EC569 Economic Growth
The Role of Technology in Growth (Lecture 7)

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February 25, 2019

The nature of technological progress

- Productivity and technology, $A = T \times E$
  - technology: knowledge about how factors of production can be combined to produce output
  - efficiency: how effectively given technology and factors of productions are actually used

Technological progress

- Solow model: no long-run growth
- Extended Solow model (or Solow model with technological progress):
  - long-run growth as a result of exogenous technological progress
- Endogenous growth models:
  - Technological progress as result of efforts by
    - researchers
    - entrepreneurs
    - inventors
  - Technology (or ideas) are produced
    - designs
    - blueprints

Ideas vs objects

- Technology as a public good technology is non-rival in its use
  - it can be used by many at the same time
  - technology can be shared with others
  - it is transferable across firms and countries
- technology is (often) non-excludable (per se)
  - owner of the technology cannot prevent others from using it without permission
  - reduces incentive for creating technology
  - cutting edge technology is usually protected by patents
- Standard goods are rival
  - a machine can be used in only one location at a time
- Goods are excludable:
  - machines stored in a factory protected by professional guards

Economics of Ideas

Ideas

$\downarrow$

Non-rivalry

$\downarrow$

Increasing returns to scale

$\downarrow$

Imperfect competition

Ideas and increasing returns to scale

- Standard replication argument
  - To double the output of factory, say computers, you can replicate the same factory across the street
  - Therefore, constant returns to scale
- You don't need to re-produce the blueprints of computer production
- Constant returns to scale in rivalrous inputs (capital, labor, material) $\Rightarrow$ Increasing returns to scale in rivalrous inputs plus ideas
- Output per person depends on the total stock of knowledge, not knowledge per person.
- One more computer, one worker more productive
- One more idea, any number of workers more productive

Ideas and imperfect competition

- Creating new ideas (technologies) requires investment
- Ideas have high fixed costs, a lot of effort to create a drug
- Ideas have low (zero) marginal costs.
- Fixed cost, low marginal cost necessitate imperfect competition
- Incentive to innovate: profits
- With perfect competition, firms will not invest in R&D, as they will have negative profits.
- involves externalities
  - non-exclusiveness leads to spillovers
  - later inventors and researchers benefit from the insights of those who came before.
  - market investment in ideas may not be socially optimum

Readings

- You should always read the relevant chapters of the course textbooks.
- Chapter 4.2 (The Economics of Ideas) of Jones and Vollrath (2013)
- Chad Jones, 'New ideas about new ideas: Paul Romer, Nobel laureate' VOX, 12 October 2018

Implications of Investment in Ideas

- Set aside, temporarily, the decision of how much to invest in technology
- Focus on implications of technology investment on the output per worker level, and growth rate of output per worker

One-country model of technology creation and growth

- Draws on Lucas(1988) and Mankiw(1995)
- The only input to production is labor. (Ignore physical capital and human capital for now)
- Labor is employed on either output production or new technology creation (R&D)

$$L = L_Y + L_A$$

- γ_A: fraction of labor force engaging in R&D.

$$\gamma_A = \frac{L_A}{L}$$

- Labor employed for output production:

$$L_Y = (1 - \gamma_A)L$$

- Output:

$$Y = AL_Y = A(1 - \gamma_A)L$$

- Output per worker:

$$y = A(1 - \gamma_A)$$

- Notice that output per worker depends on total level of technology, not technology per worker
- $A \uparrow \Rightarrow y \uparrow$
- For given A, $\gamma_A \uparrow \Rightarrow y \downarrow$
- Trade-off:
  - Higher investment in R&D reduces output per worker in the short run
  - Higher investment in R&D increase output per worker by increasing A

Productivity Growth

- Productivity growth rate:

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

where μ is the 'price' of a new invention in units of labor.

- The larger μ is, the more labor must be devoted to R&D to achieve a given rate of technological growth.
- Re-writing

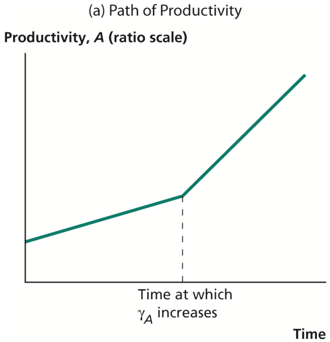
$$\hat{A} = \frac{\gamma_A}{\mu} L$$

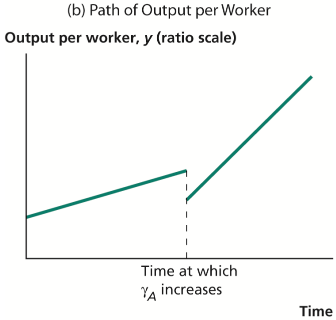
- As long as γ_A constant, $y = A(1 - \gamma_A) \Rightarrow$

$$\hat{y} = \hat{A} = \frac{\gamma_A}{\mu} L$$

- Increase in the population involved in R&D, $\gamma_A \uparrow \Rightarrow \hat{y} \uparrow$
- Decrease in the cost of innovation, $\mu \downarrow \Rightarrow \hat{y} \uparrow$

Effect of Shifting Labor into R&D





Graphics from: Weil (2013)

Predictions

- Some similarity to increase in the investment rate in the Solow model
- Consumption is lower in the short-run, higher in the long-run
- Growth rate is not affected in the Solow model, it is in this model

$$\hat{y} = \hat{A} = \frac{\gamma_A}{\mu} L$$

- No evidence that countries with larger population grow faster
    - the share of researchers are different across countries
        - the level of human capital is important
    - the closed economy setting could be false
        - international technology transfer/spillover

Two-country model of technology creation and growth

- Draws on Barro and Sala-i Martin (1997)
- Two countries: country 1 and country 2

$$y_1 = A_1(1 - \gamma_{A,1})$$

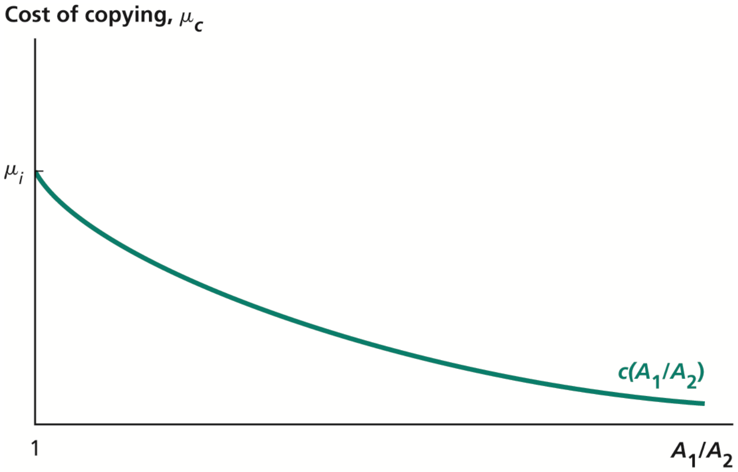
$$y_2 = A_2(1 - \gamma_{A,2})$$

- Two means of acquiring a technology
  - **Innovation**: the invention of a new technology
  - **Imitation**: copy a technology from elsewhere, available only to **'technology follower'**
- Suppose, country 1 is the **'technology leader'**: $A_1 > A_2$
- Country 2 is the **'technology follower'**: $A_1 > A_2$
- Assume $\gamma_{A,1} > \gamma_{A,2}$
  This assumption along with equal labor force sizes guarantees that country 1 is the technology leader in the model's steady state.

Productivity Growth Rate

- $$\hat{A}_1 = \frac{\gamma_{A,1}}{\mu_i} L_1,$$
  where μ_i is the cost of 'invention'.
- Productivity growth rate in the follower
  $$\hat{A}_2 = \frac{\gamma_{A,2}}{\mu_c} L_2,$$
  where μ_c is cost of 'copying'
- Cost of 'copying' is a function of technology gap between leader and follower:
  $$\mu_c = c\left(\frac{A_1}{A_2}\right)$$
- As technology gap widens, cost of copying decreases
- As $\frac{A_1}{A_2} \to \infty$, $\mu_c = c\left(\frac{A_1}{A_2}\right) \to 0$

Cost of Copying for the Follower Country



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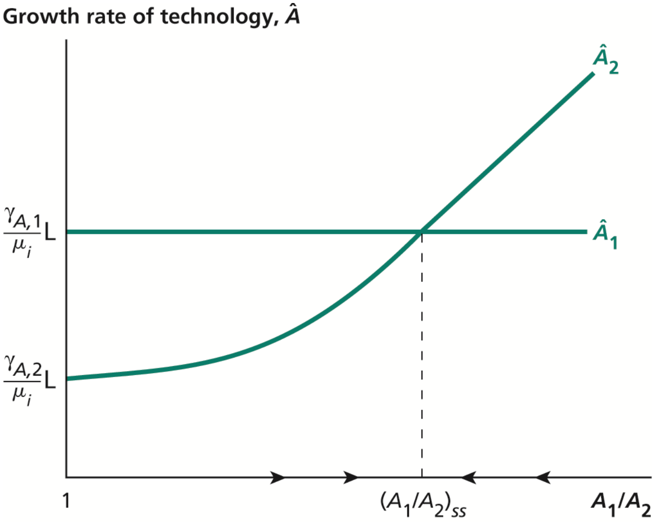
Steady State in the Two-Country Model



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- If $A_1/A_2 = 1$, then cost of invention would be the same, and country 1 will grow faster since $\gamma_{A,1} > \gamma_{A,2}$
- If $A_1/A_2 = \infty$, then cost of copying would be 0 for country 2, and it will grow much faster than country 1
- At some point $1 < A_1/A_2 < \infty$ the countries will grow at the same rate
- Steady state is stable:
    - If $A_1/A_2 > (A_1/A_2)_{ss}$, A_2 will grow faster and $A_1/A_2 \downarrow$
    - If $A_1/A_2 < (A_1/A_2)_{ss}$, A_1 will grow faster and $A_1/A_2 \uparrow$

Steady State

- In the steady state, countries grow at the same rate

$$\frac{\gamma_{A,1}}{\mu_i}L = \hat{A}_1 = \hat{A}_2 = \frac{\gamma_{A,2}}{\mu_c}L$$

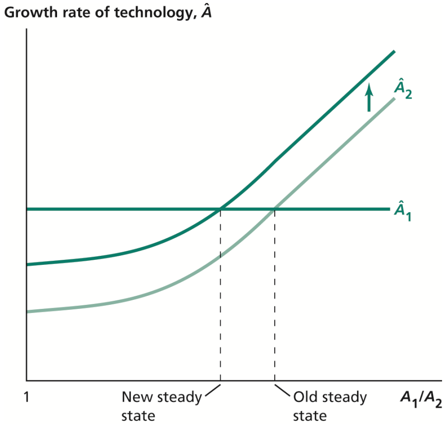
- Cost of copying:

$$\mu_c = \frac{\gamma_{A,2}}{\gamma_{A,1}}\mu_i$$

- Country 2 has lower cost of technology acquisition
- Once we know μ_c, we can solve for A_1/A_2 s.t. $c(A_1/A_2) = \mu_c = \frac{\gamma_{A,2}}{\gamma_{A,1}}\mu_i$
- Is the technology-leading country necessarily better off than the follower?

Effect of an Increase in R&D in the Follower Country on the Steady State

- Increase $\gamma_{A,2}$ but still lower than $\gamma_{A,1}$



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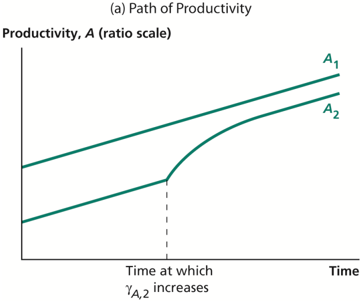
Effect of an Increase in $\gamma_{A,2}$ on Productivity and Output



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- Increase in $\gamma_{A,2}$ causes a temporary increase in growth rates, in contrast to permanent increase in one-country model
- Similar to increase in investment rate in the Solow model
- Increase in $\gamma_{A,1}$ leads to permanent changes in growth rates

Determinants of R&D Spending

- R&D done in laboratories
- Shop-floor R&D: tinkering with production process
- Inventing new products or more efficient ways of producing
- **Profit consideration**:
  - If successful, innovation raises profits
  - best case: monopoly power
  - means of producing a product at a lower cost than a firm's rivals
  - the larger the profits, the larger the incentives to engage in R&D

Profit Consideration

- The amount of R&D depends on
  - how much of an advantage a new invention will confer
    - Can the other firms easily copy the new technology?
    - Patenting is key to maintaining competitive advantage
  - the size of the market in which the product can be sold
    - The larger the available market, the greater the incentive to innovate
  - how long the advantage conferred by a new invention will last
  - the uncertainty surrounding the research process
    - Firms (countries) that are better able to share risks of R&D are more likely to undertake risky investment.

Patents and Other Forms of Intellectual Property Protection

- Non-excludability reduces incentives to create new technologies
- Patents: grant made by the government which gives the inventor monopolistic rights to make, use, and sell that invention for a set period of time (generally 20 years)
  - the invention must be novel and non-obvious
  - review of applications requires resources
  - first to file vs first to invent

Problems with Patents

- monopolies create inefficiency
- Potential users of technology cannot afford it
- More and more patent applications, harder to carefully scrutinize
- patent trolls discourage invention

Alternatives:

- secret recipe
- terminator genes
- open source software such as Linux, Python, Hadoop....

Next week

- Theoretically analyze investment in R&D
- Efficiency

Thank You!