EC569 Economic Growth
Technology and Efficiency (Lecture 8)

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Technology Production Function

- Last lecture, we assumed technology growth rate is independent of current technology level:

$$\hat{A} = \frac{L_A}{\mu}$$

- However, technology is cumulative: Researchers begin their investigations where those who came before them left off.

Cumulative Nature of Technology Development

Suppose that $\hat{A} \equiv \frac{\dot{A}}{A} = \frac{L_A^\lambda}{\mu} A^{\phi-1}$, then

$$\dot{A} = \frac{L_A^\lambda}{\mu} A^\phi$$

- If $\phi > 0$: "standing on shoulders"
  - Isaac Newton: If I have seen father than others, it is because I have stood on the shoulders of giants.
  - Larger base of knowledge
  - Larger set of tools
- If $\phi < 0$: "fishing out"
  - Fishing out effect: easiest discoveries have already been made
  - More is known today, more effort for a researcher to learn everything required

Decreasing Returns to Scale in Technology Production

- $\lambda < 1$
- Efforts of most of the researchers will be wasted if many are working at the same project
- Charles Darwin came up earlier with ‘natural selection’ than Alfred Wallace
- Two teams completed the sequencing of human genome simultaneously

Long-run growth rate

- $$\dot{A} = \frac{L_A^{\lambda}}{\mu} A^{\phi}$$
- Growth rate of A, $g_A = \frac{\dot{A}}{A} = \frac{(\gamma_A L)^{\lambda}}{\mu} A^{\phi - 1} = \frac{(\gamma_A L)^{\lambda}}{\mu A^{1-\phi}}$
- For g_A to be constant, $(\gamma_A L)^{\lambda}$ and $\mu A^{1-\phi}$ should grow at the same rate.
- Growth rate of $(\gamma_A L)^{\lambda}$ is λn, where n is the population growth rate.
- Growth rate of $\mu A^{1-\phi}$ is equal to $(1-\phi)g_A$
- $(1-\phi)g_A = \lambda n$
- Growth rate of technology: $g_A = \frac{\lambda n}{(1-\phi)}$
- g_A is positively correlated with λ and n, and negatively correlated with ϕ

Determinants of productivity growth

- In the long-run: $g_A = \frac{\lambda n}{(1-\phi)}$
  - Unaffected by the fraction of population engaging in R&D
    - Intuitively, higher γ_A leads to higher $\hat{A}$ in the short run
    - as A grows it becomes harder to make new innovations
  - g_A and n are positively correlated
- Short-run growth rate of productivity is a function of fraction of labor force engaging in R&D.

Income per capita in the long run

- Fraction of labor force engaging in R&D impacts income per capita
    - Positively: high level of productivity in the long run
    - Negatively: smaller fraction of workers in the production
- Size of labor force, $L(t)$, impacts income per capita positively (*scale effect*):
    - *demand effect*: $L \uparrow \Rightarrow$ larger market for an idea $\Rightarrow \uparrow$ return to research
    - *supply effect*: $L \uparrow \Rightarrow$ more potential creators of ideas

Romer Model

- Consists of three sectors:
  - Research
    - Produces designs and sells to intermediate goods sector
  - Intermediate goods
    - Monopolistic competition
    - Purchase design of a specific capital good from the research sector
    - Produce a particular capital good, x_j, and sell it to the final goods producers
  - Final goods
    - Large number of identical firms
    - $Y = L_Y^{1-\alpha} \sum_{j=1}^{A} x_j^{\alpha}$
- Technological progress:

  addition of new varieties of the goods to the economy, $A \uparrow$

Romer Model, cont'd

- Without going into tedious solution of the model, focus on the insights
- Return to innovation: expected discounted sum of future profits
- Fraction of labor force working in research:
  - The fastest the economy grows (higher g_A), the higher the fraction of population that works in research.
  - The higher the discount rate, the lower the return to innovation, the lower the fraction of population doing research.

Schumpeterian Model

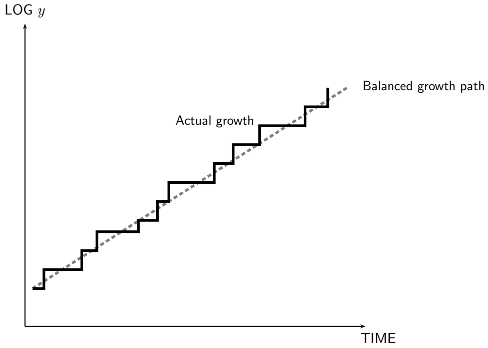
- Technological progress in Romer:
  - increase in the number of intermediate goods
  - steam engines and electric motors are used alongside each other
- Technological progress in the Schumpeterian model:
  - Developed by Aghion and Howitt (1992) and Grossman and Helpman (1991)
  - Insights of Joseph Schumpeter, creative destruction
  - Technological progress: an innovation replaces an existing intermediate good

Schumpeterian model, cont'd

- Consists of three sectors:
  - Final goods
    - Large number of competitive firms
    - $Y = L_Y^{1-\alpha} A_i^{1-\alpha} x_i^{\alpha}$
    - One variety of intermediate input is used in production
    - i: version of the intermediate input.
    - Example: A_4: modern cars, A_3 : the Model T Ford, A_2 : horse cart, A_1 : walking
    - x_i : quantity of intermediate input i used in production.
  - Intermediate good
    - Monopoly
    - Purchases design of a single version of the capital good
    - Produces capital good and sells to the final goods producers
  - Research
    - Produces designs and sells to intermediate goods sector

Research Sector

- With certain probability an innovation occurs
- If an innovation occurs, version of the intermediate good increases from A_i to A_{i+1}
- After an innovation, previous versions of the capital good becomes useless



Graphic from: Jones and Vollrath (2013)

Research sector, cont'd

Fraction of labor force working in research

- Negatively on the discount rate
- Positively on the probability of innovation
    - The higher the chance of a successful innovation, the higher the incentives to innovate
- Negatively on the probability of innovation
    - The higher the chance of being replaced by subsequent innovators, the lower the incentives to innovate

Comparison of the Romer model and the Schumpeterian model

- In both models, long-run *growth* is independent of the fraction of labor force engaging in research
- In both models, *level* of income per capita in the long run is impacted by the fraction of labor force engaging in research
- If the discount rate applied to monopoly profits is large, the Schumpeterian model imply a larger fraction of labor force engaging in innovation
  - because relative importance of being replaced by others is small
- If the discount rate is relatively small, the Schumpeterian model imply a smaller fraction of labor force engaging in research
  - because people are sensitive to the future destruction of profits

Optimal R&D

- Because of the externalities in the innovation process, competitive equilibrium R&D level is not optimum.
- Three distortions:
  Remember that $\dot{A} = \frac{L_A}{\mu} A^{\phi}$
  - if $\phi > 0$: "standing on shoulders"
    - Researchers do not benefit from the positive impact on the subsequent innovators
  - if $\lambda < 1$: "stepping on toes"
    - Researchers do not take into account potential duplication of research efforts
  - Consumer surplus effect
    - Private gain of an innovation = profit ¡ Consumer surplus = Social gain
- Ground for government interference to correct for the externalities

Efficiency

Productivity = Technology × Efficiency

- Technology: Knowledge about how factors of production can be combined to produce output
- Efficiency: How effectively given technology and factors of production actually used
- Productivity is much lower in poor countries than in rich countries
- Not obvious the only reason is a gap of technology
- Many of the most advanced technologies are being used in poor countries

Types of Inefficiency

- Unproductive activities
- Idle resources
- Misallocation among sectors
- Misallocation among firms
- Technology blocking

Unproductive Activities

- rent seeking: involve the use of laws or government institutions to bring private benefits
- Economic rent: payment to a factor of production in excess of what is required to elicit the supply of that factor
- E.g.: quotas to limit the imports of some goods, lobbying, ...
- Costs: a good deal of effort, bright people work in unproductive activities
- Illegal activities: theft, smuggling, kidnapping for ransom, ..

Idle Resources

- Factors of production not used at all
- Unemployment, underemployment
- Factory that sits unused
- Factory running at less than full capacity
- capital hoarding: factory shutdown during recessions
- Example: Air Afrique: 500 employees per airplane, EasyJet: 66 employees per airplane
- ‘Fireman’ employed in diesel engines of the United States and Canada railroads during the middle of the 20th century

Misallocation Among Sectors

Misallocation among sectors: marginal product of inputs are not equal across sectors

- barriers to mobility
  - geographical isolation
  - wage policy: e.g. sectoral minimum wage
- wages $\neq$ marginal product of labor
  - market segmentation: potentially productive people are unable to work in certain sectors

Efficiency Gains from Sectoral Reallocation

Reallocation from agriculture to manufacture

- Taiwan: 0.7% of 5.4% annual growth over 1966-1991
- Korea: 0.7% of 5.7% annual growth over 1960-1990
- US: fraction of agricultural labor 50% to 3% over 1880-1980
- China: fraction of agricultural labor 69% to 40% over 1980-2009

Misallocation Among Firms

Misallocation among firms: marginal product of inputs are not equal across firms

- government-owned firms over-employ: political power
- monopolies under-employ: monopolistic profit
- financial frictions prevent efficient allocation of capital: financial development and growth

Technology Blocking

Agents deliberately prevent the use of technology

- Gutenbergs printing press (1453): scribes
- automated weaving loom (19th century): Luddites
- margarine (late 19th century): dairy farmers
- Netscape browser: Microsoft

Isn't technological progress beneficial to the economy?

- creative destruction and technology blocking
- the success of technology blocking depends on the relative power of the opposer/supporter
- rich countries are more prone to technology blocking
- technology blocking requires a well functioning government