Redistributive effects of different pension structures when longevity varies by socioeconomic status

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Motivation: Increasing longevity heterogeneity in the US (cohort and income)

Socio-economic differentials in life expectancy are widening in many countries.

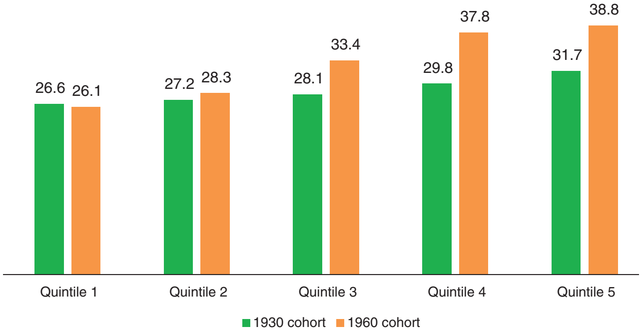

Figure 1: US Male Life Expectancy at Age 50 by Midcareer Average Labor Income Quintile, as Estimated by NRC (2015), for Birth Cohorts of 1930 and 1960 (Extrapolated).
Source: National Academy of Sciences, Engineering, and Medicine (2015). *The Growing Gap in Life Expectancy by Income: Implications for Federal Programs and Policy Responses*.

Motivation (cont'd): Implications of Growing Heterogeneity

Mortality differences interact with government programs for the elderly like the pension system and may reduce or even reverse the direction of redistribution

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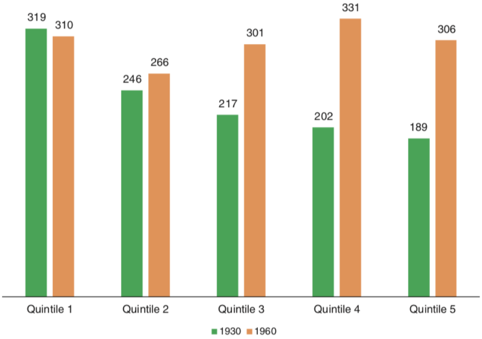

Figure 2: Average total lifetime net benefits at age 50 for males (present value in thousands of dollars), by lifetime earnings quintile.

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Introduction

Expect behavioral responses (education, consumption, hours worked, retirement, ...) due to mortality differences

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- Studying the redistributive effects of public pension systems (NDC, DB) when longevity varies by SES
- Providing a general framework for comparing different pension systems

General pension model

Pension point (pp) system (Börsch-Supan, 2006; OECD, 2005)

Case: Old-age survivor's pensions

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The increase in the total number of pension points accumulated (pp) at the exact age t by an individual of type $i \in \mathcal{I}$ in any pension system can be formulated as follows

$$\frac{\partial \mathrm{pp}_i(t)}{\partial t} = (\tilde{\mathrm{r}} + \tilde{\mu}(t))\mathrm{pp}_i(t) + \phi \tau y_i(t) \text{ with } \mathrm{pp}_i(0) = 0 \tag{1}$$

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where

$\tilde{\mathrm{r}}$	capitalization factor of pension points
$\tilde{\mu}(t)$	mortality hazard rate at age x used by the pension system
$y_i(t)$	labor income of a worker belonging to group i at age x
τ	contribution rate
ϕ	pension points earned per unit of social contribution paid, where $\phi = 1$ (in DC) and $\phi = \rho/\tau$ (in DB)

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Pension benefits

$$b_i(R_i) = \mathbf{f}_i(R_i)\mathrm{pp}_i(R_i) \tag{2}$$

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The dynamics of P_i is given by (P evolves differently by life expectancy) figure

$$\frac{1}{\mathrm{P}_i(t)}\frac{\partial \mathrm{P}_i(t)}{\partial t} = (r - \tilde{\mathrm{r}}) + (\mu_i(t) - \tilde{\mu}(t)). \qquad (4)$$

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$$\frac{1}{\mathrm{P}_i(t)} \frac{\partial \mathrm{P}_i(t)}{\partial t} = \underbrace{(r - \tilde{\mathrm{r}})}_{\text{Intergenerational effect}} + \underbrace{(\mu_i(t) - \tilde{\mu}(t))}_{\text{Mortality differential effect}} . \quad (4)$$

Behavioral reactions: Economic problem

The individual optimally chooses

the length of schooling, S_i

the retirement age, R_i

the consumption path, $c_i(t)$, and

hours worked path, $\ell_i(t)$,

maximizing a lifetime expected utility subject to a life cycle budget constraint and social security rules

Economic Problem

Optimal Decisions - consumption and labor supply

Optimal Decisions - length of schooling and retirement

PAYG pension systems

Table 1: Modeled PAYG pension systems

Pension system	Acronym	Replacement Rate	Diff. in Life Expectancy across income groups
Defined Benefits	DB-I	Constant	No
Defined Benefits	DB-II	Progressive	No
Defined Benefits	DB-III	Progressive	Yes (at retirement)
Defined Contribution	NDC-I	Remaining life	No
Defined Contribution	NDC-II	Remaining life	Yes (at retirement)
Defined Contribution	NDC-III	Remaining life	Yes (all ages)

Notes: (i) DB-II case matches the US pension system Progressiveness, (ii) NDC-II and DB-III cases implements the proposal of Ayuso, Bravo, and Holzmann (2017).

Parametrization

Redistributive effects of each pension system: Internal rate of return by income quintile and pension system

Those groups with an IRR $< 2\%$ transfer resources to those groups with an IRR $> 2\%$

Internal rate of return by income quintile and pension system

Those groups with an IRR $<$ 2% transfer resources to those groups with an IRR $>$ 2%

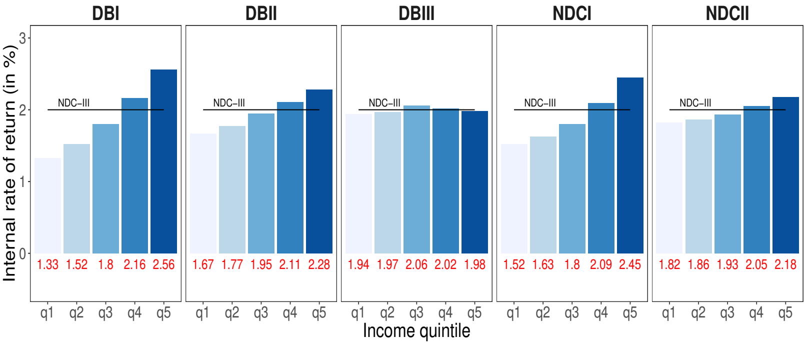

Figure 3: US males, **Mortality regime of 1930 cohort**

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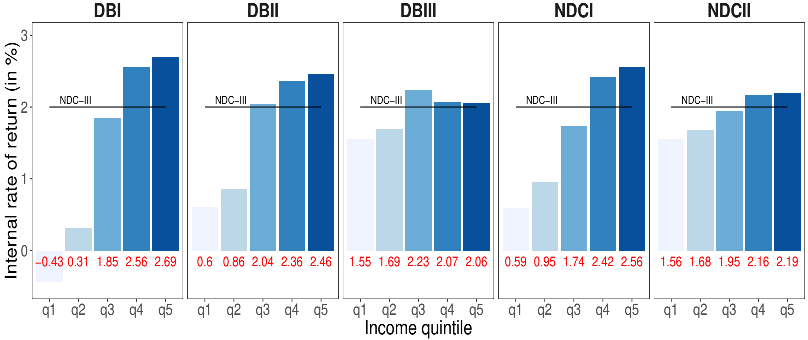

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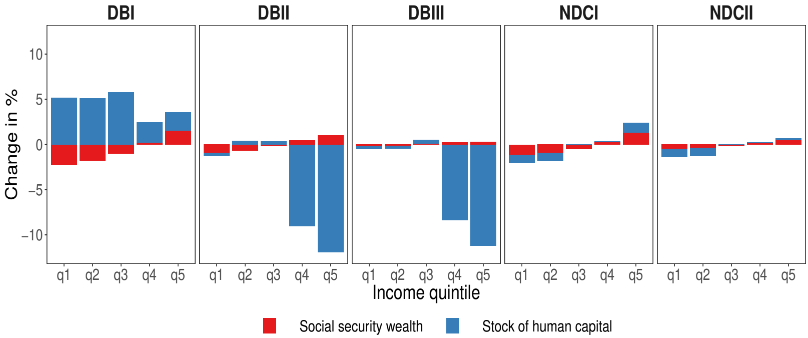
Impact of each pension system on wealth by income quintile (relative to the NDC-III system)



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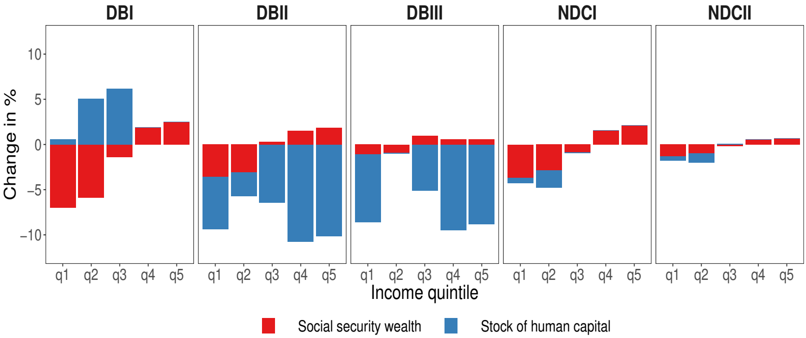

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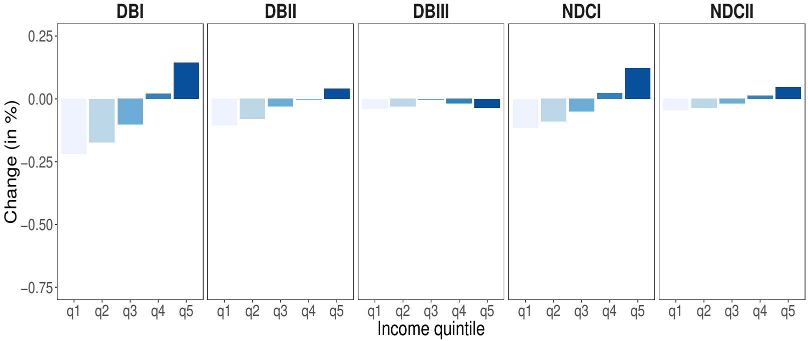

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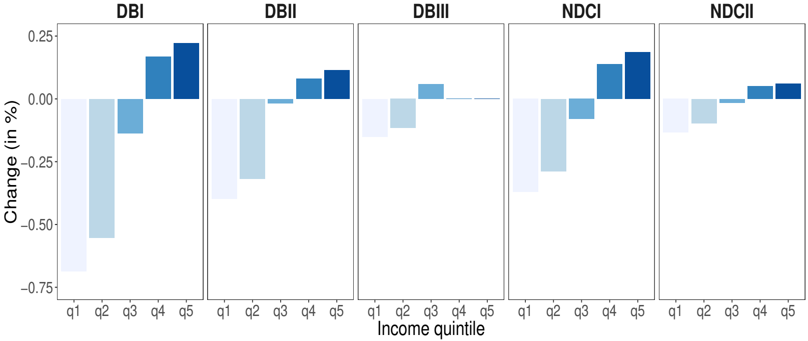

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Conclusions

We have developed a general framework for analyzing any pension system

We have assessed the direct and indirect effects of a variety of policy adjustments to DB and NDC pension programs in environments of more or less mortality heterogeneity

Achieving progressivity in lifetime benefits would require more than current progressivity in annual benefits in combination with life tables for each group

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Conclusions (cont'd)

Indirect effects on wealth:

- NDCs small and regressive
- Non-progressive DBs strong and positive (small LE diff.) and regressive (big LE diff.)
- Progressive DBs strong and negative at high income

Indirect effect on welfare:

- Losses for lower incomes and small gains for higher incomes
- This is reduced with progressive DB plans

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Thank you!

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Value of investing one dollar in the pension system

The value of P_i at retirement is

$$\mathrm{P}_i(t) = \phi \mathrm{f}_i(R_i) A_i(R_i, r) e^{\int_t^{R_i} \tilde{\mathrm{r}} + \tilde{\mu}(j) - (r + \mu_i(j)) dj}. \quad (5)$$

The term $\phi \mathrm{f}_i(R_i) A_i(R_i, r)$ PV of the stream of benefits from retirement until death that results from the contribution of a dollar.
The exponential term accounts for the difference from age t until retirement between the rate of return of the pension system, $\tilde{\mathrm{r}} + \tilde{\mu}$, and the rate of return of the capital market, $r + \mu_i$.

back

Redistributive effects of each pension system: Relative value of one additional dollar invested in the pension system

$\overline{\mathcal{P}}_i(t) = \mathrm{P}_i(t)(1-\varepsilon_i)$ is the relative value of investing one **additional** dollar in the pension system to the value of investing on **additional** dollar in the capital market

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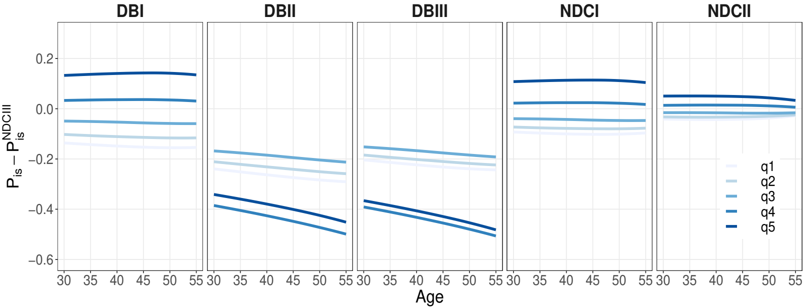

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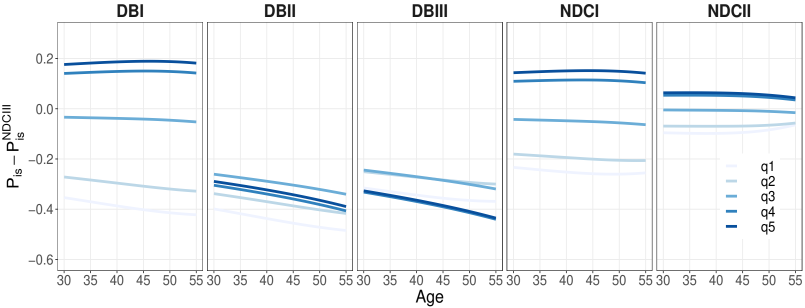

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Average vs. Marginal P values

Economic problem

Maximize the expected lifetime utility at age x

$$V_i(x) = \int_x^{\omega} e^{-\int_x^t \rho+\mu_i(j)dj} U\left(c_i(t)\right) dt - \int_{S_i}^{R_i} e^{-\int_x^t \rho+\mu_i(j)dj} \alpha_i v\left(\ell_i(t)\right) dt$$
$$- \int_x^{S_i} e^{-\int_x^t \rho+\mu_i(j)dj} \eta dt + \int_{R_i}^{\omega} e^{-\int_x^t \rho+\mu_i(j)dj} \varphi(t) dt. \tag{6}$$

Maximize the expected lifetime utility at age x

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subject to

$$\int_x^{\omega} e^{-\int_x^t r+\mu_i(j)dj} c_i(t)dt = a_i(x) + \int_x^{R_i} e^{-\int_x^t r+\mu_i(j)dj} y_i(S_i,t)dt + \mathrm{SSW}_i(x), \tag{7}$$

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where

$$y_i(S_i, t) = w_i(S, t)\ell_i(t), \quad (8)$$
$$w_i(S, t) = h_i(S)\bar{w}(t-S) = h_i(S)\exp(\beta_0(t-S) - \beta_1(t-S)^2), \quad (9)$$
$$\frac{\partial h_i(t)}{\partial t} = \theta_i h_i(t)^{\gamma} - \delta h_i(t) \text{ for } t \in (x_0, S_i),\ h_i(x_0) = 1. \quad (10)$$

back

Optimal decisions (consumption and labor supply)

The **optimal consumption** path and **labor supply**, conditional on a length of schooling S_i and a retirement age R_i, are characterized by

$$\frac{1}{c_i(t)}\frac{\partial c_i(t)}{\partial t} = \sigma_c(r-\rho), \tag{11}$$

$$\frac{1}{\ell_i(t)}\frac{\partial \ell_i(t)}{\partial t} = \sigma_l\left(\frac{\frac{\partial \overline{w}(t-S_i)}{\partial t}}{\overline{w}(t-S_i)} - (r-\rho) + \frac{\tau\overline{\mathcal{P}}_i(t)}{1-\tau+\tau\overline{\mathcal{P}}_i(t)}\frac{\frac{\partial \overline{\mathcal{P}}_i(t)}{\partial t}}{\overline{\mathcal{P}}_i(t)}\right), \tag{12}$$

where $\overline{\mathcal{P}}_i(t) = \mathrm{P}_i(t)\,(1-\varepsilon_i)$ compares the value of one additional dollar invested in the pension system to the value of investing the same additional dollar in the capital market.

back

Optimal decisions (length of schooling and retirement)

An **optimal length of schooling** satisfies

$$r_i^h(S^*) = r_i^w(S^*, R_i) + \frac{\eta}{U'(c_i(S^*))W_i(S^*, R_i)}. \tag{13}$$

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An interior **optimal retirement age** satisfies

$$U'(c_i(R^*))y_i(S, R^*)(1 - \tau_i^{GW}(R^*)) = \alpha_i v\left(\ell_i(R^*)\right) + \varphi(R^*). \tag{14}$$

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back

US OAI pension system (DB-II)

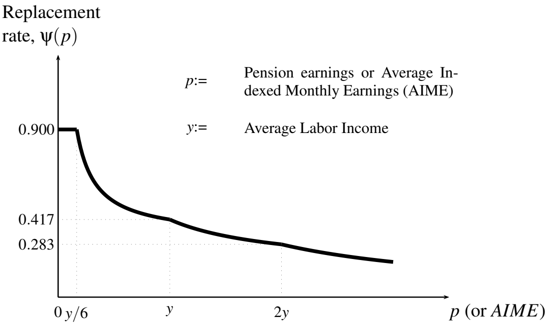

Figure 7: Old-Age Insurance replacement rate in the US

Note: AIME is calculated as 1/12 of the mean of the 35 highest labor incomes over the working life, measured in real terms. back

Marginal and average replacement rates at the normal retirement age across pension systems

Table 2: Marginal and average replacement rates at the normal retirement age

Case	Marginal replacement rate $\mathrm{f}_i(R_n, \mathrm{pp}_i(R_n))(1-\varepsilon_i)$	Replacement rate $\mathrm{f}_i(R_n, \mathrm{pp}_i(R_n))$
DB-II DB-III	$\begin{cases} 0.90 & \text{for } \mathrm{pp}_i \leq \bar{y}/6, \\ 0.32 & \text{for } \bar{y}/6 < \mathrm{pp}_i < \bar{y}, \\ 0.15 & \text{for } \bar{y} < \mathrm{pp}_i \leq 2\bar{y}, \\ 0.00 & \text{for } 2\bar{y} < \mathrm{pp}_i, \end{cases}$	$\begin{cases} 0.90 & \text{for } \mathrm{pp}_i \leq \bar{y}/6, \\ 0.32 + \frac{0.58}{6}\frac{\bar{y}}{\mathrm{pp}_i} & \text{for } \bar{y}/6 < \mathrm{pp}_i < \bar{y}, \\ 0.15 + \frac{1.60}{6}\frac{\bar{y}}{\mathrm{pp}_i} & \text{for } \bar{y} < \mathrm{pp}_i \leq 2\bar{y}, \\ \frac{3.40}{6}\frac{\bar{y}}{\mathrm{pp}} & \text{for } 2\bar{y} < \mathrm{pp}_i, \end{cases}$
DB-I NDC-I NDC-II NDC-III	0.417	0.417

Notes: The term $\bar{y}$ denotes the average labor income of the economy.

back

Optimal length of schooling

Table 3: Optimal length of schooling by income quintile (R_i), US male birth cohorts 1930 and 1960

	Defined Contribution (NDC)			Defined Benefit		
	Avg. LT NDC-I	Corrected Avg. LT NDC-II	i–th LT NDC-III	Non–progressive DB-I	Progressive DB-II	Progressive Corrected DB-III
Cohort 1930						
Quintile 1	11.4	11.4	11.5	11.9	11.3	11.3
Quintile 2	11.8	11.8	11.9	12.3	11.8	11.7
Quintile 3	12.4	12.4	12.4	12.9	12.3	12.3
Quintile 4	14.4	14.4	14.4	14.6	13.2	13.3
Quintile 5	15.8	15.7	15.7	15.9	14.2	14.3
Cohort 1960						
Quintile 1	11.3	11.3	11.3	11.3	10.6	10.4
Quintile 2	12.4	12.5	12.6	13.0	12.2	12.4
Quintile 3	15.7	15.7	15.7	16.3	14.7	14.9
Quintile 4	18.8	18.8	18.8	18.8	17.2	17.4
Quintile 5	19.0	19.0	19.0	19.0	17.5	17.7

Optimal retirement ages

Table 4: Optimal retirement age by income quintile (R_i), US male birth cohorts 1930 and 1960

	Defined Contribution (NDC)			Defined Benefit		
	Avg. LT NDC-I	Corrected Avg. LT NDC-II	i–th LT NDC-III	Non–progressive DB-I	Progressive DB-II	Progressive Corrected DB-III
Cohort 1930						
Quintile 1	60.9	60.9	61.1	63.2	62.7	62.8
Quintile 2	61.5	61.5	61.7	63.8	63.3	63.3
Quintile 3	62.5	62.5	62.5	64.6	64.0	64.1
Quintile 4	64.6	64.6	64.5	65.3	64.7	64.7
Quintile 5	66.8	66.6	66.4	67.1	65.2	65.2
Cohort 1960						
Quintile 1	60.1	60.2	60.6	61.1	62.0†	62.0†
Quintile 2	62.2	62.4	62.7	64.8	63.4	64.7
Quintile 3	67.3	67.5	67.4	69.8	68.4	68.6
Quintile 4	70.0	70.0	70.0	70.0	70.0	70.0
Quintile 5	70.0	70.0	70.0	70.0	70.0	70.0

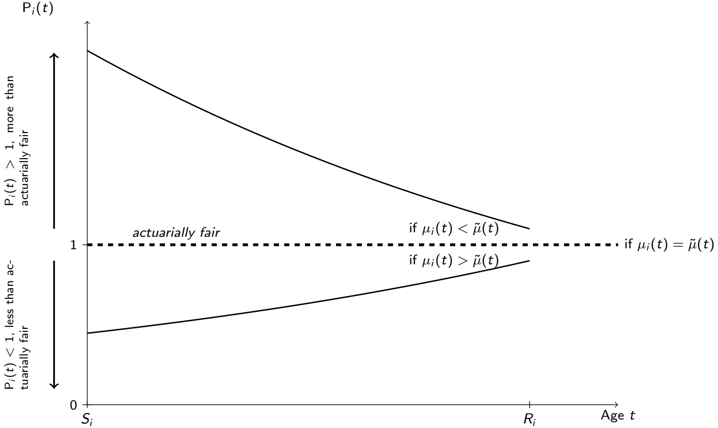

Figure 8: Stylized evolution over the working life of the value of one dollar contributed to the pension system for an individual who plans to retire at age R_i, $P_i(t)$. Case: when $\tilde{r} = r$. Back

Parametrization

Table 5: In-sample performance of the model: Optimal length of schooling (S_i), retirement age (R_i), and present value of lifetime benefits (PVB) by income quintile. US males born in 1930, US pension system (DB-II)

	Schooling		Retirement		PVB at age 50 (in \$1 000s)		Life expectancy at $S_i + 6$	Years-worked	Years-retired to years-worked
	S_i		R_i				$e_i(S_i + 6)$	YW_i	$\frac{e_i(S_i+6)-YW_i}{YW_i}$
Quintile	Bench.	Data	Bench.	Data	Bench.	Data	Bench.	Bench.	Bench.
q1	11.30	11.20	62.70	63.18	132	126	54.31	41.91	0.30
q2	11.80	11.04	63.30	63.60	149	141	54.63	42.12	0.30
q3	12.30	12.28	64.00	63.56	170	166	55.33	42.49	0.30
q4	13.20	12.84	64.70	63.52	198	192	56.25	42.50	0.32
q5	14.20	14.55	65.20	64.23	225	226	58.03	42.76	0.36

Notes: Small figures highlighted in gray are data from the HRS on length of schooling and retirement age for males born in 1930, and from the NASEM (2015) on the present value of lifetime benefits for the same cohort.

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Parametrization

Table 6: Model parameters

Parameter	Symbol	Value	Parameter	Symbol	Value
Demographics			**Preferences**		
First age at entrance	x_0	14	Subjective discount factor	ρ	0.005
Maximum age	ω	114	Utility cost of not being retired	$\varphi(t)$	$186.29(\mathrm{e}(t))^{-1.8559}$
Annual population growth	n	0.005	Labor elasticity of substitution	σ_ℓ	0,33
Minimum length of schooling	$\underline{S}$	10	Utility weight of labor	$\alpha(q1)$	200
Maximum length of schooling	$\bar{S}$	20		$\alpha(q2)$	160
				$\alpha(q3)$	140
Technology				$\alpha(q4)$	130
Market interest rate	r	0.030		$\alpha(q5)$	130
Labor-augmenting technological progress growth rate	g	0,015			
			Education		
Social security system			Returns of scale in education	γ	0.65
Minimum retirement age	$\underline{R}$	NDC=55, DB=62	Disutility of schooling	η	3.5
Maximum retirement age	$\bar{R}$	70	Mincerian eq.	β_0	0.07
Capitalization factor	$\bar{\mathrm{r}}$	0.02		β_1	0.0011
Accrual rate in DB systems	ϕ	1/45	Learning ability	$\theta(q1)$	0.110
Avg. replacement rate in DB systems	$f(\mathrm{pp})$	0.4167		$\theta(q2)$	0.110
Social contribution rate				$\theta(q3)$	0.110
Cohort 1930	τ_{1930}	0.1192		$\theta(q4)$	0.115
Cohort 1960	τ_{1960}	0.1460		$\theta(q5)$	0.115

Behavioral reactions vs. no behavioral reactions: Wealth

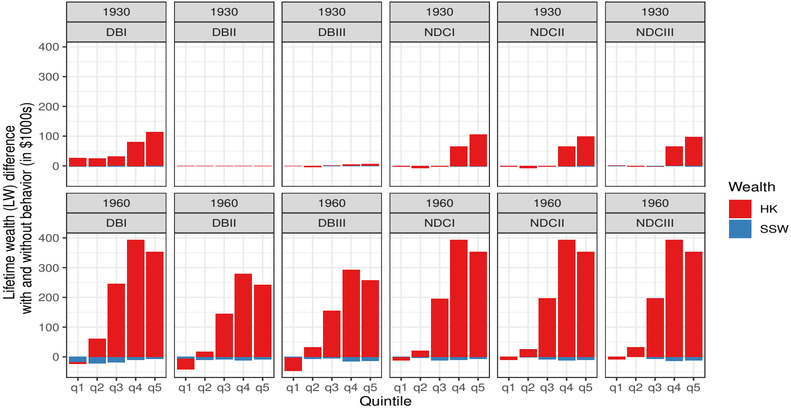

Figure 9: Difference in lifetime wealth between a model with and without behavioral reactions by pension system and mortality regime (1930 cohort vs 1960 cohort).

Behavioral reactions vs. no behavioral reactions: Welfare

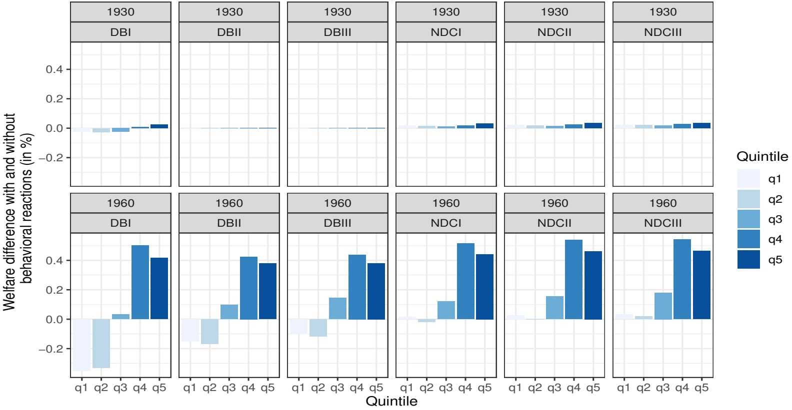

Figure 10: Relative difference in welfare between a model with and without behavioral reactions by pension system and mortality regime (1930 cohort vs 1960 cohort).