at age *a*) is driven by the within-year, time-varying retirement incentives in the PERS system.

In column (1), we add *frac_retire* to an extended version of the specification in column (1) of Table 5. The estimated coefficient is 27.024, which is both statistically significant at the one-percent level and economically significant. Interpreted as a peer effect, a one-standard deviation increase in the fraction of peers retiring (3.36 percent) increases the probability of retirement by 0.91 percentage points, which is large given that the unconditional probability of retirement in month *t* is 1.46 percent. Therefore, within our sample, there is a strong correlation be-

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[23] If peer effects are driven by social norms, then various social peer groups might be important. This is the idea underlying the analysis in Hong, Kubik, and Stein (2004) which uses survey evidence on whether households interact with their neighbors or attend church to measure peer interaction. On the other hand, if either peer effects are driven by word-of-mouth communications or the information needed to make the retirement decision is employer-related, then employer-based peers are arguably the most important peer group since it is precisely those peers who are informed about the details of PERS.

tween individual retirement decisions and average retirements within the same employer and month, even controlling for individual-level predictors of retirements, age fixed effects, and date-by-employer type fixed effects. In fact, the estimated coefficients on the other variables—including employee i's short-run retirement incentives based on stale returns and changing actuarial equivalency factors—are almost identical to those estimated in Table 5, suggesting that *frac_retire* is essentially uncorrelated with our set of individual-level determinants.

5.4.1. Controls for Correlated and Exogenous Effects

A key question is whether the error term in column (1) is correlated with the peer effects variable due to unobserved employee characteristics or employer shocks. If so, the positive coefficient on *frac_retire* cannot be interpreted as a peer effect. Since *frac_retire* varies at the employer-date level, to help rule out correlated and exogenous effects, column (1) also includes three control variables that vary at the employer-date level.

First, to control for time-series variation in the quality of the employee's workplace (for example, whether the new boss is overbearing), we include turnover of non-retirement eligible employees within the same employer and month. Second, we control for the retirement behavior of PERS members who work for other employers located in the same county. We conjecture that these individuals might retire together because of common economic factors in their county, or because they are responding to common information in the local media outlets. Third, under the assumption that the former employees of employer *j* are a good control group for the current employees of employer *j*, we control for the fraction of former employees that retire in month *t*. The fact that the estimated coefficient on *frac_retire* is positive and statistically significant with these controls in the regression increases our confidence that we are identifying peer effects.

5.4.2. Instrumental Variables

To provide further evidence that we are identifying a peer effect, in the remaining columns of Table 6, we switch our economic model from OLS to instrumental variables. Our goal is to isolate variation in the fraction of coworker retirements that is being driven by exogenous variation in coworker's retirement incentives—rather than variation due to selection, firm-specific shocks or other unobserved commonality in individual characteristics—and ask whether this variation helps to predict the retirement of employee *i* in month *t*. In each column between (2) and (5), we estimate a different instrumental variables regression using a different instrument. Each instrument is calculated using all retirement-eligible employees who work at employer *j* in month *t*, excluding employee *i*. In column (6), we use estimate a single regression using all four instruments.

The first instrument is the average retirement incentive due to stale pricing in January or February; the second instrument is the average retirement incentive in the 12 months leading up to the change in actuarial equivalency factors in July 2003; and the third instrument is the average retirement incentive due to changing actuarial equivalency factors in the employee's birth month, which we can calculate between January 1990 and December 1996. The larger each of these instruments, the stronger the short-term retirement incentives faced by an individual's retirement-eligible coworkers. When employee *i* is eligible for the DC or DCDB retirement benefit calculations, the first and second instruments will be positively correlated with employee *i*'s own retirement incentives, which we control for directly in the regression. In contrast, the third instrument captures variation in coworker retirement incentives driven by the distribution of coworker birth months over the calendar year, which should be uncorrelated with employee *i*'s own retirement incentives. In other words, whereas the first and second instruments correspond to situations in which coworker retirements are informative about general retirement incentives, the third instrument is not.

When we use coworkers' average retirement incentives due to stale returns in January and February as our instrument in column (2), the estimated peer-effect coefficient increases to 36.445, and remains statistically significant at the 1-percent level despite a 5-fold increase in its standard error. In contrast, when we use coworkers' average retirement incentives due to changes in the actuarial equivalency factors in 2003 as our instrument in column (3), the estimated coefficient falls to 15.364 and loses statistical significance (with a *p*-value of 0.243). One possible explanation for the different results in columns (2) and (3) is a difference in saliency. Whereas PERS repeatedly told employees about changes to the actuarial equivalency factors in July 2003, allowing employees to determine their own retirement incentives, PERS did not tell employees about the effect of stale returns on their retirement benefit calculations, forcing coworkers to learn about stale returns from coworkers. Of course, this explanation presupposes that peer effects are about the diffusion of information on retirement incentives, rather than the increased disutility of labor that comes from having friends retire.

When we use coworker retirement incentives based on the number of months to their birthday as our instrument in column (4), the estimated peer-effect coefficient is large and negative although the standard error is even larger. This is further evidence that peer effects are about the diffusion of information about retirement incentives that generalize to other coworkers. In column (5), we use the fraction of employee i's coworkers that have a birthday in month t as our instrument to explain variation in the fraction of employee *i*'s coworkers who retire in month *t*.

Our original thinking was that employees who retire in their birth month will be less sensitive to retirement incentives, and that this instrument will allow us to measure peer effects driven by non-financial retirements. However, we found in Table 5 that employees retiring in their birth month are at least as sensitive to expected retirement benefits, local labor market conditions, and their own short-run retirement incentives as other employees. Therefore, the estimated coefficient of 22.659 in column (5) may also reflect the diffusion of information driven by time-series variation in the fraction of recently-informed coworkers.

In column (6), when we use all four instruments at the same time, the estimated peer-effect coefficient is 20.454, and it is statistically significant at the 1-percent level. According to this estimate, a one standard deviation increase in *frac_retire* increases the probability that employee *i* retires in month t by 0.69 percent, which is slightly less than half of the unconditional probability of 1.46 percent. The overall evidence in Table 6 suggests both that we are identifying true peer effects, and that these peer effects reflect the diffusion of information about retirement incentives, rather than the increased disutility of labor associated with the retirement of friends.

5.4.3. Do Peer Effects Reflect Shared Retirement Incentives?

To test more directly whether peer effects reflect the diffusion of information about retirement incentives, we adopt the identification strategy of Bertrand, Luttmer, and Mullainathan (2000).[24] Because PERS retirement benefits are calculated using three different benefit formulas (DC, DCDB, and BD), different coworkers can face different retirement incentives within the same month. For example, while employees facing the DC benefit formula can time their retirement to exploit stale returns within the PERS retirement account, employees facing the DB benefit formula cannot. We use this fact to test whether individuals are *disproportionately* more likely to respond to their own retirement incentive when more of their coworkers face the same incentive.

In Table 7, we replace the fraction of employee *i*'s coworkers retiring in month *t* with variables that measure the quantity and expected behavior of coworkers facing the same retirement benefit calculation as employee *i*. First, for each employee, we calculate the fraction of her retirement-eligible coworkers who would retire under her same retirement benefit calculation (i.e., DC, DCDB, or DB) that she does in month *t*. The larger this fraction, the larger the number

[24] Bertrand, Luttmer, and Mullainathan (2000) study the decision by individuals to participate in welfare programs. To test for peer effects, they interact the quantity of people who live in the same area and speak the same language as employee *i* with the average welfare participation rate for people who speak that language in the full cross section. They find that the interaction term is positive and statistically significant.

of peers with whom employee *i* can discuss her own retirement incentives. Second, within the full sample of employers, we calculate the fraction of retirement-eligible coworkers facing each retirement benefit that retire in month *t*. This variable measures the strength of the retirement incentives that employees facing each of the three retirement benefits has in month *t*. For example, by controlling for the fraction of employees who retire under the DC benefit in January 1998, we capture the average retirement incentive due to stale returns within the PERS account balance that month. Finally, we interact the fraction of coworkers facing the same retirement benefit calculation as employee *i* in month *t* with the average fraction of retirement-eligible workers facing this retirement benefit calculation who retire in month *t*. This interaction term is our new variable of interest.

In the first column of Table 7, we report coefficients for the linear probability model:

$$\Pr(retire_{ijkt}) = \left(fracsame_{-ijkt} \times \overline{retire}_{kt} \right)\alpha + (fracsame_{-ijkt})\gamma + X_{ijkt}\beta + \eta_{kt} + \delta_{jt} + \varepsilon_{ijkt}$$

where $frac\_same_{-ijkt}$ is the fraction employee i's retirement-eligible coworkers at employer j, facing retirement benefit k, in month t, $\overline{\text{retire}}_{kt}$ is the fraction of retirement-eligible employees facing retirement benefit k that retire in month t (measured across all employers), and X_{ijkt} contains many of the control variables from Table 6, including all of employee *i*'s individual retirement incentives. Including a separate fixed effect for each retirement benefit calculation-date combination (η_{kt}) allows us to control for the average effect of benefit-specific retirement incentives on retirements in month *t* (and causes $\overline{\text{retire}}_{kt}$ to drop from the regression). Because we are focused on the interaction term, we are also able to include a separate fixed effect for each employer-date combination (δ_{jt}). By controlling for the average propensity of the employees of employer *j* to retire in month *t*, we are able to control for any employer-date specific shocks—something that we were not able to control for in Table 6. (On the other hand, we can no longer include the fraction of employee i's coworkers that retire in month *t*, or any other variable that varies solely at the employer-date level.) Standard errors are clustered on employer.

If employees are disproportionately more likely to respond to their retirement incentives when more coworkers face the same incentive, α will be positive. Indeed, the estimated coefficient on the interaction term in column (1) is positive and statistically significant (p-value of 0.000). It is also economically significant. Following Bertrand, Luttmer, and Mullainathan (2000), we estimate that PERS employees are 89.6% more likely to respond to their aggregate retirement incentives than they would be in the absence of any peer effects.[25] The fact that employees are significantly more likely to respond to incentives when more of their coworkers face the same incentives strongly suggests that peer effects reflect the diffusion of information about retirement incentives.

The test in column (1) assumes that employee *i*'s peer group is best defined by her retirement benefit calculation or, alternatively, that any employee is equally likely to talk about retirement with any other employee. In the remaining columns of Table 7, we include interaction terms based on alternative definitions of employee *i*'s coworkers.[26] In column (2), we include the fraction of coworkers who are the same gender as employee *i* in employer *j* in month *t*, the average fraction of coworkers who are the same gender as employee *i* that retire (from any employer) in month t, and the interaction between these variables. The coefficient estimate on the interaction term is negative and statistically indistinguishable from zero, while the coefficient estimate on the original retirement benefit calculation interaction term is almost identical to the one in column (1). In column (3), we include an interaction term based on the fraction of coworkers who are the same gender and face the same retirement benefit calculation as employee *i*. Relative to column (1), this specification allows for the possibility that employees are more likely to discuss retirement incentives with coworkers of their own gender. While the estimated coefficient on this interaction term is positive, it is statistically indistinguishable from zero. Moreover, it has little effect on the size or significance of the original interaction term.

Police and fire officers have their own, more generous versions of the DCDB and DB benefit calculations, and may be more likely to interact with other police and fire officers than with general employees. Therefore, in the remaining columns of Table 7, we distinguish police and fire officers from other employees. In column (4), we include the fraction of coworkers who have the same job type as employee *i* in employer j in month t, the average fraction of coworkers who are have the same job type as employee *i* that retire (from any employer) in month *t*, and the

[25] To calculate the multiplier in column (1) of Table 6 as $\sum_{k=\{DB,DCDB,DC\}} frac_k\left(1/\left(1-\alpha(fracsame_k)\right)-1\right)$ which depends on the average value of *fracsame* for each of the three retirement benefit calculations ($fracsame_{DB}$, $fracsame_{DCDB}$, and $fracsame_{DC}$), and the fraction of retirees whose retirement benefits are determined by DB, DCDB, and DC ($frac_{DB}$, $frac_{DCDB}$, and $frac_{DC}$). When we interact retirement benefit calculation type with job type, for example, the number of categories doubles from {*DB, DCDB, DC*} to {*DB, DCDB, DC*} x {PF, not PF}.

[26] When testing for peer effects in the decision by university employees to participate in a supplemental tax-deferred retirement savings account, Duflo and Saez (2002) argue that a priori restrictions on which coworkers are peers can be used to help identify peer effects. They construct subgroups based on gender, years of service, age, faculty versus staff, and academic department. Because we are focused on the retirement timing decision, we do not attempt to construct subgroups based on years of service or age, but we do construct subgroups based on gender, police and fire versus normal, and employer (which is our analog to department).

interaction between these variables. The coefficient estimate on the new interaction term is positive, but statistically indistinguishable from zero, while the coefficient estimate on the retirement benefit calculation interaction term is slightly attenuated, but remains economically and statistically significant.

In column (5), we include an interaction term based on the fraction of coworkers who have the same job type and face the same retirement benefit calculation as employee *i*. This final specification allows for the possibility that police and fire officers are more likely to respond to their own retirement incentives when more of their police and fire officer coworkers face the same retirement incentives, and that the same is true for general employees. Indeed, the estimated coefficient on this final interaction term is positive and statistically significant. In contrast, the estimated coefficient on the original interaction term falls sharply and loses statistical significance at conventional levels (p-value of 0.112). In other words, whereas the findings in the earlier columns suggest that peers groups can be defined as those coworkers facing the same retirement benefit calculation in month *t*, the findings in column (5) suggest that peer groups are better defined as coworkers with the same job type who are facing the same retirement benefit calculation. When we focus solely on the interaction term based on job type and retirement benefit calculation in column (5), we estimate that PERS employees are 40.1% more likely to respond to aggregate retirement incentives than they would be in the absence of peer effects. In column (6), when we drop the original interaction term from the regression, the social multiplier increases from 40.1% to 73.0%.

5.4.4. Are Peer Effects Helpful or Harmful to Employees?

We find evidence of peer effects in the retirement timing decision using two different identification strategies. Similar to our analysis of mistakes in Section 5.2 and Table 4, in this section we ask a somewhat more nuanced question about whether peer effects have a discernible impact on employee welfare. We consider two cases. First, peer effects are good for retirees because they reflect the diffusion of information about shared retirement incentives. Second, peer effects reflect herding behavior on the part of retirees and unless the employee's optimization problem resembles that of her coworkers peer effects may lead to "mistakes." The fact that the peer effects we identify are concentrated among coworkers who face the same retirement incentive in the same month suggests that they arise from the diffusion of information about retirement incentives, and that coworkers understand when they face the same the incentives.

Nevertheless, some employees may mistakenly respond to retirement incentives that they do not actually face. To shed light on potential welfare consequences, we estimate reduced form regressions for different samples of retirement-eligible employees. The specification that we estimate in Table 8 is similar to Table 6, except that we replace the fraction of employee *i*'s coworkers retiring in month *t* with three instrumental variables: (a) the average retirement incentive of employee i's coworkers in January and February arising from stale returns; (b) the average retirement incentives of employee *i*'s coworkers in the twelve months leading up to the reduction in retirement benefits in July 2003; (c) the fraction of employee *i*'s coworkers with a birthday in month *t*. To the extent that individuals primarily mimic peers whose retirement incentives are aligned with their own, we expect our measures of average retirement incentives within each employer and month to strongly predict DC retirements, weakly predict DCDB retirements (since DCDB benefits are a linear combination of the DC and DB retirement benefit calculations), but to not predict DB retirements. Therefore, in each column, we restrict the sample to employees who are eligible to retire under DB, DCDB, or DC. Columns (1)-(3) focus on the full sample of retirees; columns (4)-(6) focus on employees whose annual salary is in the bottom quartile of all PERS employees (within the calendar year); and columns (7)-(9) focus on female employees.

Looking across the columns in Table 8, we find no evidence of employees responding to incentives they do not face. The estimated coefficients on all three of the instrumental variables are statistically indistinguishable from zero in all three of the specifications that focus on employees who are eligible for the *DB* retirement benefit calculation. In contrast, the estimated coefficients on the instrument measuring retirement incentives from stale returns is positive and statistically significant from zero in all three of the specifications that focus on employees who are eligible for the DC retirement benefit calculation. In other words, the reduced form regressions reveal that coworker retirement incentives only matter when they match the employee's own retirement incentives, which is consistent with what we find in Table 7. The fact that the retirement incentives we study do not apply to the *DB* benefit calculation may also help to explain why adjusted R-squared is so much lower when we restrict the sample to those eligible to retire under DB (e.g., 2.02% in column (1) versus 7.45% in column (3)).

6. Conclusion

In this paper, we provide evidence on the costs of a hybrid pension plan from the perspective of an employer. Not surprisingly, offering employees both the certainty of a defined benefit pension plan and the option to earn higher retirement benefits when market returns are high is costly. Over our sample period, this option increased the *ex post* costs of providing pension benefits by approximately 50% relative to a counterfactual traditional defined benefit pension plan, increasing PERS pension obligations by $7 billion. Moreover, at a time when the emphasis is on encouraging employees to work longer and retire later (Goda, Shoven, and Slavov (2009)), we find that the DC benefit option encourages early retirements relative to a traditional DB benefit during our sample period of high market returns. We also find that fluctuations in retirement benefits contribute to retirement waves. For example, we observe 5,217 employees retire in the first six months of 2003, the period before PERS benefit formulas were adjusted to reflect the increased life expectancies of retirees. The highest number we observe in a full year is 4,314 in 1999, the year before the last known rate benefit calculation was eliminated. These lumpy retirements resulting from changes to PERS are likely to have generated significant administrative costs for employers, and, in some cases, may have disrupted the provision of public services.[27]

It is worth noting that there is a distinction between the expected level of retirement benefits and the form in which those benefits are delivered to employees. Rather than offer a hybrid plan, PERS could have offered a traditional DB pension plan and used the payout factor to increase pension generosity. Doing so, would have increased the expected benefits for all retirees—not simply those whose careers happened to coincide with periods of higher-than-average equity market returns.[28] And, a traditional DB pension plan would have discouraged early retirements relative to the hybrid pension plan. One potential argument in favor of the hybrid pension plan is that, if we expect stock returns to be higher when inflation is higher, it insures employees against a situation in which the inflation rate is high but the growth rate in wages is low. However, this insurance is costly for employers to provide, and it may not be the most cost-effective way to compete for high-quality employees. This begs the question of whether and how much changes to PERS have affected Oregon's ability to hire high-quality employees. For example, Oregon should ideally weigh the costs savings associated with reforming PERS against any reduction in teacher quality resulting from lower pension benefits. Quantifying the effect of pension generosity on employee quality is a challenging but important area for future research.

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[27] For example, state newspapers carried stories of firefighters, teachers, and other public employees claiming that the impending changes to PERS forced them to retire in 2003. See, for example, "Pension Changes Prompt Early Retirement for State workers in Corvallis, OR," *Oregonian*, August 4, 2003, and "Oregon Public Employee System Puts Retirees in Work Predicament," *Oregonian*, September 11, 2003.

[28] Of course, increasing the payout factor while holding employee contributions into the plan constant necessarily increases the expected level of underfunding, as discussed in Novy-Marx and Rauh (2011).

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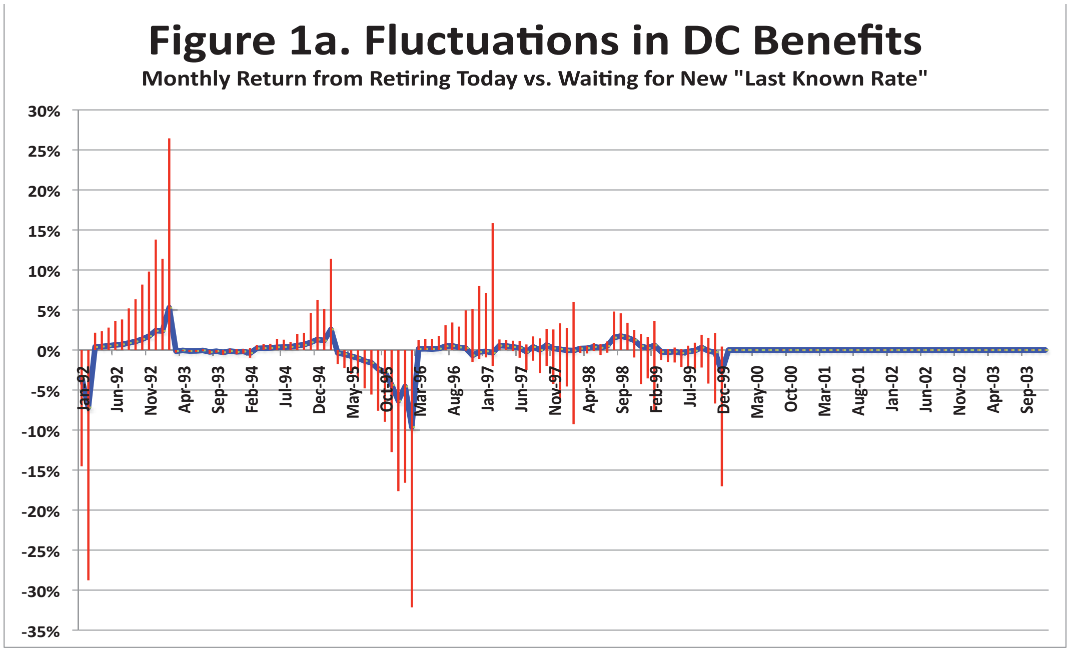
Figure 1a. Fluctuations in DC Benefits
Monthly Return from Retiring Today vs. Waiting for New "Last Known Rate"
30%
25%
20%
15%
10%
5%
0%
-5%
-10%
-15%
-20%
-25%
-30%
-35%
Jan-92
Jun-92
Nov-92
Apr-93
Sep-93
Feb-94
Jul-94
Dec-94
May-95
Oct-95
Mar-96
Aug-96
Jan-97
Jun-97
Nov-97
Apr-98
Sep-98
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Nov-02
Apr-03
Sep-03

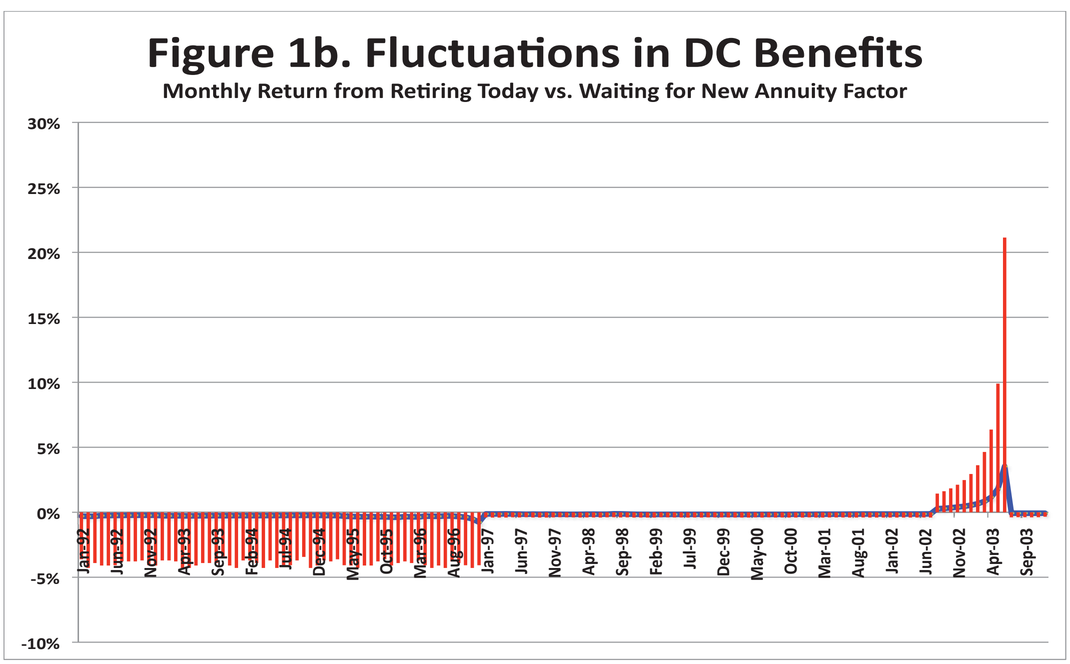
Figure 1b. Fluctuations in DC Benefits
Monthly Return from Retiring Today vs. Waiting for New Annuity Factor
30%
25%
20%
15%
10%
5%
0%
-5%
-10%
Jan-92
Jun-92
Nov-92
Apr-93
Sep-93
Feb-94
Jul-94
Dec-94
May-95
Oct-95
Mar-96
Aug-96
Jan-97
Jun-97
Nov-97
Apr-98
Sep-98
Feb-99
Jul-99
Dec-99
May-00
Oct-00
Mar-01
Aug-01
Jan-02
Jun-02
Nov-02
Apr-03
Sep-03

Figure 2. Retirements are Lumpy

Fraction of Retirement-Eligible Employees that Retire, Jan 92 - Dec 03

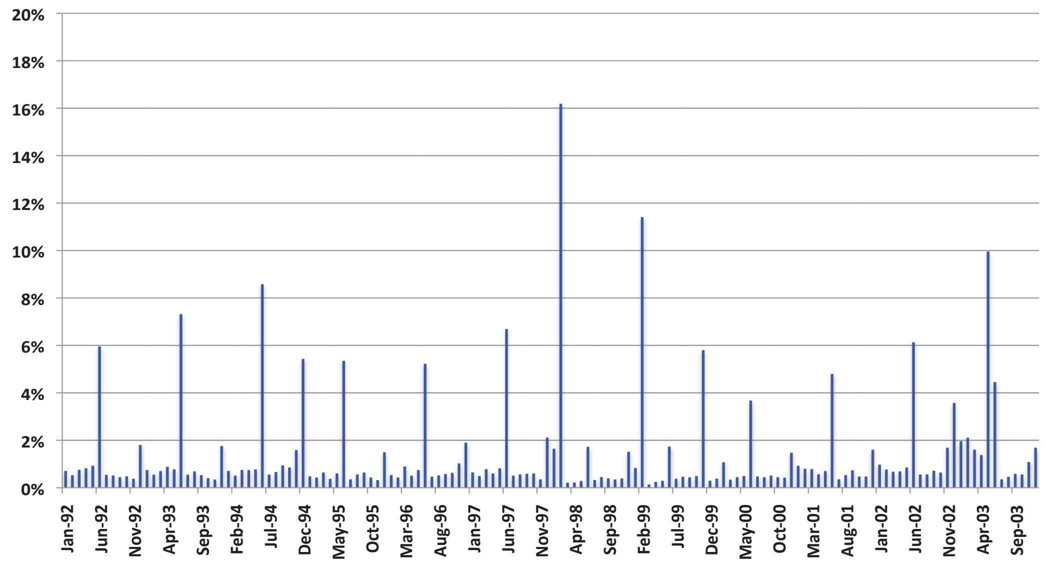

Figure 3. Ex Ante Estimate of DC/DB

Based on 50,000 sample pension paths for employment ages 20 - 58

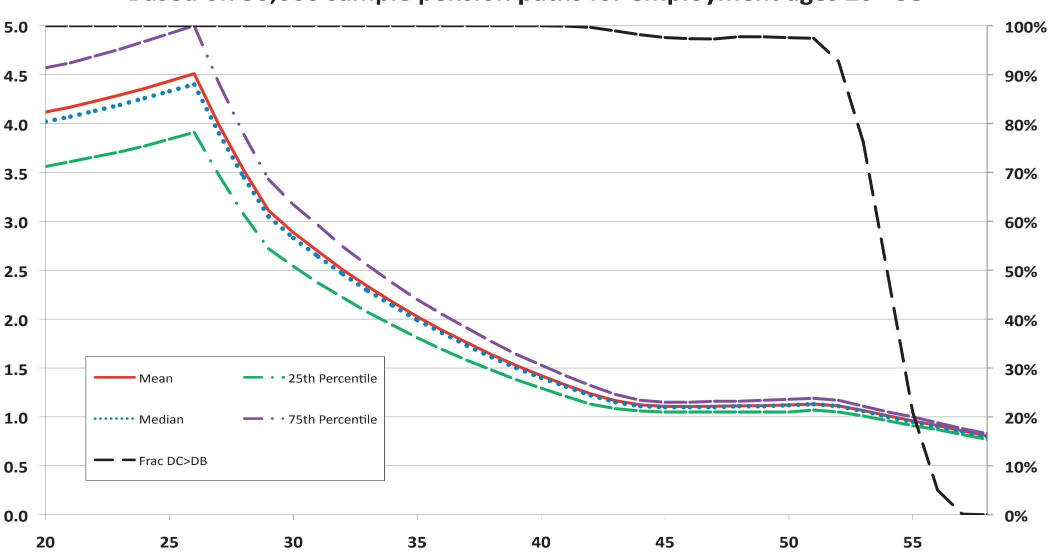

Table 1. Annual Employee-Level Summary Statistics, 1990-2003

	EMPLOYED & ELIGIBLE TO RETIRE NORMAL (#)	EMPLOYED & ELIGIBLE TO RETIRE EARLY (#)	AVERAGE MONTHLY SALARY PAST 12 MONTHS ($)	REPLACE-MENT RATE (%)	YEARS OF SERVICE (# years)	AGE (# years)	FEMALE (%)	POLICE OR FIRE (%)	PERS TIER 2 (%)	DCDB BENEFITS (%)	DC BENEFITS (%)
Panel A. Eligible to Retiree											
1990	7,724	1,266	$2,319	0.27	15.1	59.1	54.7%	5.7%	0.0%	49.6%	21.8%
1991	8,061	1,424	$2,454	0.33	15.3	59.1	54.4%	6.0%	0.0%	24.7%	57.7%
1992	8,266	1,402	$2,587	0.29	15.4	59.0	54.9%	6.4%	0.0%	41.8%	27.6%
1993	8,554	1,602	$2,694	0.30	15.5	59.0	55.7%	6.4%	0.0%	31.6%	39.0%
1994	8,516	2,282	$2,809	0.30	15.6	58.9	56.1%	6.8%	0.0%	32.1%	34.0%
1995	7,937	1,141	$2,794	0.36	15.2	58.7	56.5%	6.9%	0.0%	8.9%	73.0%
1996	8,839	1,475	$2,928	0.33	15.6	58.7	56.6%	7.5%	1.1%	14.0%	58.8%
1997	9,381	1,768	$3,055	0.38	15.7	58.5	56.7%	8.0%	3.8%	7.3%	73.5%
1998	9,495	2,469	$3,177	0.39	15.6	58.4	57.1%	7.9%	6.9%	4.8%	79.5%
1999	9,114	2,247	$3,239	0.39	14.9	58.3	57.9%	8.1%	11.4%	3.4%	83.0%
2000	9,123	1,055	$3,299	0.37	14.5	58.3	58.8%	8.1%	15.5%	2.7%	78.3%
2001	10,734	1,653	$3,442	0.37	14.8	58.3	59.4%	7.7%	18.5%	3.0%	70.4%
2002	11,634	2,503	$3,593	0.36	15.0	58.3	60.0%	7.0%	21.0%	3.0%	63.9%
2003	11,439	3,295	$3,667	0.33	14.8	58.3	60.5%	6.7%	24.1%	3.0%	58.9%
Panel B. Choose to Retire											
1990	1,266	240	$2,801	0.35	18.9	60.6	52.4%	4.7%	0.0%	59.7%	19.7%
1991	1,424	283	$2,994	0.41	19.3	60.5	49.8%	5.7%	0.0%	41.1%	45.7%
1992	1,402	276	$3,183	0.38	19.5	60.6	49.2%	6.8%	0.0%	52.6%	29.0%
1993	1,602	353	$3,351	0.41	19.7	60.5	51.0%	6.1%	0.0%	42.1%	41.6%
1994	2,282	493	$3,506	0.41	20.6	60.0	53.9%	7.5%	0.0%	46.0%	34.6%
1995	1,141	313	$3,260	0.45	18.8	60.4	54.1%	4.3%	0.0%	17.7%	67.2%
1996	1,475	310	$3,581	0.44	19.9	60.0	53.0%	6.5%	0.2%	25.4%	56.6%
1997	1,768	470	$3,735	0.50	20.4	59.7	55.0%	8.6%	0.4%	15.6%	72.7%
1998	2,469	1,138	$3,866	0.58	21.3	59.2	55.0%	6.5%	0.8%	7.6%	86.1%
1999	2,247	1,215	$4,019	0.59	20.9	58.6	55.0%	7.5%	1.4%	6.1%	88.2%
2000	1,055	614	$4,093	0.56	19.2	58.7	54.5%	7.3%	4.5%	4.3%	88.0%
2001	1,653	695	$4,303	0.58	20.6	58.8	57.0%	7.9%	4.1%	5.2%	84.7%
2002	2,503	1,125	$4,534	0.60	21.7	58.7	57.7%	6.8%	4.2%	4.9%	84.3%
2003	3,294	2,022	$4,490	0.56	21.2	58.5	59.0%	6.6%	4.5%	4.8%	82.2%

Note: The unit of observation is retirement-eligible employee i in year t. For employees who do not retire in year t, variables are measured in December. For employees who retire, variables are measured in the month of retirement.

Table 2. Retirement benefits owed to new retirees, January 1990 - December 2003

	Number of Retirements			Average Replacement Rate (ignoring Social Security)		Implicit Payout Factor		PV Retirement Benefits Owed New Retirees ($ millions)		PV of Actual Benefits relative to PV
	Total	DB	DCDB or DC	Capped at DB	Additional Benefit	Capped at DB	Additional Benefit	Capped at DB	Additional Benefit	of Benefits Capped at DB
Panel A. Realized Retirement Benefits										
1990	1,774	388	1,386	31.5%	4.4%	1.65%	0.36%	317.6	44.5	114.0%
1991	2,008	261	1,747	32.3%	9.2%	1.65%	0.53%	391.8	115.6	129.5%
1992	2,001	357	1,644	33.2%	6.1%	1.66%	0.33%	451.2	81.0	118.0%
1993	2,323	394	1,929	32.9%	8.3%	1.65%	0.41%	591.1	152.4	125.8%
1994	3,361	639	2,722	34.5%	7.3%	1.66%	0.35%	799.3	169.5	121.2%
1995	1,771	270	1,501	30.7%	14.3%	1.63%	0.67%	386.0	190.6	149.4%
1996	2,193	398	1,795	32.8%	12.0%	1.65%	0.55%	526.3	194.1	136.9%
1997	2,576	315	2,261	34.0%	16.9%	1.66%	0.74%	682.5	344.0	150.4%
1998	4,314	263	4,051	34.7%	24.0%	1.63%	1.09%	1,297.7	895.2	169.0%
1999	4,188	231	3,957	33.9%	25.9%	1.62%	1.12%	1,253.9	963.1	176.8%
2000	1,992	146	1,846	31.5%	25.6%	1.61%	1.12%	536.1	439.9	182.1%
2001	2,752	277	2,475	34.1%	25.3%	1.62%	1.05%	889.9	658.4	174.0%
2002	4,374	454	3,920	35.8%	25.8%	1.62%	1.03%	1,660.0	1,174.7	170.8%
2003	6,313	795	5,518	34.5%	22.7%	1.60%	0.93%	2,459.3	1,593.1	164.8%
1990-2003	41,940	5,188	36,752	33.8%	18.3%	1.63%	0.80%	12,242.4	7,016.0	157.3%
Panel B. Counterfactual Retirement Benefits Using Life Annuity Pricing Available from TIAA										
1990	1,774	458	1,316	31.5%	3.7%	1.65%	0.31%	317.6	37.7	111.9%
1991	2,008	319	1,689	32.3%	7.8%	1.65%	0.45%	391.8	100.2	125.6%
1992	2,001	470	1,531	33.2%	4.5%	1.66%	0.25%	451.2	61.4	113.6%
1993	2,323	709	1,614	32.9%	4.2%	1.65%	0.22%	591.1	79.6	113.5%
1994	3,361	1,607	1,754	34.5%	2.3%	1.66%	0.12%	799.3	55.4	106.9%
1995	1,771	451	1,320	30.7%	8.3%	1.63%	0.39%	386.0	114.5	129.7%
1996	2,193	755	1,438	32.8%	4.7%	1.65%	0.22%	526.3	78.8	115.0%
1997	2,576	687	1,889	34.0%	8.4%	1.66%	0.36%	682.5	176.6	125.9%
1998	4,314	829	3,485	34.7%	11.1%	1.63%	0.51%	1,297.7	424.8	132.7%
1999	4,188	1,025	3,163	33.9%	10.5%	1.62%	0.44%	1,253.9	396.6	131.6%
2000	1,992	443	1,549	31.5%	15.4%	1.61%	0.65%	536.1	270.1	150.4%
2001	2,752	704	2,048	34.1%	12.8%	1.62%	0.51%	889.9	339.8	138.2%
2002	4,374	1,175	3,199	35.8%	11.0%	1.62%	0.42%	1,660.0	503.1	130.3%
2003	6,313	2,523	3,790	34.5%	6.6%	1.60%	0.26%	2,459.3	465.1	118.9%
1990-2003	41,940	12,155	29,785	33.8%	8.2%	1.63%	0.36%	12,242.4	3,103.7	125.4%

Note: This table decomposes the retirement benefits of new retirees into those due to the DB formula, and any extra benefit due to the DC and DCDB formulas. Panel A is based on retirement benefits using the actual retirement benefit formulas. The average replacement rate of all 41,940 retirees based on the DB formula is 33.8%. However, because of the two additional benefit formulas, the average realized replacement rate is 52.1% (33.8% plus 18.3%). The average payout factor under the DB formula is 1.63%, which is lower than the 1.67% available to normal participants and the 2.00% available to police and fire because some employees retire when they face an early retirement penalty under the DB formula. The implicit payout factor measures what the payout factor would need to be in the DB formula to generate the same benefit; it averages 2.43%. "PV Benefits Owed New Retirees" sums the expected present value of the retirement benefits owed to each retiree. We use retiree i's gender and age at retirement and life tables from the Social Security Administration for 2004 to determine the probability that she receives each future monthly payment, we assume an constant annual cost of living adjustment of 2.00%, and we use the yield on 10-year U.S. Treasury notes at the time of retirement as our discount rate. The last column shows that the expected present value of retiree benefit payments are 57.3% higher than they would have been if retirement date choices were held constant and monthly benefits were calculated using the DB formula. Panel B is based on counterfactual retirement benefits using the AEFs offered by TIAA instead of the AEFs offered by PERS. Because AEFs only enter the DC and DCDB formulas, the average values under the DB formula do not change. However, the number of retirees for whom the DB formula provides the highest retirement benefit increases from 5,188 to 12,155.

Table 3. Probability of Early Retirement and Distribution of Retirement Ages by Benefit Formula, 1990-2003

Panel A. Sample of retirees for whom early retirement age is 55 and normal retirement age is 58

Age at	Retires with DB Benefits			Retires with DCDB Benefits			Retires with DC Benefits		
Retirement	#	%	Cum. %	#	%	Cum. %	#	%	Cum. %
55	105	3.1%	3.1%	141	2.9%	2.9%	3,660	17.2%	17.2%
56	135	4.0%	7.1%	191	3.9%	6.8%	2,039	9.6%	26.8%
57	206	6.1%	13.1%	383	7.8%	14.6%	2,112	9.9%	36.8%
58	542	15.9%	29.1%	1,101	22.4%	37.0%	2,941	13.8%	50.6%
59	313	9.2%	38.3%	560	11.4%	48.4%	1,630	7.7%	58.3%
60	289	8.5%	46.8%	480	9.8%	58.2%	1,437	6.8%	65.1%
61	316	9.3%	56.1%	506	10.3%	68.5%	1,587	7.5%	72.5%
62	566	16.7%	72.7%	654	13.3%	81.8%	1,841	8.7%	81.2%
63	230	6.8%	79.5%	244	5.0%	86.8%	807	3.8%	85.0%
64	203	6.0%	85.5%	201	4.1%	90.9%	768	3.6%	88.6%
65	238	7.0%	92.5%	256	5.2%	96.1%	1,019	4.8%	93.4%
66	92	2.7%	95.2%	75	1.5%	97.7%	337	1.6%	95.0%
67	58	1.7%	96.9%	41	0.8%	98.5%	227	1.1%	96.1%
After 67	106	3.0%	100.0%	74	1.4%	100.0%	833	3.6%	100.0%
All	3,399			4,907			21,238		

Panel B. Full sample of retirees

	Retires with DB Benefits		Retires with DCDB Benefits		Retires with DC Benefits	
	#	% Retiring Early	#	% Retiring Early	#	% Retiring Early
1990-2003	4,388	14.0%	6,750	12.2%	23,991	33.8%
1990-1996	2,245	8.8%	5,292	12.0%	5,323	26.9%
1997-2003	2,143	19.6%	1,458	12.8%	18,668	35.7%
Change		10.8% ***		0.8%		8.8% ***
1996 only	320	8.1%	454	9.5%	1,011	23.8%
1997 only	262	13.7%	350	11.7%	1,626	24.2%
Change		5.6% *		2.2%		0.3%

Note: In Panel A, we report the distribution of retirement ages for employees retiring under each of the three benefit formulas. We begin with the full sample of retirees described in Panel B of Table 1. However, to facilitate comparisons across benefit formulas, we exclude 2,385 retirees who are police and fire officers, 632 retirees whose normal retirement age is 60, and 2,568 retirees whose normal retirement age is 58 but who qualify for normal retirement benefits based on years of service rather than age. This leaves us with a sample of 29,544 retirees for whom the early retirement age is 55 and the normal retirement age is 58. In Panel B, we focus on the full sample of retirees described in Panel B of Table 1. For employees retiring under each of the three benefit formulas, we report the total number of retirements and the fraction of retirements by employees who face (or would face) an early retirement penalty under the DB and DCDB benefit formulas. Because the frequency with which the early retirement penalty is updated changes from annual to monthly on January 1, 1997, we also report separate statistics for these two regimes. To test whether the likelihood of an early retirement changes across these regimes, we regress a dummy variable indicating whether employee i faces (or would face) an early retirement penalty under the DB and DCDB formulas on a dummy variable indicating whether the early retirement penalty is updated monthly. To allow for correlated behavior within employers, we cluster the standard errors on employee i's employer identification number.

Table 4. Retirement Timing Decisions and Stale Returns

Panel A. Distribution of Retirements Under DC Benefit Formula Across Months

Regime		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1990-1999	#	565	4,100	280	244	330	4,099	233	314	298	273	1,093	1,278
	%	4.3%	31.3%	2.1%	1.9%	2.5%	31.3%	1.8%	2.4%	2.3%	2.1%	8.3%	9.8%
2000-2002	#	348	399	254	232	261	2,718	167	198	265	222	390	1,061
	%	5.3%	6.1%	3.9%	3.6%	4.0%	41.7%	2.6%	3.0%	4.1%	3.4%	6.0%	16.3%

Panel B. Impact of Stale Returns on DC Benefits in February

Benefit from	February Retirees					March Retirees				
Stale Returns?	#	Mean	Min.	Med.	Max.	#	Mean	Min.	Med.	Max.
Yes	3,436	1.9%	0.0%	1.9%	28.9%	140	-8.0%	-28.1%	-8.5%	0.0%
No	664	-4.0%	-27.1%	-3.2%	0.0%	92	7.1%	0.0%	6.4%	23.3%
All Retirees	4,100	1.0%	-27.1%	1.9%	28.9%	232	-2.0%	-28.1%	-1.0%	23.3%

Panel C. Retiree Characteristics

Benefit from Stale Returns?	#	Monthly Salary	Replace. Rate	Years of Service	Age	Female?	Police or Fire?	Tier 2?	Invest in Variable?
Yes	3,576	3,853	61.6%	21.9	59.3	57.3%	2.0%	0.2%	15.0%
No	756	3,875	65.0%	21.7	59.6	48.4%	2.6%	1.1%	43.3%
All Retirees	4,332	3,857	62.2%	21.9	59.4	55.7%	2.1%	0.3%	19.9%

Note: Between 1990 and 1999, PERS finalizes returns for calendar year t in March of year t+1. For those retiring before March, PERS applies the returns from calendar year t-1 to calendar years t and t+1. Beginning January 2000, PERS eliminates the use of stale returns. In Panel A, we report the number of retirements under the DC benefit formula each month for 1990-1999 and 2000-2002. February retirements are significantly more common when PERS relies on stale returns. In Panel B, we distinguish between two types of retirees. The first group successfully respond to the retirement incentives arising from stale returns by either retiring in February when the stale returns increased the PERS account balance or retiring in March when the stale returns would have decreased the PERS account balance in February. The second group unsuccessfully respond to the retirement incentives arising from stale returns by either retiring in February when the stale returns decreased the PERS account balance or retiring in March when the stale returns would have increased the PERS account balance in February. We report the number of retirees who belong to each group and summarize the of stale returns on the PERS account balance in February. For example, the 140 retirees who retired in March would have received retirement benefits that were, on average, 8.0% lower had they instead retired in February. In Panel C, we report the average values of the final average monthly salary, replacement rate, years of service, and age at retirement. We also report the fraction of retirees who are female, police or fire officers, eligible for Tier 2 benefits, and who allocate a fraction of their PERS contributions to the variable account.

Table 5. Linear Probability Model Predicting Retirement Date, 1990-2003

Dependent Variable:	*1 if employee i retires on date t, 0 otherwise*			
Sample:	**All members**	**Female = 1**	**PF = 1**	**Birth Month = 1**
Estimation:	**OLS**	**OLS**	**OLS**	**OLS**
	(1)	**(2)**	**(3)**	**(4)**
Replacement rate of total life annuity benefit	3.451 ***	3.080 ***	2.774 ***	6.704 ***
	[0.189]	[0.219]	[0.734]	[0.527]
EPV benefit of waiting until t*	0.003	0.002	-0.009	-0.001
	[0.002]	[0.002]	[0.006]	[0.007]
Incentive due to stale returns x {Mar-Dec}?	-0.045	-1.373	-2.975	-10.489 **
	[0.890]	[1.007]	[4.009]	[4.173]
Incentive due to stale returns x {Jan-Feb}?	11.663 ***	13.259 ***	0.479	12.362 ***
	[0.875]	[1.173]	[2.564]	[3.026]
Incentive due to changes in AEFs x ('90-'96}?	7.707 **	4.010	38.824 **	
	[3.298]	[3.214]	[17.190]	
Incentive due to changes in AEFs x {'03}?	87.156 ***	100.436 ***	86.192 ***	101.373 ***
	[5.659]	[6.652]	[23.697]	[14.987]
Eligible for early retirement -- month 1	0.009	0.198	-1.169 **	-2.000 ***
	[0.224]	[0.264]	[0.503]	[0.711]
Eligible for early retirement -- months 2-12	-1.179 ***	-0.952 ***	-1.977 ***	0.280
	[0.131]	[0.124]	[0.356]	[0.275]
Eligible for early retirement -- month 13+	-0.496 ***	-0.397 ***	-1.311 ***	1.275 ***
	[0.081]	[0.079]	[0.214]	[0.220]
Eligible for normal retirement -- month 1	3.032 ***	2.311 ***	10.123 ***	3.341 ***
	[0.330]	[0.311]	[1.894]	[0.341]
Eligible for normal retirement -- months 2-12	0.331 ***	0.098	1.100 ***	0.939 ***
	[0.078]	[0.080]	[0.360]	[0.238]
Birth month?	0.878 ***	0.702 ***	0.567 ***	
	[0.092]	[0.105]	[0.182]	
Member dies in months 1-12?	0.819 ***	0.774 ***	0.473	1.215
	[0.191]	[0.258]	[0.566]	[0.804]
Member dies in months 13-48?	0.210 ***	0.125	0.340	0.744 **
	[0.055]	[0.087]	[0.313]	[0.299]
Years of Service	0.036 ***	0.043 ***	0.017	0.056 ***
	[0.005]	[0.006]	[0.022]	[0.015]
Unemployment rate within county	-2.647 ***	-2.527 ***	-0.353	-5.411 **
	[0.941]	[0.912]	[2.831]	[2.483]
Female?	-0.049 *		0.038	-0.326 ***
	[0.025]		[0.063]	[0.092]
Police or Fire Fighter?	-0.033	-0.089		-0.332
	[0.092]	[0.114]		[0.268]
PERS Tier Two?	0.022	0.062	0.192	-0.463 ***
	[0.039]	[0.048]	[0.142]	[0.135]
Full life annuity calculated under DB	-0.081 *	-0.024	-0.241	-0.520 ***
	[0.045]	[0.034]	[0.172]	[0.154]
Full life annuity calculated under DC	-0.258 ***	-0.151 ***	-0.480 ***	-0.744 ***
	[0.036]	[0.037]	[0.141]	[0.153]
Separate fixed effect for each age (in years)?	Yes	Yes	Yes	Yes
Date-by-employer type FE?	Yes	Yes	Yes	Yes
N	2,407,980	1,386,758	174,114	221,770
R-Squared	0.0630	0.0659	0.0487	0.0692

Note: Estimation is via OLS. Dependent variable equals 1 if employee i retires in month t and 0 otherwise. Employees who retiree in month t are dropped from the sample in month t+1. For consistency with tests for peer effects in later tables, the sample is restricted to employers with two or more employees eligible to retire in month t. Independent variables are described in Section 5.3. The range in retirement incentives due to the use of stale returns in the retirement account balance calculation is plotted in Figure 1a. The range in retirement incentives due to changes to actuarial equivalency tables is plotted in Figure 1b. Standard errors are clustered on employer. Statistically significance at the 10-percent, 5-percent, and 1-percent levels is denoted by *, **, and ***. Coefficients are multipled by 100, so that 1.000 represents 1 percentage point.

Table 6. Linear Probability Model Testing for Peer Effects in the Choice of Retirement Dates, 1990-2003

Dependent Variable:	*1 if employee i retires on date t, 0 otherwise*					
Sample:	**All members**	**All members**	**All members**	**All members**	**All members**	**All members**
Estimation:	**OLS**	**IV**	**IV**	**IV**	**IV**	**IV**
Instruments:		**Stale Returns**	**AEFs '03**	**AEFs '90-'96**	**Birth Month**	**All**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Fraction of current employees retiring	27.024 ***	36.445 ***	15.364	-115.515	22.659 ***	20.454 ***
	[2.108]	[11.447]	[13.150]	[328.915]	[8.555]	[7.906]
Fraction of current employees retiring from other employers in same county in month t	0.092	0.067	0.122	0.465	0.103	0.109
	[2.981]	[2.586]	[3.469]	[8.906]	[3.163]	[3.256]
Fraction of non-retirement eligible employees leaving employer j in month t	2.794 ***	2.507 ***	3.149 ***	7.138	2.927 ***	2.994 ***
	[0.780]	[0.755]	[0.958]	[10.453]	[0.852]	[0.860]
Fraction of former employees retiring in month t	0.084	0.085	0.082	0.064	0.083	0.083
	[0.272]	[0.238]	[0.314]	[0.799]	[0.288]	[0.296]
Replacement rate of total life annuity benefit	3.421 ***	3.412 ***	3.432 ***	3.559 ***	3.425 ***	3.427 ***
	[0.186]	[0.185]	[0.187]	[0.347]	[0.188]	[0.187]
EPV benefit of waiting until t*	0.003	0.003	0.003	0.002	0.003	0.003
	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
Incentive due to stale prices x {Mar-Dec?}	0.001	0.016	-0.016	-0.219	-0.005	-0.008
	[0.868]	[0.860]	[0.876]	[1.190]	[0.869]	[0.871]
Incentive due to stale prices x {Jan-Feb?}	11.366 ***	11.262 ***	11.494 ***	12.933 ***	11.414 ***	11.438 ***
	[0.838]	[0.839]	[0.856]	[3.830]	[0.848]	[0.844]
Incentive due to changes in AEFs x ('90-'96?}	7.463 **	7.371 **	7.577 **	8.857	7.506 **	7.527 **
	[3.285]	[3.281]	[3.279]	[5.536]	[3.281]	[3.278]
Incentive due to changes in AEFs x {'03?}	86.433 ***	86.190 ***	86.733 ***	90.105 ***	86.545 ***	86.602 ***
	[5.564]	[5.533]	[5.571]	[10.935]	[5.591]	[5.571]
Eligible for early retirement -- month 1	0.003	0.001	0.006	0.033	0.004	0.005
	[0.225]	[0.225]	[0.225]	[0.238]	[0.225]	[0.225]
Eligible for early retirement -- months 2-12	-1.184 ***	-1.185 ***	-1.181 ***	-1.157 ***	-1.183 ***	-1.182 ***
	[0.131]	[0.131]	[0.131]	[0.147]	[0.131]	[0.131]
Eligible for early retirement -- month 13+	-0.498 ***	-0.498 ***	-0.497 ***	-0.486 ***	-0.497 ***	-0.497 ***
	[0.081]	[0.081]	[0.081]	[0.087]	[0.081]	[0.081]
Eligible for normal retirement -- month 1	3.030 ***	3.029 ***	3.031 ***	3.049 ***	3.031 ***	3.031 ***
	[0.328]	[0.326]	[0.329]	[0.356]	[0.328]	[0.328]
Eligible for normal retirement -- months 2-12	0.327 ***	0.325 ***	0.329 ***	0.351 ***	0.328 ***	0.328 ***
	[0.078]	[0.077]	[0.077]	[0.105]	[0.077]	[0.077]
Birth month?	0.876 ***	0.875 ***	0.877 ***	0.889 ***	0.876 ***	0.877 ***
	[0.092]	[0.092]	[0.092]	[0.093]	[0.092]	[0.092]
Member dies within next 12 months?	0.828 ***	0.832 ***	0.823 ***	0.772 ***	0.826 ***	0.825 ***
	[0.191]	[0.191]	[0.191]	[0.241]	[0.191]	[0.191]
Member dies within next 48 months?	0.212 ***	0.212 ***	0.211 ***	0.208 ***	0.211 ***	0.211 ***
	[0.055]	[0.055]	[0.055]	[0.059]	[0.055]	[0.055]
Years of service	0.035 ***	0.035 ***	0.036 ***	0.040 ***	0.035 ***	0.036 ***
	[0.005]	[0.005]	[0.005]	[0.013]	[0.005]	[0.005]
Unemployment rate in county	-1.809 **	-1.519 **	-2.167 **	-6.189	-1.943 **	-2.011 **
	[0.739]	[0.770]	[0.935]	[10.534]	[0.834]	[0.838]
Female?	-0.047 *	-0.046 *	-0.048 *	-0.063	-0.047 *	-0.048 *
	[0.025]	[0.025]	[0.025]	[0.046]	[0.025]	[0.025]
Police or Fire Fighter?	-0.012	-0.006	-0.020	-0.111	-0.015	-0.017
	[0.087]	[0.084]	[0.088]	[0.239]	[0.087]	[0.087]
PERS Tier Two?	0.029	0.032	0.025	-0.012	0.028	0.027
	[0.039]	[0.040]	[0.040]	[0.105]	[0.039]	[0.039]
Full life annuity calculated under DB	-0.073 *	-0.070	-0.077 *	-0.117	-0.075 *	-0.075 *
	[0.044]	[0.044]	[0.045]	[0.117]	[0.045]	[0.044]
Full life annuity calculated under DC	-0.253 ***	-0.250 ***	-0.255 ***	-0.286 ***	-0.254 ***	-0.254 ***
	[0.036]	[0.036]	[0.036]	[0.091]	[0.036]	[0.036]
Other individual controls from Table 2?	Yes	Yes	Yes	Yes	Yes	Yes
Separate fixed effect for each age (in years)?	Yes	Yes	Yes	Yes	Yes	Yes
Date-by-employer type FE?	Yes	Yes	Yes	Yes	Yes	Yes
N	2,407,980	2,407,959	2,407,959	2,407,959	2,407,959	2,407,959
Adj. R-Squared	0.0659	0.0656	0.0654		0.0659	0.0658

Note: Estimation is via OLS in column (1) and 2SLS in the remaining columns. The dependent variable and sample restrictions are the same as in Table 5. The instrument in column (1) is the average value of *DC_delta* for employee i's coworkers at employer j in month t. The instruments in columns (2) and (3) are the average values of *AEF_delta* for employee i's coworkers at employer j in month t, in the periods 2003 and 1990-1996, respectively. The instrument in column (4) is the fraction of coworkers with a birthday in month t. We use all four instruments in column (5). Additional control variables include the fraction of current employees retiring from other employers in same county in month t, the fraction of non-retirement eligible employees leaving employer j in month t, and the fraction of employer j's former employees retiring in month t. Standard errors are clustered on employer. Statistically significance at the 10-percent, 5-percent, and 1-percent levels is denoted by *, **, and ***. Coefficients are multipled by 100, so that 1.000 represents 1 percentage point.

Table 7. Interaction based test for Peer Effects, 1990-2003

Dependent Variable:	*1 if employee i retires on date t, 0 otherwise*					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Fraction coworkers with same **benefit type** (t) *	85.921 ***	85.974 ***	81.479 ***	77.792 ***	30.596	
Fraction all employees with same **benefit type** who retire (t)	[15.649]	[15.614]	[18.910]	[15.813]	[19.229]	
Fraction coworkers with same **benefit** type (t)	-0.812 ***	-0.811 ***	-0.618 ***	-0.766 ***	-0.442	
	[0.161]	[0.161]	[0.206]	[0.163]	[0.271]	
Fraction coworkers with same **gende**r (t) *		-3.090				
Fraction all employees with same **gender** who retire (t)		[5.843]				
Fraction coworkers with same **gender** (t)		-0.173 *				
		[0.091]				
Fraction coworkers with same **benefit type and gender** (t) *			7.523			
Fraction all employees with same **benefit type and gender** who retire (t)			[9.629]			
Fraction coworkers with same **benefit type and gender** (t)			-0.215 *			
			[0.116]			
Fraction coworkers with same **PF status** (t) *				13.568		
Fraction all employees with same **PF status** who retire (t)				[12.028]		
Fraction coworkers with same **PF status** (t)				-0.148		
				[0.236]		
Fraction coworkers with same **benefit type and PF status** (t) *					52.900 ***	76.236 ***
Fraction all employees with same **benefit type and PF status** who retire (t)					[18.442]	[14.296]
Fraction coworkers with same **benefit type and PF status** (t)					-0.373	-0.716 ***
					[0.279]	[0.159]
Controls and FE from T4 column (1)?	Yes	Yes	Yes	Yes	Yes	Yes
Date-by-benefit calculation-by-gender FE?	Yes	Yes	Yes	---	---	---
Date-by-benefit calculation-by-police/fire FE?	---	---	---	Yes	Yes	Yes
Date-by-employer FE?	Yes	Yes	Yes	Yes	Yes	Yes
N	2,407,959	2,407,959	2,391,709	2,407,959	2,402,768	2,402,768
Adj. R-Squared **(demeaned)**	0.0226	0.0226	0.0226	0.0226	0.0227	0.0227
Multiplier for interaction term introduced in column (1)	89.6%	89.7%	80.4%	73.5%	19.0%	---
Multiplier for additional interaction term	---	-1.6%	4.1%	14.0%	40.1%	73.0%

Note: Estimation is via OLS. We describe our empirical strategy, which is based on Bertrand, Luttmer, and Mullainathan (2000), and the calculation of the multiplier effect due to peer effects in Section 5.4.3. We include all of the independent variables from Table 6 that vary within employer-month, do do not report the estimated coefficients. Standard errors are clustered on employer. Statistically significance at the 10-percent, 5-percent, and 1-percent levels is denoted by *, **, and ***. Coefficients are multipled by 100, so that 1.000 represents 1 percentage point.

Table 8. Reduced form regressions of coworker incentives on individual retirements, 1990-2003

Sample:	All Retirement-Eligible Employees			Low Income Employees			Female Employees		
Retirement Benefit Calculation:	*DB*	*DCDB*	*DC*	*DB*	*DCDB*	*DC*	*DB*	*DCDB*	*DC*
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Individual's incentive		-1.236	22.559 ***		5.621	28.091 ***		-6.537 *	25.964 ***
due to stale returns		[3.200]	[1.651]		[10.562]	[3.063]		[3.760]	[2.256]
Individual's incentive		97.553	51.495 ***		-179.332	77.708 ***		411.247 **	97.564 ***
due to changes in AEFs in 2003		[114.736]	[11.356]		[235.952]	[13.603]		[189.199]	[13.984]
Coworkers' incentive	-1.779	3.548	10.359 **	-3.194	3.253	8.211 *	1.383	-0.279	12.900 **
due to stale prices	[2.239]	[3.664]	[5.201]	[3.874]	[5.674]	[4.890]	[2.830]	[4.827]	[6.529]
Coworkers' incentive	0.977	289.331 **	42.900	32.946	1019.102	-7.203	-10.782	120.074	35.066
due to changes in AEFs	[18.699]	[124.892]	[34.246]	[38.586]	[707.611]	[39.741]	[20.817]	[145.575]	[40.544]
Fraction of coworkers with	-0.104	0.492	0.453 **	0.026	-0.164	0.498 *	-0.100	-0.083	0.561 *
birthday in month t	[0.175]	[0.433]	[0.229]	[0.290]	[0.604]	[0.297]	[0.236]	[0.487]	[0.295]
Separate fixed effect for each age?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Date-by-employer type FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Date-by-benefit calculation FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	648,818	361,340	1,397,801	195,699	64,125	342,196	375,042	229,625	782,077
R-Squared	0.0202	0.0843	0.0745	0.0143	0.0625	0.0435	0.0225	0.0864	0.0770

Note: Estimation is via OLS. The dependent variable and sample restrictions are the same as in Table 4 with three exceptions. We include the actual retirement incentives that employees face due to stale returns and changes to AEFs in month t, as well as the average actual retirement incentives that their coworkers face in month t. In addition, because the actual retirement incentives apply most strongly to those retiring under DC and not at all to those retiring under DB, we estimate separate specifications for employees retiring under the DB, DCDB, and DC benefit formulas. Finally, we further restrict the sample to employees with monthly salaries in the bottom quartile (measured within the calendar year) and females. Standard errors are clustered on employer. Statistically significance at the 10-percent, 5-percent, and 1-percent levels is denoted by *, **, and ***. Coefficients are multipled by 100, so that 1.000 represents 1 percentage point.

Web Appendix for "Pension Costs and Retirement Decisions in Plans that Combine DB and DC Elements: Evidence from Oregon"

Brief History of Changes to PERS

The history of the PERS plan reflects the countervailing tensions between providing competitive pension benefits and managing the costs of providing and managing those benefits.[1] PERS came into existence on July 1, 1946. At the time, it was argued that an orderly pension system would help Oregon state and local employers compete more effectively for employees. It initially resembled a DC plan, with employees contributing into an account that earned interest, but with retirement payments from the State capped at $125 per month. In 1953, PERS employees began contributing into Social Security. In 1967, PERS became a hybrid system, combining DC-style and DB-style benefits into a single benefit formula. Specifically, PERS began to calculate the retirement benefits of new and existing employees using the DCDB ("Formula plus annuity") benefit formula. In the same year, PERS began investing up to 10% of its portfolio in equities.

As quoted in the introduction, Governor Tom McCall argued that benefits for Oregon state employees were hampering the State's ability to attract and retain the talented employees that it needed to prosper. Between the late 1960s and the early 1980s, as a result of perceived labor market pressures and periods of high inflation, PERS increased employee's expected retirement benefits. In 1969, employees were given the choice between two investment options. The "regular" option guaranteed a minimum return of 5.5% per year, whereas the "variable annuity" option invested more heavily in U.S. and international equity. PERS also added an annual cost of living adjustment to retirement benefits calculated under the existing DCDB benefit formula. In 1973, PERS increased the maximum annual COLA from 1.5% to 2.0%. In 1979, in lieu of increasing nominal wages, employers began to "pick up" the 6% employee contribution on behalf of their employees. Because these changes increased the generosity of the PERS pension plan, between 1978 and 1981, the actuarial firm working for PERS issued warnings about a potential underfunding problem. In 1981, the DB benefit formula ("Full Formula") was introduced, and the DCDB formula was discontinued for new employees.

In 1994, Ballot Measure 8 passed which eliminated both the 6% employer contribution and the guaranteed minimum return of 8% per year offered by the "regular" investment option.

[1] The sources for this discussion are web-based documents available from the PERS website. They include "The Oregon Public Employees Retirement System History: The first 60 Years," published by PERS on July 6, 2010 and "Public Employee Retirement in Oregon: Where does the system stand and where could Oregon go from Here?," prepared by ECONorthwest for The Chalkboard Project and The Oregon Business Council on August 31, 2007.

However, in 1996, the Oregon Supreme Court overturned Ballot Measure 8 for violating the contract clause of the U.S. Constitution. The basic argument was that PERS could not change the expected retirement benefits of existing employees. In response, "Tier 2" retirement benefits were established for employees hired after December 31, 1995. The normal retirement age was increased from 58 to 60, and the guaranteed return of 8% per year in the "regular" investment option was eliminated. In January 1997, PERS began updating early retirement penalties and actuarial equivalency factors monthly instead of once per year, in the employee's birth month. This removed the disincentive for employees expecting to retire with DC or DCDB benefits to retire immediately before their birth month

PERS employees retired in waves during the late 1990s. One likely explanation was the political uncertainty created by ongoing court cases and proposed legislation. Another explanation, for which we find strong empirical support, is that the use of stale returns to calculate employee retirement account balances generated lumpy retirements. There is anecdotal evidence that these lumpy retirements had real costs. Beginning in 1997, Oregon school districts began reporting teacher shortfalls because they were unable to replace all of the retiring teachers. The use of the "last known rate" to calculate retirement account balances was eliminated in January 2000.

In the spring of 2003, the difference between PERS' assets and liabilities was $17B. In 2003, PERS took several steps to close this funding gap. First, PERS established a third tier of pension benefits, called the Oregon Public Service Retirement Program (OPSRP), for employees hired after August 29, 2003. OPSRP lowered the payout factor used in the DB benefit formula from 1.67% to 1.50%, and increased the normal retirement age from 60 to 65. These changes reduced the generosity of the DB benefit formula. More significantly, PERS eliminated the DC benefit formula. Instead, employee retirement contributions were directed into individual retirement ("IAP") accounts in which employees receive market returns and, therefore, bear market risk. In other words, for new employees, PERS became a system in which employer contributions fund a traditional defined benefit retirement plan and employee contributions are invested just as in a traditional defined contribution retirement plan. It is an open empirical question whether this reduction in expected retirement benefits, which reduced the expected pension costs of employers, lowered the average quality of new state and local employees.[2]

[2] We explored the idea of testing whether Oregon public schools were less able to attract high-quality teachers after 2003, but were unable to obtain any proxies for teacher quality before or after 2003. Even basic measures that might

Second, effective January 2003, PERS began offering a full lump sum payout option at retiremen (equal to twice the PERS account balance). Because PERS life annuity payments were better than actuarially fair when compared to the existing partial lump sum payout option (Chalmers and Reuter (2012)), this option had the potential to reduce underfunding. In Table 2, we estimate that demand for the full lump sum reduced underfunding by approximately $0.1B in 2003.

Third, the legislature made changes to PERS that reduced the expected retirement benefits of existing Tier1 and Tier 2 employees. The retirement account underlying the DC benefit formula was closed to new contributions. While existing investments in the regular and variable options continued to earn returns, the absence of new contribution reduced the expected PERS account balance at retirement. Instead, employee contributions were directed into the same IAP retirement account as employees hired into OPSRP, exposing the existing employees to market risk. New regulations also required PERS to update every two years the actuarial equivalency factors used to convert retirement account balances into initial monthly retirement benefits, with the first update occurring in July 2003. Because this change reduced life annuity payments under the DC and DCDB benefit formulas, it created strong incentives for some employees to retire before July 2003. We find strong empirical support for the hypothesis that employees recognized this incentive. Finally, as a result of court decisions, PERS changed the DC benefit formula in July 2004 so that only the counterfactual returns that the employee would have earned by investing 100% in the regular account are doubled.[3] As a result of these many changes, the likelihood that the DC benefit formula provides the maximum retirement benefit has declined substantially. While over 85% of retirees retired under DC in 2003, just over 50% did so in 2010.[4] Furthermore, the 2003 changes significantly reduced the level of underfunding. According to a recent actuarial report by Mercer on PERS, the fraction of funded liabilities exceeded 86% on December 31, 2010.[5]

allow us to measure teacher shortages, such as teacher-to-student ratios are unavailable from the Department of Education before 2004.

[3] This change, which did not apply to retirements during our sample period, was the consequence of litigation between various public entities and the Public Employees Retirement Board. See section 1.1 of the settlement agreement: http://www.oregon.gov/pers/docs/board_information/board_meeting_2005/settlement_agreement.pdf.

[4] Despite the widespread belief that the effect of the 2008 financial crisis on retirement assets forced employees to delay retirements, Goda, Shoven, and Slavov (2010) find only modest evidence that market returns delay retirement. The effect of market returns on the decision to retire is a potentially interesting research question to explore within PERS, as the effect of market returns on retirement account balances varies from Tier 1 to Tier 2 to OPSRP.

[5] See the Mercer's report to PERS, "December 31, 2010 Actuarial Valuation Oregon Public Employees Retirement System," September 30, 2011.