Economic Growth and Technological Progress

GRADUATE MACRO – LAB SESSION 12

ETTORE GALLO

Class Outline

1. **Ch. 11: Saving, Capital Accumulation, and Output (Solow Model)**

   11-1 Interactions between Output and Capital

   11-2 The Implications of Alternative Saving Rates

   11-3 Getting a Sense of Magnitudes

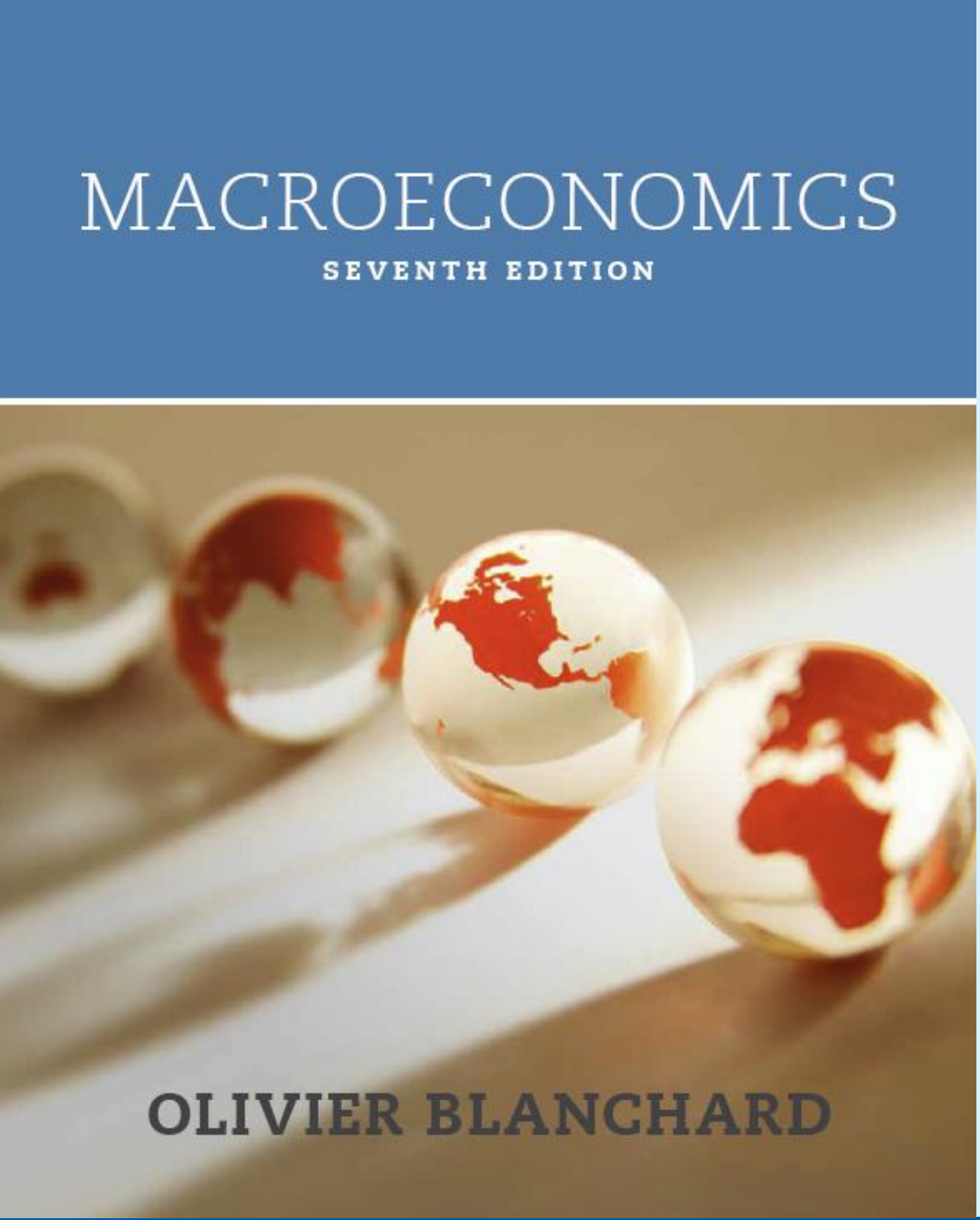
2. **Ch. 12: Technological Progress and Growth (Extended Solow Model)**

   12-1 Technological Progress and the Rate of Growth

   12-2 The Determinants of Technological Progress

   12-3 Institutions, Technological Progress, and Growth

   12-4 The Facts of Growth Revisited



Technological Progress and Growth

Chapter 12

Technological Progress and Growth

- Chapter 11: relation between saving rates, capital accumulation and economic growth

  → ***Solow Model***

- Chapter 12: the role of technological progress in growth

  → ***Extended Solow Model***

12-1 Technological Progress and the Rate of Growth

- Technological progress can lead to:
  - larger quantities of output for given quantities of capital and labor
  - better products
  - new products
  - a large variety of products
- The **state of technology** (A) is a variable that tells us how much output can be produced from given amounts of capital and labor at any time:

$$Y = F(K, AN) \tag{12.1}$$

so AN is the amount of **effective labor *(or labor in efficiency units)***.

12-1 Technological Progress and the Rate of Growth

- With **constant returns to scale** and a given state of technology (A), if the amounts of capital and labor changes by *x* times, output changes by *x* times:

$$xY = F(xK, xAN)$$

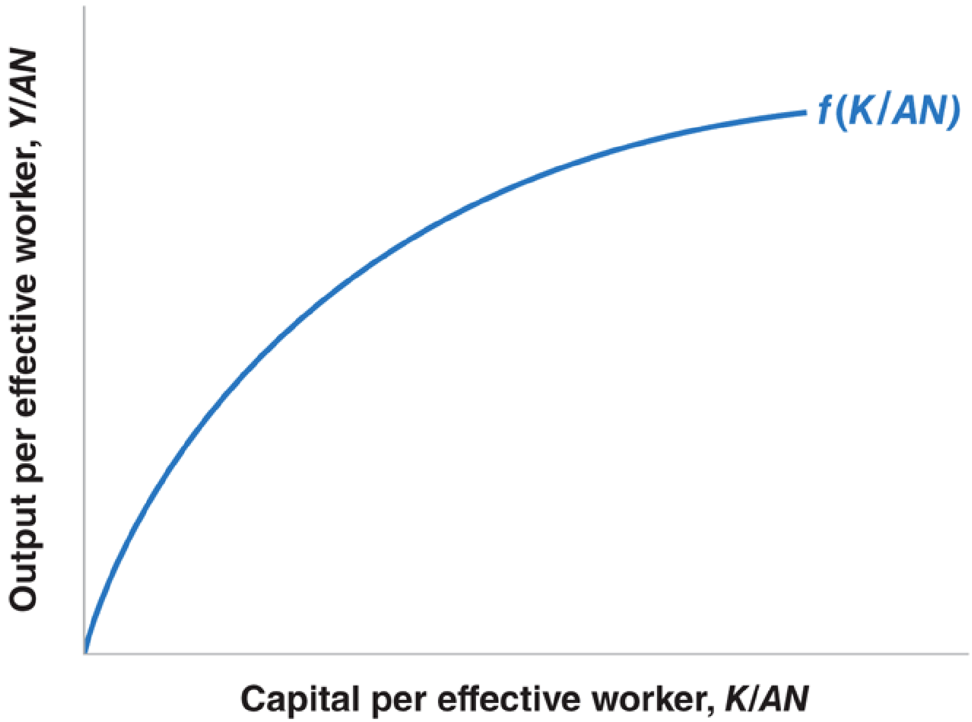
- If $x = 1/AN$, *output per effective worker* is a function of *capital per effective worker*:

$$\frac{Y}{AN} = f\left(\frac{K}{AN}\right) \qquad (12.2)$$

12-1 Technological Progress and the Rate of Growth

Figure 12-1 Output per Effective Worker versus Capital per Effective Worker

Because of decreasing returns to capital, increases in capital per effective worker lead to smaller and smaller increases in output per effective workers.



12-1 Technological Progress and the Rate of Growth

- Recall Chapter 11: $I = S = sY$, so that equation (12.2) becomes (lower curve in Figure 12-2):

$$\frac{I}{AN} = sf\left(\frac{K}{AN}\right)$$

- The line in Figure 12-2 shows the level of investment per effective worker needed to maintain a given level of capital per effective worker because:

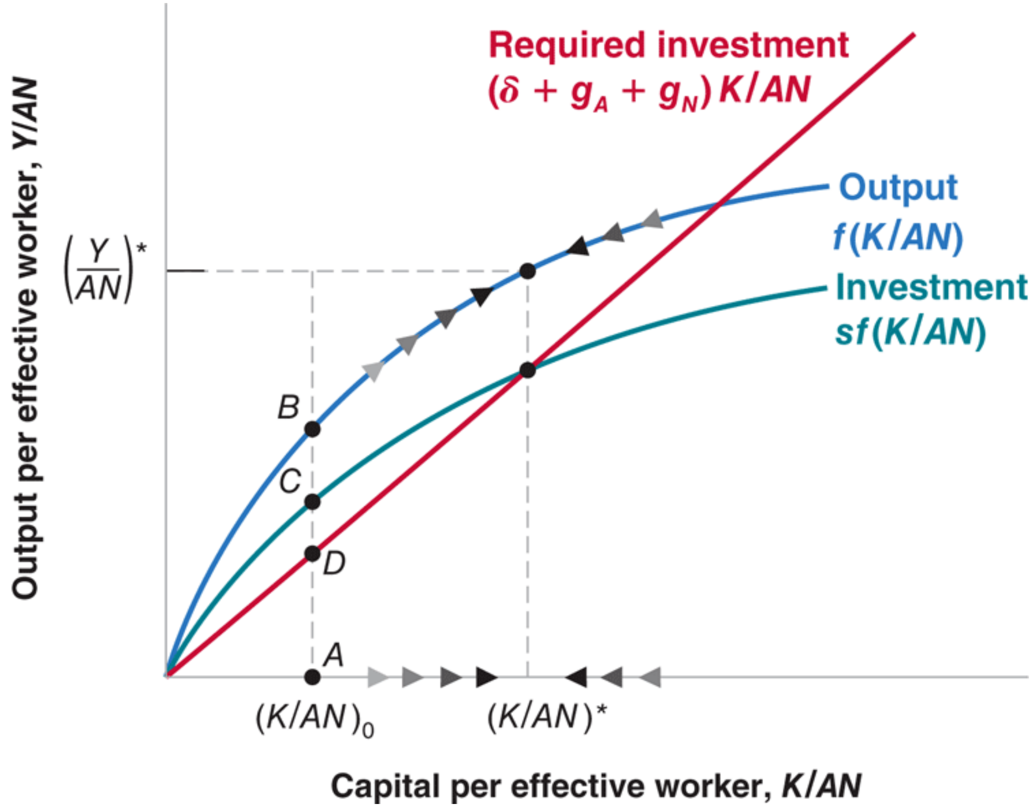
$$I = (\delta + g_A + g_N)K \qquad (12.3)$$

where δ is the capital depreciation rate, g_A is the rate of technological progress, and g_N is the rate of population growth.

12-1 Technological Progress and the Rate of Growth

Figure 12-2 The Dynamics of Capital per Effective Worker and Output per Effective Worker

Capital per effective worker and output per effective worker converge to constant values in the long run.



12-1 Technological Progress and the Rate of Growth

- The steady state of the economy is such that capital per effective worker and output per worker are constant, and equal to $(K/AN)^*$ and $(Y/AN)^*$, respectively.
- When the economy is in steady state, output per worker grows at the rate of technological progress (g_A).

12-1 Technological Progress and the Rate of Growth

Table 12-1 The Characteristics of Balanced Growth

		Growth Rate:
1	Capital per effective worker	0
2	Output per effective worker	0
3	Capital per worker	g_A
4	Output per worker	g_A
5	Labor	g_N
6	Capital	$g_A + g_N$
7	Output	$g_A + g_N$

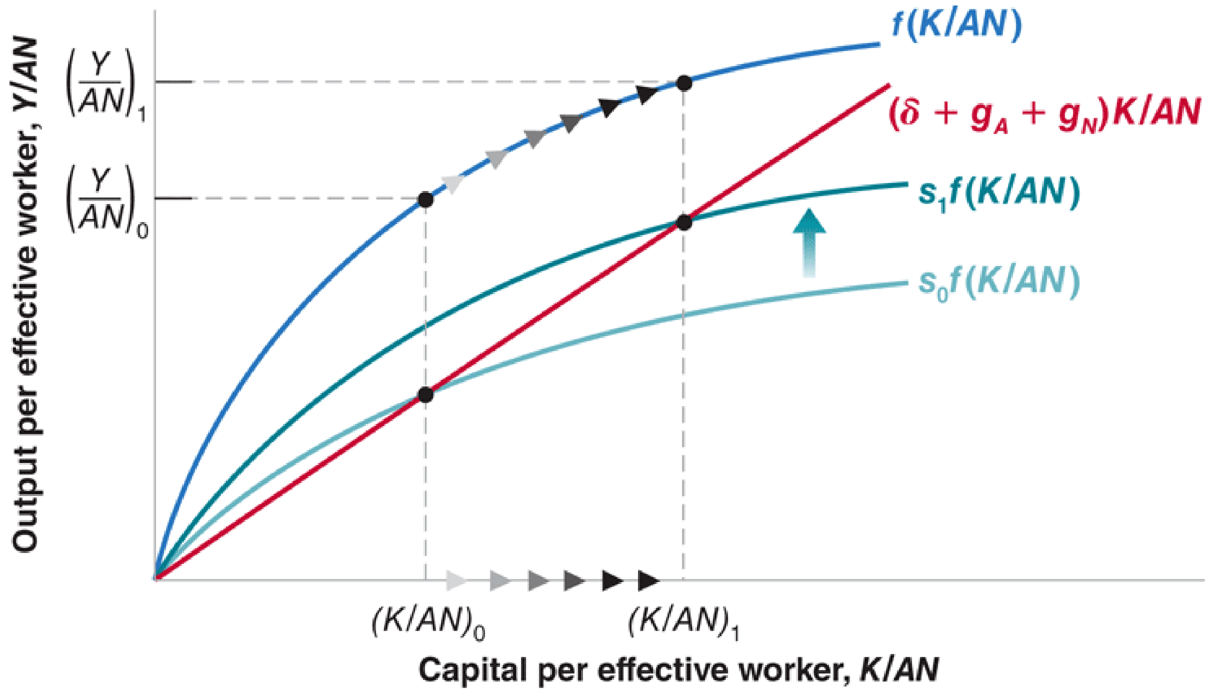
12-1 Technological Progress and the Rate of Growth

- On the balanced growth path (steady state or long run):
  - Capital per effective worker and output per worker are constant.
  - Capital per worker and output per worker are growing at the rate of technological progress.
  - Capital and output are growing at a rate equal to the sum of population growth and the rate of technological progress.

12-1 Technological Progress and the Rate of Growth

Figure 12-3 The Effects of an Increase in the Saving Rate: I

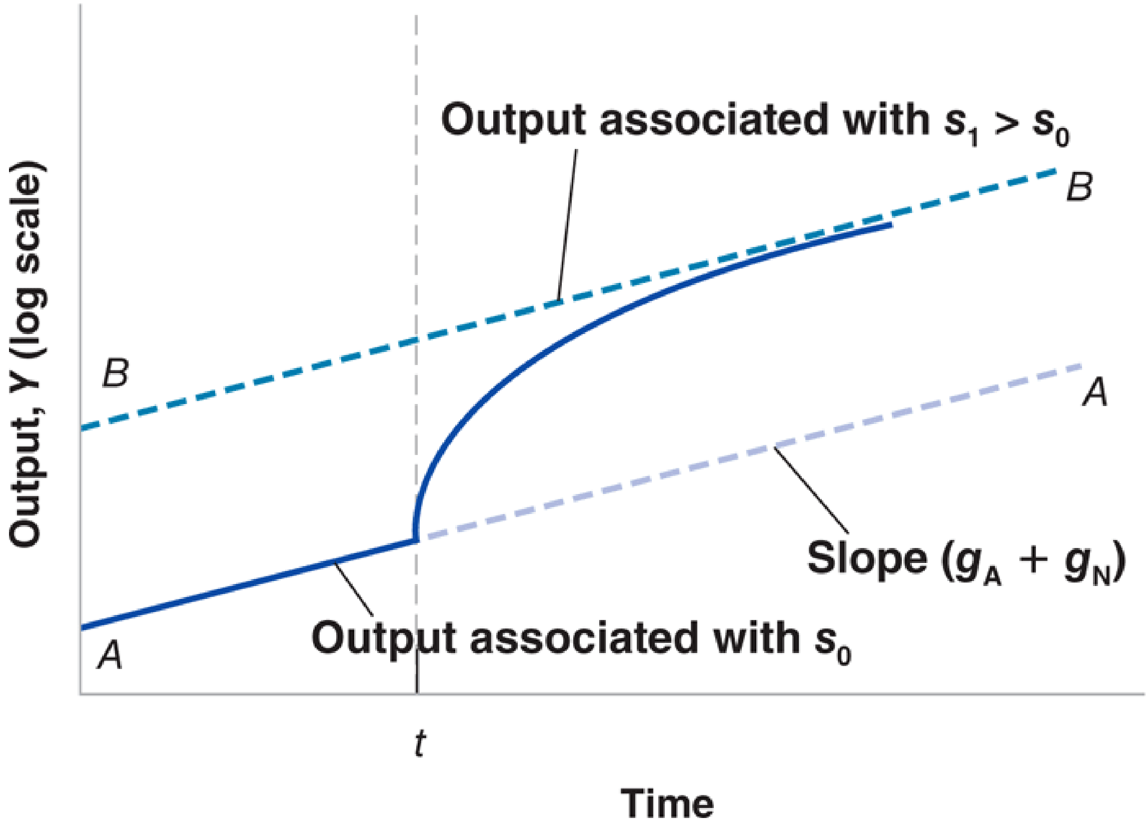
An increase in the saving rate leads to an increase in the state-state levels of output per effective worker and capital per effective worker.



12-1 Technological Progress and the Rate of Growth

Figure 12-4 The Effects of an Increase in the Saving Rate: II

The increase in the saving rate leads to higher growth until the economy reaches its new, higher, balance growth path.



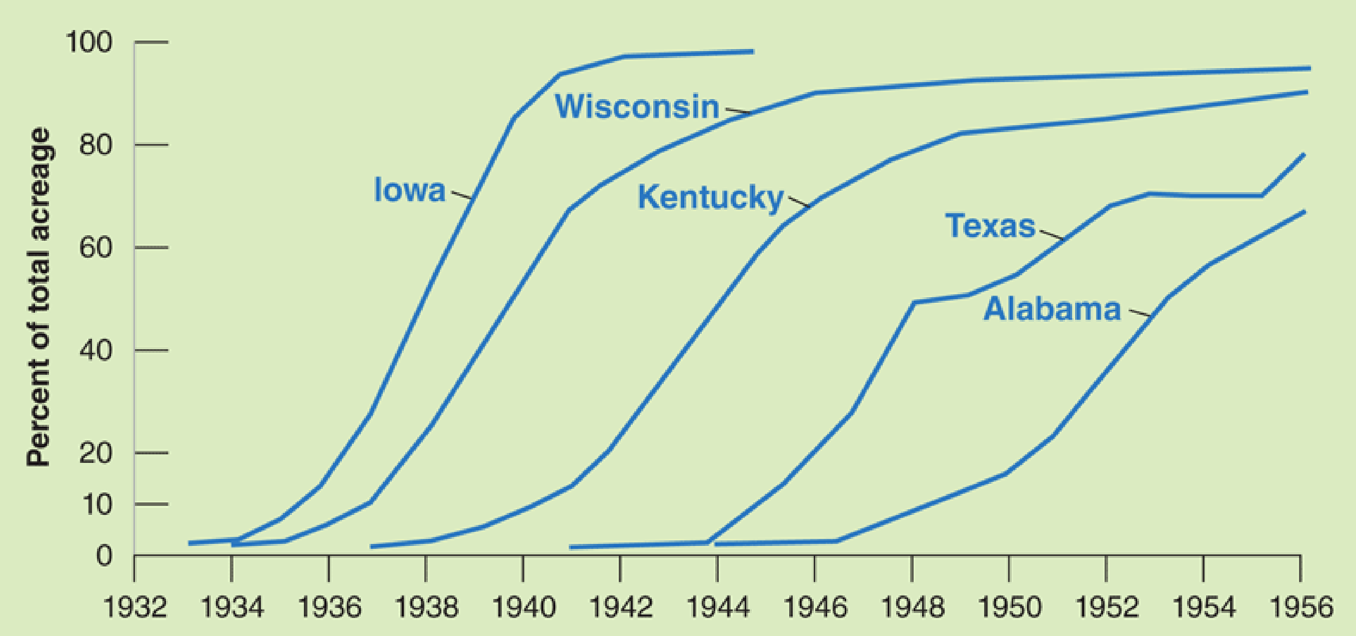
12-2 The Determinants of Technological Progress

- Most technological progress is the outcome of firms' research and development (R&D) activities.
- The level of R&D spending depends not only on the **fertility of research** (how spending on R&D translates into new ideas and new products) but also on the **appropriability** of research results (the extent to which firms can benefit from the results of their own R&D).
- **Patents** give a firm that has discovered a new product the right to exclude anyone else from the production or use of that new product for some time.

FOCUS: The Diffusion of New Technology: Hybrid Corn

Figure 1 Percentage of Total Corn Acreage Planted with Hybrid Seed, Selected U.S. States, 1932–1956

Each state's speed of adopting hybrid corn, which increased the corn yield by up to 20%, was a function of its profitability.



Source: Zvi Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change," *Econometrica*, 1957, Vol 25, No. 4, pp 501–522.

FOCUS: Management Practices: Another Dimension of Technological Progress

- Some researchers believe that management practices might be stronger than many of the other factors that determine a firm’s performance, including technological innovations.
- In a study of management practices and performance of more than 4,000 medium-sized manufacturing operations in Europe, the U.S. and Asia, two economists found that firms used the same technology but applied good management practices perform significantly better than those that did not.

12-2 The Determinants of Technological Progress

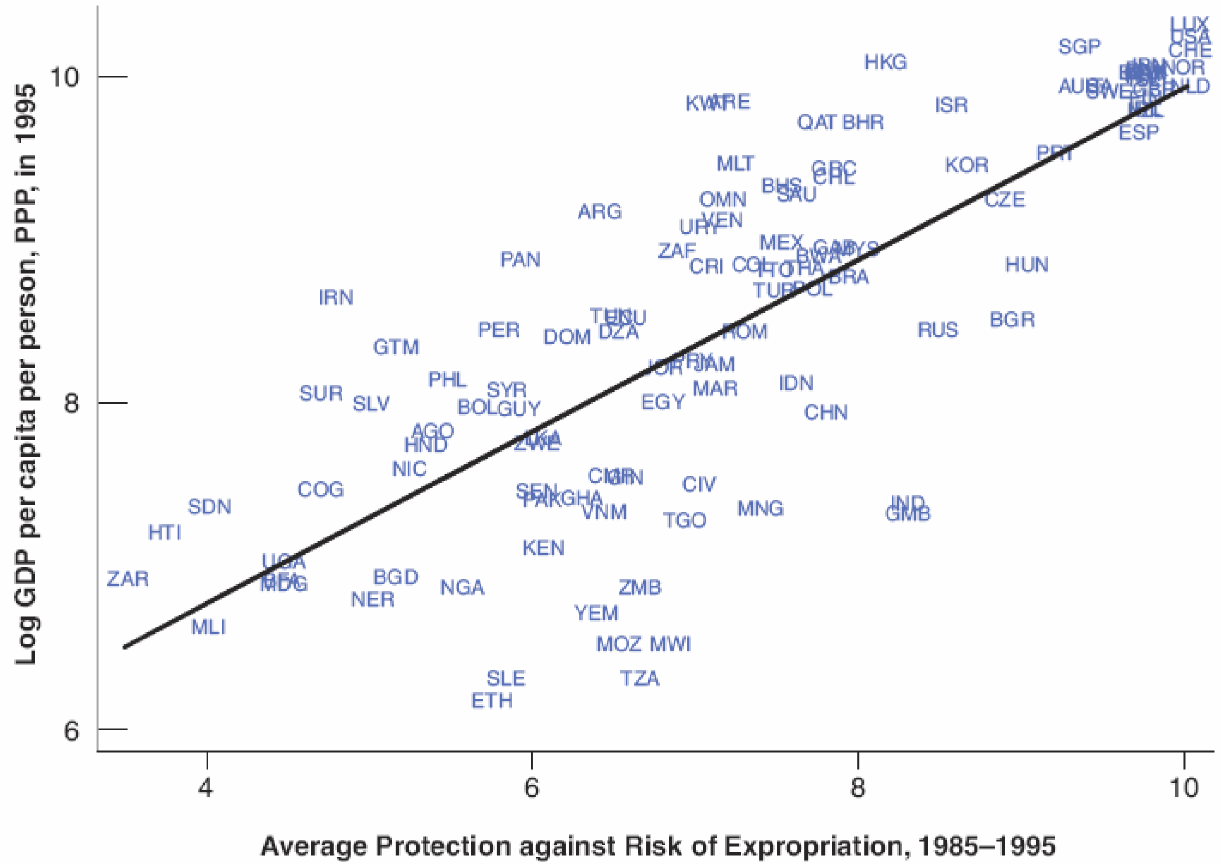
- To sustain growth, advanced countries that are at the technology frontier must innovate.
- The difference between innovation and imitation explains why countries that are less technologically advanced often have poor patent protection.

12-3 Institutions, Technological Progress, and Growth

Figure 12-5 Protection from Expropriation and GDP per Person

There is a strong positive relation between the degree of protection from expropriation and the level of GDP per person.

This highlights the importance of the protection of **property rights**.

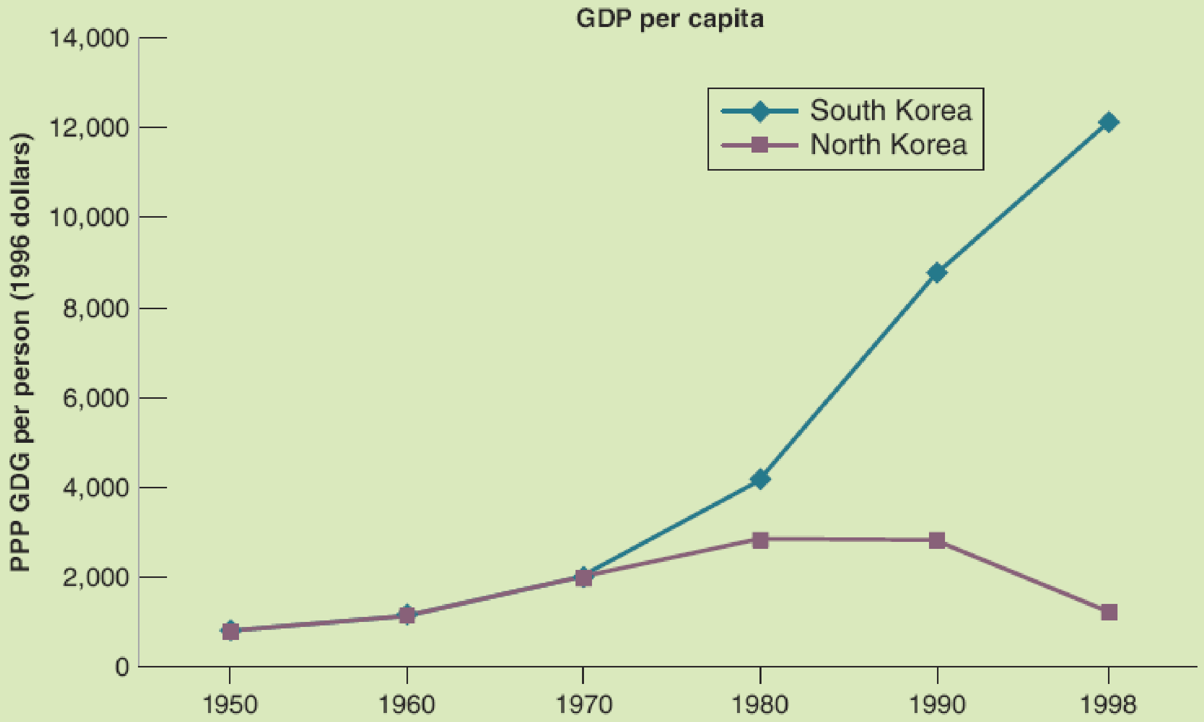


Source: Daron Acemoglu, "Understanding Institutions," Lionel Robbins Lectures, 2004. London School of Economics. http://economics.mit.edu/files/1353.

FOCUS: The Importance of Institutions: North Korea and South Korea

Figure 1 PPP GDP per Person: North and South Korea, 1950−1998

After the Korean War, South Korea has provided private ownership and legal protection of private producers, while North Korea relied on central planning with no property rights for individuals.
Fifty years later, GDP per person was 10 times higher in South Korea.



Source: Daron Acemoglu, "Understanding Institutions," Lionel Robbins Lectures, 2004. London School of Economics. http://economics.mit.edu/files/1353.

FOCUS: What Is Behind Chinese Growth?

- Average growth of output per worker in China has increased from 2.5% between 1977, to more than 9% since then.
- Unlike Central and Eastern Europe, China's state sector has declined slowly and that decline has been more than compensated by strong private sector growth.
- Also, the Chinese political system did not change, and the government was able to control the pace of transition to a market economy.
- As property rights are still not well established and the banking system is still inefficient, the limits of Chinese growth are clear.

12-4 The Facts of Growth Revisited

Table 12-2 Average Annual Rates of Growth of Output per Worker and Technological Progress in Four Rich Countries since 1985

	Rate of Growth of Output per Worker (%) 1985–2014	Rate of Technological Progress (%) 1985–2013
France	1.3	1.4
Japan	1.6	1.7
United Kingdom	1.9	1.4
United States	1.7	1.4
Average	1.6	1.5

Source: Calculations from the OECD Productivity Statistics.

- Over the period 1985–2014, output per worker has grown at rather similar rates across the five countries.
- Growth since 1985 has mostly come from technological progress, not from unusually high capital accumulation.

12-4 The Facts of Growth Revisited

Table 12-3 Average Annual Rate of Growth of Output per Worker and Technological Progress in China, 1978–2011

Period	Rate of Growth of Output (%)	Rate of Growth of Output per Worker (%)	Rate of Technological Progress (%)
1978–1995	10.1	7.4	7.9
1996–2011	9.8	8.8	5.9

Source: Penn World Table version 8.1.

- Over the period 1978–1995, China was on a balanced growth path as the rate of technological progress was close to the rate of growth of output per worker.
- Since 1996, although growth of output per worker has remained high, the contribution of technological progress has decreased.
- Technological progress in China comes from productivity growth due to labor transferring from the countryside to cities, and imported technology from more technologically advanced countries.

APPENDIX: Constructing a Measure of Technological Progress

- In 1957, Robert Solow devised a way to construct an estimate of technological progress under the assumption that each factor of production is paid its marginal product.
- Denote output by *Y*, labor by *N*, and the real wage by *W/P*, and the symbol Δ as change, so

$$\Delta Y = \frac{W}{P}\Delta N$$

- Rearrange terms to get:

$$\frac{\Delta Y}{Y} = \frac{WN}{PY}\frac{\Delta N}{N}$$

or in symbols:

$$g_Y = \alpha g_N$$

APPENDIX: Constructing a Measure of Technological Progress

- The growth in output attributable to growth in both labor and capital is equal to $(g_N + (1 - \alpha)g_K)$.
- The **rate of growth of total factor productivity** (or the **rate of TFP growth**), also called the **Solow residual**, measures the effects of technological progress as:

$$\text{residual} = g_N - (g_N + (1 - \alpha)g_K)$$

- The Solow residual is also equal to the share of labor times the rate of technological progress:

$$\text{residual} = \alpha g_A$$