

The Past and Future of Economic Growth: A Semi-Endogenous Perspective

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Motivation and Introduction

- The essence of SEG models: ideas are nonrival - once an idea is invented, it is feasible for the idea to be used by everyone simultaneously.
 - income per person depends on the aggregate stock of ideas, not the stock of ideas per person.
 - income per person depends on the number of researchers → depends on the growth rate of researchers → depends on population growth
- However, population growth contributes only around 20 percent of US economic growth since 1950. How do we explain this?

A Simple Model - Setup

- Basic production function of the consumption good: $Y_t = A_t^\sigma L_{yt}$ where σ reflects the overall degree of increasing returns.
→ Labor itself is rival, thus constant returns to scale, but labor + ideas exhibit increasing returns to scale.
- Idea production function: $\dot{A}_t / A_t = R_t^\lambda A_t^\beta$ where λ captures duplication effects and $\beta > 0$ implies that ideas are getting harder to find.
- Resource constraint: $R_t + L_{yt} = L_t$
- Population growth: $L_t = L_0 e^{nt}$
- Allocation of labor: $R_t = \bar{s}L_t$

A Simple Model - Balanced Growth Path

- Output per person is given by: $y_t = Y_t/L_t = A_t^\sigma(1 - \bar{s})$
- From the idea production function, along the balanced growth path we have:

$$A_t^* = \left(\frac{1}{g_A}\right)^{1/\beta} R_t^{\lambda/\beta} = \left(\frac{1}{g_A}\right)^{1/\beta} (\bar{s}L_t)^{\lambda/\beta}$$

- Thus, output per person along the balanced growth path is:

$$y_t^* = (1 - \bar{s}) \left(\frac{1}{g_A}\right)^{\sigma/\beta} R_t^\gamma$$

where $\gamma = \lambda\sigma/\beta$

- Along the balanced growth path, we can further derive:

$$g_A = \lambda n / \beta$$

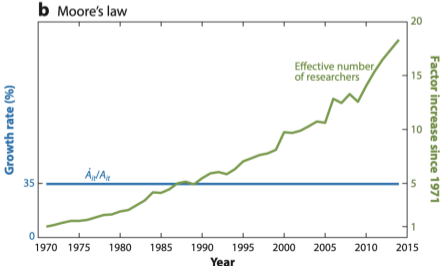
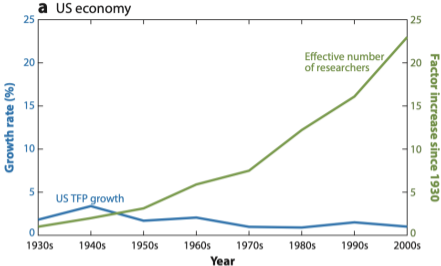
$$g_y = \sigma g_A = \gamma n$$

→ the long-run growth rate of the economy is proportional to the rate of population growth, where the factor of proportionality is the degree of increasing returns to scale.

A Simple Model - Evidence

- Bloom et al. (2020) study the null hypothesis that $\beta = 0$ —i.e., the hypothesis of fully endogenous growth models that proportional improvements in productivity are not getting harder to find.
- If $\beta = 0$, the time series of TFP growth and the time series of research effort should move together, but the data is consistent with $\beta \approx 3$ if we assume $\lambda = 1$.
- Looking into an individual technology, computer chips - the famous Moore's law: the number of transistors that can fit on a computer chip doubled on average every two years between 1971 and 2010.
- If $\beta = 0$ had characterized the idea production function for Moore's law, then the growth rate of chip density would have risen by a factor of 18 over the 50 year period, just like the research effort. Instead, growth was stable.
- Everywhere Bloom et al. (2020) find evidence for $\beta > 0$, with values ranging from a low of 0.2 for Moore's law to values of around 6 or 7 for corn and soybeans.

A Simple Model - Evidence



Accounting for Historical Growth - Puzzle

- Puzzle: in SEG models, the ultimate source of long-run economic growth is population growth, but historical growth accounting suggests that population growth accounts for only around 20% of US growth in recent decades.
- The remaining 80% is accounted for by rising educational attainment, increases in the fraction of the population devoted to R&D, and declines in misallocation.
- Answer: Changes in these other factors have level effects in the long run rather than growth effects. However, over any historical period, these level effects could potentially be large, especially when transition dynamics are slow

Accounting for Historical Growth - Formal Model

- Add physical capital, human capital, and labor force participation to the SEG framework:

$$Y_t = K_t^\alpha (Z_t h_t L_{Y_t})^{1-\alpha}$$

$$Z_t = A_t M_t$$

where h_t is human capital per person and M_t is a misallocation term.

- Solving for income per person, we have:

$$y_t = \left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}} A_t M_t h_t l_t (1 - s_t)$$

- There are two ways to approach the growth accounting (a) in the long run and (b) historically (level effects).

Accounting for Historical Growth - Long Run

- In the long run, notice that the capital-output ratio must be constant, so the contribution from K/Y will be zero.
- For human capital h_t , since time spend in school on average is bounded from above, so educational attainment also leads to level effects but no long-run growth effects.
- The fraction of people working, l_t , and the fraction of people working as researchers, s_t , are between zero and one, so these variables must be constant in the long run.
- For the misallocation term, if the distortions are constant, then M_t will be eventually constant as well. Moreover, in the long run M_t is bounded from above by one.
→ In the end, this leaves us only with the growth rate of the labor force, which equals population growth in the long run. Therefore, long-run growth is proportional to population growth and everything else has level effects in the long run.

Accounting for Historical Growth - Level Effects

- Take log and differences of the real income per capita equation, we have:

$$\underbrace{d \log y_t}_{\text{GDP per person}} = \underbrace{\frac{\alpha}{1-\alpha} d \log K_t / Y_t}_{\text{capital-output ratio}} + \underbrace{d \log h_t}_{\text{educ attainment}} + \underbrace{d \log l_t}_{\text{emp-pop ratio}} \\
 + \underbrace{d \log 1 - s_t}_{\text{goods intensity}} + \underbrace{d \log M_t + d \log A_t}_{\text{TFP growth}}$$

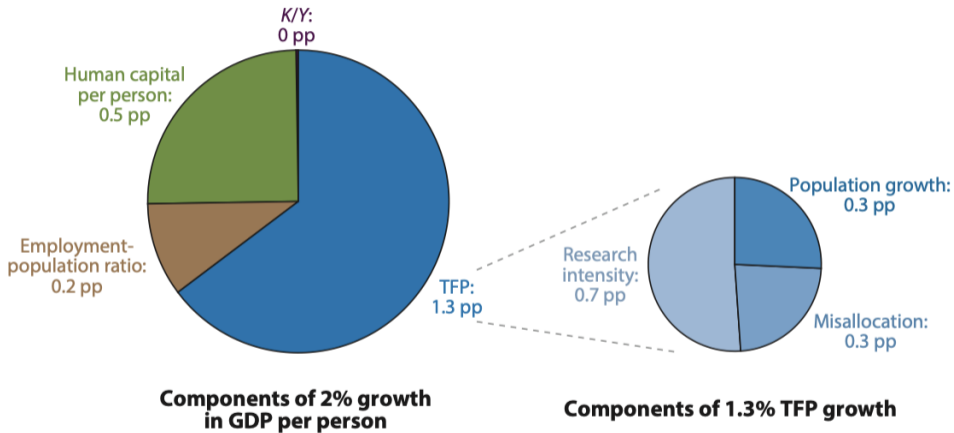
$$\text{TFP Growth} = \underbrace{d \log M_t}_{\text{misallocation}} + \underbrace{d \log A_t}_{\text{ideas}} = \underbrace{d \log M_t}_{\text{misallocation}} + \underbrace{\gamma d \log s_t}_{\text{research intensity}} + \underbrace{\gamma d \log L_t}_{\text{LF growth}}$$

- From 1950-2010: $d \log y_t = 2\%$, K/Y stable, $1 - s_t \approx 1$ over time.

Accounting for Historical Growth - Level Effects

- Human Capital: Goldin & Katz (2008) educational attainment throughout the twentieth century rose by slightly under 1 year per decade, that is, from 4 years in 1900 to 13 years by the end of the century. A standard Mincerian return to education is 5% → rising educational attainment increased GDP per worker by about 0.5% each year.
- But in the last two decades, we have seen educational attainment for each cohort flatten out → Historically, rising educational attainment has contributed a large amount to growth, but in the long run, educational attainment per person seems likely to level off and to contribute nothing to growth.
- Labor Force Participation: Since 1950, the employment -population ratio has risen from around 55% to around 62%, or by around 0.2% per year.

Accounting for Historical Growth - Level Effects



Accounting for Historical Growth - Level Effects

- Misallocation: Insight from previous literature - misallocation at the micro level aggregates up into TFP differences.
- Hsieh et al. (2019a) find that improvements in the allocation of talent associated with declines in discrimination against women and Black Americans have reduced misallocation substantially. They suggest that growth in output per worker between 1960 and 2010 was higher by 0.3pp per year because of this declining misallocation.
- Ideas: simply impose $\gamma = 1/3$ and assume that labor force growth is 1% per year \rightarrow then recover the growth rate of research intensity as 2% per year.

Connections to the Broader Literature

- Essentially any model that possesses increasing returns to scale is likely a SEG model. These models will likely imply that the growth rate is an increasing function of the population growth rate.
- Examples include canonical models in international trade (Krugman, Grossman & Helpman, Melitz, Eaton & Kortum models).
- Future work? Can introduce sectoral heterogeneity into the framework to answer the question: Why do different industries have different TFP growth rates?

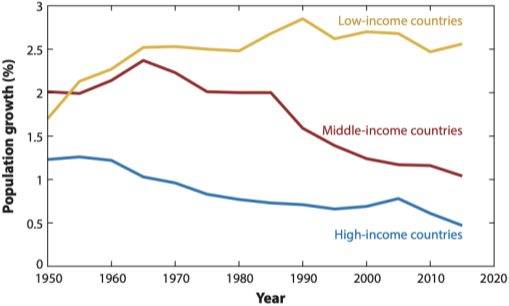
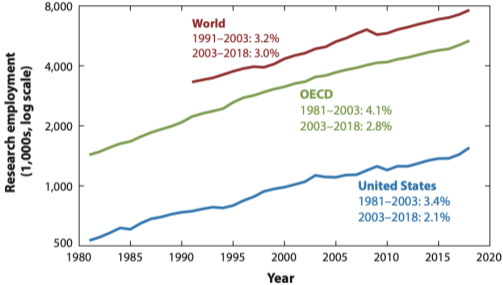
Why Growth might be Slower in the Future

- The sources other than population growth are inherently transitory, and once these sources have run their course, all that will remain is the 0.3 percentage point contribution from population growth.
- The increase in educational attainment is a much larger increase than the rise in life expectancy, so people have been spending a larger fraction of their lifetimes in school. In the long run, this fraction must level out: we cannot spend more than 100% of our time in school - The cohorts born in more recent decades seem to be getting fewer than 14 years of education.
- The same argument applies to the fraction of the labor force devoted to research.
- Misallocation can also decline only so much: Once we have an allocation of resources that is optimal, there is no more growth to be had from reducing misallocation.

Why Growth might be Slower in the Future

- **Research Effort:** The growth rate of research effort appears to be slowing, especially for the US and OECD countries.
- Adding in the large increase in research employment in China is enough to mitigate most of this slowdown, as shown in the “world” number.
 - the slowdown in the growth rate of research effort implies an equally large slowdown in long-run growth.
- **Population Growth:** Population growth has been slowing down in high-and middle-income countries since at least 1965 and characterizes low-income countries since 1990. It might even become negative in the future.
 - when population growth is negative, both the SEG model and the fully endogenous growth model imply that the stock of knowledge—and therefore income per person and overall living standards—converges to some finite value.

Why Growth might be Slower in the Future



Why Growth might not be slower and could be faster

- Finding Einsteins: There is ample scope for substantially increasing the number of researchers over the next century, even if population growth slows or is negative.
 - The rise of China, India, and other countries: As economic development proceeds in China, India, and throughout the world, the pool from which we may find new talented inventors will multiply.
 - Women in research: eliminating the barriers that lead to this misallocation of talent could raise economic growth in the US by up to 0.3 pp per year.
- Automation and Artificial Intelligence: many growth models try to incorporate automation into the production function but sometimes these produce implications that are inconsistent with data.

Future Research

- How Large Is the Degree of Increasing Returns to Scale? Knowing its value is essential for calibrating models and answering questions such as, What is the value of the sustainable long run growth rate, and what is the optimal top income tax rate?
- What Is the Social Rate of Return to R&D?
- How Can We Best Measure Ideas? More than 70% of US corporate patents are in manufacturing, a sector employing less than 10% of the labor force. Most firms do not patent, so patents capture only one part of idea production.
- Better Growth Accounting