Public Pensions in the age of Automation

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Background

- Automation can reduce labor shares of GDP[3] and equilibrium wages across routine sectors.[4]
- Pensions generally PAYG funded through payroll taxes
  - Funding issues?
    - Problematic for individuals who rely on public pensions
- More productive robots/capital increases returns to investments
  - Increases the opportunity cost of contributing to a PAYG system
  - Increases inequality between private and PAYG public pension savings

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[3] Hémous and Olsen (2021), Hubmer and Restrepo (2021)

[4] Acemoglu and Restrepo (2019)

Research questions

What are the consequences of improved automation for...

1. pension and lifetime income inequality?
2. the optimal size and design of public pensions?

To answer these, we build a structural model, calibrate it, and run numerical experiments.

Model environment

- Retirement decisions and pension policy
  - Overlapping generations
- Wage and capital inequality
  - General equilibrium
- Conceptualizing automation
  - Intensive vs extensive margins of automation
- Welfare role of pensions
  - Consumption smoothing - rational and irrational savers
  - Income inequality - skill heterogeneity

Model

- Time t is continuous
- Population size constant $N = 1$
- Lifetime T is certain
- Rational RS and rule-of-thumb workers
  - A fixed fraction lives hand-to-mouth HTM
- High- and low-skilled workers H, L
  - Endogenous skill formation
- Representative firm
  - Capital-skill-complementarity CSC[5]
  - Task-based TB[6]
- Two-pillar public pension system

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[5] see, e.g., Krusell et al (2000), Prettner and Strulik (2020)

[6] see, e.g., Acemoglu and Restrepo (2018), Kina (2024)

Workers

- Derive utility from consumption $c(t)$ and (retirement) leisure $T - R$
  - R is endogenous.
- Saves in capital $k(t)$.
  - Savings appreciate by interest rate r.
- Enjoy wage income $w(1-\tau)$ during working life
  - τ is a contribution rate to the public pension system
- Enjoy pension benefits b during retirement

Workers

A rational worker will enroll in college education and become High-skilled H iff:

$$\begin{aligned}\psi \leq &\int_0^T U(c_H^{RS*}(t), k_H^{RS*}(t), R_H^{RS*})e^{-\theta t}dt \\ &- \int_0^T U(c_L^{RS*}(t), k_L^{RS*}(t), R_L^{RS*})e^{-\theta t}dt\end{aligned} \tag{1}$$

where ψ is a fixed cost drawn from an exponential distribution.

Workers

Rational workers of skill type $j = H, L$:

$$\max_{\{c(t),R\}} \left\{ \int_0^T \frac{c_j^{RS}(t)^{1-\sigma} - 1}{1-\sigma} e^{-\theta t} dt + \beta \int_{R_j^{RS}}^T e^{\gamma t} (T-t)^{-\phi} e^{-\theta t} dt \right\}$$

subject to:

$$w_j(1-\tau_l) \int_0^{R_j^{RS}} e^{-rt} dt + b_j^{RS} \int_{R_j^{RS}}^T e^{-rt} dt = \int_0^T c_j^{RS}(t) e^{-rt} dt,$$

and $k(0) = k(T) = 0$.

HTM workers

HTM workers do not save, but decide when to retire. As such:

$$c^{HTM}(t) = \begin{cases} w_L(1-\tau_l) & \text{for } t \in [0, R^{HTM}) \\ b^{HTM} & \text{for } t \in [R^{HTM}, T] \end{cases} \tag{2}$$

and their optimization problem can then be stated as:

$$\max_{R^{HTM}} U^{HTM} = \int_0^{R^{HTM}} \frac{(w_L(1-\tau_l))^{1-\sigma} - 1}{1-\sigma} e^{-\theta t} dt + \int_{R^{HTM}}^{T} \frac{(b^{HTM})^{1-\sigma} - 1}{1-\sigma} e^{-\theta t} dt + \beta \int_{R_j^{HTM}}^{T} e^{\gamma t} (T-t)^{-\phi} e^{-\theta t} dt. \tag{3}$$

Firms

- Perfect competition, representative firm
- Use capital (robots) K and human labor L to produce Y

$$Y = \Omega\left[L_H^{\rho_F} + B\Big(G(K, L_L)\Big)^{\rho_F}\right]^{\frac{1}{\rho_F}} \tag{4}$$

- We consider two different specifications of $G(K, L_L)$

Model - CSC specification

Following Prettner and Strulik (2020):

$$G(K, L_L) = (AK^{\rho_G} + L_L^{\rho_G})^{\frac{1}{\rho_G}} \tag{5}$$

where factor productivity A is the state of automation.

$$Y = \Omega\left[L_H^{\rho_F} + B\left(AK^{\rho_G} + L_L^{\rho_G}\right)^{\frac{\rho_F}{\rho_G}}\right]^{\frac{1}{\rho_F}}. \tag{6}$$

Model - TB specification

Following AR (2018), output is produced by assemblying a range of tasks $u \in [0, 1]$:

$$G(K, L_L) = \left(\int_0^1 y(u)^{\rho_H} du \right)^{\frac{1}{\rho_H}} \tag{7}$$

where task-specific labor and capital quantitites are perfect substitutes:

$$y(u) = \psi(u)k(u) + l_L(u). \tag{8}$$

Model - TB specification

- Specification of capital productivity $\psi(u)$ so that:
  - Capital has a comparative advantage for all tasks $u \in [0, a)$
  - Labor has a comparative advantage for all tasks $u \in (a, 1]$

$$\psi(a^*) = D\left(u^{-\eta} - 1\right) = \frac{r^* + \delta}{w_L^*}$$

- Intensive vs extensive margin of automation
  - An increase in ψ
    - Robots become better at the tasks they are already performing
  - An increase in a
    - Increases the number of tasks that can be automized
    - Displacement effect!

CSC vs TB

- Capital-skill-complementarity (CSC)
  - G is a CES function with higher degree of substitutability between K and L_L
  - Improved automation = increased marginal product of capital
- Task-based (TB)
  - G is a composite of a range of tasks $u \in [0, 1]$
  - K and L_L are perfect substitutes in each task u.
  - Improved automation = increase in a
    - Includes a displacement effect

Public pension system

- A worker's benefit level is computed as:

$$b_j^i = \frac{\tau}{T - R_j^i}(\kappa w_j R_j^i + (1-\kappa)\Psi) \tag{9}$$

- κ fraction of contributions τ_l goes towards a "Bismarckian" pillar.
- The complement $1 - \kappa$ towards a "Beveridgean" pillar.
- Ψ is aggregate labor income.
- The worker treats the Bismarckian pillar as endogenous, but the Beveridgean as exogenous.

Market clearing

- Factor prices clear each factor market
- The steady state satisfies the aggregate resource constraint:

$$Y = C + I, \tag{10}$$

where

$$C = \int_0^T \left[\Lambda_H^{RS*} c_H^{RS*} + \Lambda_L^{RS*} c_L^{HS*} + \Lambda^{HTM} c^{HTM} \right] dt, \tag{11}$$

is the aggregate consumption, and

$$I = \delta \int_0^T \left[\Lambda_H^{RS*} k_H^*(t) + \Lambda_L^{RS*} k_L^*(t) \right] dt = \delta K, \tag{12}$$

aggregate investments, which is equal to depreciated capital, in the steady state.

Calibration

Pre-shock steady state

1. Calibrate CSC specification to match a set of targets:
   - Capital-output ratio : 3
   - Real interest rate : 4%
   - Average retirement age : 63.5
   - Skill-premium : 75%
   - Share of high-skilled: 34%
2. Determine equilibrium values for $\{Y_1^*, w_H^*, w_L^*, K^*, L_L^*, L_H^*\}$
3. Calibrate TB specification to the same equilibrium values

Post-shock steady state

1. 10 % increase in MP_K in the CSC-specification
2. Determine equilibrium value for Y_2^*
3. Calibrate the automation shock to the TB-specification to Y_2^*

Some key parameters

- Share of hand-to-mouth = 0.2
- EIS = 0.5
- Frisch elasticity w.r.t replacement income = 0.3
- $\tau = 0.154$
- $\kappa = 0.67$
- Elasticity of substitution L_H and $G = 0.76$
- Elasticity of substitution L_L and $K = 1.66$

Comparative statics

Table: Comparative statics - elasticities

Model	K/Y	L_H/Y	L_L/Y	r	w_H	w_L	b_H^{RS}	b_L^{RS}	b^{HTM}
Automation (CSC)	0.51	0.288	-0.04	0.07	1.21	0.25	0.50	0.31	0.37
Automation (TB)	0.72	0.27	-0.49	0.21	1.14	0.20	0.39	0.18	0.30

Effect on retirement ages

- Average retirement age increases by ≈ 0.1 years
    - High skilled workers delay by 1 year
    - Low-skilled rational workers retire 0.5 years earlier
        - Since the pension system is partially redistributive, low-skilled workers experience a larger (relative) increase in their replacement income.

Results are more or less the same for the TB specification.

Dependence on public pensions

Table: Public pension income share of retirement consumption.

Group	High Skill	Low Skill
Baseline	0.288	0.414
Automation growth (CSC)	0.259	0.402
Automation growth (TB)	0.254	0.395

Note: The Table shows how the ratio of public pension income to retirement consumption changes for the different growth scenarios under both the CSC and TB specifications. We do not present figures for the Hand to Mouth group, since in this case public pension income funds the entirety of consumption in retirement.

Effect of pensions on automation

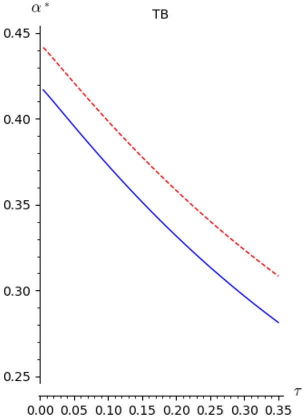

Figure: Blue = Pre-growth, Red = post-growth

The elasticity of a^* w.r.t to $\tau \approx -0.18$

Optimal policy

1. Quantify the optimal size of contribution rate τ_l^* and Bismarckian factor κ^* for baseline calibration(s)
2. Quantify how τ_l^* and κ^* changes given growth in the productivity of robots/capital

Some details:

- Steady state comparisons
- population-weighted Utilitarian welfare function

Optimal public pension size

Table: Optimal public pension contribution rate τ^*

	CSC	**TB**
τ^*		
Baseline	0.090	0.135
Post growth	0.095	0.130
κ^*		
Baseline	0	0
Post growth	0	0

Conclusions

- We study how increased automation affects:
    - The size and distribution of pension benefits
    - The optimal size of public pension systems
- Automation-driven growth
    - Increases inequality in wages and benefits
    - Increases inequality between private savings and mandated savings
- Increasing the size of the pension system reduces automation
- A model with displacement merits a larger pension system