'The Child is Father of the Man:' Implications for the Demographic Transition

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Introduction

- New theory of the demographic transition
- Evidence (natural sciences): Body development during childhood is an important determinant of life expectancy
- Continuous time OLG model where fertility, longevity and education result all from individual decisions
- Main result: The model dynamics displays the key features of the demographic transition

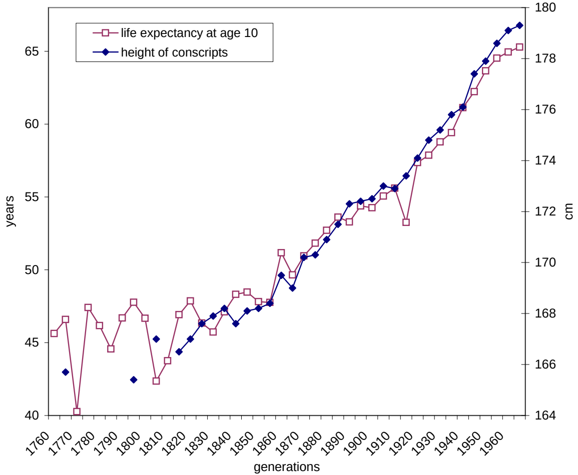
The demographic transition

- From a world of low population growth with high fertility and mortality
- To a world of low population growth with low mortality and fertility
- In the transition, a hump in the population growth rate

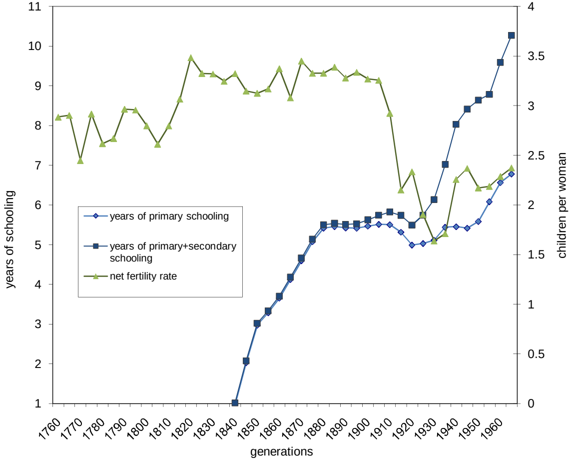
Childhood development

- Positive relation between early body development and adult mortality
  - Body height a proxy of body development is a good predictor of adult mortality
  - Good nutrition and low exposition to infections (hygienic habits) favor early body development
- Wordsworth's aphorism: 'The Child is Father of the Man'
  - The way a child is brought up determines what he will be
- The new mechanism: Trade-off between the number of children and their body development
- Nature vs nurture

Height and Life Expectancy in Sweden



Fertility and Education in Sweden



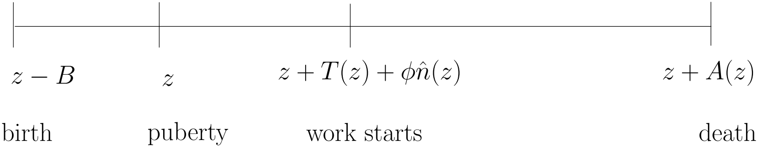
The Timing of the Demographic Transition

- (Net) Fertility is hump shaped, reducing in the modern era
- Years of secondary schooling increase during the modern era
- Reductions in adult mortality arrive well before

Continuous time OLG model

- The economy is composed by a continuum of dynasties
- Each dynasty is a sequence of generations $i \in \{1, 2, 3, ...\}$
- *Individuals* take their life expectancy A as given
    - Optimally decide on its own schooling time T
    - Number of children $\hat{n}$ and children' life expectancy $\hat{A}$
- At equilibrium, *dynasty* life expectancy follows: $A_{i+1} = f_A(A_i)$
- *Aggregates* are then computed and the dynamics solved

Individuals life



- Cohorts are index by the time of puberty, z
  - Birth date is $z - B$, were B is puberty age, $B > 0$
- Life expectancy at age B is A
  - The survival law is rectangular
- Seniority is reached at $z + T + \phi n$
  - The schooling time is $\theta + T$, $0 < \theta < B$ and $T > 0$
  - An individual has n children at $z + T(z)$
  - Raising a children takes ϕ, $\phi > 0$

Individual Problem

$$\max \int_0^A c(z)\ \mathrm{d}z + \left(\beta \ln \hat{n} + \delta \ln \hat{A}\right)$$

$$\text{s.t.} \quad \int_0^A c(z)\ \mathrm{d}z = g(T)\left(A - T - \phi \hat{n}\right) - \hat{n}\,\Psi(\hat{A})$$

$$T \geq 0, \qquad \int_0^A c(z)\ \mathrm{d}z \geq 0$$

- Preferences satisfy $\delta < 2\beta$
- Human capital technology $g(T) = \mu(\theta + T)^{\alpha}$
  - productivity, $\mu > 0$
  - child schooling time, $\theta > 0$
  - returns to schooling time, $\alpha \in (0, 1)$
- Quadratic childhood development costs $\Psi(\hat{A}) = \left(\frac{\kappa}{2}\frac{\hat{A}^2}{A}\right)$
  - cost parameter, $\kappa > 0$

Individual Problem (2)

$$\max_{c,T,\hat{A},\hat{n}} c + \left(\beta \ln \hat{n} + \delta \ln \hat{A}\right)$$

$$\text{s.t. } c = \underbrace{\mu(\theta + T)^{\alpha}}_{\text{human capital}} \underbrace{(A - T - \phi\hat{n})}_{\text{working life}} - \underbrace{\hat{n}\left(\frac{\kappa}{2}\frac{\hat{A}^2}{A}\right)}_{\text{child cost}}$$

$$T \geq 0, \qquad c \geq 0$$

- Quasilinear preferences and subsistence consumption
- Trade-off between number and survival of descendants

Solution to the individual problem

There exist $\underline{A}$ and $\bar{A}$, $0 < \underline{A} < \bar{A}$, s.t.

- *Malthusian Regime*: For $0 < A < \underline{A}$, corner solution with $T = 0$ and zero consumption
- *Intermediary Regime*: For $\underline{A} \leq A < \bar{A}$, corner solution with $T = 0$ but positive consumption
- *Modern Regime*: For $A \geq \bar{A}$, interior solution

Mechanics: Modern Regime ($A \geq \bar{A}$)

- Childhood development
  - Parents like to have children, but care about their longevity
  - Trade-off: Negative relation between fertility and longevity

$$\hat{A}^2 = \frac{\delta A}{\kappa \hat{n}}$$

- The Ben-Porath mechanism
  - The return to education depends on life expectancy
  - Larger life expectancy makes schooling more profitable

$$T = \frac{\alpha}{1+\alpha}(A - \phi \hat{n}) - \frac{\theta}{1+\alpha}$$

- Trade-off education vs fertility
  - Individuals allocating more time to education have less children

$$\hat{n} = \frac{\beta - \delta/2}{\mu \phi}(\theta + T)^{-\alpha}$$

Malthusian Regime ($0 < A < \underline{A}$)

- Consumption and schooling are both at a corner
- Parents living longer can afford more and healthier children

$$\hat{A}^2 = \frac{\delta}{\kappa} \frac{\mu \theta^\alpha \phi}{\beta - \delta/2} A,$$

$$T = 0,$$

$$\hat{n} = \frac{\beta - \delta/2}{\beta \phi} A.$$

Intermediary Regime ($\underline{A} \le A < \bar{A}$)

- Schooling is at a corner and fertility is time invariant
- Parents living longer consume more and invest more in childhood development

$$\hat{A}^2 = \frac{\delta}{\kappa \hat{n}} A,$$

$$T = 0,$$

$$\hat{n} = \frac{\beta - \delta/2}{\mu \phi \theta^{\alpha}}.$$

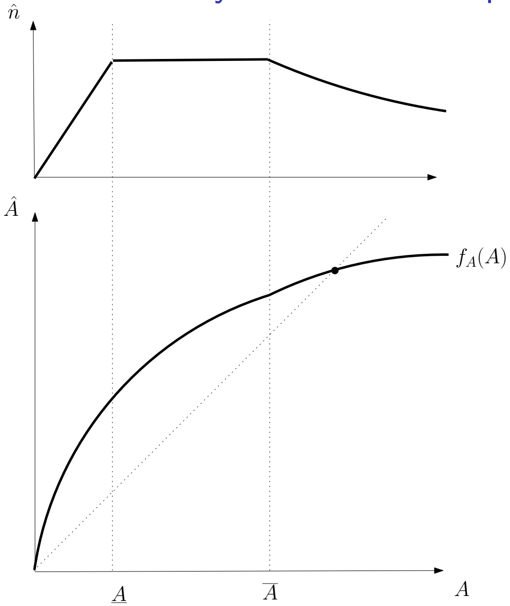
Dynamics of life expectancy

A dynasty is a sequence of generations $i = 1, 2, 3, \ldots$, such that

$$A_{i+1} = f_A(A_i)$$

- A stationary solution $A = f_A(A)$ exists, is unique and globally stable
- It may belong to any of the three regimes above
- Then, a solution path for n and T exists and is unique

Dynamics of life expectancy



The interior regime in the long-run

The steady state is in the interior regime if

$$\kappa < \frac{4\alpha\delta\theta^{2\alpha}\mu^2\phi}{(2\beta-\delta)\left(\alpha[2\beta-\delta]+2\theta^{1+\alpha}\mu\right)} \equiv \overline{\kappa} \qquad (1)$$

if childhood development technology is cheap enough, there is an interior steady state with positive education

Total population

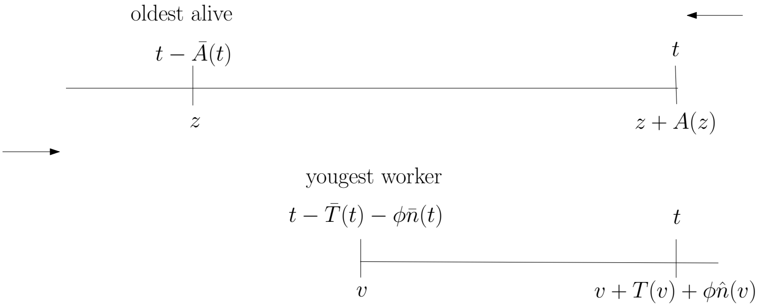
$$N(t) = \int_{t-\bar{A}(t)}^{t+B} P(z)\ \mathrm{d}z$$

$$\bar{A}(t) = A\left(t - \bar{A}(t)\right)$$

Cohort size $P(z)$ follows

$$P(z + T(z) + B) = \hat{n}(z)\, P(z)$$

Population at time t



- $\bar{A}(t)$ is the age of the oldest cohort still alive at t
- $\bar{T}(t)$ is schooling time of the youngest active cohort at t
- $\bar{n}(t)$ is the number of kids of the youngest active cohort at t

Balanced growth path

The growth rate of population converges to

$$\eta = \frac{\ln(n)}{T + B}$$

Demographic Transition

- The economy is initially on the Malthusian regime
  - $B = 13.5$, $\phi = 1$, $\theta = 6$, $\alpha = 1/6$
  - μ, κ, β, δ are set to reproduce basic facts before the 18th C
    $A = 27$ $(B + A = 40.5)$, $T = 0$, $\eta = .005$, $\underline{A} = 28 \rightarrow \bar{A} = 37$
- A slow reduction in childhood development costs makes investing in life expectancy more profitable
  - Logistic function: 95% of the change between 1700 and 2050
- The economy converges to the modern regime
  - Life expectancy increases from 40.5 to 90
- Mortality and fertility shape the demographic transition

Rise in medical knowledge?

Common view: The period 1500-1870 does not contain major technology changes in health that could have increased life expectancy

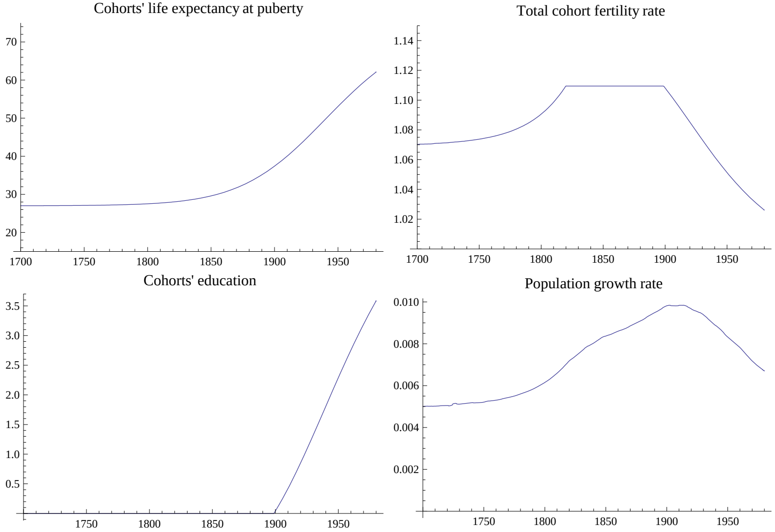
But

- 1500-1800: medicine showed an increasingly experimental attitude: no improvement on theory but advances on practice and empirical observations. (new drugs coming from the New World)
- As early as 1829, Dr.F.B. Hawkins wrote a book entitled *Elements of Medical Statistics*, in which he described a set of diseases which were leading causes of death but can now (in 1829) be treated effectively: leprosy, plague, sweating sickness, ague, typhus, smallpox, syphilis and scurvy.
- Number of books containing lifestyle advice increasing significantly over the period 1750-1800.

Number of books on health published in England, 1600-1800

Period	Number of books
1600-24	9
1625-49	16
1650-74	17
1675-99	25
1700-24	28
1725-49	34
1750-74	53
1775-1800	81

The demographic transition



Unified Growth Theory

Unified explanation of:

$$\begin{cases}\text{Transition from Malthusian stagnation to sustained growth}\\ \text{Demographic transition } (\downarrow \text{ fertility-mortality}, \frown \text{ popul. growth})\end{cases}$$

Parents' *trade-off* between number of children and education

Industrial Revolution →
Increasing demand for skilled workers→
Households increase education of offspring →
Demographic transition and take-off (Galor)

Validation: rise in the skill premium ?

Validation

Clark (2005) measures over 1220-1990 the relative wage of skilled building workers relative to all laborers.

"The market premium for skills does not explain the increased investment in human skills evident after 1600."

Doubts

Can the fertility transition in the 19th century be explained through greater demand for educated children?

Modeling Growth

Assumptions:

- Human capital as an engine of growth

$$h(z) = \mu \left(\theta + T(z)\right)^{\alpha} \bar{H}(z)$$

  $\bar{H}$ is human capital per worker

- Preferences and childhood technology face the same externality, then the individual problem does not change

Human Capital

$$H(t) = \int_{t-\bar{A}(t)}^{t-\bar{T}(t)-\phi\bar{n}(t)} P(z) \underbrace{\mu(\theta + T(z))^{\alpha} \bar{H}(z)}_{h(z)} \, \mathrm{d}z$$

Human capital per worker is

$$\bar{H}(t) = \frac{H(t)}{E(t)}$$

The technology producing the final good is linear in H with productivity one

Output per capita is then $\frac{H(t)}{N(t)}$.

Active population

$$E(t) = \int_{t-\bar{A}(t)}^{t-\bar{T}(t)-\phi\bar{n}(t)} P(z)\,\mathrm{d}z$$

$$\bar{T}(t) = T(t - \bar{T}(t) - \phi\bar{n}(t))$$

$$\bar{n}(t) = \hat{n}(t - \bar{T}(t) - \phi\bar{n}(t))$$

Balanced Growth Path

- Population grows at rate

$$\eta = \frac{\ln(n)}{T + B}$$

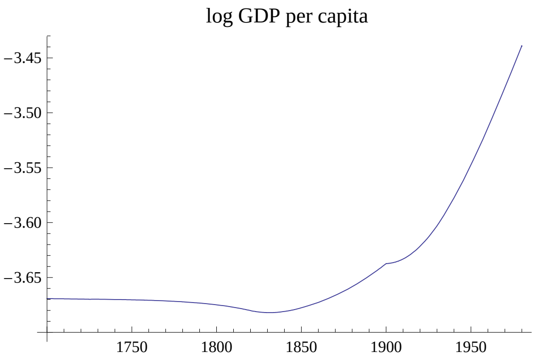
- Human capital grows at rate

$$\gamma = \frac{P^{\star}}{E^{\star}} \mu(\theta + T)^{\alpha} \left(e^{-\gamma(T+\phi n)} - e^{-\gamma A} \right)$$

  - Human capital per worker
  - All cohorts share the same human capital technology
  - But, growing externality

- Per capita output grows at $\gamma - \eta$

From Malthus to Modern Growth



- There is no growth in the Malthusian regime
- In the intermediary regime, per capita growth rates increase slowly due to the reduction in the dependency ratio
- In the modern regime, human capital accumulation accelerates per capita growth

Conclusion

A new theory of the demographic transition

Fertility, longevity and education are decided by individuals

Based on the evidence that adult life expectancy depends on body development during childhood (natural sciences)

Replicate the main characteristics of the demographic transition

Adding human capital as a growth engine replicates the transition from the Malthusian era to Modern growth

Further test of our theory

Look at the relation between family size and to childhood development (height) on historical micro-data?