Population, Ideas, and the Speed of History

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I'll refer to this as **scale-based growth**, separating it from growth that is caused by allocative improvements

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This concern is now relatively widespread:

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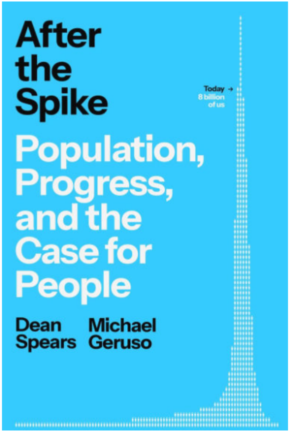
The economics of falling populations

A shrinking global population could slow technological progress

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



The size of the population governs the *speed of history*

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I will argue: This movement of lives between periods can neutralize the effect of scale-based growth

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Regardless of per-period population size, we should expect that each:

- $i < \frac{1}{p^{mc}}$ must live without her ideas
- $i > \frac{1}{p^{mc}}$ benefit from her ideas

(where i identifies an individual by her birth-order in history)

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A larger population brings forward the arrival of a Marie Curie, but it also brings forward all other lives

This paper makes two related contributions:

1) Formalizes this logic in a standard Romer/Jones semi-endogenous growth setting
   - To a first-order, population size per-period has no effect on innovation rates **per human life**
     (even if it *does* affect innovation per period)
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     (even if it *does* affect innovation per period)
   - More generally, I identify parameters which can rescue (or reverse) the original intuition
2) Assesses potential *extensive margin* effects of population size on per capita outcomes
   - Histories with larger populations may get through more total lives
   - Open question: whether and how to value these contingent existences?

When non-rival ideas drive growth, population size does not necessarily improve individual outcomes

Standard 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
    (I'll start with $\lambda = 1$ to generate analytical insight; relaxed later)

$A(t)$ 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

Individual welfare unaffected by population sizes

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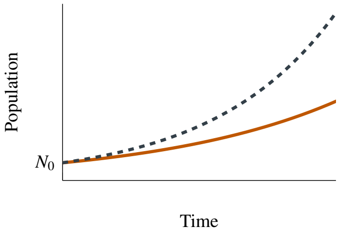
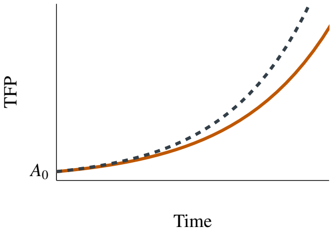
Because $i = \int_0^t N(\tau)d\tau$, we can rewrite as:

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

Result: The income of the ith person-year is determined by i's order in history (conditional on θ, β)

Larger populations speed up technological progress...

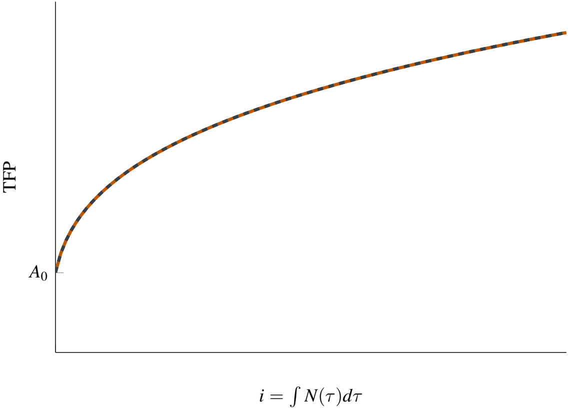




Blue dotted line is the history with faster population growth

- For each t it has reached higher levels of TFP and population

...without any improvements to individual lives.



$A(i)$ is independent of population growth or size

Overlapping lives complicate the interpretation, but do not break the result

If populations became larger next year, that would improve your life

- More would be discovered in your lifetime

The trade-off: More people need to live soon

- “Soon” is the worst time to be alive, conditional on not having been born yet

Larger populations can reduce inequality, but do not improve average outcomes

Recall $i(t) = \int_0^t N(\tau) d\tau$

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A planner with an individual and time-separable objective function will not care about this...

- ...because I already showed you the quality of each person-year is independent of per period population size

Model relaxations highlight parameters that generate a non-zero effect of population size

Three model relaxations

1. Endogenous research effort
   - No straightforward effect on main result
2. Non-linearity in returns to research effort
   - Likely *reverses* the usual intuition
     (negative rather than independent relationship)
3. Depreciation of knowledge over time
   - Rescues the usual positive intuition, but of uncertain magnitude

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Previously under-appreciated parameters determine which side of the knife's edge we live on

- Exact neutrality won't hold, but there are no strong reasons to assume the relationship is positive or negative

Intra-period non-linearity in research effort does not appear to rescue original intuition

I assumed the exponent on N within a period was one:

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

If $\lambda > 1$, collaboration effects imply large populations disproportionately speed up idea creation

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But: researchers in this field seem to think $\lambda < 1$ is more likely

- That would mean each i **benefits from smaller populations**, even when non-rival idea-production is the only externality

  (An exact reversal of what Romer (1990) has been thought to imply!)
- Granted, very little work on this; maybe $\lambda > 1$, or becomes greater than one for tiny populations

Knowledge depreciation *does* rescue the positive relationship

Suppose knowledge depreciates over time

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

This addition does rescue original intuition, and for the ‘right’ reasons

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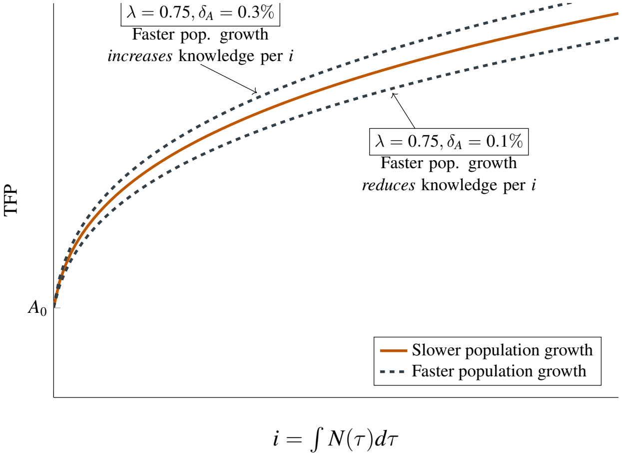
Imagine $\delta_A = 1$

- Then, ideas are only accessible in the period they are discovered

More contemporaries $\Rightarrow$ more ideas for you that period

- Is knowledge depreciation quantitatively meaningful?

Knowledge depreciation vs. $\lambda < 1$



Larger populations – moving through lives and discoveries faster – can improve or worsen individual outcomes depending on parameters

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The relationship between per-period population size and total lives depends on extinction assumptions

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Suppose a natural event (e.g., asteroid) will end humanity in some future year

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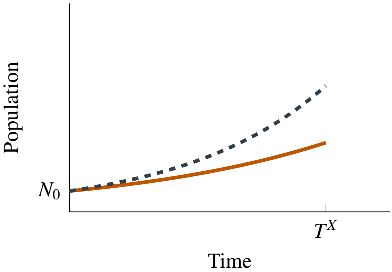
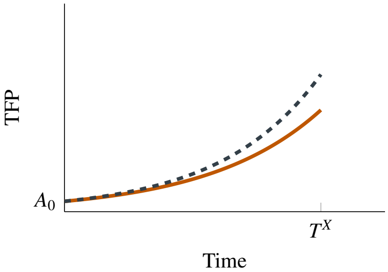
The larger population will, ex-post, **get through more lives** (and discoveries)

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

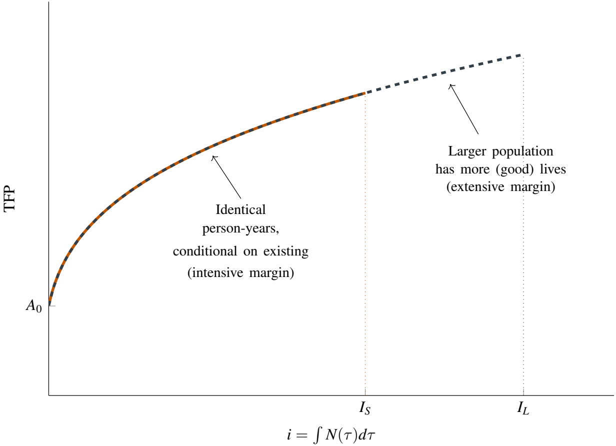
(a) Each population makes it to T^X.



(b) Faster growth → higher TFP reached.



Larger populations make it through more history



Notice: identical to extending humanity's lifespan temporally

- How valuable would it be to push extinction off for z years?

Case II: Endogenous extinction (e.g., Jones 2016,2024)

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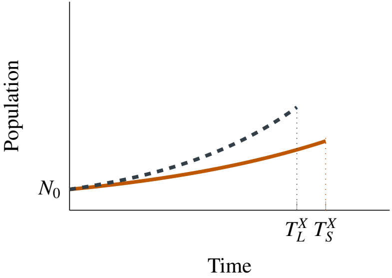
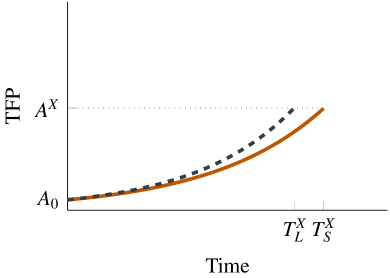
If extinction is endogenous in this way, we **bring forward extinction** along with lives and innovations

In this case, extinction is brought forward with people and ideas

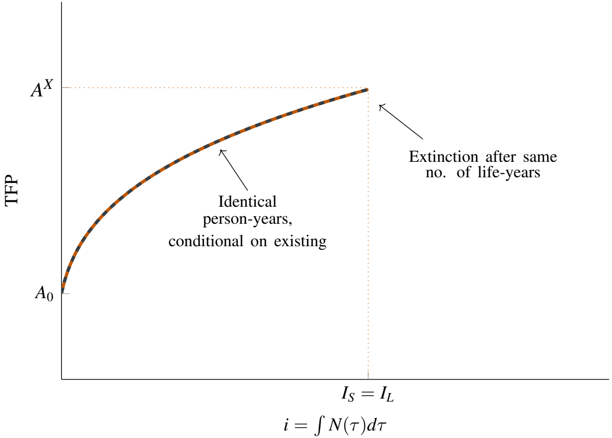
(a) A^X later with small populations.



(b) Extinction happens at A^X.



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



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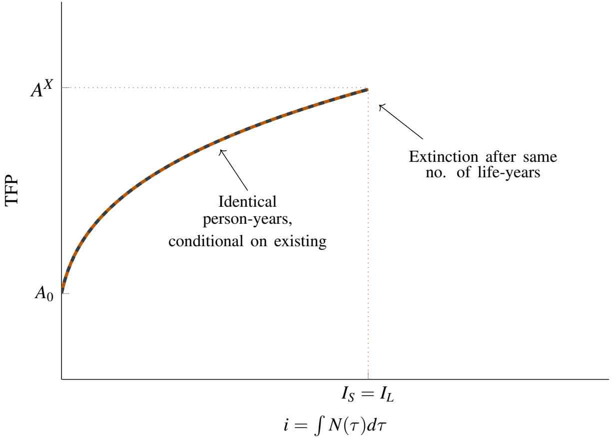

A human-caused extinction event is a non-rival bad, offsetting the non-rival good of knowledge

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

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2. Per capita outcomes increase in the number of total existences
   - (More good lives are lived $\Rightarrow$ per capita outcomes increase)
3. So, what matters is how current population size/growth influences the total number of existences
   - Which depends on assumptions about extinction

The effect of N on long-run welfare depends on extinction risks and returns to per-period populations

	$\lambda < 1$ (& $\delta_A = 0$)	$\lambda = 1$ (& $\delta_A = 0$)	$\lambda > 1$ (or $\delta_A > 0$)
T^X causes extinction (e.g., asteroid)		$\bar{y}_L \geq \bar{y}_S$ $I_L > I_S$	
A^X causes extinction (e.g., advanced A.I.)	$I_L > I_S$	$\bar{y}_L = \bar{y}_S$ $I_L = I_S$	$I_L < I_S$
I^X causes extinction (e.g., rogue actor)	$\bar{y}_L < \bar{y}_S$	$\bar{y}_L = \bar{y}_S$ $I_L = I_S$	$\bar{y}_L > \bar{y}_S$
A decreases risk (e.g., carbon capture)		$\bar{y}_L > \bar{y}_S$ $I_L > I_S$	
$\bar{N}$ causes extinction (e.g., ecological collapse)		$\bar{y}_L (?) \bar{y}_S$ $I_L (?) I_S$	