Chapter 8: Economic Growth II: Technology, Empirics, and Policy*

MACROECONOMICS

Seventh Edition

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*Slides based on Ron Cronovich's slides, adjusted by Marcel Bluhm for lecture in Macroeconomics at the Wang Yanan Institute for Studies in Economics at Xiamen University.

Learning Objectives

This chapter introduces you to understanding:

- technological progress in the Solow model
- the connection between growth theory and growth empirics

8.1) Technological Progress (TP)

➔ SGM: So Far Assumed Constant Technology

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:

- examples of technological progress abound (see next slide).
- 1908-2008: U.S. real GDP per person grew by a factor of 7.8, or 2.05% per year.

8.1) Technological Progress (TP)

➔ Examples For TP

- 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: 361 million Internet users, 740 million cell phone users
  2010: 2.0 billion Internet users, 3.8 billion cell phone users
- 2001: iPod capacity = 5gb, 1000 songs. Not capable of playing episodes of True Blood.

  2010: iPod touch capacity = 64gb, 16,000 songs. Can play episodes of True Blood.

8.1) Technological Progress (TP)

➔ SGM: Including TP

A new variable: ***E*** = labor efficiency

Assume:
Technological progress is **labor-augmenting**:
it increases labor efficiency at the exogenous rate ***g***:

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

8.1) Technological Progress (TP)

➔ SGM: Including TP

We now write the production function as:

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

- 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.

8.1) Technological Progress (TP)

➔ SGM: Including TP (ctd.)

Notation:

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

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

Production function per effective worker:

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

Saving and investment per effective worker:

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

8.1) Technological Progress (TP)

➔ SGM: Including TP (ctd.)

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

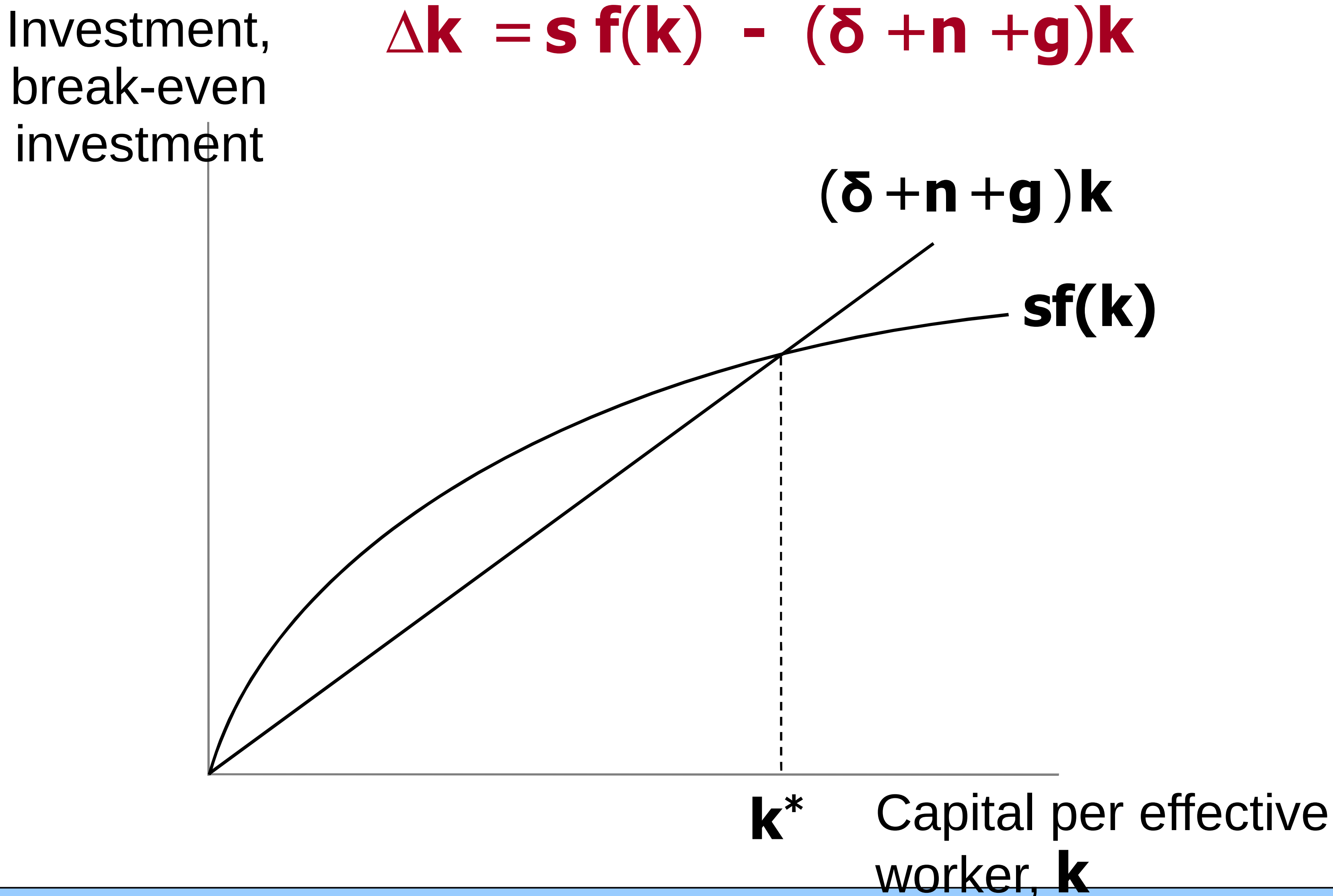
Consists of:

- $\boldsymbol{\delta}\,\boldsymbol{k}$ to replace depreciating capital
- $\boldsymbol{n}\,\boldsymbol{k}$ to provide capital for new workers
- $\boldsymbol{g}\,\boldsymbol{k}$ to provide capital for the new “effective” workers created by technological progress

8.1) Technological Progress (TP)

➔ SGM: Including TP (ctd.)

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



8.1) Technological Progress (TP)

➔ SGM with TP: Steady-State Growth Rates

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	$(Y/L) = y \times E$	g
Total output	$Y = y \times E \times L$	$n + g$

8.1) Technological Progress (TP)

➔ SGM with TP: The Golden Rule

To find the Golden Rule capital stock, express $\boldsymbol{c}^*$ in terms of $\boldsymbol{k}^*$:

$$\boldsymbol{c}^* = \boldsymbol{y}^* - \boldsymbol{i}^*$$

$$= \boldsymbol{f}(\boldsymbol{k}^*) - (\delta + \boldsymbol{n} + \boldsymbol{g})\,\boldsymbol{k}^*$$

$\boldsymbol{c}^*$ is maximized when

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

or equivalently,

$$MPK - \delta = \boldsymbol{n} + \boldsymbol{g}$$

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.

Learning Objectives

This chapter introduces you to understanding:

- technological progress in the Solow model ✓
- the connection between growth theory and growth empirics ⇐

8.2) Growth Empirics

➔该你们了

An economy described by the Solow growth model has the following production function: $y = k^{(1/2)}$.

a. Solve for the steady-state value of *y as a function* of *s, n, g, and δ.*

b. A developed country has a saving rate of 28 percent and a population growth rate of 1 percent per year. A less developed country has a saving rate of 10 percent and a population growth rate of 4 percent per year. In both countries, $g = 0.02$ and $\delta = 0.04$. *Find the* steady-state value of *y for each country.*

c. What policies might the less developed country pursue to raise its level of income?

8.2) Growth Empirics

➔ Balanced Growth

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 the same rate (***g***).

➔ 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.

8.2) 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?

8.2) Growth Empirics

➔ Convergence (ctd.)

- No, because “other things” aren’t equal.
- In samples of countries with similar savings & pop. growth rates, income gaps shrink about 2% per year.
- In larger samples, after controlling for differences in saving, pop. growth, and human capital, incomes converge by about 2% per year.

8.2) Growth Empirics

➔ Convergence (ctd.)

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.

➔ This prediction comes true in the real world.

8.2) Growth Empirics

➔ Factor Accumulation vs. Efficiency

- Differences in income per capita among countries can be due to differences in:

  1. capital – physical or human – per worker

  2. the efficiency of production
  (the height of the production function)

- Studies:

  1. Both factors are important.

  2. The two factors are correlated: countries with higher physical or human capital per worker also tend to have higher production efficiency.

8.2) Growth Empirics

➔ Factor Accumulation vs. Efficiency (ctd.)

Possible explanations for the correlation between capital per worker and production efficiency:

1. Production efficiency encourages capital accumulation.
2. Capital accumulation has externalities that raise efficiency.
3. A third, unknown variable causes capital accumulation and efficiency to be higher in some countries than others.

8.2) 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%

8.2) Growth Empirics

➔ Production Efficiency and Free Trade

- To determine causation, Frankel and Romer exploit geographic differences among countries:
- Some nations trade less because they are farther from other nations, or landlocked.
- Such geographical differences are correlated with trade but not with other determinants of income.
- Hence, they can be used to isolate the impact of trade on income.
- Findings: increasing trade/GDP by 2% causes GDP per capita to rise 1%, other things equal.

Summary

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