Economic Growth II
(Chapter 8)

macroeconomics
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PowerPoint® Slides
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macro

Learning objectives

- Technological progress in the Solow model
- Policies to promote growth
- Growth empirics:
  Confronting the theory with facts
- Endogenous growth:
  Two simple models in which the rate of technological progress is endogenous

Introduction

In the Solow model of Chapter 7,

- the production technology is held constant
- income per capita is constant in the steady state.

Neither point is true in the real world:

- 1929-2001: U.S. real GDP per person grew by a factor of 4.8, or 2.2% per year.
- examples of technological progress abound *(see next slide)*

Examples of technological progress

- 1970: 50,000 computers in the world
  2000: 51% of U.S. households have 1 or more computers
- The real price of computer power has fallen an average of 30% per year over the past three decades.
- The average car built in 1996 contained more computer processing power than the first lunar landing craft in 1969.
- Modems are 22 times faster today than two decades ago.
- Since 1980, semiconductor usage per unit of GDP has increased by a factor of 3500.
- 1981: 213 computers connected to the Internet
  2000: 60 million computers connected to the Internet

Tech. progress in the Solow model

- A new variable: $\boldsymbol{E}$ = labor efficiency
- Assume:
  Technological progress is **labor-augmenting**: it increases labor efficiency at the exogenous rate $\boldsymbol{g}$:

$$g = \frac{\Delta E}{E}$$

Tech. progress in the Solow model

- We now write the production function as:

$$Y = F(K, L \times E)$$

- where $L \times E$ = the number of effective workers.
  – Hence, increases in labor efficiency have the same effect on output as increases in the labor force.

Tech. progress in the Solow model

- Notation:

  $\boldsymbol{y} = \boldsymbol{Y/LE}$ = output per effective worker

  $\boldsymbol{k} = \boldsymbol{K/LE}$ = capital per effective worker

- Production function per effective worker:

  $\boldsymbol{y = f(k)}$

- Saving and investment per effective worker:

  $\boldsymbol{s\,y = s\,f(k)}$

Tech. progress in the Solow model

$(\delta + \boldsymbol{n} + \boldsymbol{g})\boldsymbol{k}$ = break-even investment: the amount of investment necessary to keep $\boldsymbol{k}$ constant.

Consists of:

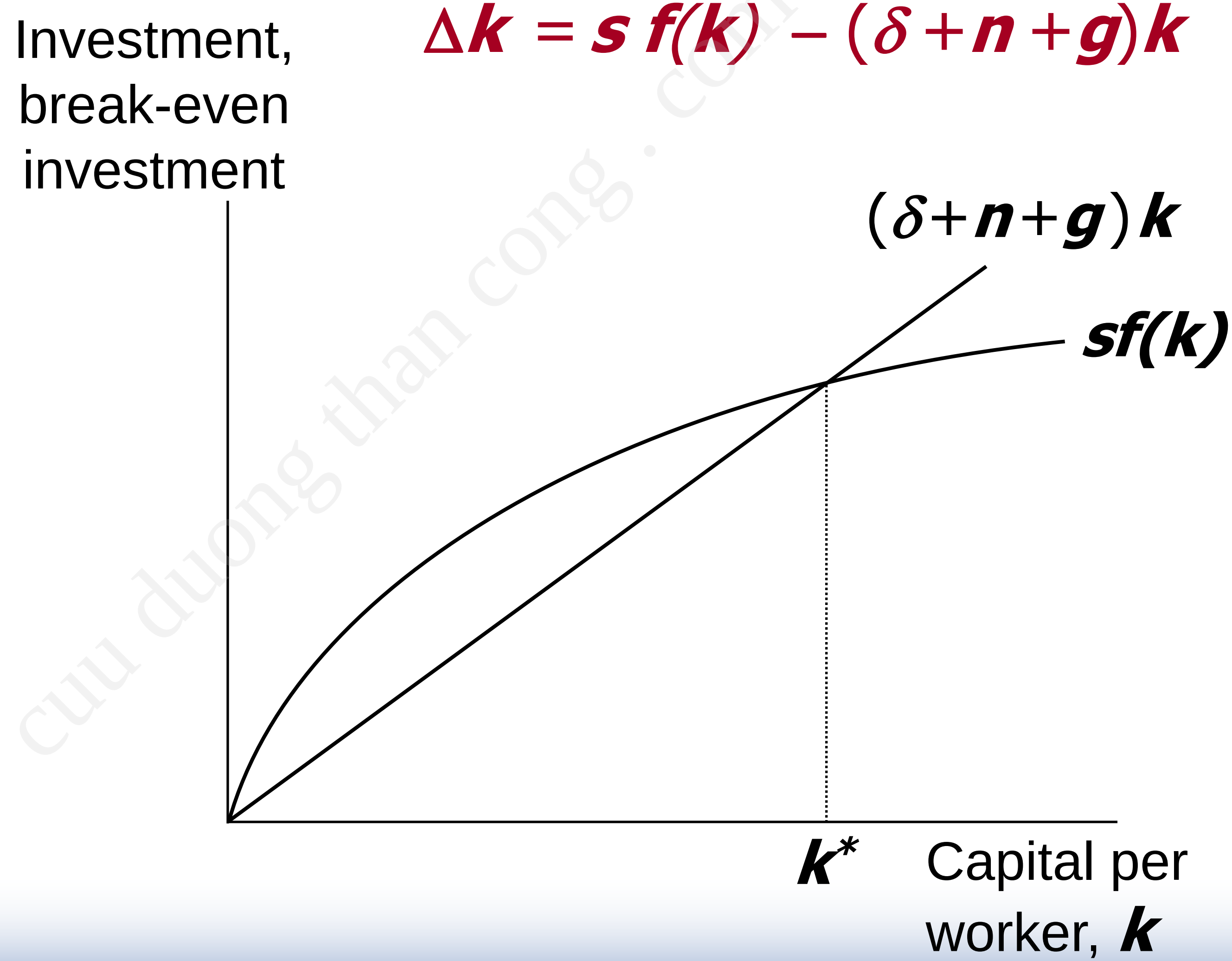
$\delta \boldsymbol{k}$ to replace depreciating capital

$\boldsymbol{n k}$ to provide capital for new workers

$\boldsymbol{g k}$ to provide capital for the new "effective" workers created by technological progress

Tech. progress in the Solow model

$$\Delta k = s\,f(k) - (\delta + n + g)k$$



Steady-State Growth Rates in the Solow Model with Tech. Progress

Variable	Symbol	Steady-state growth rate
Capital per effective worker	$\boldsymbol{k} = \boldsymbol{K}/(\boldsymbol{L} \times \boldsymbol{E})$	0
Output per effective worker	$\boldsymbol{y} = \boldsymbol{Y}/(\boldsymbol{L} \times \boldsymbol{E})$	0
Output per worker	$(\boldsymbol{Y}/\boldsymbol{L}) = \boldsymbol{y} \times \boldsymbol{E}$	$\boldsymbol{g}$
Total output	$\boldsymbol{Y} = \boldsymbol{y} \times \boldsymbol{E} \times \boldsymbol{L}$	$\boldsymbol{n} + \boldsymbol{g}$

The Golden Rule

To find the Golden Rule capital stock, express c^* in terms of k^*:

$$c^* = y^* - i^*$$
$$= f(k^*) - (\delta + n + g)\,k^*$$

c^* is maximized when

$$\text{MPK} = \delta + n + g$$

or equivalently,

$$\boxed{\text{MPK} - \delta = n + g}$$

In the Golden Rule Steady State, the marginal product of capital net of depreciation equals the pop. growth rate plus the rate of tech progress.

Policies to promote growth

Four policy questions:

1. Are we saving enough? Too much?
2. What policies might change the saving rate?
3. How should we allocate our investment between privately owned physical capital, public infrastructure, and "human capital"?
4. What policies might encourage faster technological progress?

1. Evaluating the Rate of Saving

- Use the Golden Rule to determine whether our saving rate and capital stock are too high, too low, or about right.
- To do this, we need to compare $(\text{MPK} - \delta)$ to $(\boldsymbol{n} + \boldsymbol{g})$.
- If $(\text{MPK} - \delta) > (\boldsymbol{n} + \boldsymbol{g})$, then we are below the Golden Rule steady state and should increase $\boldsymbol{s}$.
- If $(\text{MPK} - \delta) < (\boldsymbol{n} + \boldsymbol{g})$, then we are above the Golden Rule steady state and should reduce $\boldsymbol{s}$.

1. Evaluating the Rate of Saving

To estimate ($\text{MPK} - \delta$), we use three facts about the U.S. economy:

1. $\boldsymbol{k} = 2.5\,\boldsymbol{y}$
   The capital stock is about 2.5 times one year's GDP.
2. $\delta\,\boldsymbol{k} = 0.1\,\boldsymbol{y}$
   About 10% of GDP is used to replace depreciating capital.
3. $\text{MPK} \times \boldsymbol{k} = 0.3\,\boldsymbol{y}$
   Capital income is about 30% of GDP

1. Evaluating the Rate of Saving

1. $\boldsymbol{k} = 2.5\ \boldsymbol{y}$
2. $\delta\,\boldsymbol{k} = 0.1\ \boldsymbol{y}$
3. MPK $\times\ \boldsymbol{k} = 0.3\ \boldsymbol{y}$

To determine δ, divided 2 by 1:

$$\frac{\delta\,\boldsymbol{k}}{\boldsymbol{k}} = \frac{0.1\,\boldsymbol{y}}{2.5\,\boldsymbol{y}} \quad \Rightarrow \quad \delta = \frac{0.1}{2.5} = 0.04$$

1. Evaluating the Rate of Saving

1. $\boldsymbol{k} = 2.5\ \boldsymbol{y}$
2. $\delta\, \boldsymbol{k} = 0.1\ \boldsymbol{y}$
3. $\text{MPK} \times \boldsymbol{k} = 0.3\ \boldsymbol{y}$

To determine MPK, divided 3 by 1:

$$\frac{\text{MPK} \times \boldsymbol{k}}{\boldsymbol{k}} = \frac{0.3\ \boldsymbol{y}}{2.5\ \boldsymbol{y}} \quad \Rightarrow \quad \text{MPK} = \frac{0.3}{2.5} = 0.12$$

Hence, $\text{MPK} - \delta = 0.12 - 0.04 = 0.08$

1. Evaluating the Rate of Saving

- From the last slide: MPK – δ = 0.08
- U.S. real GDP grows an average of 3%/year, so $n + g$ = 0.03
- Thus, in the U.S.,

$$\text{MPK} - \delta = 0.08 > 0.03 = n + g$$

- Conclusion:

The U.S. is below the Golden Rule steady state: if we increase our saving rate, we will have faster growth until we get to a new steady state with higher consumption per capita.

2. Policies to increase the saving rate

- Reduce the government budget deficit (or increase the budget surplus)
- Increase incentives for private saving:
  - reduce capital gains tax, corporate income tax, estate tax as they discourage saving
  - replace federal income tax with a consumption tax
  - expand tax incentives for IRAs (individual retirement accounts) and other retirement savings accounts

3. Allocating the economy's investment

- In the Solow model, there's one type of capital.
- In the real world, there are many types, which we can divide into three categories:
  - private capital stock
  - public infrastructure
  - **human capital**: the knowledge and skills that workers acquire through education
- How should we allocate investment among these types?

Allocating the economy's investment: *two viewpoints*

1. Equalize tax treatment of all types of capital in all industries, then let the market allocate investment to the type with the highest marginal product.
2. **Industrial policy**: Govt should actively encourage investment in capital of certain types or in certain industries, because they may have *positive externalities* (by-products) that private investors don't consider.

Possible problems with industrial policy

- Does the govt have the ability to "pick winners" (choose industries with the highest return to capital or biggest externalities)?
- Would politics (e.g. campaign contributions) rather than economics influence which industries get preferential treatment?

4. Encouraging technological progress

- Patent laws:
  encourage innovation by granting temporary monopolies to inventors of new products
- Tax incentives for R&D
- Grants to fund basic research at universities
- Industrial policy:
  encourage specific industries that are key for rapid tech. progress
  (subject to the concerns on the preceding slide)

CASE STUDY:
The Productivity Slowdown

	Growth in output per person (percent per year)	
	1948-72	1972-95
Canada	2.9	1.8
France	4.3	1.6
Germany	5.7	2.0
Italy	4.9	2.3
Japan	8.2	2.6
U.K.	2.4	1.8
U.S.	2.2	1.5

Explanations?

- *Measurement problems*

  Increases in productivity not fully measured.
  - But: Why would measurement problems be worse after 1972 than before?

- *Oil prices*

  Oil shocks occurred about when productivity slowdown began.
  - But: Then why didn't productivity speed up when oil prices fell in the mid-1980s?

Explanations?

- *Worker quality*
  1970s - large influx of new entrants into labor force (baby boomers, women).
  New workers are less productive than experienced workers.

- *The depletion of ideas*
  Perhaps the slow growth of 1972-1995 is normal and the true anomaly was the rapid growth from 1948-1972.

The bottom line:

We don't know which of these is the true explanation, it's probably a combination of several of them.

CASE STUDY:
I.T. and the "new economy"

	Growth in output per person (percent per year)		
	1948-72	1972-95	1995-2000
Canada	2.9	1.8	2.7
France	4.3	1.6	2.2
Germany	5.7	2.0	1.7
Italy	4.9	2.3	4.7
Japan	8.2	2.6	1.1
U.K.	2.4	1.8	2.5
U.S.	2.2	1.5	2.9

CASE STUDY:
I.T. and the "new economy"

Apparently, the computer revolution didn't affect aggregate productivity until the mid-1990s.

Two reasons:

1. Computer industry's share of GDP much bigger in late 1990s than earlier.
2. Takes time for firms to determine how to utilize new technology most effectively

The big questions:

- Will the growth spurt of the late 1990s continue?
- Will I.T. remain an engine of growth?

Growth empirics: Confronting the Solow model with the facts

Solow model's steady state exhibits **balanced growth** - many variables grow at the same rate.

- Solow model predicts ***Y/L*** and ***K/L*** grow at same rate (***g***), so that ***K/Y*** should be constant.

  This is true in the real world.

- Solow model predicts real wage grows at same rate as ***Y/L***, while real rental price is constant.
  Also true in the real world.

Convergence

- Solow model predicts that, other things equal, "poor" countries (with lower ***Y/L*** and ***K/L***) should grow faster than "rich" ones.
- If true, then the income gap between rich & poor countries would shrink over time, and living standards "converge."
- In real world, many poor countries do NOT grow faster than rich ones. Does this mean the Solow model fails?

Convergence

- No, because "other things" aren't equal.
  - In samples of countries with similar savings & pop. growth rates, income gaps shrink about 2%/year.
  - In larger samples, if one controls for differences in saving, population growth, and human capital, incomes converge by about 2%/year.
- What the Solow model *really* predicts is **conditional convergence** - countries converge to their own steady states, which are determined by saving, population growth, and education. And this prediction comes true in the real world.

Factor accumulation vs. Production efficiency

Two reasons why income per capita are lower in some countries than others:

1. Differences in capital (physical or human) per worker
2. Differences in the efficiency of production (the height of the production function)

Studies:

- both factors are important
- countries with higher capital (phys or human) per worker also tend to have higher production efficiency

Endogenous Growth Theory

- Solow model:
  - sustained growth in living standards is due to tech progress
  - the rate of tech progress is exogenous
- Endogenous growth theory:
  - a set of models in which the growth rate of productivity and living standards is endogenous

A basic model

- Production function: $\boldsymbol{Y} = \boldsymbol{A K}$
  where $\boldsymbol{A}$ is the amount of output for each unit of capital ($\boldsymbol{A}$ is exogenous & constant)
- Key difference between this model & Solow: MPK is constant here, diminishes in Solow
- Investment: $\boldsymbol{sY}$
- Depreciation: $\delta \boldsymbol{K}$
- Equation of motion for total capital:

$$\Delta \boldsymbol{K} = \boldsymbol{sY} - \delta \boldsymbol{K}$$

A basic model

$$\Delta K = sY - \delta K$$

- Divide through by K and use $Y = AK$, get:

$$\frac{\Delta Y}{Y} = \frac{\Delta K}{K} = sA - \delta$$

- If $sA > \delta$, then income will grow forever, and investment is the "engine of growth."
- Here, the permanent growth rate depends on s. In Solow model, it does not.

Does capital have diminishing returns or not?

- Yes, if "capital" is narrowly defined (plant & equipment).
- Perhaps not, with a broad definition of "capital" (physical & human capital, knowledge).
- Some economists believe that knowledge exhibits <u>increasing</u> returns.

Chapter summary

1. Key results from Solow model with tech progress
   - steady state growth rate of income per person depends solely on the exogenous rate of tech progress
   - the U.S. has much less capital than the Golden Rule steady state
2. Ways to increase the saving rate
   - increase public saving (reduce budget deficit)
   - tax incentives for private saving

Chapter summary

3. Productivity slowdown & "new economy"
   - Early 1970s: productivity growth fell in the U.S. and other countries.
   - Mid 1990s: productivity growth increased, probably because of advances in I.T.
4. Empirical studies
   - Solow model explains balanced growth, conditional convergence
   - Cross-country variation in living standards due to differences in cap. accumulation and in production efficiency

Chapter summary

5. Endogenous growth theory: models that examine the determinants of the rate of tech progress, which Solow takes as given