Wittgenstein Centre
FOR DEMOGRAPHY AND GLOBAL HUMAN CAPITAL
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The impact of medical progress on the increasing inequality in life expectancy

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Wittgenstein Centre Conference 2023: Exploring Population Heterogeneities
Vienna, 6-12-2023

Motivation

1. **Empirical evidence**: Vast evidence on the increasing inequality in life expectancy across the income distribution (Waldron, 2007; Chetty et al., 2016; Haan et al., 2020, among many others).

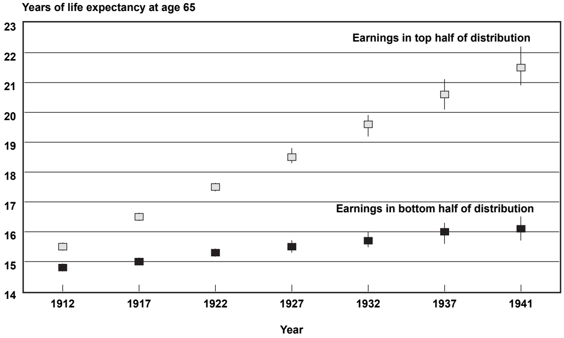


Figure: Cohort life expectancy at age 65 (and 95 percent confidence intervals) for US male Social Security-covered workers, by selected birth years and earnings group. Source: Waldron (2007).

Motivation

2. **Consequences**: the increasing inequality in life expectancy affects.
   - Economic justice (equitable life-cycle outcomes)
   - The public transfer system, making it more regressive
   - The health care sector with a possible misallocation of spending biased towards the wealthy
3. **Research question**: Investigate the sources of the increasing inequality in life expectancy such that effective policy responses to mitigate its consequences can be found.

The Model

Short Description

- Life cycle model with endogenous survival and heterogeneous agents with demographic foundations.

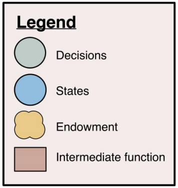
Strengths of the model

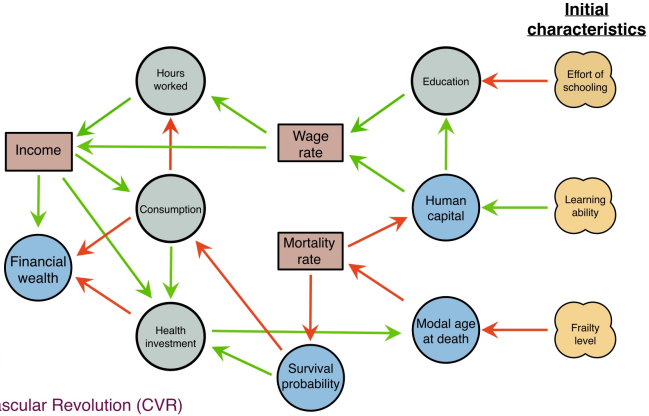
- Assess the direction of causality between health and income.
- Rigorous demographic modelling based on frailty and the modal age at death.
- Able to explain the increase in life span inequality across cohorts and socio-economic groups.

Preliminary results of the model

- Increasing gap in the life span across income groups, as well as the increasing income inequality across educational groups can be explained by medical progress that started in the 1970s, known as the cardiovascular revolution.

Individual Life Cycle Model





Exogenous Factors

Medical progress

Reduction in infectious diseases

Wage rate increase

Time at introducing the Cardiovascular Revolution (CVR)

Model Setup

- Stages of life-cycle, the length of which is determined endogenously, are:
    1. Education
    2. Working life
    3. Retirement
- Model outcomes by cohort:
    1. Distribution of education
    2. Income distribution by education
    3. Modal age at death by income and education group
    4. Mortality rates by income and education group
    5. Contribution of exogenous factors to increase in life expectancy

Model Setup (Economic Problem)

- Individual Problem

$$max \int_0^T e^{-\rho t} S(t) u(c(t), z(t)) dt - \xi_E \int_0^E e^{-\rho t} S(t) dt. \tag{1}$$

$$\tag{2}$$

- Budget Constraint

$$\int_0^T (c(t) + p\, m(t)) e^{-rt} dt = \int_E^T w(t) H(t) (1 - z(t)) e^{-rt} dt \tag{3}$$

$$\tag{4}$$

- Dynamics of age-specific productivity (Kotschy, 2021)

$$\dot{H}(t) = \begin{cases} \xi_H H(t)^\gamma - \phi\mu(t, M(t; Z)) H(t) & \text{for } t \leq E, \\ \big(f(t, E) - \phi\mu(t, M(t; Z))\big) H(t) & \text{for } t > E, \end{cases} \tag{5}$$

Model Setup (Demographic Foundation)

- Dynamics of survival probability

$$\dot{S}(t) = -\mu(t, M(t; Z))S(t), \tag{6}$$

- Mortality rate (Canudas-Romo, 2008; Horiuchi et al., 2013; Missov et al., 2015)

$$\mu(t, M(t; Z)) = a + be^{b(t-M(t;Z))}, \tag{7}$$

- Dynamics of the modal age at death

$$\dot{M}(t; Z) = A_m(t)m(t)^{\sigma_m}, \tag{8}$$

- Initial modal age at death (Canudas-Romo, 2008; Vaupel et al., 1979)

$$M(0; Z) = \frac{\log b - \log \alpha}{b} - \frac{\log Z}{b} \text{ with } Z \sim \Gamma(k, \lambda). \tag{9}$$

- Education-adjusted medical progress (Skinner and Staiger, 2015)

$$\dot{A}_m(t) = \begin{cases} 0 & \text{if } t < t_A, \\ g_m(E)(A_m^* - A_m) & \text{if } t \geq t_A, \end{cases} \tag{10}$$

Parameterization/Calibration

- calibrated on males born between 1900 and 1960 in the US

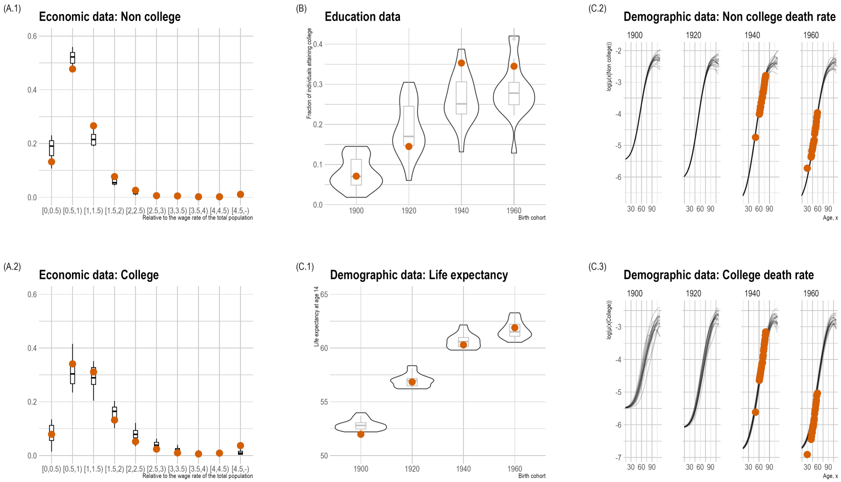
Table: Model parameters

Preferences			**Prices**		
Share of consumption	α	0.2000	Productivity growth	$g_i(t)$	$\begin{cases} 3\% & \text{for } i+t < 1970 \\ 0\% & \text{for } i+t \geq 1970 \end{cases}$
IES	σ	0.9000	Interest rate	r	0.0250
Discount factor	ρ	0.0000	Price of health services	p	1.0
			Initial wage rate	w	1.0
Mortality					
Senescence rate	b	0.1100	**Human capital**		
Minimum mortality rate	α	-9.5773	Returns to experience	β_1	0.0700
			Returns to experience-squared	β_2	. -0.0009
Health investments			Returns-to-scale to education	γ	0.6600
Initial health technology	A_m	0.15	Health impact on income	ϕ	2.0 (Kotschy, 2021)
Final health technology	A_m^*	0.20			
Returns-to-scale of health	σ_m	0.20			

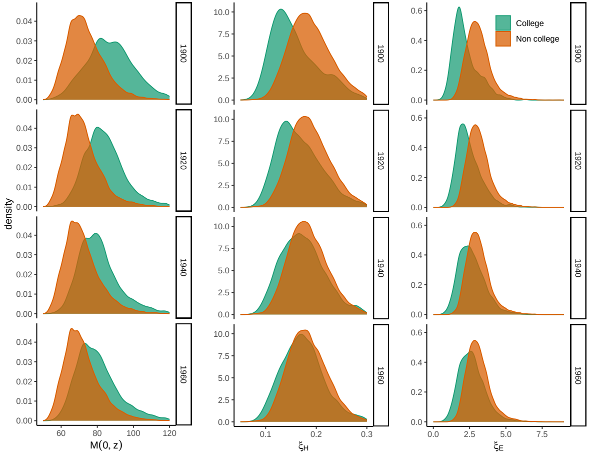
Calibration

- Bayesian Melding method with the IMIS algorithm (Raftery and Bao, 2010) used to calibrate unobservable time-constant characteristics of agents
  1. Frailty level Z_j
  2. Learning ability ξ_H, j
  3. Effort of gaining education ξ_E, j
- Z_j, $\xi_{H,j}$ and $\xi_{E,j}$ are drawn from copulas of gamma distributions
- We need to calibrate 6 parameters ▸ marginal posterior distribution
  1. μ_{ξ_H} and μ_{ξ_E}
  2. σ_{ξ_H}, σ_{ξ_E} and ρ_ϵ
  3. The shape parameter (set equal to scale parameter) of the gamma distributed initial frailty level)
- We use uninformative priors, where we just set the boundaries of the possible distribution.
- We run the life cycle model 223 millions of times until the model fits a subset of the outputs to the actual data

Model Fitting

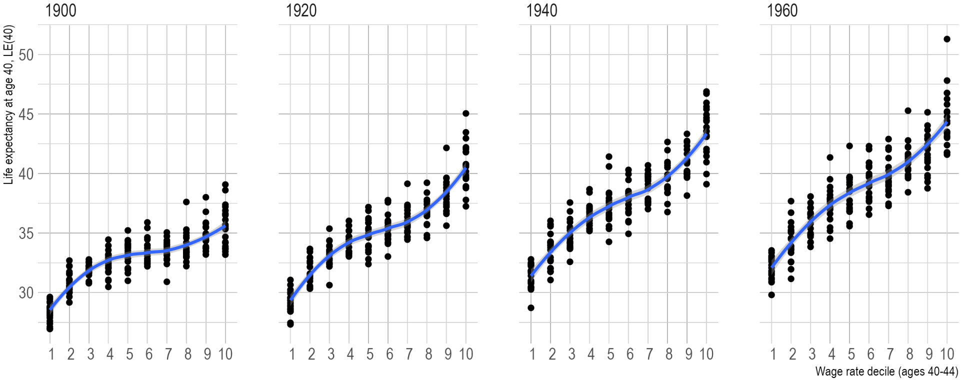


Results I:
Effort of Schooling and Learning Ability

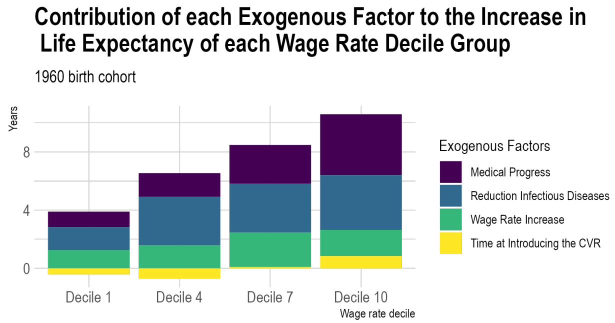


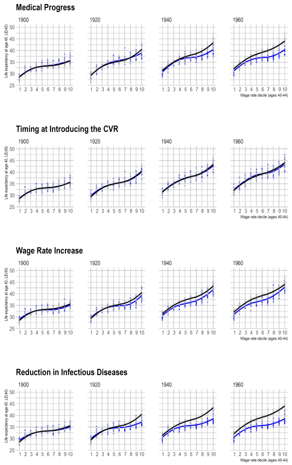
- Surprisingly the calibration suggests that the initial characteristics of individuals are converging

Results II:
Evolution of Life Expectancy by Wage Decile



Results III:
Contributions to the Increasing Life Expectancy Gap





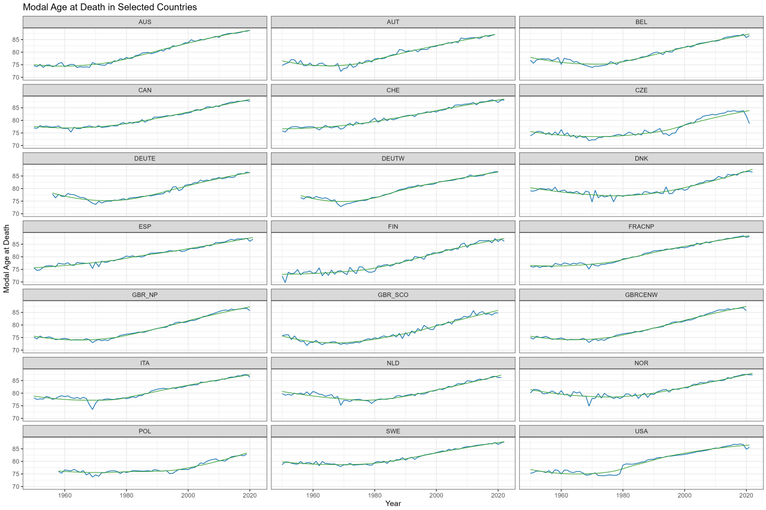
Outlook

1. Embed the life cycle model in an overlapping generations model to analyse the implication of various pension reforms on income, wealth and life span inequality within and across generations.
2. Investigate policies tackling income, wealth and life span inequality within and across generations.

Thank you for listening!

Acknowledgments: This project has received funding from the Austrian National Bank (OeNB) under Grant no. 18744.

Evolution of the modal age at death for a set of selected countries



Law of motions

We solve the model using the present value Hamiltonian. From FOC and envelope theorem we obtain the optimal:

- Investment in health care

$$m(t) = \left(A_m(t) \psi_M(t) \frac{\sigma_m}{p} \right)^{\frac{1}{1-\sigma_m}} . \tag{11}$$

- A_m state of medical technology
- ψ_M value of reducing mortality
- p is price of health care
- σ_m price elasticity of health-care demand

Law of motions

- Consumption

$$\frac{\dot{c}(t)}{c(t)} = \frac{-u_c}{cu_{cc}}\big(r - \rho - \mu(t, M(t;Z))\big), \tag{12}$$

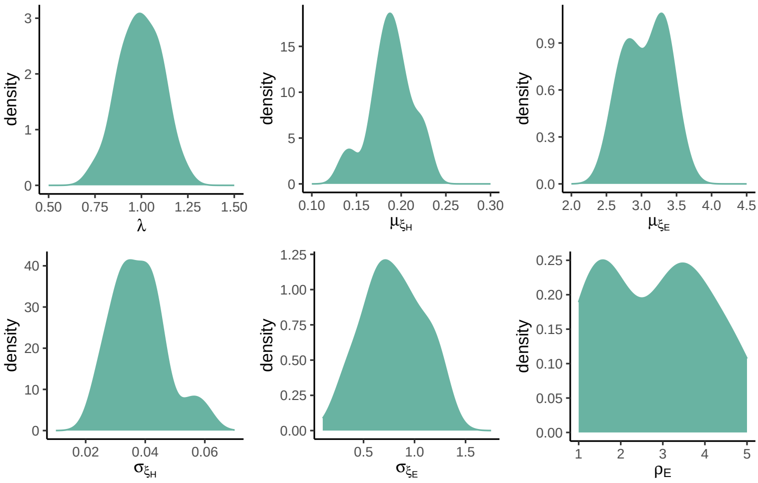
- Labour supply

$$\frac{\dot{\ell}(t)}{\ell(t)} = \frac{z(t)}{1-z(t)} \frac{-u_z}{zu_{zz}}\big(f(t,E) + (1-\phi)\mu(t, M(t;Z)) + \rho - r\big), \tag{13}$$

- Health care utilization

$$\frac{\dot{m}(t)}{m(t)} = \frac{1}{1-\sigma_m}\left(r + \frac{\dot{A}_m(t)}{A_m(t)} - \frac{-\dot{\psi}_M(t)}{\psi_M(t)}\right). \tag{14}$$

Marginal posterior distributions of the inputs



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