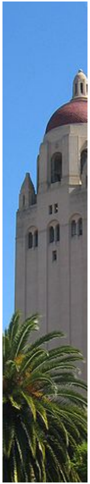

The End of Economic Growth?
Unintended Consequences of a Declining Population

Chad Jones

Hoover Lunch – March 3, 2021

Motivating the Question

- Paul Romer's Nobel Price: Ideas are special = infinitely usable
  - A barrel of oil or an hour of a surgeon's time: you can use it or I can
  - But the invention of the mRNA COVID-19 vaccine: everyone can use it!

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More people $\Rightarrow$ more Edisons and Doudnas $\Rightarrow$ more ideas $\Rightarrow$ we are all richer

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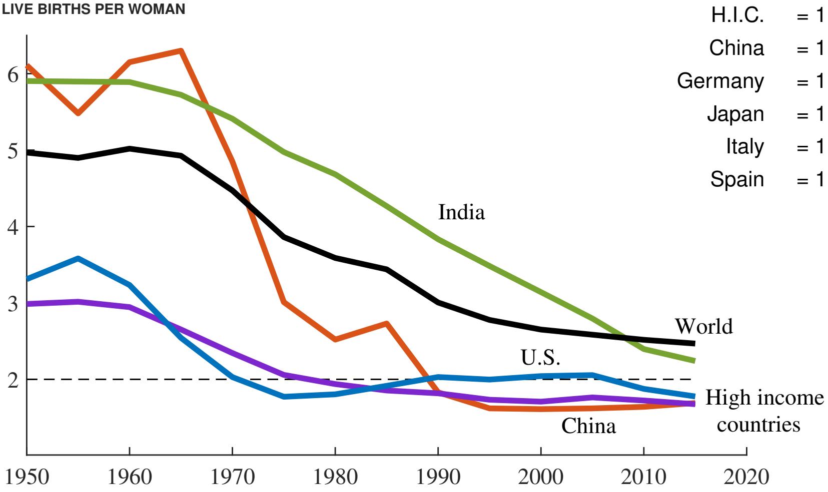
More people $\Rightarrow$ more Edisons and Doudnas $\Rightarrow$ more ideas $\Rightarrow$ we are all richer

But what if population declines?

Key Role of Population

- People $\Rightarrow$ ideas $\Rightarrow$ economic growth
  - Romer (1990), Aghion-Howitt (1992), Grossman-Helpman
  - Jones (1995), Kortum (1997), Segerstrom (1998)
  - And most idea-driven growth models
- The future of global population?
  - Conventional view: stabilize at 8 or 10 billion
- Bricker and Ibbotson's *Empty Planet* (2019)
  - Maybe the future is **negative population growth**
  - High income countries already have fertility below replacement!

The Total Fertility Rate (Live Births per Woman)



U.S. = 1.8
H.I.C. = 1.7
China = 1.7
Germany = 1.6
Japan = 1.4
Italy = 1.3
Spain = 1.3

What happens to economic growth if population growth is negative?

- Exogenous population decline
  - **Empty Planet Result**: Living standards stagnate as population vanishes!
  - Contrast with standard **Expanding Cosmos** result: exponential growth for an exponentially growing population
- Endogenous fertility
  - Parameterize so that the equilibrium features negative population growth
  - A planner who prefers **Expanding Cosmos** can get trapped in an **Empty Planet** – if society delays implementing the optimal allocation

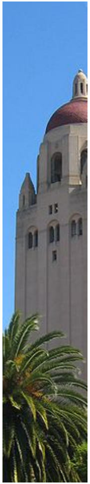
Literature Review

- Many models of fertility and growth (but not $n < 0$)
  - Too many papers to fit on this slide!
- Falling population growth and declining dynamism
  - Krugman (1979) and Melitz (2003) are semi-endogenous growth models
  - Karahan-Pugsley-Sahin (2019), Hopenhayn-Neira-Singhania (2019), Engbom (2019), Peters-Walsh (2019)
- Negative population growth
  - Feyrer-Sacerdote-Stern (2008) and changing status of women
  - Christians (2011), Sasaki-Hoshida (2017), Sasaki (2019a,b) consider capital, land, and CES
  - Detroit? Or world in 25,000 BCE?

Outline

- Exogenous negative population growth
  - In Romer / Aghion-Howitt / Grossman-Helpman
  - In semi-endogenous growth framework

- Endogenous fertility
  - Competitive equilibrium with negative population growth
  - Optimal allocation



The Empty Planet Result

A Simplified Romer/AH/GH Model

Production of goods (IRS)	$Y_t = A_t^\sigma N_t$
Production of ideas	$\frac{\dot{A}_t}{A_t} = \alpha N_t$
Constant population	$N_t = N$

- Income per person: levels and growth

$$y_t \equiv Y_t/N_t = A_t^\sigma$$

$$\frac{\dot{y}_t}{y_t} = \sigma \frac{\dot{A}_t}{A_t} = \sigma\alpha N$$

- Exponential growth with a constant population
    - But population growth means exploding growth? (Semi-endogenous fix)

Negative Population Growth in Romer/AH/GH

Production of goods (IRS)	$Y_t = A_t^{\sigma} N_t$
Production of ideas	$\frac{\dot{A}_t}{A_t} = \alpha N_t$
Exogenous population decline	$N_t = N_0 e^{-\eta t}$

- Combining the 2nd and 3rd equations (note $\eta > 0$)

$$\frac{\dot{A}_t}{A_t} = \alpha N_0 e^{-\eta t}$$

- This equation is easily integrated...

The Empty Planet Result in Romer/GH/AH

- The stock of knowledge A_t is given by

$$\log A_t = \log A_0 + \frac{g_{A0}}{\eta}\left(1 - e^{-\eta t}\right)$$

  where g_{A0} is the initial growth rate of A

- A_t and $y_t \equiv Y_t/N_t$ converge to constant values A^* and y^*:

$$A^* = A_0 \exp\left(\frac{g_{A0}}{\eta}\right)$$

$$y^* = y_0 \exp\left(\frac{g_{y0}}{\eta}\right)$$

- **Empty Planet Result**: Living standards stagnate as the population vanishes!

Semi-Endogenous Growth

Production of goods (IRS)	$Y_t = A_t^\sigma N_t$
Production of ideas	$\frac{\dot{A}_t}{A_t} = \alpha N_t^\lambda A_t^{-\beta}$
Exogenous population growth	$N_t = N_0 e^{nt}, \quad n > 0$

- Income per person: levels and growth

$$y_t = A_t^\sigma \quad \text{and} \quad A_t^* \propto N_t^{\lambda/\beta}$$

$$g_y^* = \gamma n, \quad \text{where} \quad \gamma \equiv \lambda\sigma/\beta$$

- **Expanding Cosmos**: Exponential income growth for growing population

Negative Population Growth in the Semi-Endogenous Setting

Production of goods (IRS)	$Y_t = A_t^{\sigma} N_t$
Production of ideas	$\frac{\dot{A}_t}{A_t} = \alpha N_t^{\lambda} A_t^{-\beta}$
Exogenous population decline	$N_t = N_0 e^{-\eta t}$

- Combining the 2nd and 3rd equations:

$$\frac{\dot{A}_t}{A_t} = \alpha N_0^{\lambda} e^{-\lambda \eta t} A_t^{-\beta}$$

- Also easily integrated...

The Empty Planet in a Semi-Endogenous Framework

- The stock of knowledge A_t is given by

$$A_t = A_0 \left(1 + \frac{\beta g_{A0}}{\lambda\eta}\left(1 - e^{-\lambda\eta t}\right)\right)^{1/\beta}$$

- Let $\gamma \equiv \lambda\sigma/\beta$ = overall degree of increasing returns to scale.

- Both A_t and income per person $y_t \equiv Y_t/N_t$ converge to constant values A^* and y^*:

$$A^* = A_0 \left(1 + \frac{\beta g_{A0}}{\lambda\eta}\right)^{1/\beta}$$

$$y^* = y_0 \left(1 + \frac{g_{y0}}{\gamma\eta}\right)^{\gamma/\lambda}$$

Numerical Example

- Parameter values
  - $g_{y0} = 2\%, \quad \eta = 1\%$
  - $\beta = 3 \quad \Rightarrow \quad \gamma = 1/3$ (from BJVW)

- How far away is the long-run stagnation level of income?

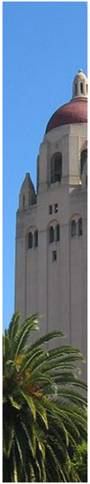
	y^* / y_0
Romer/AH/GH	7.4
Semi-endog	1.9

- The Empty Planet result occurs in both, but quantitative difference

First Key Result: The **Empty Planet**

- Fertility has trended down: 5, 4, 3, 2, and less in rich countries
  - For a family, nothing special about "above 2" vs "below 2"

- But macroeconomics makes this distinction critical!
  - Negative population growth may condemn us to stagnation on an **Empty Planet**
    - Stagnating living standards for a population that vanishes
  - Vs. the exponential growth in income and population of an **Expanding Cosmos**



Endogenous Fertility

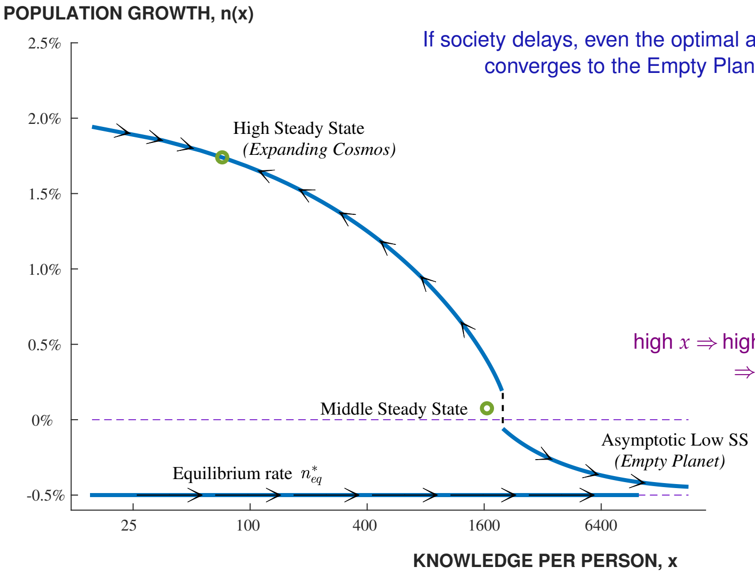
Overview of Endogenous Fertility Setup

- Equilibrium: ideas are an externality (simple)
  - We have kids because we like them
  - We ignore that they might create ideas that benefit everyone
  - Planner will desire higher fertility
- This is a modeling choice — other results are possible
- Abstract from the demographic transition. Focus on where it settles

Key Insight: Planner can get trapped in the Empty Planet

- Population growth depends on $x \equiv \frac{A^\beta}{N^\lambda}$ (knowledge per person)
- Equilibrium with $n < 0$: x rises forever (A levels off, N falls)
- Optimal fertility: kids valued because
  - We love them
  - They produce new ideas that riase everyone's income
- But if society waits to long to switch to optimal fertility, x will have risen so much that the idea value of extra kids gets small
  - Planner's higher fertility may still lead to negative population growth
  - ... then trapped in the Empty Planet

Even the optimal allocation can get trapped



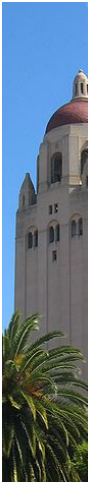
If society delays, even the optimal allocation converges to the Empty Planet

high $x \Rightarrow$ high ideas per person $\Rightarrow$ low $\mu \dot{A}$

$$x = \frac{A^\beta}{N^\lambda}$$

Conclusion

- Fertility considerations may be more important than we thought:
  - Negative population growth may condemn us to stagnation on an **Empty Planet**
  - Vs. the exponential growth in income and population of an **Expanding Cosmos**
- This is not a prediction but rather a study of one force...
- Other possibilities, of course!
  - Technology may affect fertility and mortality
  - Evolution may favor groups with high fertility
  - Can AI produce ideas, so people are not necessary?



Extra Slides

The Economic Environment

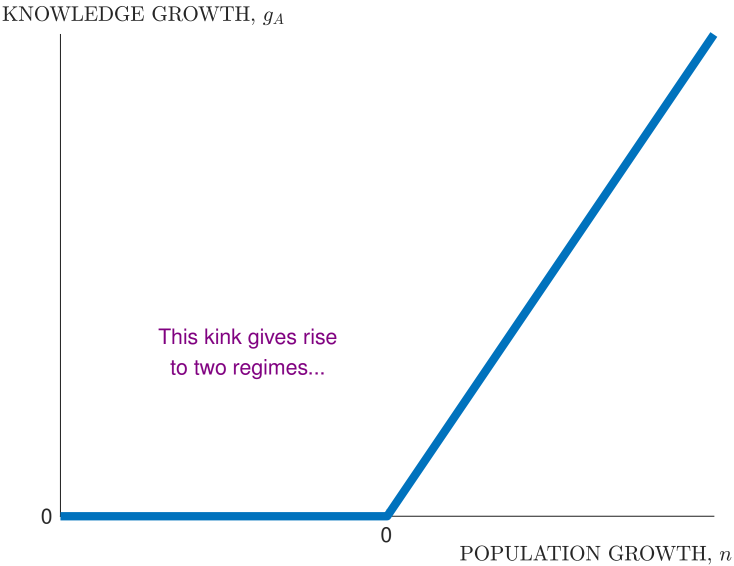
ℓ = time having kids instead of producing goods

Final output	$Y_t = A_t^\sigma (1 - \ell_t) N_t$
Population growth	$\frac{\dot{N}_t}{N_t} = n_t = b(\ell_t) - \delta$
Fertility	$b(\ell_t) = \bar{b}\ell_t$
Ideas	$\frac{\dot{A}_t}{A_t} = N_t^\lambda A_t^{-\beta}$
Generation 0 utility	$U_0 = \int_0^\infty e^{-\rho t} u(c_t, \tilde{N}_t) dt, \quad \tilde{N}_t \equiv N_t / N_0$
Flow utility	$u(c_t, \tilde{N}_t) = \log c_t + \epsilon \log \tilde{N}_t$
Consumption	$c_t = Y_t / N_t$

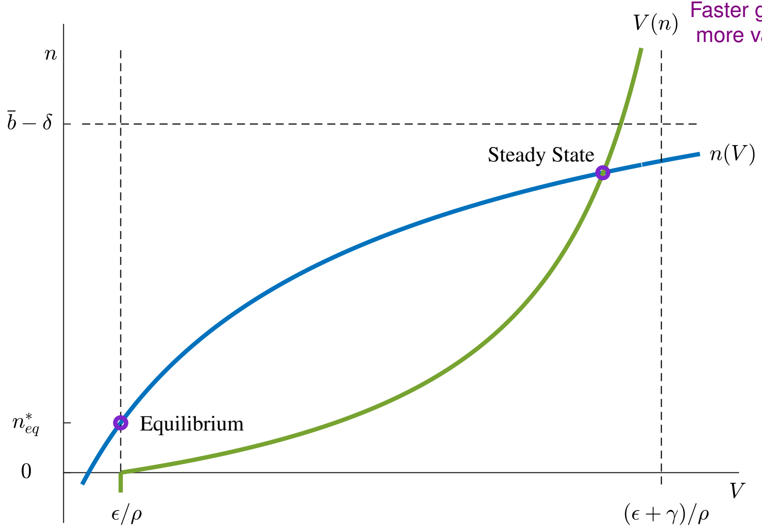
Overview of Endogenous Fertility Setup

- All people generate ideas here
  - Learning by doing vs separate R&D
- Equilibrium: ideas are an externality (simple)
  - We have kids because we like them
  - We ignore that they might create ideas that benefit everyone
  - Planner will desire higher fertility
- This is a modeling choice — other results are possible
- Abstract from the demographic transition. Focus on where it settles

Steady State Knowledge Growth

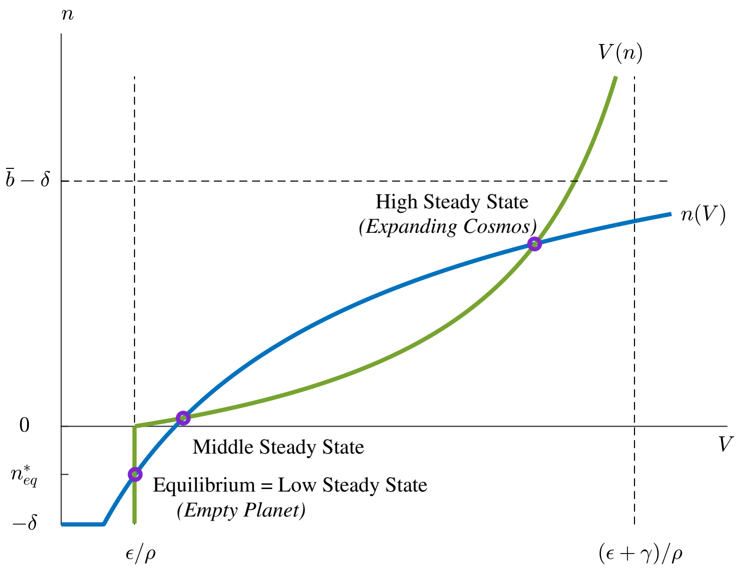


A Unique Steady State for the Optimal Allocation when $n^*_{eq} > 0$



Faster growth makes people more valuable – more ideas

Multiple Steady State Solutions when $n^*_{eq} < 0$



Transition Dynamics

- State variables: N_t and A_t
- Redefine "state-like" variables for transition dynamics solution: N_t and

  $x_t \equiv A_t^\beta / N_t^\lambda$ = "Knowledge per person"

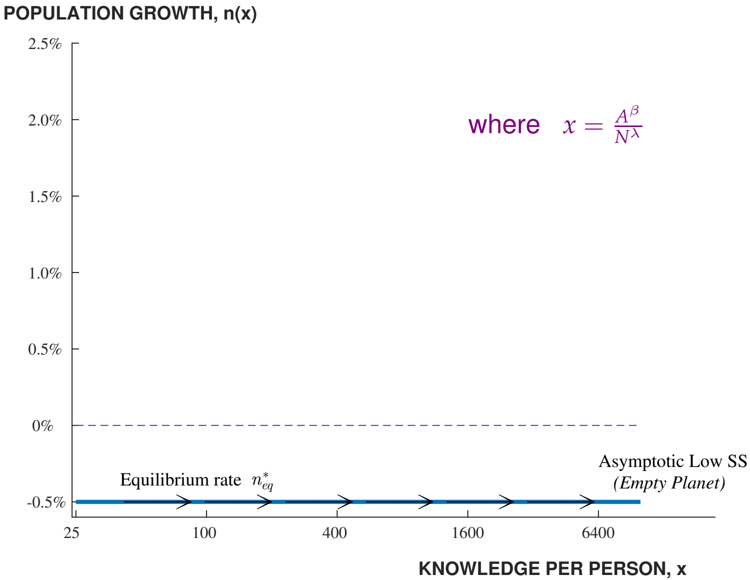
- Why?

$$\frac{\dot{A}_t}{A_t} = \frac{N_t^\lambda}{A_t^\beta} = \frac{1}{x_t}$$

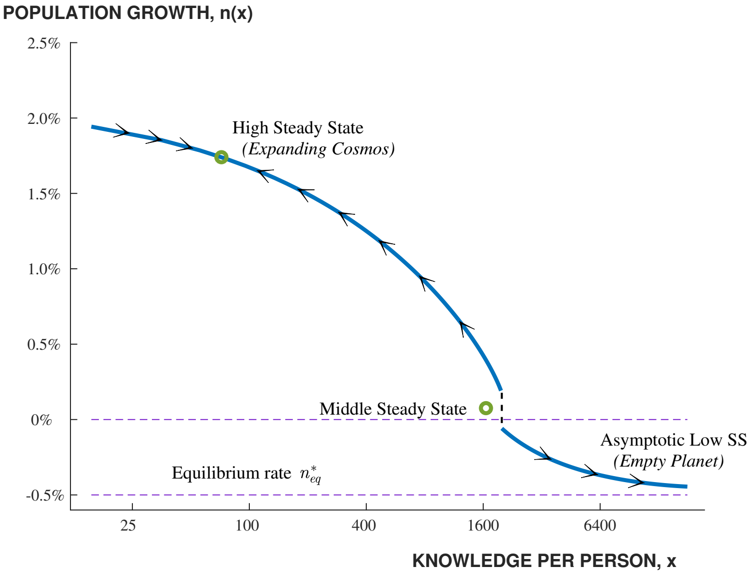
Key insight: optimal fertility only depends on x_t

- Note: x is the ratio of A and N, two stocks that are each good for welfare.
  - So a bigger x is not necessarily welfare improving.

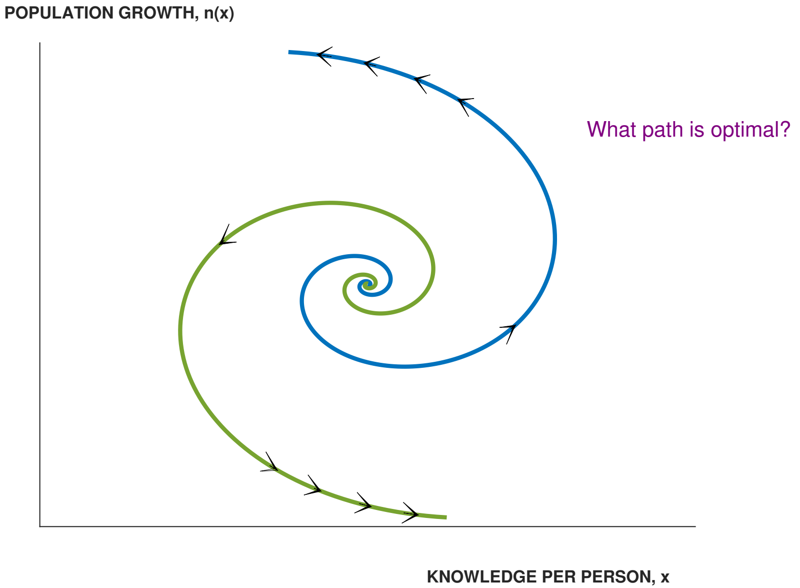
Equilibrium Transition Dynamics



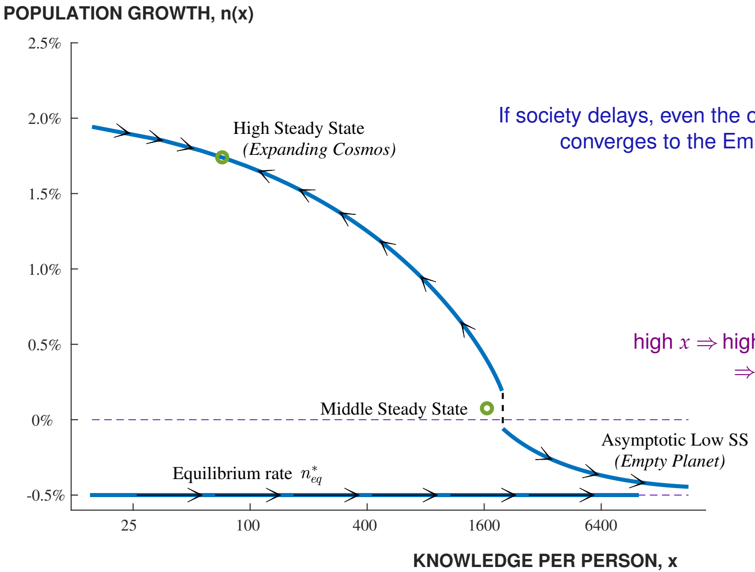
Optimal Population Growth



The Middle Steady State: Unstable Spiral Dynamics



Even the optimal allocation can get trapped



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