Chapter 9

Economic Growth II: Technology, Empirics, and Policy

IN THIS CHAPTER, YOU WILL LEARN:

- how to incorporate technological progress in the Solow model
- about policies to promote growth
- about growth empirics: confronting the theory with facts
- two simple models in which the rate of technological progress is endogenous

Introduction

In the Solow model of Chapter 8,

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

Neither point is true in the real world:

- 1908–2008: U.S. real GDP per person grew by a _____ per year.
- examples of technological progress abound (see next slide).

Examples of technological progress

- From 1950 to 2000, U.S. farm sector productivity nearly tripled.
- The real price of computer power has fallen an average of 30% per year over the past three decades.
- 2000: _____ Internet users, _____ cell phone users
  2010: _____ billion Internet users, _____ billion cell phone users
- 2001: iPod capacity = ___ gb, _____ songs. Not capable of playing episodes of *True Blood*.

  2011: iPod touch capacity = ____ gb, _____ songs. Can play episodes of *True Blood*.

(64, 16,000) (5, 1000) (2.0, 3.8) (361 million, 740 million)

Technological progress in the Solow model

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

Technological progress in the Solow model

- We now write the production function as:

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

Technological progress in the Solow model

- Notation:

  y = _____ = output per effective worker

  k = _____ = capital per effective worker

- Production function per effective worker:

  y = _____

- Saving and investment per effective worker:

  sy = _____

Technological progress in the Solow model

What was the breakeven investment that makes the economy staying in steady state?

Now with technological growth,

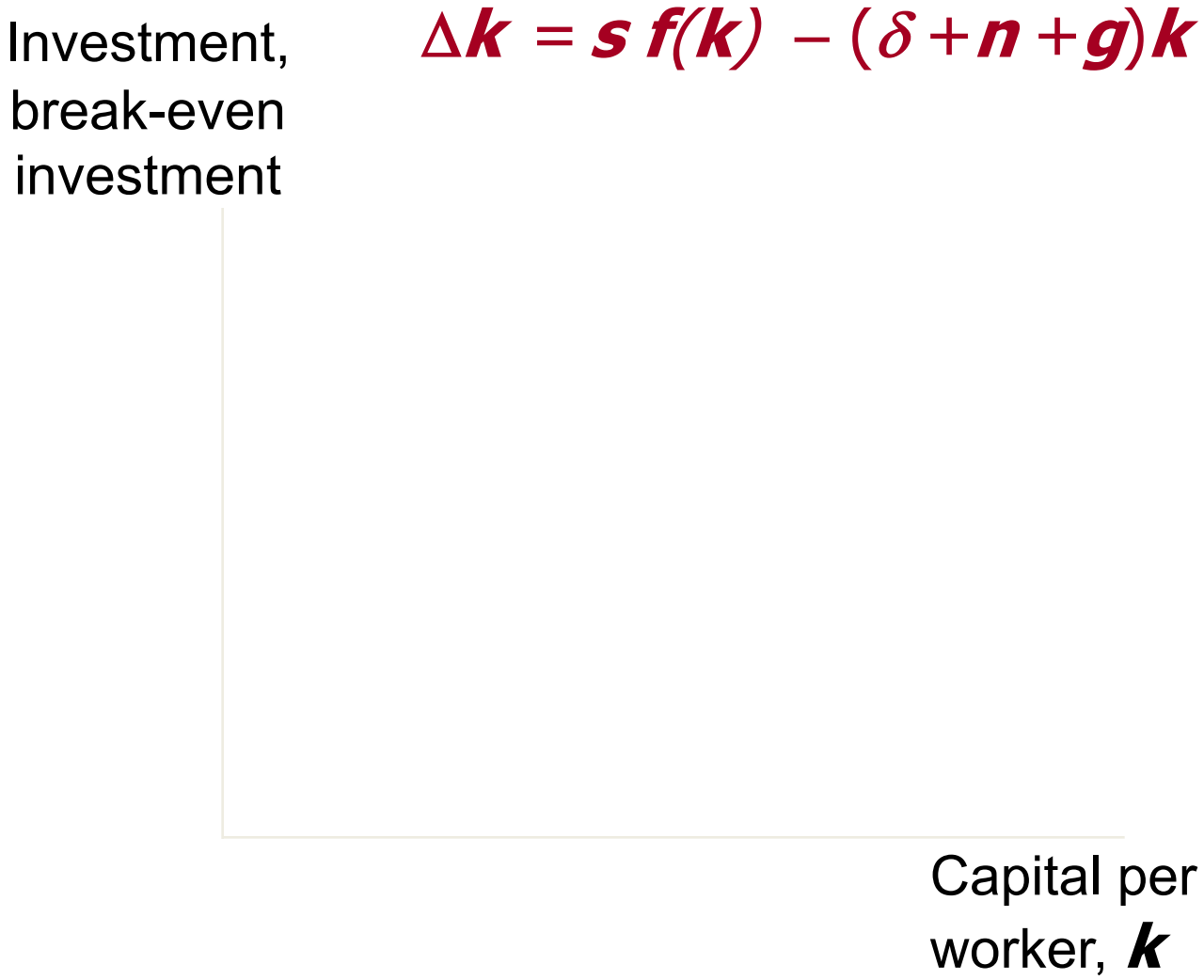
break-even investment: _____
the amount of investment necessary
to keep k constant.

Consists of:

- δk to replace depreciating capital
- $n k$ to provide capital for new workers
- $g k$ to provide capital for the new "effective" workers created by technological progress

Technological 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	$k = K/(L \times E)$	0
Output per effective worker	$y = Y/(L \times E)$	0
Output per worker	$(Y/L) = y \times E$	____
Total output	$Y = y \times E \times L$	____

The Golden Rule with technological progress

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

$$c^* = y^* - i^*$$

$$= \_\_\_\_\_ - \_\_\_\_\_$$

c^* is maximized when

$$\_\_\_\_\_$$

or equivalently,

$$MPK - \delta = n + g$$

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.

Growth empirics: 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, causing living standards to *converge*.
- In real world, many poor countries do NOT grow faster than rich ones. Does this mean the Solow model fails?

Growth empirics: Convergence

- What the Solow model really predicts is _____ **convergence**—countries converge to their own steady states, which are determined by saving, population growth, and education.
- This prediction comes true in the real world.

Growth empirics: Production efficiency and free trade

- Since Adam Smith, economists have argued that free trade can increase production efficiency and living standards.
- Research by Sachs & Warner:

Average annual growth rates, 1970–89		
	open	closed
developed nations	2.3%	0.7%
developing nations	4.5%	0.7%

Policy issues

- Are we saving enough? Too much?
- What policies might change the saving rate?
- How should we allocate our investment between privately owned physical capital, public infrastructure, and human capital?
- How do a country's institutions affect production efficiency and capital accumulation?
- What policies might encourage faster technological progress?

Policy issues: Evaluating the rate of saving

- Use the Golden Rule to determine whether the U.S. saving rate and capital stock are too high, too low, or about right.
  - If $(MPK - \delta) > (\boldsymbol{n} + \boldsymbol{g})$, U.S. economy is below the Golden Rule steady state and should increase ***s***.
  - If $(MPK - \delta) < (\boldsymbol{n} + \boldsymbol{g})$, U.S. economy is above the Golden Rule steady state and should reduce ***s***.

Policy issues: Evaluating the rate of saving

To estimate ($MPK - \delta$), 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. $MPK \times \boldsymbol{k} = 0.3\ \boldsymbol{y}$
   Capital income is about 30% of GDP.

Policy issues:
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, divide **2** by **1**:

$\Rightarrow$

Policy issues:
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 *MPK,* divide **3** by **1**:

$$\Rightarrow$$

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

Policy issues: Evaluating the rate of saving

- From the last slide: $MPK - \delta = 0.08$
- U.S. real GDP grows an average of 3% per year, so $\boldsymbol{n} + \boldsymbol{g} = 0.03$
- Thus,

  $MPK - \delta = 0.08 > 0.03 = \boldsymbol{n} + \boldsymbol{g}$
- Conclusion:

The U.S. is _____ the Golden Rule steady state: Increasing the U.S. saving rate would increase consumption per capita in the long run.

Below or above

Policy issues: How to increase the saving rate

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

Reduce or increase Replace

Policy issues: 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:
  - _____ capital stock
  - _____ infrastructure
  - _____: the knowledge and skills that workers acquire through education
- How should we allocate investment among these types?

Private or public **human capital**