Population Growth, Ideas and the Speed of History

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2. A larger economy/population produces more non-rival ideas (Romer, 1990; Jones, 1995)
   - I.e., the production of ideas depends on people
3. So, a small and shrinking population generates less economic growth (Jones, 2022)
   - In the limit, growth goes to zero in these models without population growth (Jones, 1995)

     ("semi-endogenous" growth)

Should we be concerned about the loss of innovation in a small or shrinking world?

It seems straightforward that—if these theories are correct—**this could be an important loss coming from depopulation**

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And, in fact, there *is* concern:

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The economics of falling populations

A shrinking global population could slow technological progress

Poorer Countries Will Find It Harder to Get Richer

Declining birth rates are a challenge to economic growth everywhere, but especially in less developed nations.

January 15, 2024 at 5:30 AM CST

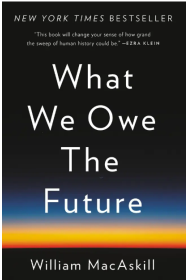
By Tyler Cowen

Tyler Cowen is a Bloomberg Opinion columnist, a professor of economics at George Mason University and host of the Marginal Revolution blog.

The End of Economic Growth? Unintended Consequences of a Declining Population†

By Charles I. Jones*

In many models, economic growth is driven by people discovering new ideas. These models typically assume either a constant or growing population. However, in high income countries today, fertility is already below its replacement rate: women are having fewer than two children on average. It is a distinct possibility that global population will decline rather than stabilize in the long run. In standard models, this has profound implications: rather than continued exponential growth, living standards stagnate for a population that



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I will argue: No individual is made better off by living in a larger population world in these SEG settings

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2. **Exogenous** (e.g., nature-caused): The faster history moves, the more advanced we would be by the time an (e.g.,) asteroid is bearing down; population size *does* matter

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General Lesson: Formalizing which factors evolve per human life vs. per unit time is crucial for understanding how per capita variables are affected by population size

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Result 3: Generally, we need to clarify how time *per se* matters for different economic processes

- To make lives better, we need to change the arrival rate of people *relative* to something
- Agglomeration/natural resource constraints can be framed as time-based considerations

Simple Model: Scale-based growth does not improve individual living standards

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Consider a world with two possible levels of technology

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For concreteness, let's say it takes 1 trillion people-years of effort to get to state H

Does increasing the population size increase individual welfare?

Let's focus on a marginal increase in population from (constant) $N = 10$ (billion) to $N = 11$ (billion)

- So it takes either 100 years or 91 years to get to H, respectively

What are the effects of getting there faster?

From the perspective of each individual, **there is no difference**

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We've stipulated that it takes 1 trillion people-years to get to H

- So the first $i \leq 1$ trillion **do not benefit** from technological progress being accelerated in this way

  (They have more contemporaries, but I'll set that aside)

Do people $i > 1$ trillion benefit?

What changes for the people who come afterwards?

Consider things from the vantage of person $i = 1$ trillion $+ 1$

- She lives in the H-state, *no matter what*
- What changes for her is *when* she comes into existence

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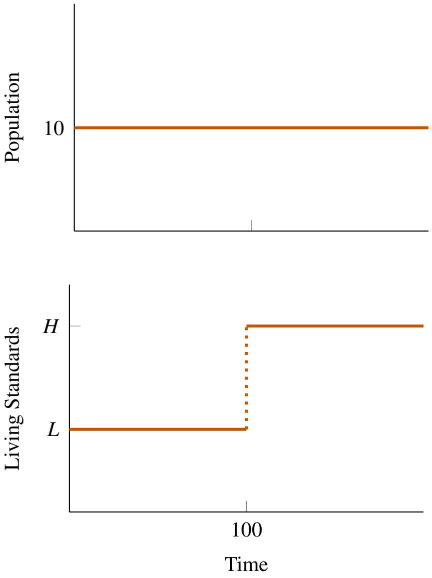
No individual is made better off by increasing population sizes

Larger populations speed up technological progress...



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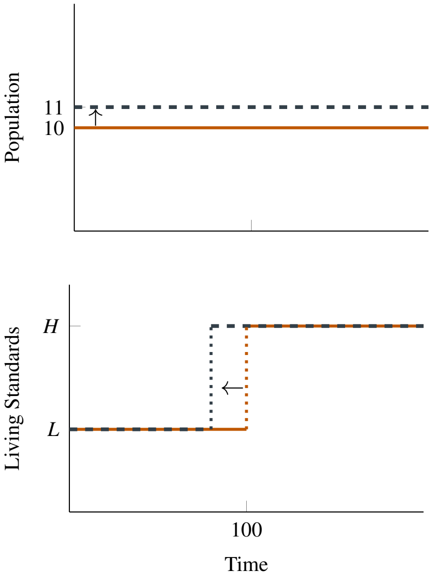

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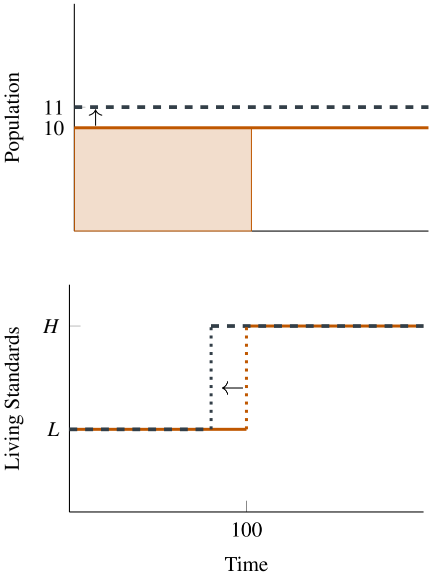

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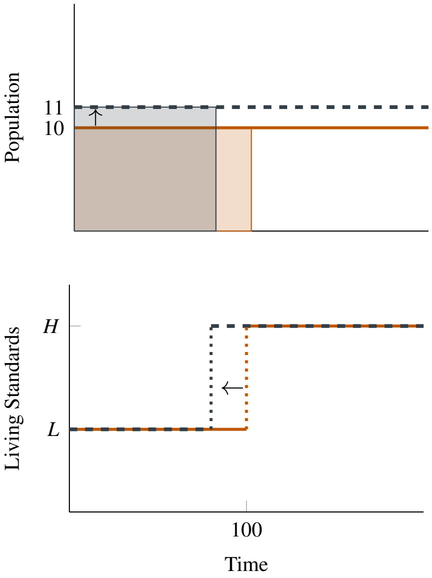

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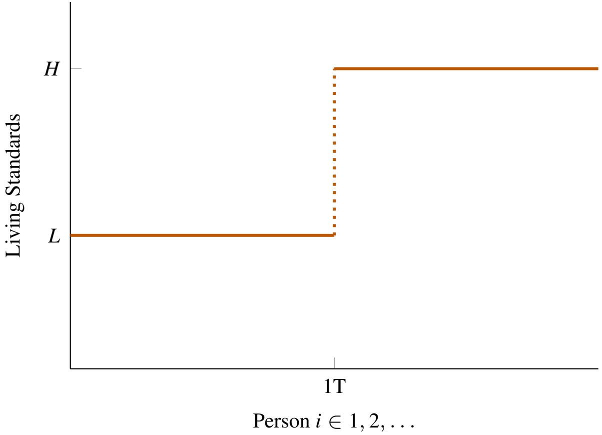

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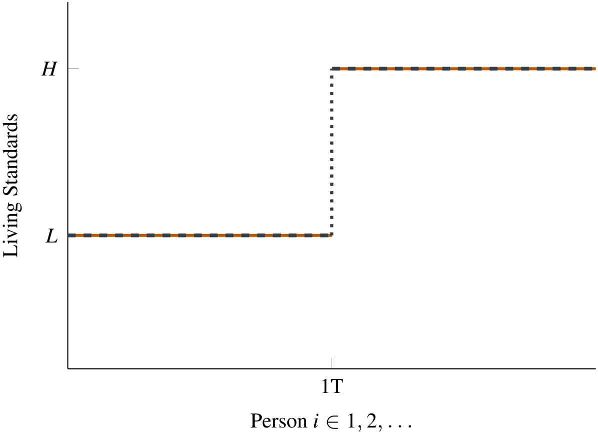

Result: Being in a larger population world, with faster technological progress, has not made anyone's life better

This invariance can be formalized in standard models

Aggregate TFP growth increases in scale

Standard semi-endogenous growth setting (Jones, 1995):

$$\frac{\dot{A}(t)}{A(t)} = \theta(t)N(t)^{\lambda}A(t)^{-\beta}$$

$\dot{A}(t)$ is the (instantaneous) growth in TFP
$N(t)$ is the population size
$\theta(t)$ captures human or physical capital per person
(Assume constant, to isolate scale effects)

λ, β govern the degree of diminishing returns
(For simplicity, and exactness, I'll start with $\lambda = 1$)

$A(t)$ determined by cumulative people-years

Integrate with respect to time:

$$A(t) = \left(\beta\theta \underbrace{\int_0^t N(\tau)d\tau}_{\textbf{People-years} \text{ by } t} + A_0^{\beta}\right)^{\frac{1}{\beta}}$$

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Notice: time, *per se*, does not increase TFP

- It is cumulative human effort that increases TFP

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Because $i = \int_0^t N(\tau)d\tau$, we can rewrite as:

$$\boxed{A(i) = \left(\beta\theta i + A_0^\beta\right)^{\frac{1}{\beta}} = y(i)}$$

Result: The wellbeing of the ith person-year is predetermined by i's order in history

From this perspective, what matters is only how many lives are ever lived

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We need to make assumptions about extinction

Case I: Endogenous extinction (e.g., Bostrom, 2019; Jones 2016,2024; Ord, 2020)

Consider Jones' "Russian Roulette" model of growth:

- Each new idea carries some risk of ending civilization
  - Weapons of mass destruction; etc.

Or: conditional on A, each person has a chance of ending civilization

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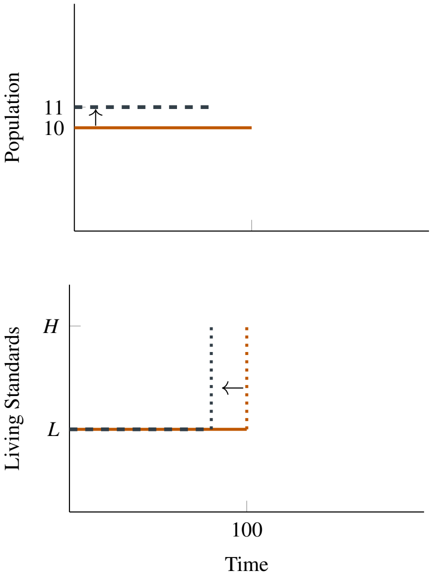
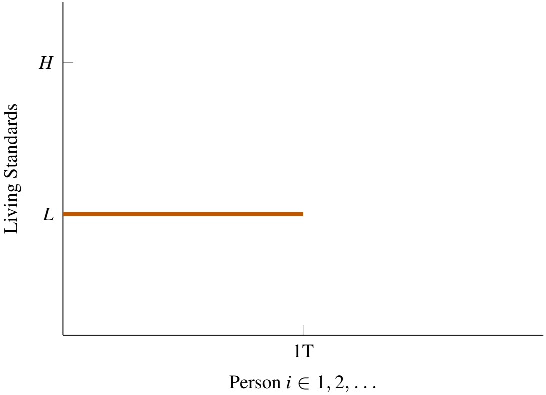
If extinction is endogenous in this way, we **bring forward extinction** along with lives and innovations

- Under linearity assumptions, exactly proportionately

In this case, extinction is brought forward



Large and small populations traverse exactly the same quantity and quality of lives



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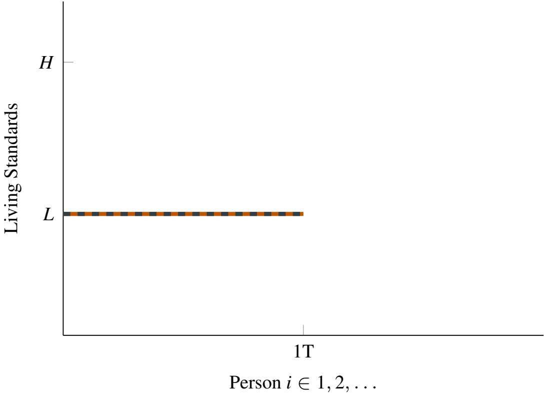

A human-caused extinction event is a non-rival bad, offsetting the non-rival good of knowledge

- (i.e., if scale brought forward mRNA vaccine development, why shouldn't we also think it brought forward the covid pandemic?)

Case II: Exogenous extinction (e.g., Stern, 2006)

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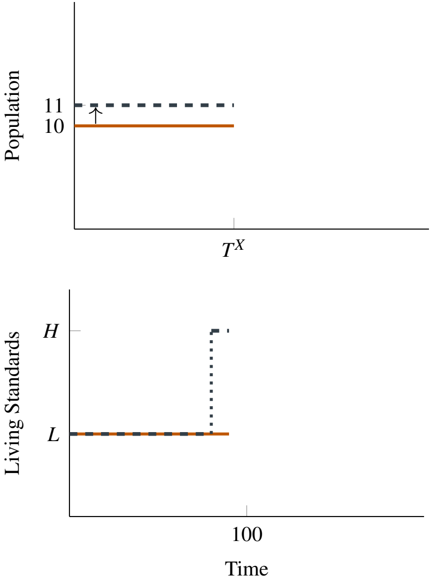
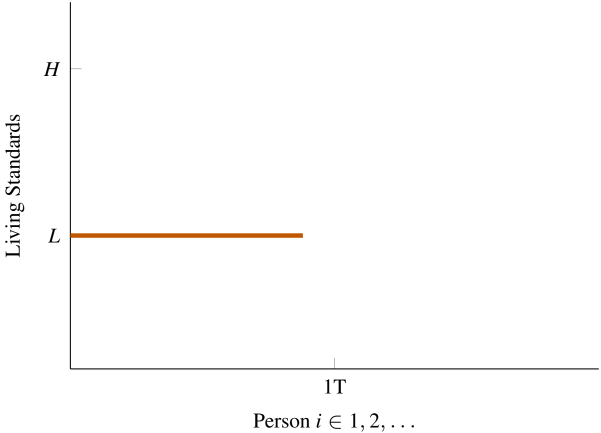
Trivially, the larger population will, ex-post, get through more lives (and discoveries)

- Similarly, if the planner intrinsincally prefers that things happen earlier in time (i.e., a positive rate of pure time preference) then there will be value in speeding up history

Each population lives for the same number of periods, but the larger population has more happen in those periods



Larger populations make it through more of our potential history



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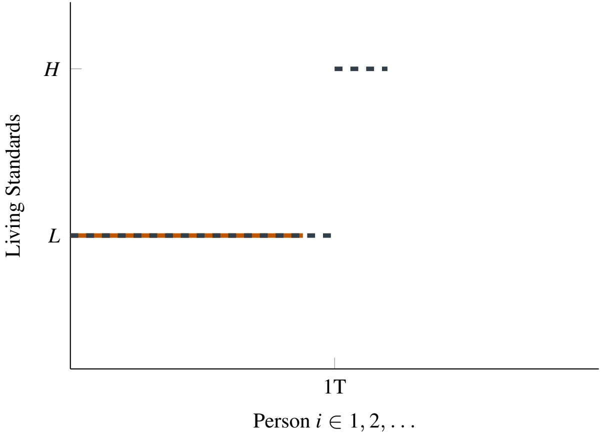

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We need more research on this: **the demographic-implications of idea-based growth models rely on a stance about how the model ends**

General Lesson: Clarifying how time, per se, matters for different processes will be crucial to understanding the effects of population size

Density effects (**resource sharing** vs. agglomeration) can be framed as time-based considerations

Imagine a tree that drops C fruit each period (or e.g., any natural resource producing ecosystem services)

Individual fruit consumption: $\frac{C(t)}{N(t)}$

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Speeding up the arrival of humans, without speeding up fruit production, is equivalent to *slowing down* the speed of fruit production

- There is less fruit *per human life*

(Similar phenomenon for the existing stock of capital—it produces economic services per unit of time)

Density effects (resource sharing vs. **agglomeration**) can be framed as time-based considerations

Consider **specialization**: To fill a niche in the economy, we need someone who **currently** knows a particular skill

Learning a task is a fixed cost that needs to be re-paid once every 40-50 years

- E.g., Someone learns something once, can apply it for 40-50 years

This will be more affordable per person if more people live per unit of time

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Or: Imagine that knowledge depreciates per unit of time

- It will cost less to preserve for the next M people the earlier they live

Other time-based effects that will interplay with how fast ideas/people arrive?

1. Psychological impatience
2. Legal regimes (e.g., patents)
3. Removing carbon from the atmosphere prior to reaching equilibrium warming

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I've found thinking about the **arrival rate of humans** (and everything we do) speeding up or slowing down as a useful way to clarify which things will be impacted by population size, and which will not