CHAPTER 8

Economic Growth II: Technology, Empirics, and Policy

MACROECONOMICS SIXTH EDITION

N. GREGORY MANKIW

PowerPoint® Slides by Ron Cronovich

In this chapter, you will learn…

- how to incorporate technological progress in the Solow model
- about growth empirics: confronting the theory with facts
- about policies to promote growth
- a simple model 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:
- 1904-2004: U.S. real GDP per person grew by a factor of 7.6, or 2% 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.
- Percentage of U.S. households with ≥ 1 computers: 8% in 1984, 62% in 2003
- 1981: 213 computers connected to the Internet
  2000: 60 million computers connected to the Internet

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:

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

Technological 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.
  - Increases in labor efficiency have the same effect on output as increases in the labor force.

Technological progress in the Solow model

- Notation:
  $y = Y/LE$ = output per effective worker
  $k = K/LE$ = capital per effective worker
- Production function per effective worker:
  $y = f(k)$
- Saving and investment per effective worker:
  $sy = sf(k)$

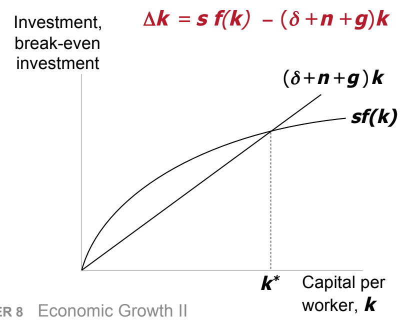
Technological progress in the Solow model

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

Consists of:

- δk to replace depreciating capital
- nk to provide capital for new workers
- gk to provide capital for the new "effective" workers created by technological progress

Technological progress in the Solow model



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

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
$MPK = \delta + n + g$

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: 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), so 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.
  - This is also true in the real world.

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

- Solow model predicts that, other things equal, "poor" countries (with lower ***Y***/***L*** and ***K***/***L***) should grow faster than "rich" ones.
- 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.

Growth empirics: Convergence

- 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.

Growth empirics: Factor accumulation vs. production 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:
  - both factors are important.
  - the two factors are correlated: countries with higher physical or human capital per worker also tend to have higher production efficiency.

Growth empirics: Factor accumulation vs. production efficiency

- Possible explanations for the correlation between capital per worker and production efficiency:
  - Production efficiency encourages capital accumulation.
  - Capital accumulation has externalities that raise efficiency.
  - A third, unknown variable causes capital accumulation and efficiency to be higher in some countries than others.

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%

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.

Policy issues

- Are we saving enough? Too much?
- What policies might change the saving rate?
- 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. 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**:

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

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**:

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

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

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

Policy issues: How 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.

Policy issues: Establishing the right institutions

- Creating the right institutions is important for ensuring that resources are allocated to their best use. Examples:
  - Legal institutions, to protect property rights.
  - Capital markets, to help financial capital flow to the best investment projects.
  - A corruption-free government, to promote competition, enforce contracts, etc.

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

Possible explanations for the productivity slowdown

- *Measurement problems:*
  Productivity increases 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?

Possible explanations for the productivity slowdown

- *Worker quality:*
  1970s - large influx of new entrants into labor force (baby boomers, women).
  New workers tend to be less productive than experienced workers.
- *The depletion of ideas:*
  Perhaps the slow growth of 1972-1995 is normal, and the rapid growth during 1948-1972 is the anomaly.

CASE STUDY: I.T. and the "New Economy"

	Growth in output per person (percent per year)		
	1948-72	1972-95	1995-2004
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CASE STUDY: I.T. and the "New Economy"

Apparently, the computer revolution did not 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, open question:

- How long will I.T. remain an engine of growth?

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

A basic model

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

- Divide through by K and use $Y = AK$ to 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?

- Depends on definition of "capital."
- If "capital" is narrowly defined (only plant & equipment), then yes.
- Advocates of endogenous growth theory argue that knowledge is a type of capital.
- If so, then constant returns to capital is more plausible, and this model may be a good description of economic growth.

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 is 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.