Inequality in Health

Lecture V: Health Deficit Accumulation

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Outline

Recap of Last Lecture

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- The properties of the concentration index depend on the measurement **characteristics** of the health variable of interest.
- When the health variable is cardinal and has finite upper and lower bounds, the **Erreygers index** $E(h)$ and the **Wagstaff index** $W(h)$ satisfy the desired properties (sign, scale invariance, mirror property) and are superior to the CI.
- Level-dependent indices allow for decomposition into within- and between-subgroup inequality.
- Applying decomposition methods to inequality indicators (like the CI) allows to analyse income-related inequalities in health across the **entire** income **distribution** (income proxying for SES).
- In this case, each source of inequality is quantified – and not just the difference between the two groups.

Introduction

The Preston Curve

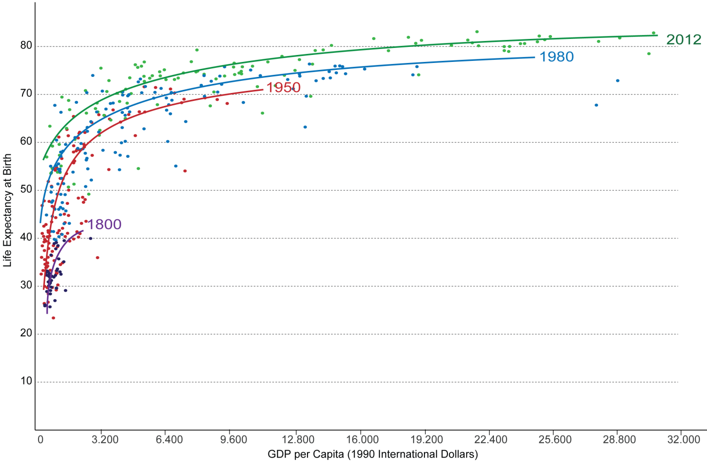


Figure 1. The Preston Curve: Life Expectancy versus GDP Per Capita.

What is Ageing?

- An intrinsic, cumulative, progressive and deleterious process that ends with death.
- Great **heterogeneity**: Only imperfectly captured by calendar age. There is no ‘biological clock’.
- But at the population level: age is the best predictor of death.

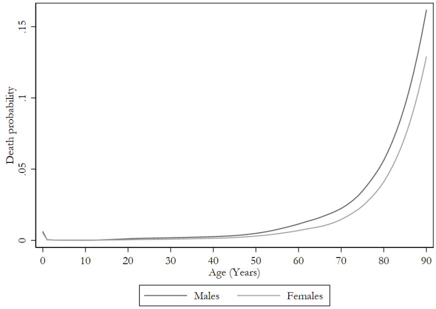


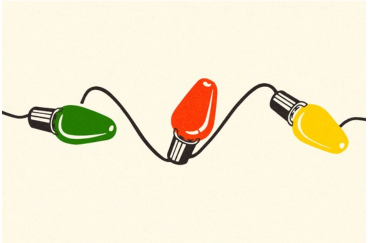
Figure 2. Gompertz-Makeham Law of Mortality. Data: U.S in 2019.

The Reductionist Approach

- The **body** ages
- Because its **organs** age
- Because **tissue** ages
- Because **cells** age
- ...
- But **molecules do not age**!

Reliability Theory

- **Failure** (death): a required function is terminated.
- Ageing is degradation to failure.
- A reliability structure: arrangement of components required for system reliability.
  - Connected in series.
  - Connected in parallel.
- Combination of the two: **series-parallel**.



The Human Body is Series-Parallel

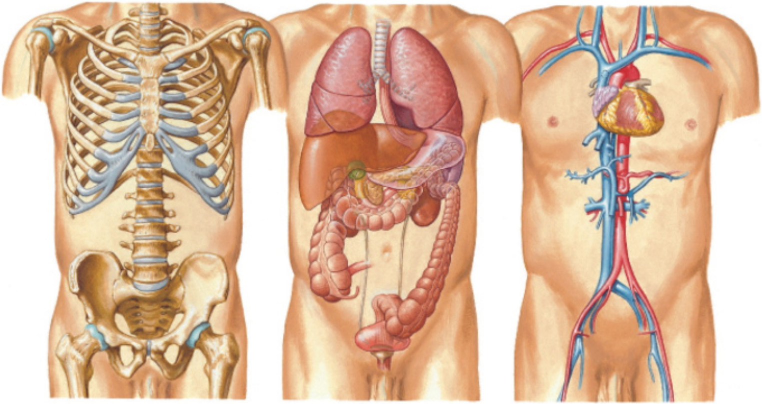


Figure 3. A Series-Parallel System.

Redundancy

Redundancy (given by parallel blocks) has two implications

- **Damage tolerance**: damage does not lead to failure/death.
- **Damage accumulation** – the organism ages.

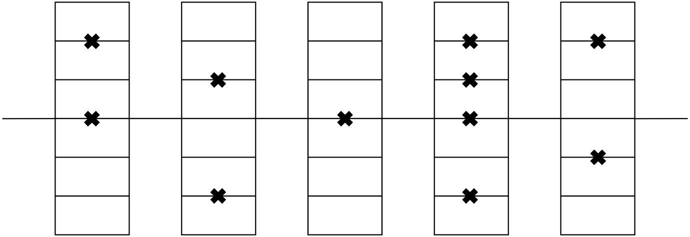


Figure 4. Redundancy.

Modeling Human Ageing

Deficit Accumulation

- Ageing is thus the collection of deficits – reduced vision, strokes...
- Mitnitski et al. (2002) fit deficit accumulation equation

$$D\left(t\right) = E + Be^{\mu t} \tag{1}$$

- The **force of ageing** μ is a physiological parameter: drives the process of ageing.
- E is common for men and women; B and μ are gender specific.
- Now differentiate with respect to age:

$$\dot{D}\left(t\right) = \mu\left(D\left(t\right) - E\right) \tag{2}$$

- Hence, E **slows down** ageing.
- Think of it as malleable part of deficit accumulation ($\Rightarrow$ investment).

Dalgaard & Strulik's Specification

Dalgaard and Strulik (2014) assume the following specification for E:

$$\dot{D}(t) = \mu \left(D(t) - a - Ah(t)^{\gamma}\right) \tag{3}$$

where

- Parameter a captures **exogenous** environmental factors.
- $A > 0$ and $0 < \gamma < 1$ represent state of **health technology**:
  - A: general power of expenditure
  - γ: returns to scale.
- h is **health investment**.
- μ is **constant** across time and space.
- Death occurs whenever $D(t) > \bar{D}$

Comparison with Grossman's Model

- In contrast, Grossman (1972) models the stock of health as

$$\dot{H}(t) = I(t) - \delta H(t) \tag{4}$$

  - $I(t)$ represents **investments** and $H(t)$ is stock of health.
- **Central implication**: depreciation is greater when stock of health is large!
- Standard fix (cf. Muurinen, 1982): let it be age-dependent ($\delta(t)$).
- But where do you get this function from?
- Now use $H = \bar{H} - D$ to convert the Dalgaard-Strulik model:

$$\dot{H}(t) = \mu E - \mu\left(\bar{H} - H(t)\right) \tag{5}$$

- Here, health loss is small when health is good – increasing losses when health deteriorates.

Optimal Ageing and Death

The Optimisation Problem

- Consider an adult maximising utility from consumption $c(t)$ over his or her life:
$$\int_0^T e^{-\rho t} u(c(t))\,\mathrm{d}t \tag{6}$$
with $u(c) = \left(c^{1-\sigma} - 1\right) / (1-\sigma) + b$.
- Thus, health does not affect flow utility.
- The model is deterministic but longevity T is endogenous.
- Income can be spent on consumption goods c and health goods h with price p.
- The law of motion for individual wealth k is given by
$$\dot{k}(t) = w + rk(t) - c(t) - ph(t) \tag{7}$$

Optimal Solution

- The problem is to maximise equation (6) subject to constraints (3) and (7) – and initial/terminal conditions.
- The solution provides 'optimal ageing and death' of the individual.
- First-order conditions give Euler equations for consumption and health investment:

$$g_c \equiv \frac{\dot{c}}{c} = \frac{r - \rho}{\sigma} \tag{8}$$

$$g_h \equiv \frac{\dot{h}}{h} = \frac{r - \mu}{1 - \gamma} \tag{9}$$

- Health Euler equation: health expenditure growth
  - **increases** in r
  - **decreases** in μ: higher $\mu \Rightarrow$ health expenditure later in life ineffective.
  - **increases** in γ: small $\gamma \Rightarrow$ diseconomies of scale $\Rightarrow$ more smoothing of h.
  - Not necessarily **positive**: if $r < \mu$ people age at a rapid pace & prevention more effective than cure.

Optimal Death

- Contrary to Grossman's model, the Dalgaard-Strulik model can be solved for **optimal longevity** T.
- Impose boundary conditions $D(0) = D_0$, $k(0) = k_0$, $k(T) = \bar{k}$, $D(T) = \bar{D}$ and $h(T) = 0$.
- Then integrate constraints (3) and (7) to solve for $k(T)$ and $h(T)$.
- Then solve the associated Hamiltonian for $H(T) = 0$.
- This leads to three equations with three unknowns – and can the resulting dynamic system can be solved for optimal life cycle trajectories of c, h, k, and D.

Comparative Dynamics

Calibration for the U.S.

- Calibrated variables
  - Initial deficits, end-of-life deficits, and longevity.
  - Growth of health spending across ages (g_h).
- No restrictions put on
  - Path of deficits
  - Expenditure shares (h versus c)
- Consistency check: do the paths of health expenditure and frailty match the data?

Calibrated Parameters

Table 1. Model calibration and implications

Description	Notation	Value	Source
Capital share	α	0.33	King & Rebelo (1999)
Inverse of IES	σ	1.0	Chetty (2006)
Interest rate	r	0.06	Barro et al (1995)
Time preference rate	ρ	0.06	Browning & Ejrnæs (2009)
GDP per worker in 2000	y	77,003	Heston, Summers and Aten (2009)
Life expectancy at 20 in year 2000	T	55.2	National Vital Statistics (2009)
Life expectancy at 20 in year 1900	T	42.0	National Vital Statistics (2009)
Force of ageing	μ	0.043	Mitnitski & Rockwood (2002)
Health deficits at age 20	$D(0)$	0.027	Mitnitski & Rockwood (2002)
Health deficits at age 75.2	$D(T)$	0.10	Mitnitski & Rockwood (2002)
Growth rate of health spending	g_h	0.021	Health Canada
Bequests	$k(0), k(T)$	0.0	Benchmark: no bequests
Exogenous health parameter	a	0.013	Implied
Health technology (scale)	A	0.0014	Implied
Health technology (curvature)	γ	0.0014	Implied
Relative price of health in 2000	p	1.0	Normalisation

Model Performance

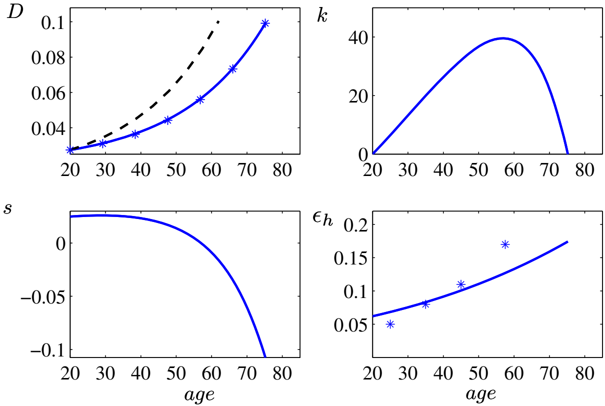


Figure 5. Model Performance, Basic Run

Experiment 1: Income

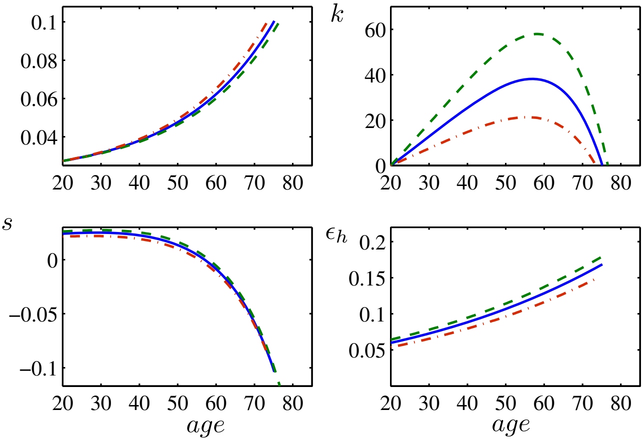


Figure 6. Variation of Labour Income.

Experiment 2: Wealth

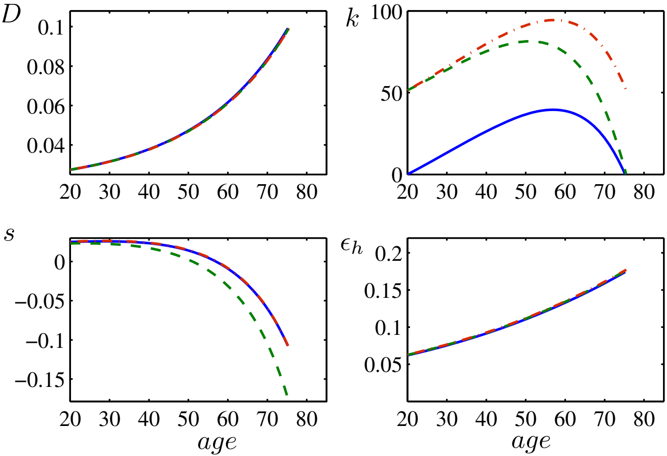


Figure 7. Variation of Wealth.

Experiment 3: Health Costs

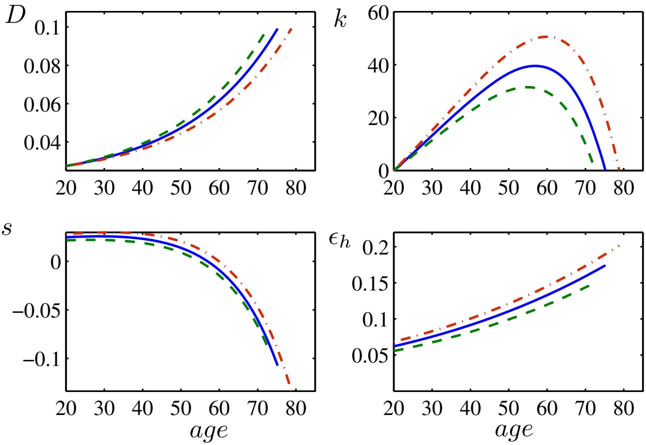


Figure 8. Variation of Health Costs.

Experiment 4: Medical Effectiveness

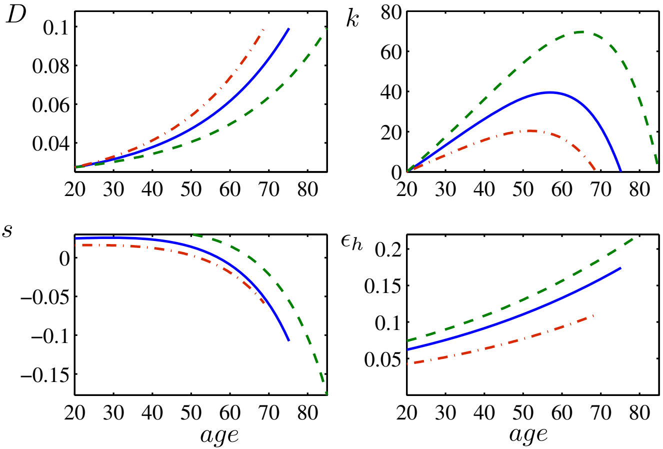


Figure 9. Variation of Medical Effectiveness (A).

Summary of Findings

- Model replicates $D(t)$ quite well, share of health expenditure somewhat less accurately.
- **Higher income** leads to more spending on health. A 33% increase in income increases longevity by 1.5 years.
- **Increased wealth** increases longevity, bequests do not matter.
- **Doubling of health costs** reduces longevity by 2.7 years.
- Increased **medical productivity** has large effect on longevity.

$\Rightarrow$ Improved technology dominates rising incomes.

Back to the Preston Curve

- The authors estimate a Preston curve for male life expectancy at 20:

$$y_i = f(z_i) + x_i\beta + \epsilon_i \tag{10}$$

- This estimated curve is then compared to the model predictions of LE as a function of income.

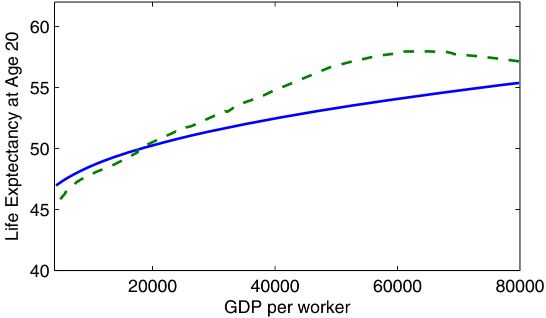


Figure 10. The Model versus the Preston Curve.

Comment

- The model replicates the Preston curve fairly well – accounts for $2/3$ of longevity-income relationship.
- Systematic deviations may be due to
  - **Reverse causation** health $\Rightarrow$ income.
  - Explains the deviation if reverse causation has steeper slope.
  - **Omitted variables –** such as cost of health care (p/A).
  - Requires prices to be higher in poorer countries.
- Overall, the underlying story appears to be: **differences in longevity** by income mainly driven by **differences in health investments**.

Extensions

Dalgaard and Strulik (2017): Retirement

- Dalgaard and Strulik (2017) introduce a **retirement decision**.
- Wages increase with experience, decrease with deficits/ageing.
- Work generates disutility.
- New health Euler while working: investing in health increases productivity.
- Increases in health prices, technological progress in health care, and rising incomes lead to **longer retirement**.
- Declining prices of health care will increase longevity and retirement age.

Results

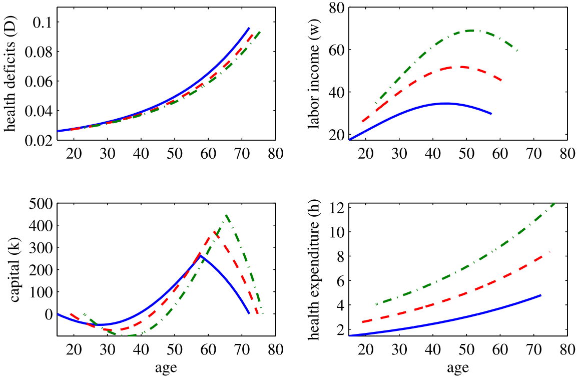


Figure 11. Model Predictions by Education.

Schünemann et al. (2017): Gender gap

- Can the gender gap in longevity be explained by behaviour?
- Now assume health gives utility: $U(c(t), D(t))$.
- Calibrate model to gender-specific particulars $(D_0, \bar{D}, T, h(t), w)$.
- Preference parameters σ (IES) and α (preference for health) are gender-specific.
- Would the gender gap be closed if females had male preferences?

Results

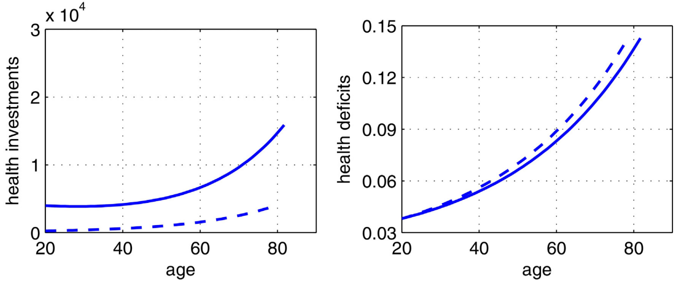


Figure 12. Female Health with Male Preferences.

Summary and Conclusions

Summary and Conclusions

- Human Ageing is best described as an accumulation of **health deficits**.
- A serial-parallel system has **redundancy**, which implies **ageing**.
- The Dalgaard and Strulik (2014) model incorporate these insights in an economic model.
- Individuals invest in health to reduce deficit accumulation.
- Model can predict the trajectory of health quite well.
- Implication for Preston curve: largely reflects causation running from income to health.

Literature I

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