EC569 Economic Growth
The Role of Technology in Growth
Lecture 7

İlhan Güner

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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

What determines productivity

- Watch this video of John Van Reenen, a World leading expert on productivity

Technological progress

Solow model: no long-run (economic) 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 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 and Imperfect competition

Ideas and increasing returns to scale

- Standard replication argument
  - To double the output of factory, say bicycle factory, you can replicate the same factory across the street
  - Therefore, constant returns to scale
- You don't need to re-produce the blueprints of bicycle production
- Constant returns to scale in rivalrous inputs (capital, labor, material)

$$\Downarrow$$

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 machine (physical capital), 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
  - 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:

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

One-country model of technology creation and growth, cont'd

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

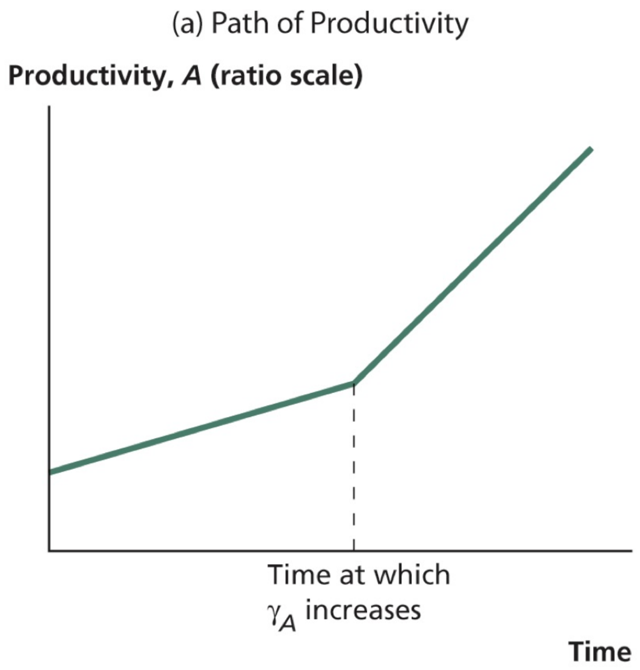
$$\hat{y} = \hat{A} = \frac{\gamma_A}{\mu} L$$

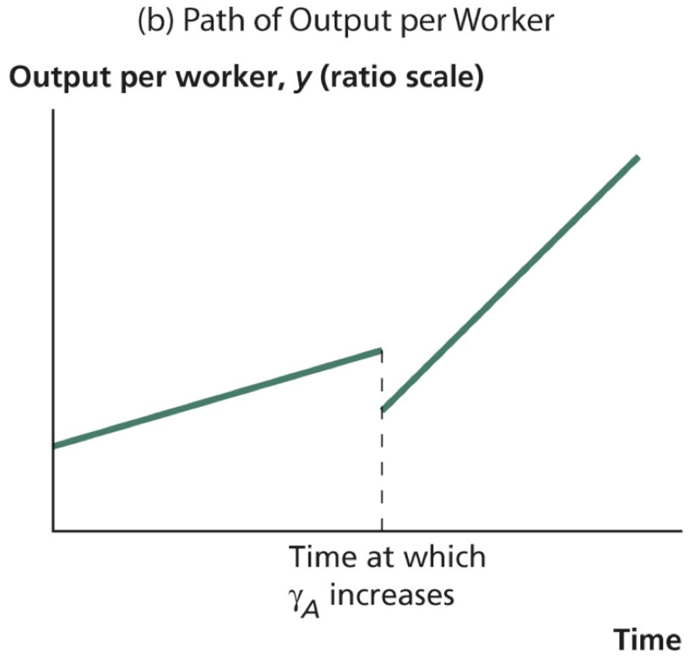
- Increase in the population involved in R&D, $\gamma_A \uparrow \Rightarrow \hat{y} \uparrow$
- Decrease in the cost of innovation, $\mu \downarrow \Rightarrow \hat{y} \uparrow$

Effect of Shifting Labor into R&D (an increase in γ_A)

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

$y = A(1 - \gamma_A)$ and $\hat{y} = \hat{A} = \frac{\gamma_A}{\mu} L$





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
- Long run economic growth rate is increasing with the resources allocated to R&D:

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

- No evidence that countries with larger population grow faster
  - the share of researchers are different across countries
  - the level of human capital is important in reality (ignored in this model)
  - 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:** copying of 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 Rates

- Productivity growth rate in the leader country

$$\hat{A}_1 = \frac{\gamma_{A,1}}{\mu_i} L_1,$$

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* (or *imitation*)

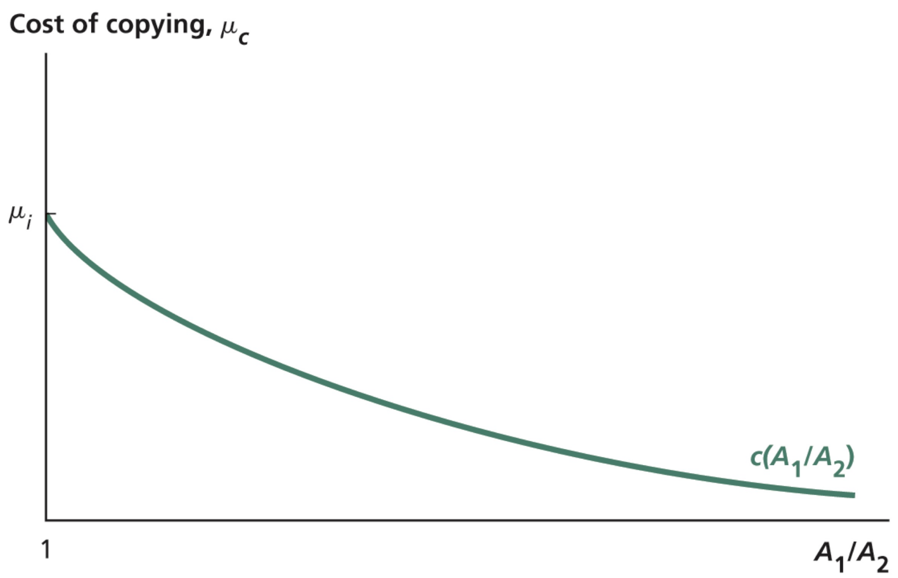
Cost of Copying for the Follower Country

- 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 $\frac{A_1}{A_2} \to \infty$, $\mu_c = c\left(\frac{A_1}{A_2}\right) \to 0$



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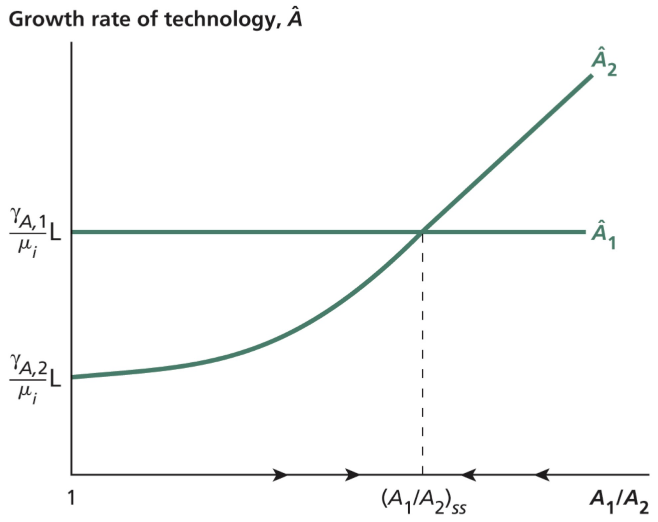
Steady State in the Two-Country Model

- 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 $A_1/A_2 \uparrow$

- Remember that $\hat{A}_2 = \frac{\gamma_{A,2}}{\mu_c} L_2$, $\mu_c \downarrow$ as $A_1/A_2 \uparrow$



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Steady state

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

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

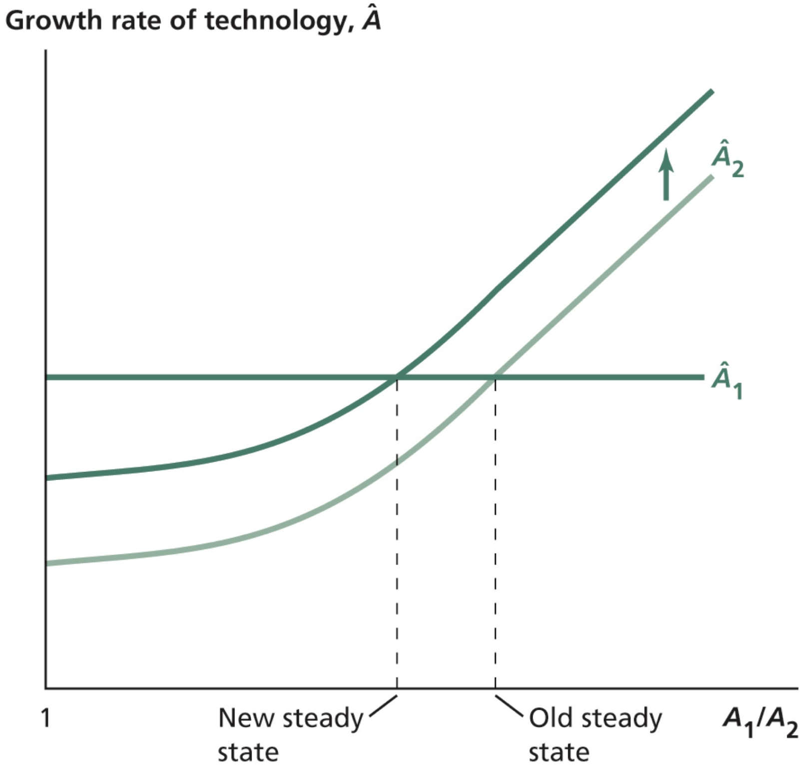
- Cost of copying:

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

- 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 $\gamma_{A,1}$
- Technology level of the follower country come closer to the technology level of the leader country
- Since $\gamma_{A,2} < \gamma_{A,1}$, $A_1 > A_2$ in the long run



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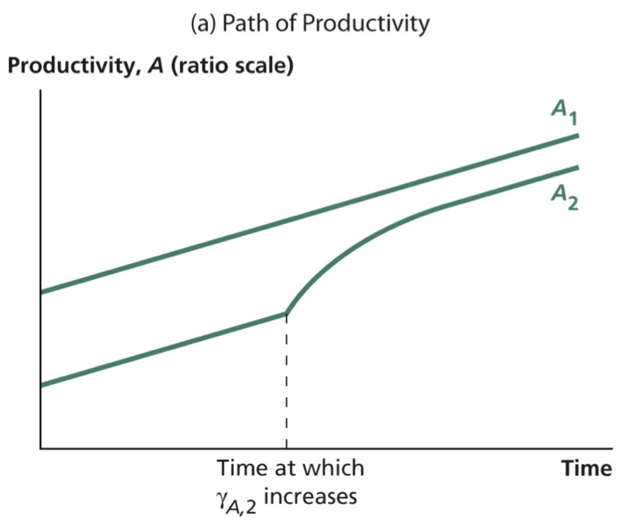
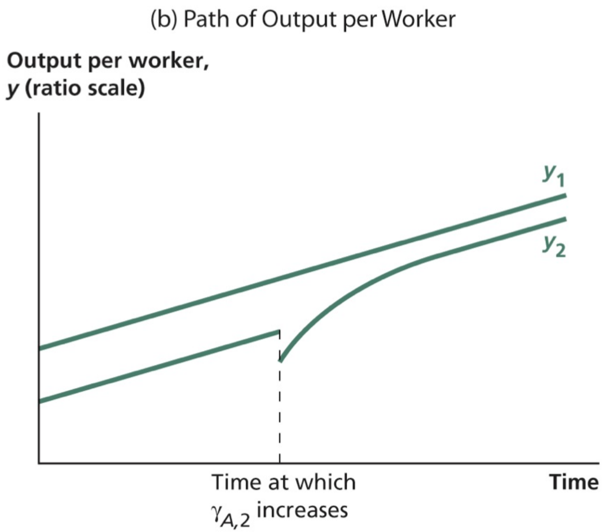
Effect of an Increase in $\gamma_{A,2}$ on Productivity and Output





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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
- In contrast, an increase in $\gamma_{A,1}$ leads to permanent changes in the growth rates

Summary

- Ideas are non-rival and non-excludable
  - leads to increasing returns to scale
  - necessitates imperfect competition
- Technological progress is a result of endogenous efforts of researchers
- Technological progress involves a trade-off:
  - current consumption versus future consumption
  - similar to saving decision in this regard
  - Growth rate of a country is permanently affected, unline the investment rate
- Countries can also imitate technology:
  - lower cost, lower technology level
  - but achieve the same growth rates of the leader countries

Next week

- Analyze investment in R&D
- Efficiency

To review this lecture read

- Chapter 4 (Introduction), 4.1 and 4.2 of Jones and Vollrath (2013)
- Chapter 8 of Weil (2013)