Working Paper

Teacher Pension Workshop: Connecting Evidence-Based Research to Pension Reform

Pension Enhancements and Teacher Retirement Behavior

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Introduction

U.S. K-12 public school teachers nearly all in Defined Benefit (DB) pension plans

- Pension rules are key factors in the retirement decision.
- Pension benefits and retirement rules vary by pension systems and over time.
- Consecutive enhancements of benefits in Missouri in the 1990s' (Common in many other states).

Policy relevance of the research

- Teachers retire earlier (58 years old in MO, 59 in U.S.) than other comparable professionals (64 years old) (Harris and Adams, 2007; Kim, et.al, 2017). Delaying retirement of experienced teachers in high-need districts can improve student achievement (Rivkin et al. 2005).
- Pensions liabilities strain government budgets, many studies call for pension reform (e.g., Novy-Marx and Rauh 2011; Malanga and McGee, 2018).
- Need behavioral models that can reliably predict retirement behavior in response to changes in pension rules.
- We develop methods using a structural model to efficiently fit a large panel data set with selection bias and time varying policies (via MLE).
- Pension enhancements provide a “stress test" for forward-looking option value models.

Research Question

- How did the 1990s' MO pension rule changes affect teacher retirement decisions?
- The bottom-line empirical finding: The pension enhancements in MO resulted in *earlier* retirements by about 0.3 years for the 1994 cohort and by about 1 year in a steady state.

Key challenges

This study estimates an extension of the Stock-Wise option value model using panel data on MO teachers. We face three challenges

Challenge	Solution
1. Sample selection bias	Use conditional probability
2. Model expectations of pension rule changes	consider competing models
3. Cost in computing likelihood	Group teachers into (age, exp) cells

Relevant Literature
Modeling Retirement Behavior

- General
  - Gustman and Steinmeyer (1986); Stock and Wise (1990), Rust and Phelan (1997), Asch, Haider, and Zissimopoulos (2005), Friedberg and Webb (2005), French and Jones (2011)
- Teachers
  - Costrell and McGee (2010), Friedberg and Turner(2010), Brown (2013), Knapp, et.al. (2016), Ni and Podgursky(2016)

Institutional Background

- Missouri's Public School Retirement System(PSRS): DB
  - Annual Benefit $B = S * R * FAS$
    S: PSRS-covered service; R: replacement factor; FAS: final average salary.
- The rules of pension system
  - Regular retirement
    - $age \geq 55 \& exp \geq 25$/ "rule of 80" $age + exp \geq 80$;
    - $age \geq 60 \& exp \geq 5$;
    - $exp \geq 30$;
  - Early retirement
    - "25 and out": $exp \geq 25$
    - Age reduced: $age >= 55$

Institutional Background

Table: PSRS Pension Rule Changes

Academic Year	Replacement Factor	COLA	Retirement Age and Experience
1994	0.023	0.56	Age $\geq$ 55 and Exp$\geq$25, or
			Age$\geq$60 and Exp$\geq$5, or Exp$\geq$30
1995	0.023	0.65	same
1997	0.023	0.75	Add “25 and out" early retirement (with Exp $\geq$25)
1999	0.025	0.75	“25 and out" formula factors increased
2000	0.025	0.75	Add “rule of 80", Age+Exp$\geq$80
2001	0.025	0.8	same
2002	0.0255 if Exp$\geq$31	0.8	same

Institutional Background

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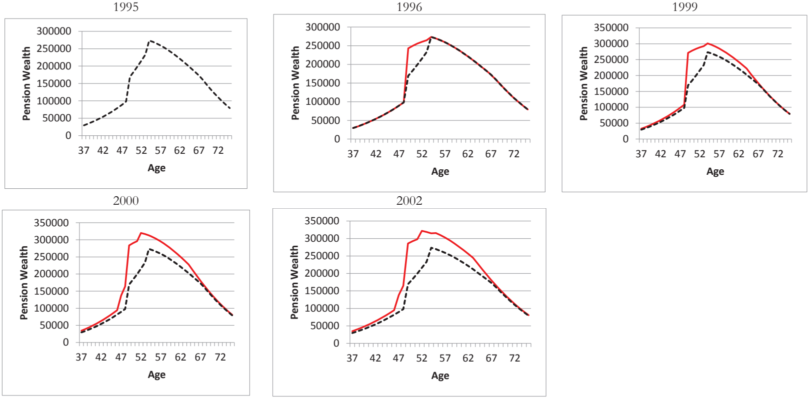
Figure 1. Pension Wealth Accrual over the Career Cycle for a Representative Teacher in Missouri Who Began her Career at Age of 25 and is 37 Years Old. Accrual is for a Fixed Salary Profile over the Career Cycle Based on Rules in 1995, 1996, 1999, 2000 and 2002. 1995 is the Base Year (Dashed).



Institutional Background

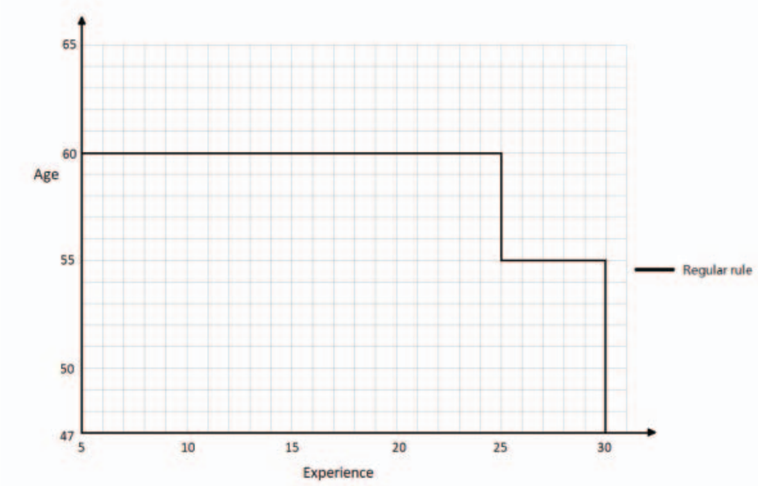


Figure: Region of Pension Rule Changes

Institutional Background

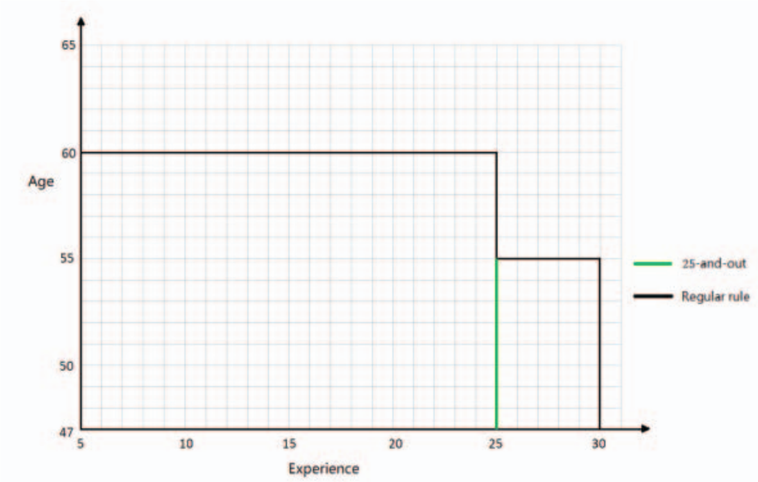


Figure: Region of Pension Rule Changes

Institutional Background

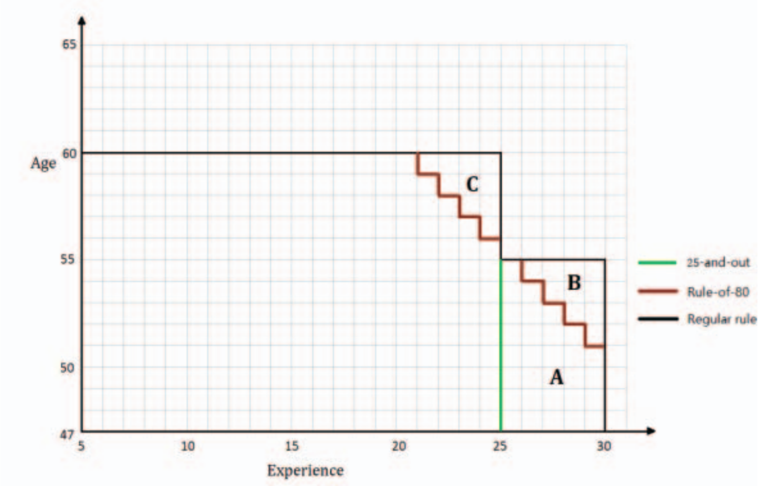


Figure: Region of Pension Rule Changes

The nature of a teacher's retirement problem

- Pension benefits usually depend on final salaries and service years, salary is predictable, separations are voluntary.
- A teacher in the current year has two choices: teach next year or retire (stop teaching and collect a pension immediately or at a future date.)
- Pension benefit is determined by the rule at the year of retirement. After retirement the benefit will not be adjusted if pension rules change in the future.
- The retirement decisions depend on the expectations of future pension rules.

Stock-Wise Option Value (SW) Model

The retirement decision in year t is choosing $m = t, \cdots, T$ that maximizes $E_t V_t^M(m, R_t)$.

$$E_t V_t(m, R_t) = E_t\{\sum_{s=t}^{m-1} \beta^{s-t}[(k_s(1-c_t)Y_s)^\gamma + w_s] + \sum_{s=m}^{T} \beta^{s-t}[(B_s(R_t, m))^\gamma + \xi_s]\}, \tag{1}$$

Unobserved innovations in preferences are AR(1):

$\omega_s = \rho\omega_{s-1} + \epsilon_{\omega_s}$, $\xi_s = \rho\xi_{s-1} + \epsilon_{\xi_s}$

$\nu_t = \rho\nu_{t-1} + \epsilon_t$, $\epsilon_t \sim N(0, \sigma^2)$

$k_s = \kappa(60/age)^{\kappa_1}$ captures the dis-utility of working.

Y_s is real salary in period s.

$B_s(R_t, m)$ is the real pension benefit collected in year s under the rules of year t, R_t, if the teacher retires in year $m \geq t$.

The superscript "M" indicates the myopic expectation of future pension rules.

Stock-Wise Option Value (SW) Model

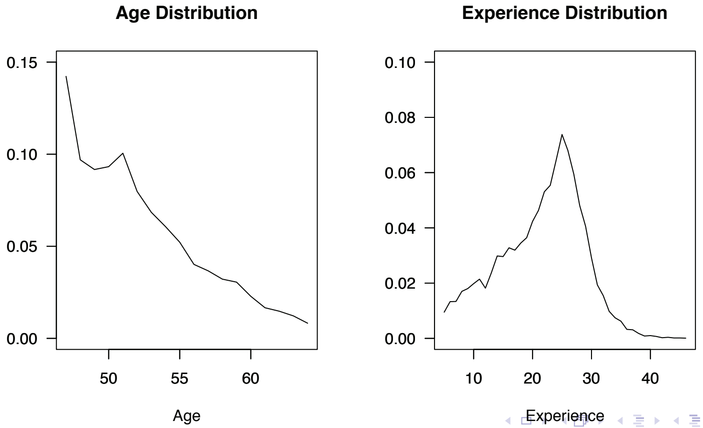
Expected gain from retirement in year m over retirement in the current period t is

$$G_t^M(m, R_t) = \mathbb{E}_t V_t(m, R_t) - \mathbb{E}_t V_t(t, R_t) = g_t(m, R_t) + K_t(m)\nu_t \qquad (2)$$

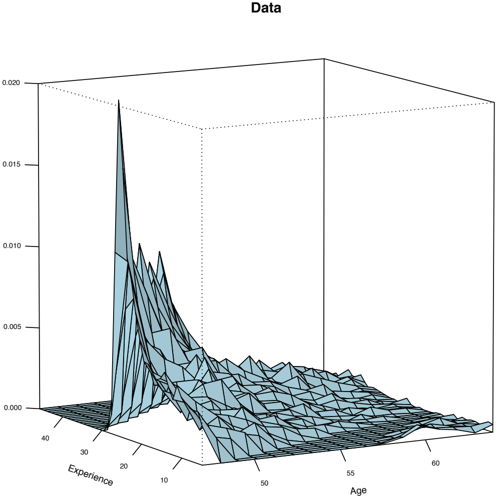
$g_t^M(m, R_t) =$ expected net utility for teaching until year M due to salary and pension.
$K_t(m) = \sum_{s=t}^{m-1} \pi(s|t)(\beta\rho)^{s-t}$ = weight on the preference error.
Let $m_t^\dagger(R_t) = argmax\ g_t(m, R_t)/K_t(m)$, then the probability of retiring in period t ($G_t(m, R_t) \leq 0$ for all $m > t$) is $Prob(\frac{g_t^M(m^\dagger, R_t)}{K_t(m^\dagger)} \leq -\nu_t)$.

Initial Sample

- Data: a cohort of teachers aged 47-64 with five or more years of experience in Missouri 1993-1994 academic year and track it forward to 2007-2008 academic year.



Initial Sample



1. Sample Selection Bias

Denote

$$f_t^+ = \frac{g_t(m^\dagger, R_t)}{K_t(m^\dagger)} = max_{m \geq t}\{\frac{g_t(m, R_t)}{K_t(m)}\}. \quad (3)$$

- Sample selection bias in the sample of senior teachers: only the “stayers" are in the sample, while the “early leavers" are absent.
- For the retirement eligible teachers, suppose a teacher in period 1 but was eligible to retire J periods ago
- It satisfies $\{\nu_{-J} > -f^+_{-J}, \nu_{-J+1} > -f^+_{-J+1}, ..., \nu_0 > -f_0^+\}$

1. Sample Selection Bias

To compute the probability of retiring in period $n > 0$, we need to take into account the fact that a teacher in period 1 but was eligible for retirement J periods ago.

The retirement probability that adjusts for the sample selection is the conditional probability

$$prob(retiring\ in\ period\ n | in\ initial\ sample) = \frac{prob(retiring\ in\ period\ n, in\ initial\ sample)}{prob(in\ initial\ sample)}.$$

1. Sample Selection Bias

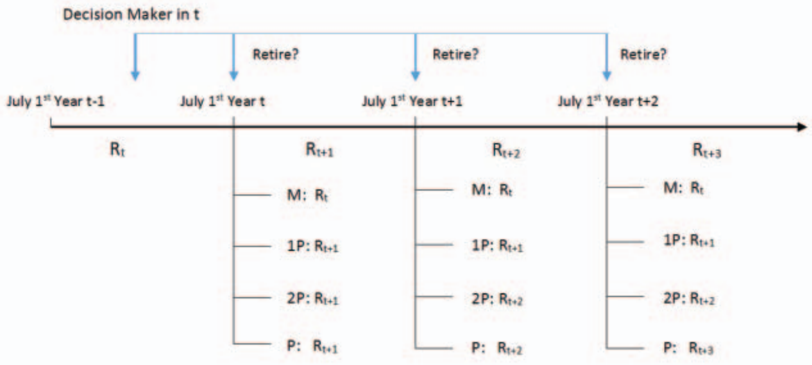
Without adjusting for sample selection bias we draw the preference shock from unconditional distribution $\nu_0 \sim N(0, \frac{\sigma^2}{1-\rho^2})$.

Adjusting for the sample selection bias $\nu_{-J} \sim N(0, \frac{\sigma^2}{1-\rho^2})$ for a teacher eligible for retirement J years ago, the probability a teacher is observed in period 1 retiring in period n is:

$$\begin{aligned}\mathbf{G}_{1,n} &= Prob[((\mathbf{f}^{+}_{1,n-1} > -\boldsymbol{\nu}_{1,n-1})\bigcap(f^{+}_{n} \leq -\nu_n))|\mathbf{f}^{+}_{-J,0} > -\boldsymbol{\nu}_{-J,0}] \\ &= \frac{Prob[((\mathbf{f}^{+}_{-J,n-1} > -\boldsymbol{\nu}_{-J,n-1})\bigcap(f^{+}_{n} \leq -\nu_n))}{Prob(\mathbf{f}^{+}_{-J,0} > -\boldsymbol{\nu}_{-J,0})}\end{aligned}$$

The algorithm for computing the probabilities in the numerator and denominator is based on the Geweke–Hajivassiliou–Keane (GHK) simulator.

2. Expectations of Pension Rule Changes



2. Expectation of Pension Rule Changes

- (M) Myopic (rule R_t)
- (1P) One step perfect foresight (rule R_{t+1})
- (2P) Two step perfect foresight (rule R_{t+1} in first period R_{t+2} from second period on)
- (1A) Adaptive expectation 1 (No change for the first X years, then p*(M) and (1-p)*(1P))
- (2A) Adaptive expectation 2 (No change for the first X years, then p*(M) and (1-p)*(2P))

2. Expectation of Pension Rule Changes

- The Optional Value Model under Different Expectation of Pension Rules
  - Under Myopic (M)

$$\mathbb{E}_t V_t^M(m, R_t) = \mathbb{E}_t\{\sum_{s=t}^{m-1} \beta^{s-t}[(k_s(1-c_t)Y_s)^\gamma + w_s] + \sum_{s=m}^{T} \beta^{s-t}[(B_s(R_t, m))^\gamma + \xi_s]\}$$

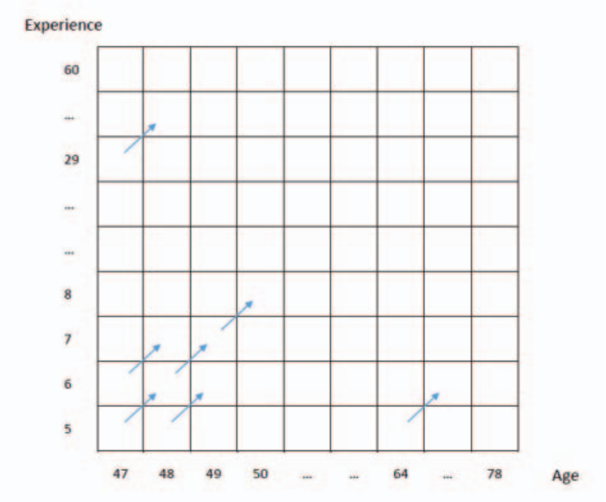
  - Under perfect foresight of one-year ahead future pension rules (P1), expected utility by retiring in year $m \geq t+1$

$$\mathbb{E}_t V_t^{P_1}(m, R_t) = \sum_{s=t}^{m-1} \pi(s|t)\beta^{s-t}\mathbb{E}_t(k_s(1-c_s)Y_s)^\gamma + \sum_{s=m}^{T} \pi(s|t)\beta^{s-t}\mathbb{E}_t(B_s(R_{t+1}, m))^\gamma$$

  - Under assumption (1A) the difference in expected utility between retiring in year $m > t$ and retiring now (in year t) is

$$\begin{aligned} V_t^{A_1}(m, R) &= \sum_{s=t}^{m-1} \pi(s|t)\beta^{s-t}\mathbb{E}_t(k_s(1-c_s)Y_s)^\gamma + \sum_{s=m}^{T} \pi(s|t)\beta^{s-t}[p(B_s(R_t, m))^\gamma \\ &+(1-p)(B_s(R_{t+1}, m))^\gamma] \end{aligned}$$

3. Likelihood by age-experience cells
Tracking movement of teachers across cells



3. Likelihood by age-experience cells

- Prob(retire in n_i)= G_{1,n_i}; Prob(not retiring)= $1 - \sum_{j=1}^{T} G_{1,j}$. Indicator $y_{it} = 1$ if teacher i retires in year t, and 0 otherwise.
- The likelihood of teacher i
  $L_i(\theta, \mathbf{y}_i) = \prod_{t=1}^{T} G_{1t}(a_i, e_i)^{y_{it}}(1 - \sum_{t=1}^{T} G_{1t}(a_i, e_i))^{1-\sum_{t=1}^{T} y_{it}}$.
- Denote $N(a, e)$ as the number of teachers with (age, experience) (a, e) in the initial period. The likelihood of the whole sample

$$L(\theta, \mathbf{y}) = \prod_{i=1}^{I} L_i(\theta, \mathbf{y}_i) = \prod_{i=1}^{I}\prod_{t=1}^{T} G_{1t}(a_i, e_i)^{y_{it}}(1 - \sum_{t=1}^{T} G_{1t}(a_i, e_i))^{1-\sum_{t=1}^{T} y_{it}} \quad (5)$$

$$= \prod_{t=1}^{T} \prod_{i|a_i=a,e_i=e} G_{1t}(a, e)^{\sum_{i|a_i=a,e_i=e} y_{it}}(1 - \sum_{t=1}^{T} G_{1t}(a, e))^{n(a,e)-\sum_{t=1}^{T}\sum_{i|a_i=a,e_i=e} y_{it}} \quad (6)$$

MLE Results

Table: Summary Statistics

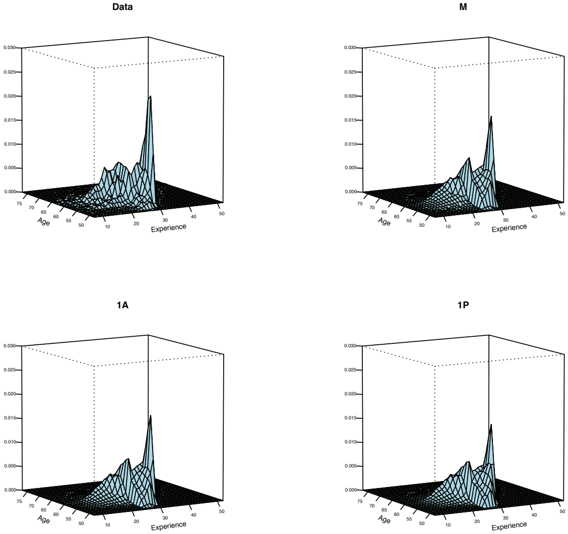
1994 cohort	Number of Teachers	Age	Experience	Male
All 1994	12871	52.15	21.48	0.26
Retirement Year				
1995	674	58.04	28.15	0.34
1996	864	58.50	28.30	0.32
1997	1176	57.00	28.74	0.33
1998	1095	57.71	28.73	0.32
1999	1193	57.85	28.64	0.29
2000	1212	57.99	28.66	0.29
2001	1373	58.49	28.68	0.26
2002	1001	59.11	28.74	0.23
2003	825	59.72	28.24	0.22
2004	742	60.34	28.86	0.20
2005	687	61.10	28.17	0.19
2006	541	61.67	28.12	0.20
2007	412	62.23	28.60	0.18
2008	302	63.17	28.36	0.14
Not Retired by 2008	774	63.28	27.88	0.17

MLE Results

Table: MLE Estimates of Structural Parameters

Female			Expectations		
Parameters	M	1P	2P	1A	2A
κ	0.630	0.673	0.664	0.621	0.621
β	0.953	0.955	0.957	0.957	0.957
γ	0.650	0.631	0.651	0.677	0.677
σ	2609.715	2648.062	2854.817	3704.905	3704.905
ρ	0.561	0.475	0.523	0.524	0.524
κ1	0.690	0.503	0.844	0.868	0.868
p				0.654	0.654
log-likelihood	-22235.740	-22227.150	-22203.001	-22064.360	-22063.000
Male			**Expectations**		
Parameters	**M**	**1P**	**2P**	**1A**	**2A**
κ	0.777	0.690	0.772	0.698	0.698
β	0.950	0.956	0.949	0.956	0.956
γ	0.600	0.656	0.614	0.648	0.648
σ	3176.834	2974.686	3065.281	4007.75	4007.75
ρ	0.391	0.532	0.384	0.433	0.433
κ1	0.729	0.453	0.942	0.888	0.888
p				0.654	0.654
log-likelihood	-7604.398	-7627.803	-7602.750	-7585.467	-7582.117

In Sample Fit



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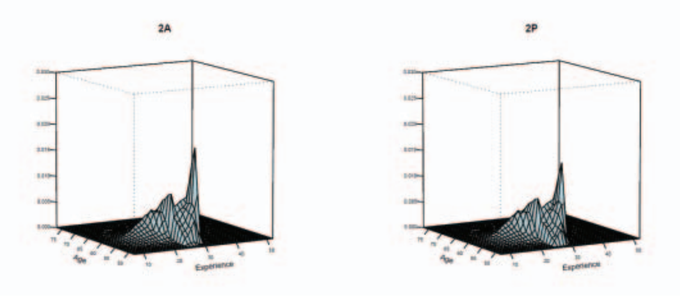

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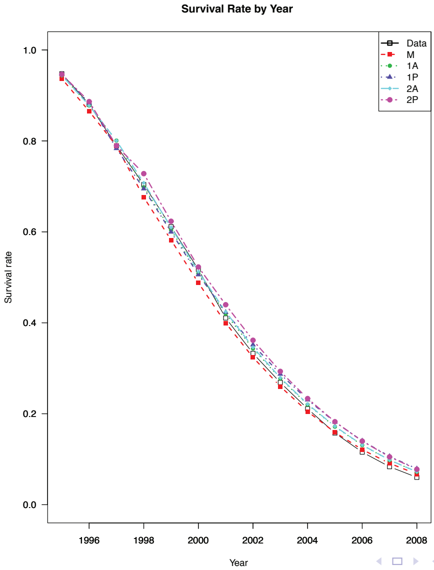

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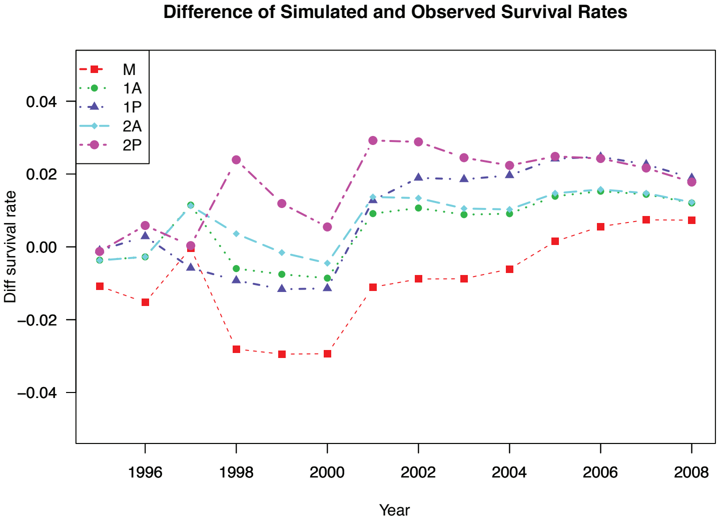

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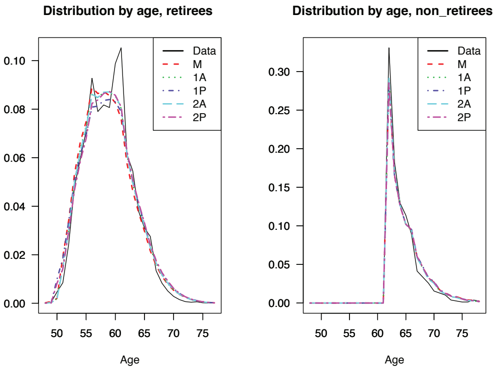

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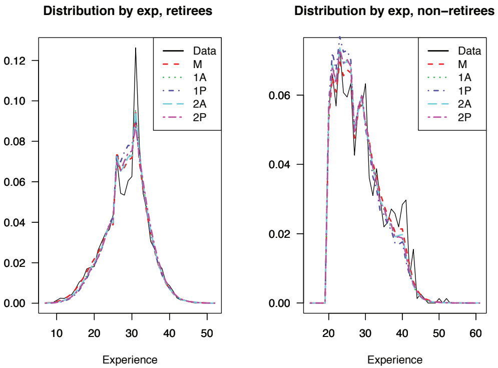


In Sample Fit

Table: MSE for Different Predicted Age Distributions

Expectation	(M)	(1A)	(1P)	(2A)	(2P)
Retired (10^{-4})	1.4031	1.0077	1.1828	0.9749	1.0048
Non-Retired (10^{-4})	8.1289	5.6950	9.0495	5.5557	7.8132

Table: MSE for Different Predict Experience Distributions

Expectation	(M)	(1A)	(1P)	(2A)	(2P)
Retired (10^{-4})	1.6573	1.5933	2.4462	1.6113	2.3867
Non-Retired (10^{-4})	0.3554	0.4837	0.6916	0.4702	0.4760

Table: MSE for Different Predicted Age-Experience Distributions

Expectation	(M)	(1A)	(1P)	(2A)	(2P)
Retired (10^{-6})	2.6700	2.5510	3.8540	2.6230	4.3830

Out of Sample Fit

Table: Observed and Simulated Survival Rate

Year	Data	(M)	(1A)	(1P)	(2A)	(2P)
2012	0.8924	0.8859	0.8954	0.8994	0.8951	0.9003
2013	0.7948	0.7803	0.7954	0.8021	0.7950	0.8039
2014	0.6939	0.6811	0.7001	0.7103	0.6998	0.7119

Table: Difference between Observed and Simulated Survival Rate

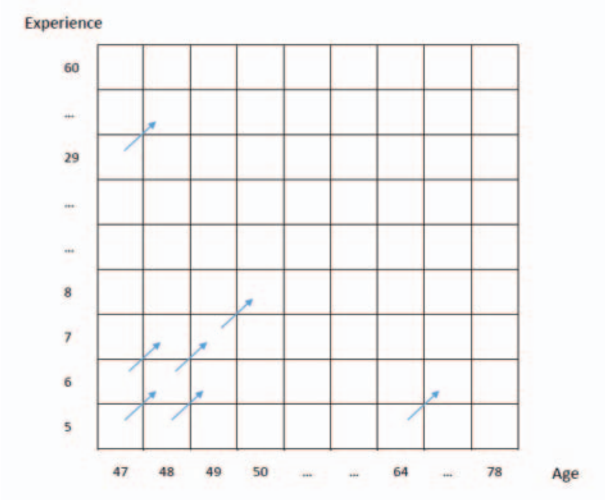
Year	(M)	(1A)	(1P)	(2A)	(2P)
2012	-0.0066	0.0029	0.0069	0.0027	0.0079
2013	-0.0145	0.0006	0.0073	0.0003	0.0091
2014	-0.0129	0.0062	0.0164	0.0059	0.0179

Counterfactual Analysis

Table: Average Retirement Age and Experience Observed and Predicted, 1994 cohort

		Average Retirement Age	Average Retirement Experience
M	Baseline	59.25	28.58
	No 25 and out	59.41 (0.16)	28.74 (0.16)
	No rule of 80	59.31 (0.06)	28.64 (0.06)
	No Enhancements	59.59 (0.34)	28.92 (0.34)
1A	Baseline	59.46	28.79
	No 25 and out	59.62 (0.16)	28.95 (0.16)
	No rule of 80	59.54 (0.08)	28.87 (0.08)
	No Enhancements	59.83 (0.37)	29.16 (0.37)
1P	Baseline	59.52	28.85
	No 25 and out	59.74 (0.22)	29.07 (0.22)
	No rule of 80	59.61 (0.09)	28.94 (0.09)
	No Enhancements	60.03 (0.51)	29.36 (0.51)
2A	Baseline	59.52	28.85
	No 25 and out	59.64 (0.12)	28.98 (0.12)
	No rule of 80	59.57 (0.05)	28.90 (0.05)
	No Enhancements	59.83 (0.31)	29.16 (0.31)
2P	Baseline	59.67	29.00
	No 25 and out	59.84 (0.17)	29.17 (0.17)
	No rule of 80	59.73 (0.06)	29.06 (0.06)
	No Enhancements	60.04 (0.37)	29.37 (0.37)

Tracking movement of teachers across cells



Counterfactual Analysis

With replacement of retired teachers, the senior teachers converge to a stationary distribution in age and experience under a given pension rule.

Comparison of stationary distributions in age and experience under different pension rules gives rise to the long-term effects.

Counterfactual Analysis

Table: Average Retirement Age and Experience Observed and Predicted, Steady State

		Avg Retirement Age	Avg Retirement Exp
M	Baseline	57.75	25.79
	No 25 and out	58.37 (0.62)	26.41 (0.62)
	No rule of 80	57.89 (0.14)	25.93 (0.14)
	No Enhancements	58.96 (1.21)	27.00 (1.21)
1A (2A)	Baseline	58.21	26.25
	No 25 and out	58.74 (0.53)	26.78 (0.53)
	No rule of 80	58.40 (0.19)	26.44 (0.19)
	No Enhancements	59.35 (1.14)	27.39 (1.14)
1P	Baseline	58.39	26.44
	No 25 and out	58.93 (0.54)	26.97 (0.54)
	No rule of 80	58.56 (0.17)	26.61 (0.17)
	No Enhancements	59.61 (1.22)	27.65 (1.21)
2P	Baseline	58.46	26.51
	No 25 and out	58.96 (0.50)	27.01 (0.50)
	No rule of 80	58.63 (0.17)	26.68 (0.17)
	No Enhancements	59.61 (1.15)	27.66 (1.15)

Counterfactual Analysis

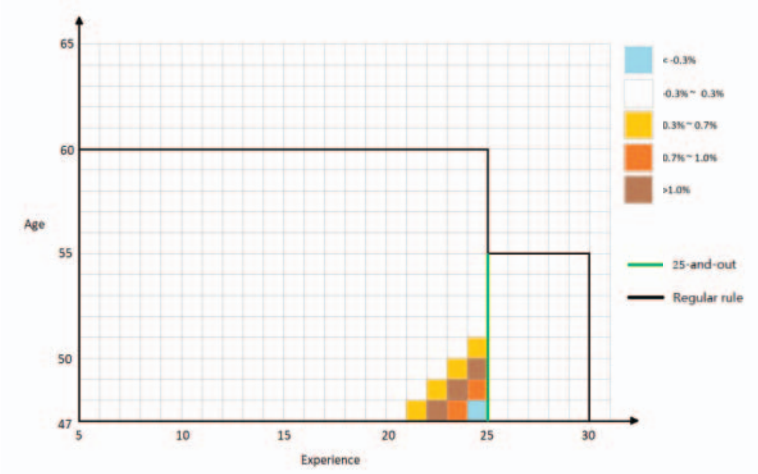


Figure: Changes in Expected Pension Wealth: 25-and-out

Counterfactual Analysis

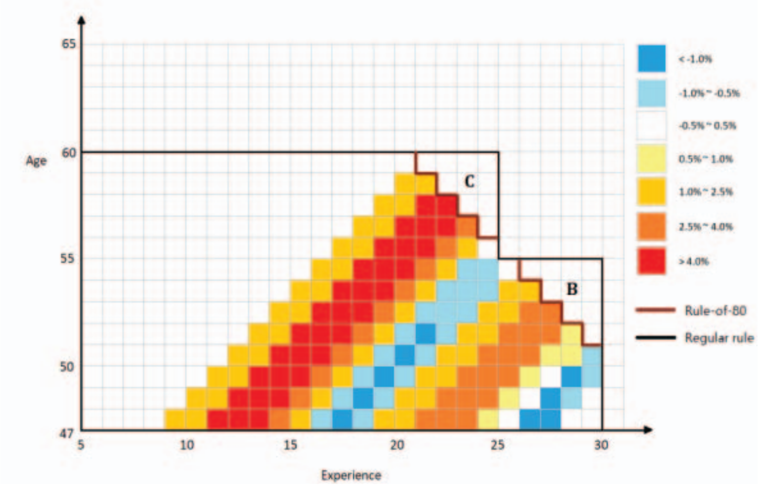


Figure: Changes in Expected Pension Wealth: Rule-of-80

Counterfactual Analysis

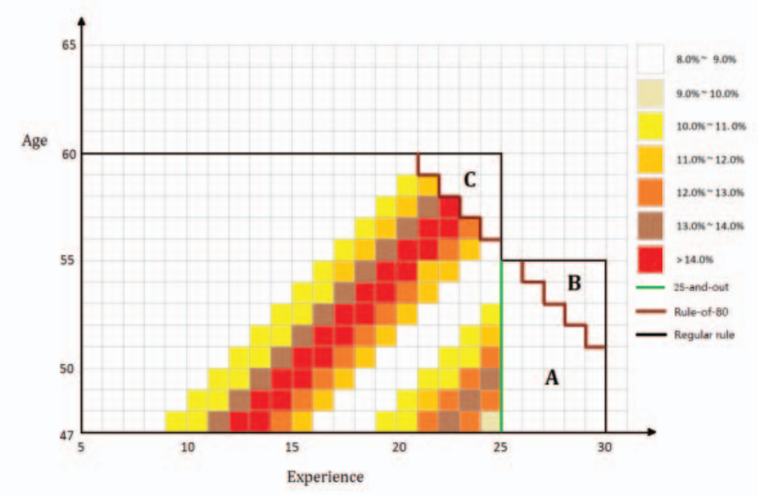


Figure: Changes in Expected Pension Wealth: All Rules

Conclusion

- Extended SW option value model
  - Model expectations of pension rule changes
  - Adjust for the sample selection bias
  - Reduce computation cost by using (age,exp) cells
  - Good in-sample and out-of-sample fit
- Counterfactual analysis
  - Three counterfactual scenarios:
    (1) no “25 and out"; (2) no “rule of 80"; (3) no enhancements.
  - Teachers would postpone retirement by about 0.3 years for the 1994 cohort and about 1 year in the absence of pension enhancements.
- Future plans