Did Longer Lives Buy Economic Growth ? From Malthus to Lucas and Ben-Porath

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European Central Bank, October 2015

Context (1)

Take-off from stagnation to growth

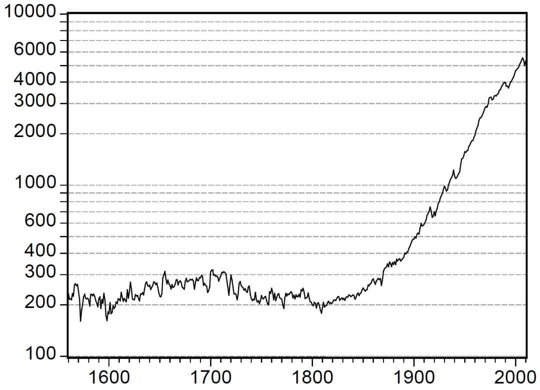
Understanding the mechanisms responsible for the take-off

Importance of the channel: longevity → education → growth

Understanding the past to discuss the future for growth

Context (2)

Figure 1. GDP per capita in Sweden, 1560-2010. SEK in constant prices, price level 1910/12.



Source: Schön & Krantz, 2012

What I do in this note

1. Refer to some empirical evidence that improvements in life expectancy occurred before the take-off to modern growth

   ↪ Establishing precedence of longevity over growth is one argument in favor of causality.

2. Show how to measure these improvements.

3. Feed them into two growth models with two different mechanisms

   - contact time effect
   - incentive effect

   Discuss their quantitative significance

4. Implications for future growth?

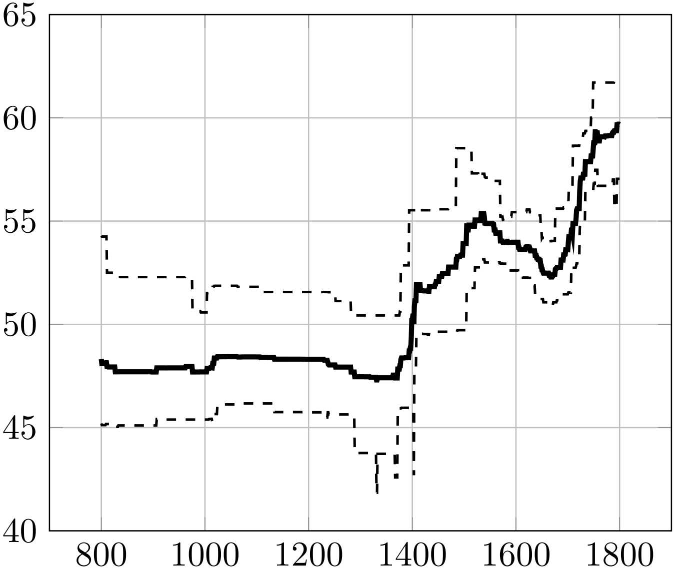
Cummins, 2014

Data from Church of Jesus Christ of the Latter Day Saints + genealogists

1.3m records, with 402,204 dates, Geo-coding of 117,975 unique addresses, categorization of nobles into 17 ranks

In the end: $N = 121,478$

Predictions for Adult Longevity in England



Results

Longevity: marked increases around 1400 and again around 1650.

Declines in violence contributed to some of this increase, but the majority must reflect other changes in individual behavior.

The areas of North-West Europe achieved greater longevity than the rest.

De la Croix & Licandro, JOEG, 2015

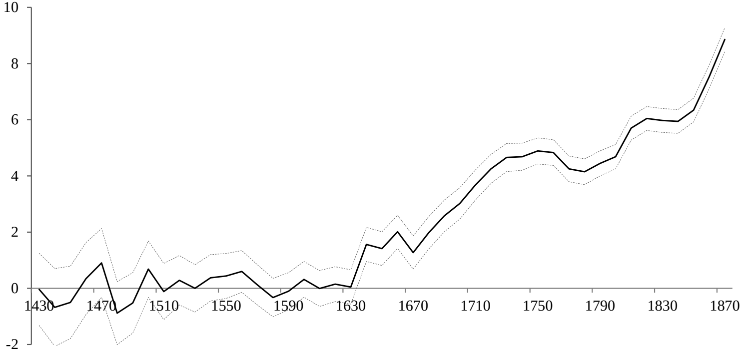
Build a new dataset of around 300,000 famous people born from the 24th century BCE (Hammurabi) to 1879 CE, Einstein's birth.

Data taken from the *Index Bio-bibliographicus Notorum Hominum* (IBN), which contains information on vital dates + some individual characteristics.

Characteristics are used to control for selection and composition biases.

Advantage: Includes much more than nobles: artists, merchants, authors, professors

Time Fixed Effect in the Longevity Regression



Results

1. *Adult mean lifetime shows no trend over most of history*.

   ↪ confirms the existence of a Malthusian era.

2. *Permanent improvements in longevity precede the Industrial Revolution*. Steady increase starting with generations born 1640-9.

   ↪ lends credence to hypothesis that human capital was important for take-off to modern growth

3. *Occurred almost everywhere over Europe*, not only in the leading countries, and *for all observed (famous) occupations*.

Measurement

Formal frameworks to measure improvements in longevity and feed them into economic models:

- Gompertz Mortality Law
- BCL law
- . . .

Gompertz Mortality Law

The logarithm of the death rate $\delta_g(a)$ is linear in age:

$$\delta_g(a) = \exp\{\rho + \mu a\}. \tag{1}$$

ρ: measures the mortality of young generations
μ: the rate at which mortality increases with age.

The corresponding survival law is

$$S_g(a) = \exp\left\{-\int_0^a \delta_g(a)\mathrm{d}a\right\} = \exp\left\{\frac{(1-\exp\{\mu a\})\ \exp\rho}{\mu}\right\}. \tag{2}$$

Widely used, but often untractable to use within economic models because of the double exponential.

BCL Law (Boucekkine, de la Croix, Licandro, 2002)

$$\delta_b(a) = \frac{\beta}{1 - \alpha \exp\{\beta a\}},$$

with $\alpha \in \mathbb{R}_+$ and $\beta \in \mathbb{R}$, and $\alpha < 1 \Leftrightarrow \beta > 0$.

The corresponding survival function is:

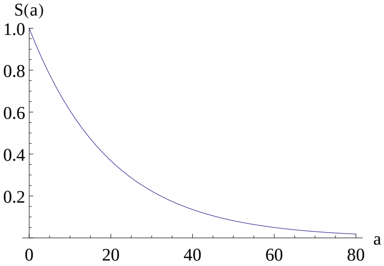
$$S_b(a) = \frac{\exp\{-\beta a\} - \alpha}{1 - \alpha}.$$

If $\alpha > 0$ maximum age:

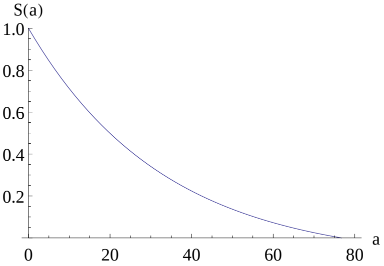
$$\bar{a} = -\frac{1}{\beta} \ln \alpha.$$

BCL is a first order approximation of the Gompertz law of mortality.

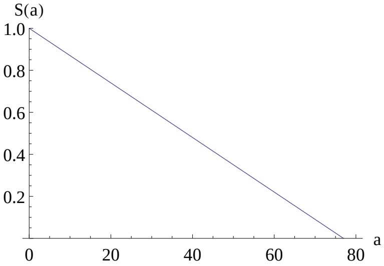
Four examples of survival functions



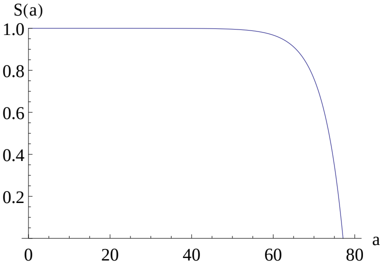
$\beta = 0.05$, $\alpha = 0$



$\alpha = 0.1$, $\beta = 0.03$



$\alpha = 0.999$ and $\beta = 0.000013$



$\alpha = 5000000$ and $\beta = -0.2$

Estimation of parameters

Place		$-\beta$	α	Source
Roman Empire	c. 100	-0.001	0.93	own computation
Geneva	1625-1674	0.005	1.45	Boucekkine, de la Croix, and Licandro (2003)
Geneva	1675-1724	0.010	2.18	
Geneva	1725-1825	0.018	3.86	
France	1875-1899	0.019	4.92	Boucekkine, de la Croix, and Licandro (2004)
France	1900-1924	0.032	15.11	
France	1925-1949	0.052	94.83	
Netherlands	1960 (p)	0.068	122.64	Heijdra and Mierau (2010)
USA	1840	0.018	5.37	Cervellati and Sunde (2013)
USA	1870	0.022	7.49	
USA	1900	0.028	13.46	
USA	1930	0.037	33.42	
USA	1960 (p)	0.054	43.98	Mierau and Turnovsky (2014)
USA	2006 (p)	0.057	78.36	

The Compensation Effect of Mortality

Any observed reduction in the mortality of the young, ρ, has to be compensated for by an increase in the mortality of the old, μ, following:

$$\rho = C_0 - C_1 \mu$$

where $C_0, C_1 > 0$, the same for all human populations.

Under the Compensation Effect, survival laws tend to rectangularize when α goes to infinity.

In the case of the BCL law of mortality, it implies:

$$\ln \frac{-\beta}{\alpha - 1} = C_0 + C_1 \beta$$

With US data:

$$\ln \frac{-\beta}{\alpha - 1} = -4.21 + 68.6\beta, \qquad R^2 = 99.6$$

Rectangularization

Rectangularization - particular economic importance.

Early increase in longevity benefits adults in their working age, affecting economic incentives to invest.

At later stages, increasing longevity benefits old workers and retired people more, and is of less importance as far as incentives are concerned.

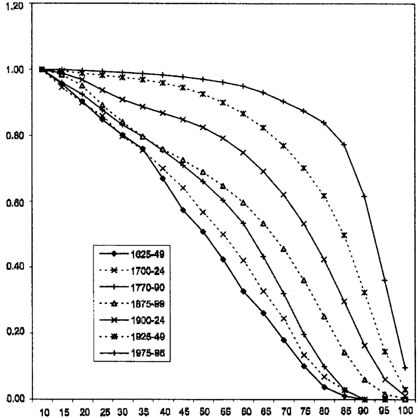


FIGURE 1 Shifts in the survival law over four centuries.

Lucas, 2009

Person-to-person interactions were (and remain) essential for learning

Longer lives increase the contact time between persons

Higher share of elders in the society makes interaction more fruitful

Learning

A person has productivity z at date t (distributed following G).

Over the time interval $(t, t+h)$ he gets ηh independent draws from another distribution H

the source of everyone's ideas is other people in the same economy: $G = H$

Let y denote the best of these draws.

Then at $t+h$ his productivity will be either his original productivity z or the best of his new ideas y, whatever is higher: $\max(z, y)$.

Maximum Stability Postulate

Each idea y gives the possibility to produce one unit of output with cost $x = y^{-1/\theta}$.

The distribution of ideas is assumed to be a Fréchet distribution

Fréchet distribution satisfies the maximum stability postulate: the maximum of two independent random variables, Fréchet distributed with parameters $(1/\theta, \lambda^\theta)$ will be itself Fréchet distributed with parameters $(1/\theta, 2^\theta \lambda^\theta)$.

→ the only state variable is the scale parameter of the distribution

Adding a Cohort Structure

$p(a)$: density of population aged a in the economy.

Growth rate of knowledge along a balanced growth path:

$$\gamma = \eta \int_0^{\bar{a}} p(a)(1 - e^{-\gamma a})\mathrm{d}a, \tag{3}$$

with BCL:

$$p(a) = \frac{S(a)}{\int_0^{\bar{a}} S(x)dx} = \frac{\beta\left(e^{-\beta a} - \alpha\right)}{1 - \alpha + \alpha \ln \alpha}. \tag{4}$$

Quantification

Steps:

1. Set some parameters a priori. $\theta = 0.5$ (estimated from the variance of earnings across workers).
2. Set η to give a realistic growth rate (2%) with a recent estimate of the survival function.
3. Impute the survival parameters from cohorts born one century before. Implies an annual growth rate of GDP per capita of 1.8%.
4. Repeat with pre-industrial levels of the survival parameters. Implies an annual growth rate of GDP per capita of 1.2%.

Longevity can explain two fifths of the increase in growth rates over the last two centuries (explaining $+0.8\%$ over $+2\%$)

Incentive Effect: BCL 2002, 2003 & Others

The Households' Problem:

$$\int_{t}^{t+\bar{a}} c(t,z)\, S(z-t)\, e^{-\varrho(z-t)} \mathrm{d}z, \tag{5}$$

Human capital:

$$h(t) = A\bar{H}(t)T. \tag{6}$$

The inter-temporal budget constraint of the agent born at t is:

$$\int_{t}^{t+\bar{a}} c(t,z)R(t,z)\mathrm{d}z = \int_{t+T}^{t+\bar{a}} h(t)R(t,z)\mathrm{d}z. \tag{7}$$

Ben-Porath Effect: Chosen T increases with "horizon"

Aggregate Human Capital & Growth

$$Y(t) = H(t) = \int_{t-\bar{a}}^{t-\overline{T}} S(t-z)h(z)\mathrm{d}z, \tag{8}$$

Average human capital:

$$\bar{H}(t) = \frac{H(t)}{P}. \tag{9}$$

Dynamics:

$$H(t) = \int_{t-\bar{a}}^{t-\overline{T}} S(t-z)\frac{AH(z)T}{P}\mathrm{d}z, \tag{10}$$

→ there exists a balanced growth path

Quantification:

1. Set the pure rate of time preference ϱ to 4% per year.
2. Calibrate A to give a realistic growth rate (2%) with a recent estimate of the survival function. (Note: Along this balanced growth path, $T = 20.8$ (too much)).
3. Compute what growth rate would be if we impute the survival parameters from cohorts born one century before. Implies annual growth rate of 1.9%.
4. Repeat with pre-industrial levels of the survival parameters. Leads to annual growth rate of GDP per capita of 1.6%. Schooling in this simulation is $T = 15.8$.

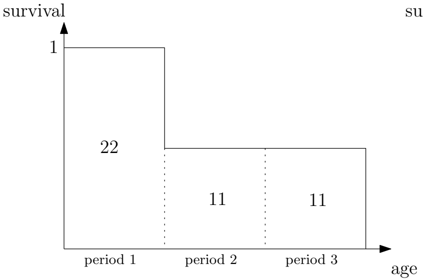
Here longevity increases explain one fifth of the increase in growth rates over the last two centuries (explaining $+0.4\%$ over $+2\%$), and one fourth of the increase in schooling

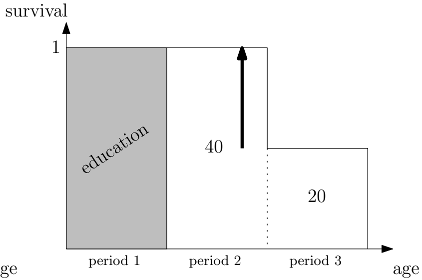
Summary

Model	(a) Lucas	(c) Ben-Porath	(d) US data
1650⟶1850	+ 0.61%	+0.30%	+1.16%
1850⟶1930	+ 0.17%	+0.10%	+0.81%
1650⟶1930	+ 0.78%	+ 0.40%	+1.97%

Discussion

Example with Increasing Longevity & Schooling but Decreasing Lifetime Labor Supply





No educ.: income per period is 22. Educ: income per period is 40.

Conclusion: Results

Increases in longevity are quantitatively significant for the increases in growth observed over the last two centuries

Calls for the consideration of demographic factors when examining determinants of growth.

Conclusion: Implications for Future Growth

In the long-run, technical progress, i.e. TFP improvements, is the source of sustained growth

Is TFP going to grow unboundedly ?

We need a theory of TFP !

The two models reviewed here provide one

Contact time effect in the 21th century

The rise in longevity increased permanently the growth rate of TFP:

- people have more chances of becoming old and hence more knowledgeable

- initially very talented people have more occasions to transmit their knowledge

No effect of aging *per se*

This is a permanent change, no reason to go back (ratchet effect)

Limitation: No effect of increased complexity on learning from others

Incentive effect in the 21th century

The rise in longevity modified permanently the incentives to get education.

If human capital is the engine behind TFP growth (endogenous growth models) the effect on growth rate is irreversible

But effect of aging: old teachers got their ideas a long time ago - not very productive

Further increase in longevity might slightly lower growth rates