Lecture 8
Ideas and Growth

Macroeconomics (Quantitative)
Econ 101B

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Ideas and Growth

- What drives modern economic growth?
- Solow model: Capital Accumulation is not fundamental engine of growth
- What about accumulation of knowledge?
- For knowledge to succeed where capital failed, there must be something fundamentally different about knowledge

Objects Versus Ideas

- Objects:
  - Raw material of the universe
  - Goods, services, capital, labor, land, barrels of oil, a particular lightbulb, a particular lawnmower, a particular oral rehydration pill, etc.
- Ideas:
  - Instructions for using the raw material of the universe
  - How to make fire from sticks, how to make plastic from petroleum, how to make paper from trees, calculus, double-entry accounting, just-in-time inventory management, oral rehydration therapy, Beethoven's 3rd symphony, etc.

What Is Special About Ideas?

- Objects are rivalrous
  - One person's use of an object reduces ability of other people to use that same object.
  - E.g.: Computers, Accountants, Land
  - Rivalry gives rise to scarcity
- Ideas are non-rivalrous
  - My use of calculus to solve a problem does not affect anyone else's ability to use calculus (at the same time)
  - Ideas are infinitely reusable

Ideas and the Production Function

- We now consider knowledge as being produced by inventors/researchers
- Assume that knowledge increases productivity A_t
- A_t no longer exogenously given. Rather, it is produced.
- Two types of production:
  - Production of goods
  - Production of knowledge
- We need to specify a production function for each of these

Production of Goods

- Very simple production function for goods:

$$Y_t = A_t L_{yt}$$

- Goods produced with labor and knowledge (ignore capital and land for simplicity)
- Assume good production is constant returns to scale in labor, i.e., constant returns in objects
- If we build a second factory, we can use same knowledge again
- No need to reinvent factory design, etc.

Returns to Scale

- Since production of goods is constant returns to objects, it is increasing returns to objects + ideas

$$F(2K, 2L, 2A) = 2A(2K)^{1/3}(2L)^{2/3} = 2 \cdot 2^{1/3} \cdot 2^{2/3} \cdot AK^{1/3}L^{2/3}$$
$$= 4 \cdot AK^{1/3}L^{2/3} = 4 \cdot F(K, L, A).$$

- Growth in ideas outside logic of replication argument
  – Replication argument: constant returns to objects
  – But we have growth in knowledge on top of that

Production of Ideas

- Production function for ideas

$$A_{t+1} - A_t = \theta L_{at} A_t$$

- New ideas are produced with labor and existing ideas
- "Standing on the shoulders of giants" view of knowledge production
  - The more knowledge you have access to, the easier it is to create yet more knowledge

Allocation of Labor

- We assume that household labor supply is N_t where N_t is the size of the population
- But how much of this is devoted to production of goods, and how much to production of ideas?
- Simple short cut:
  - A fraction $\bar{\ell}$ devoted to research
  - A fraction $\left(1 - \bar{\ell}\right)$ devoted to production of goods
- This means we have $L_{at} = \bar{\ell} N_t$

Population Growth

- We assume that the population growth at a constant rate

$$N_{t+1} - N_t = \bar{n} N_t$$

- Dividing through by N_t yields

$$\frac{N_{t+1} - N_t}{N_t} = \bar{n}$$

$$g_N = \bar{n}$$

Romer Model

1. Production of goods: $Y_t = A_t L_{yt}$
2. Production of ideas: $A_{t+1} - A_t = \theta L_{at} A_t$
3. Labor supply: $L_{at} + L_{yt} = N_t$
4. Allocation of labor: $L_{at} = \bar{\ell} N_t$
5. Population growth: $g_N = \bar{n}$

Solving Romer Model

- Notice that $L_{at} + L_{yt} = N_t$ and $L_{at} = \bar{\ell} N_t$ imply

$$L_{yt} = (1 - \bar{\ell}) N_t$$

- Combining this with the production function $Y_t = A_t L_{yt}$ yields

$$Y_t = A_t (1 - \bar{\ell}) N_t \quad \Rightarrow \quad y_t = \frac{Y_t}{N_t} = (1 - \bar{\ell}) A_t$$

- Applying growth rate formulas then yields $g_y = g_A$

Solving Romer Model

- Consider the production function for knowledge:

$$A_{t+1} - A_t = \theta L_{at} A_t \quad => \quad g_A = \frac{A_{t+1} - A_t}{A_t} = \theta \bar{\ell} N_t$$

- We thus have that

$$g_y = g_A = \theta \bar{\ell} N_t$$

- This model generates long run growth!
- Long-run growth rate proportional to the size of the population

Scale Effects I

$$g_y = g_A = \theta \bar{\ell} N_t$$

- As the population grows, output growth should rise
- Kremer (1993):
  - In Malthusian model, population proportional to productivity
  - Population growth can then be used to measure productivity growth
  - Did this for 1 million BC to present

Table 1: World Population from 1,000,000 BCE to 1500 CE

Year	Population	Growth Rate
-1,000,000	0.125	–
-300,000	1	0.000003
-25,000	3.34	0.000004
-10,000	4	0.00003
-5,000	5	0.00005
-1,000	50	0.0006
1	170	0.001
600	200	0.0003
1000	265	0.0007
1200	360	0.002
1500	425	0.0006

Scale Effects II

$$g_y = \theta\bar{\ell}N_t$$

- Implies that a doubling of the population should lead to a doubling of output growth
- Actually about research effort
- A doubling of research effort should double output growth
- This has not happened since 1930

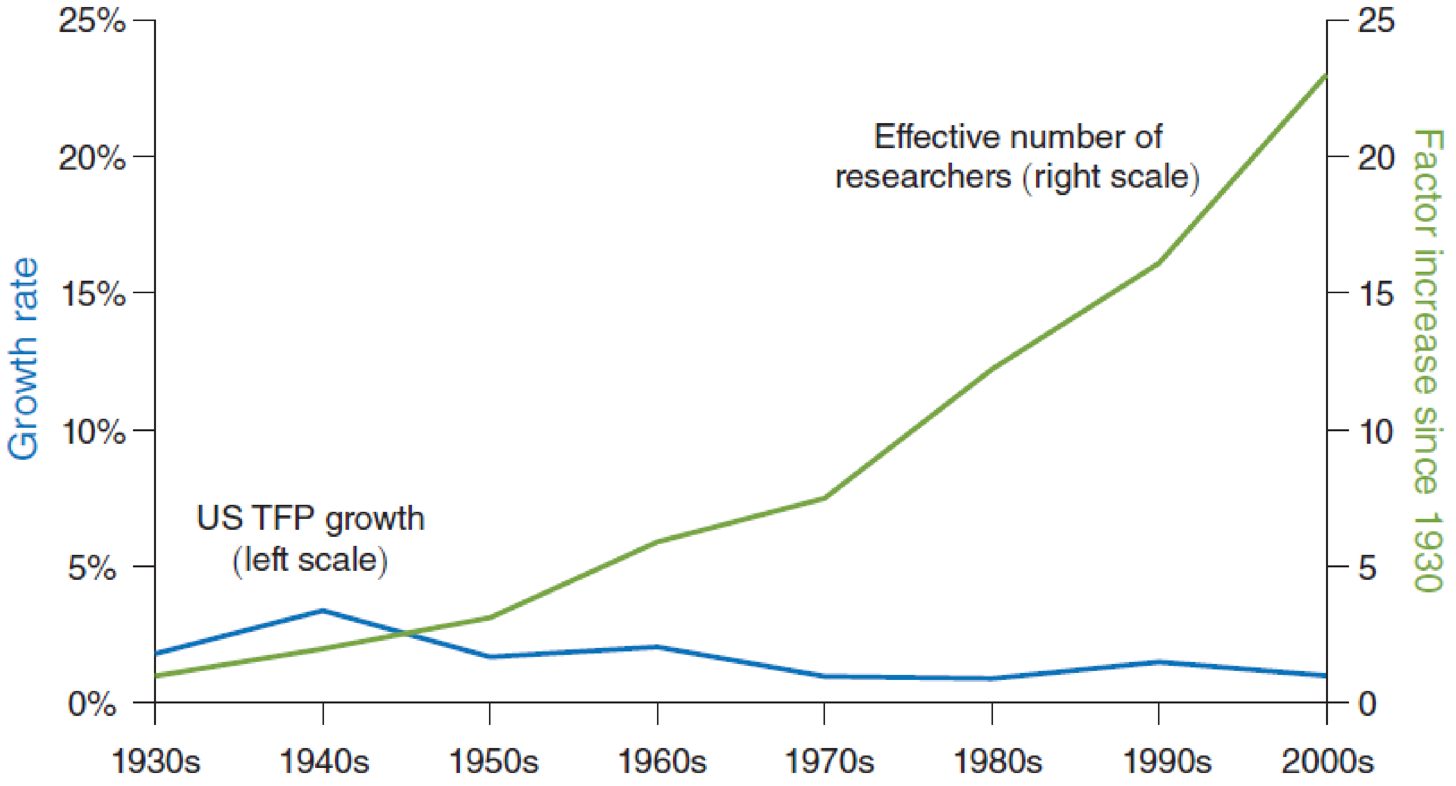


Figure 1. Aggregate Data on Growth and Research Effort

Source: Bloom, Jones, Van Reene, Webb (2020)

Weaker Scale Effects

- Scale effects in Romer model way too strong
- Jones (1995) points this out and argues for alternative production function for knowledge

$$A_{t+1} - A_t = \theta L_{at} A_t^{\phi}$$

- Romer assumes $\phi = 1$
- Jones (1995) argues $\phi < 1$

Jones Model

$$A_{t+1} - A_t = \theta L_{at} A_t^{\phi} \quad => \quad g_A = \frac{A_{t+1} - A_t}{A_t} = \theta \bar{\ell} N_t A_t^{\phi - 1}$$

- Suppose we take growth rates of this last equation
- If g_A is constant, then its growth rate is zero. So, we have:

$$0 = g_N + (\phi - 1) g_A$$

- Rearranging then yields:

$$g_y = g_A = \frac{\bar{n}}{1 - \phi}$$

- Long-run growth in $y_t = Y_t / N_t$ is proportional to population growth

Will Growth Peter Out?

Figure 4: Population Growth around the World

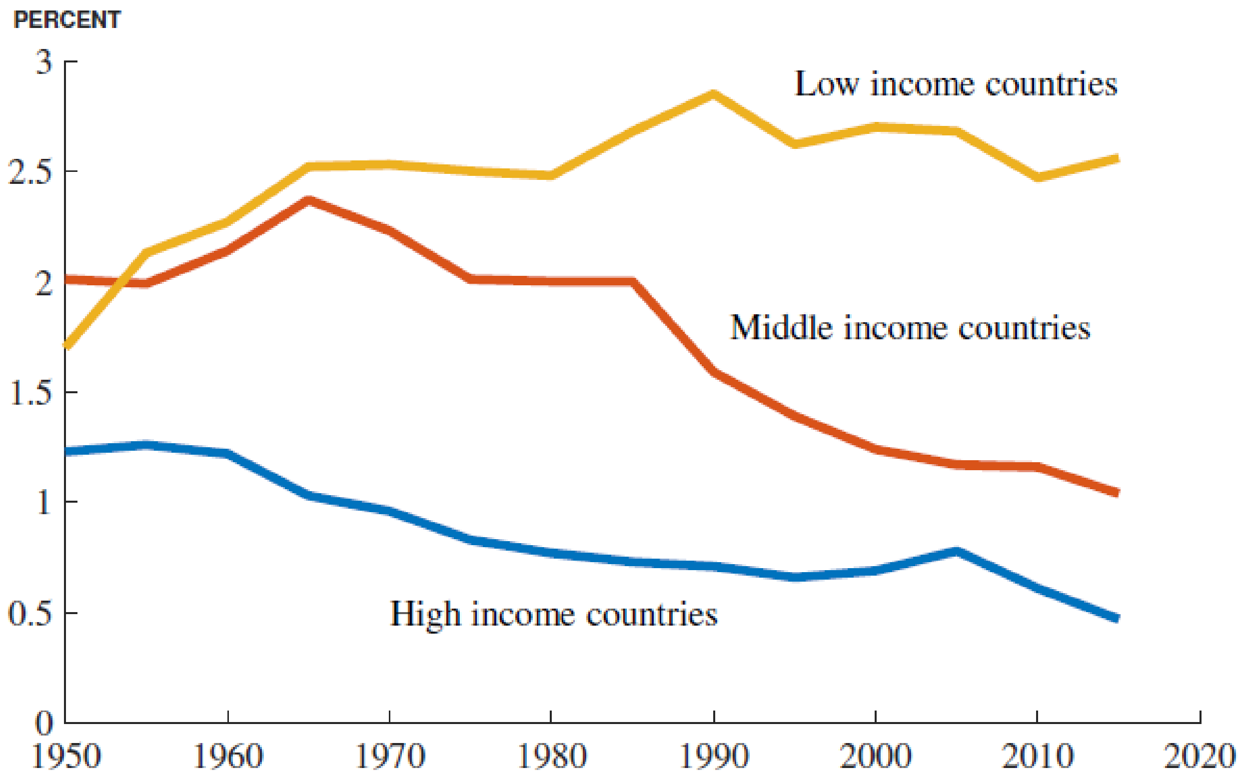
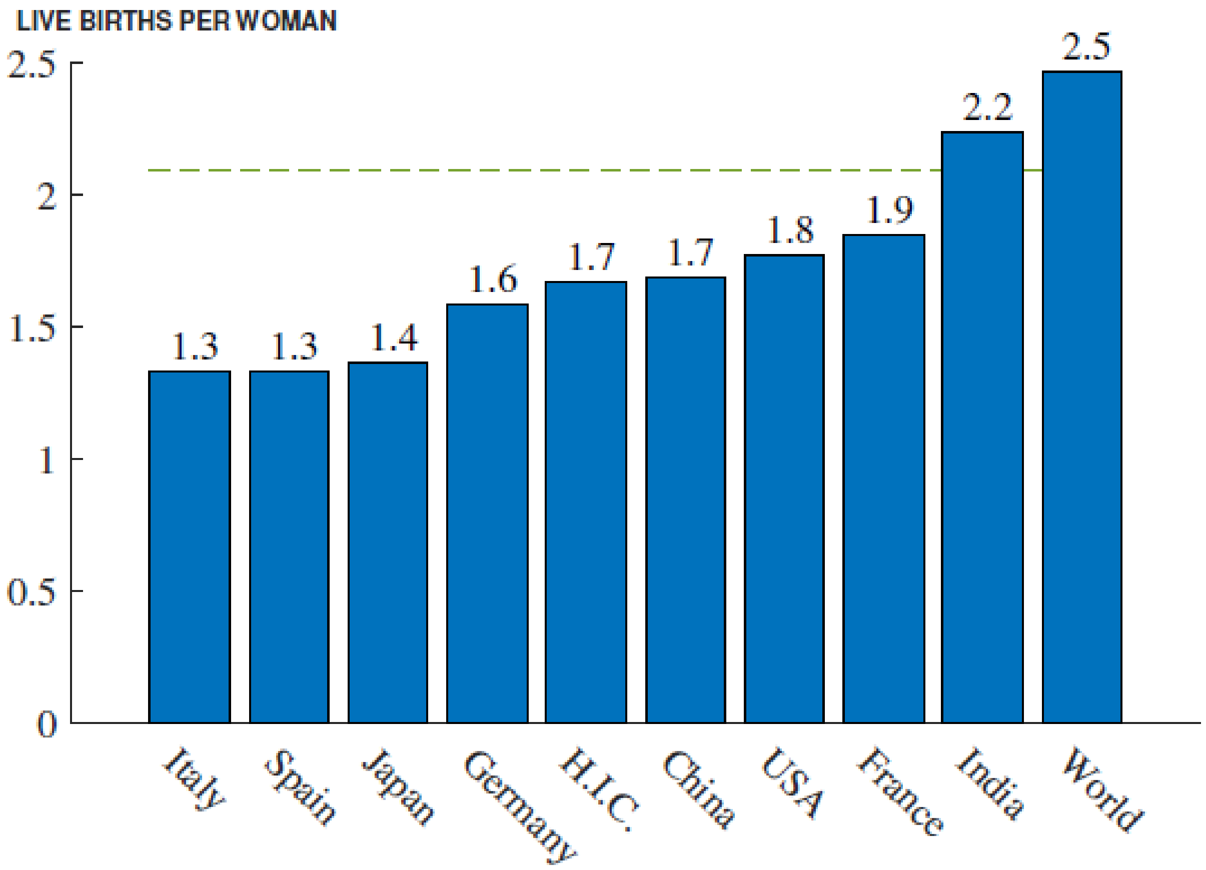


Figure 5: The Total Fertility Rate around the World



Source: Jones (2022)

Data from 2015-2022. Fertility has fallen since.

Might Growth Speed Up?

- Finding Einsteins:
  - Traditionally most people have not been able to reach their potential as producers of ideas/knowledge
  - Extreme poverty, cast/class restrictions, discrimination
  - How many Einsteins / Doudnas have we missed
- Perhaps machines can replace labor in knowledge production
  - Even if we have less people, we can have more machines producing knowledge
  - Automation of ideas could even yield “singularity” (explosive growth)

Innovation Policy

- What government policies do we have to encourage knowledge production?
  - Grant patents to inventors
  - Subsidize basic research
- Key questions:
  - Why do we need these policies?
    (What is the market failure?)
  - What are the downsides of these policies?

Production of a New Drug

- Consider the production of a new drug
- Drug development costs $800 million
- Once invented: Constant returns to scale
  - Standard replication argument
  - To double production: Build another identical factory
- Once invented: Marginal cost: $10
- How do we bring about efficient use of drug?

Efficient Use of New Drug

- How do we bring about efficient use of drug?
  - Price must equal marginal cost!
  - A competitive market would bring this about
- What is the problem with this?
  - Inventor can't recoup initial $800 million investment
  - Inventor will thus not spend resources inventing
- Conclusion: Policy of placing new knowledge in the "public domain" and relying on competitive markets yields insufficient incentives to create knowledge
- What is the market failure?

Market Failure in Market for Ideas

- If we don’t grant property rights over ideas:
  - This is the market failure
  - Inventor can’t capture full benefits of his/her efforts and thus has insufficiently strong incentives to engage in research
  - Outcome: Too little knowledge production
- If we do grant property rights over ideas:
  - Owner becomes a monopolist
  - Will price product above marginal cost
  - Outcome: Too little use of existing knowledge

Market Failure in Market for Ideas

- Imagine we could grant property rights in a special way:
  - We have a technology that guarantees that no one else can use invention without inventing it from scratch (no backward engineering)
  - In other words: Imagine that we can make invention fully excludable
  - But everyone else is free to reinvent invention at a cost of $800 million (i.e., not a patent)
  - Now what is the market failure?

Market Failure in Market for Ideas

- Will we get perfect competition?
  - No!!
  - With perfect competition: price = marginal cost
  - Firms can't recoup initial investment
  - Firms will stop entering market before we get to perfect competition.
  - We will have an "oligopolistic" market

Market for Ideas in Practice

- Full excludability is not realistic
  - Backward engineering always possible
- In practice non-excludability a serious issue
- Incentives to invest too low

Realistic policy options

1. Laissez faire
   – Insufficient incentives to invest
2. Grant “patents” (temporary monopoly)
   – Enforces temporary full excludability
   – But: Price > marginal cost
   – Inefficiently low use of invention
3. Government subsidies for research
   – Who decides what to fund?

Economics of Patents

- Benefit:
  - Provide an incentive for knowledge production.
- Cost:
  - Price = Marginal Benefit > Marginal Cost
  - Example: HIV drugs in the late 1990s
    - Had been invented. Marginal cost very low.
    - Prices much higher than marginal costs
    - Many people in poor countries could pay marginal cost but not price. Priced out of the market.
    - Huge loss in welfare (Many people died!)
- Alternative: Prizes (Michael Kremer, QJE 1998)

Prizes

- Why not just pay inventors for useful inventions?
  - But who would decide how much to pay?
- Perhaps we can get “the market” to decide. (How?)
- Hold an auction:
  - Highest bidder gets patent with 5% probability
  - With 95% probability government pays highest bid to inventor and releases knowledge to public domain

Case Against Patents

- Boldrin and Levine (2013)
- Explosion in number of patents:
  - 1983: 59,715, 2003: 189,597, 2010: 244,341
- Scant evidence of increase in productivity
- Anecdotally, many recent patents are trivial
  - Perhaps filed to be able to extract fees from others or create a barrier to entry
- First mover advantage perhaps enough of an incentive to innovate

Defensive Patenting: Smartphones

- Apple and Microsoft large incumbents with huge patent portfolios
- Google a new innovative entrant
- Google purchased Motorola Mobility for patent portfolio
- Main use of patent portfolio arguably to threaten counter-suits if Apple and Microsoft sue
- If all companies have lots of patents and all are successful in the market no one can sue because others can counter-sue
- Patents are just an added cost to innovation (and barrier to entry for small poor firms)