Lecture 11: Technological Progress and Growth

Intermediate Macroeconomics, Econ 102

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Summarizing

- In the Solow (1956) growth model, sustained economic growth **cannot come from capital accumulation alone**.
- Indeed, we saw that in the long run, there is convergence of K^*/N for a given saving rate s.
- In this lecture, we ask conceptually where sustained economic growth might instead come from.

Technological Progress and the Production Function

- Technological progress may lead to:
  1. larger quantities of output for given quantities of capital and labor. (think of new management practices, which makes a firm more efficient)
  2. better products. (computers...)
  3. new products. (self-driving cars...)
  4. a larger variety of products. (toothpastes...)

- 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:

$$Y = F(K, N, A)$$

  with Y increasing in A.

- We shall use a more restrictive version of that specification:

$$Y = F(K, AN)$$

  so AN is the amount of **effective labor**.

Technological Progress and the Production Function

- Technological progress reduced the number of workers needed to produce a given amount of output. What matters is only AN.

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

$$xY = F\left(xK, xAN\right)$$

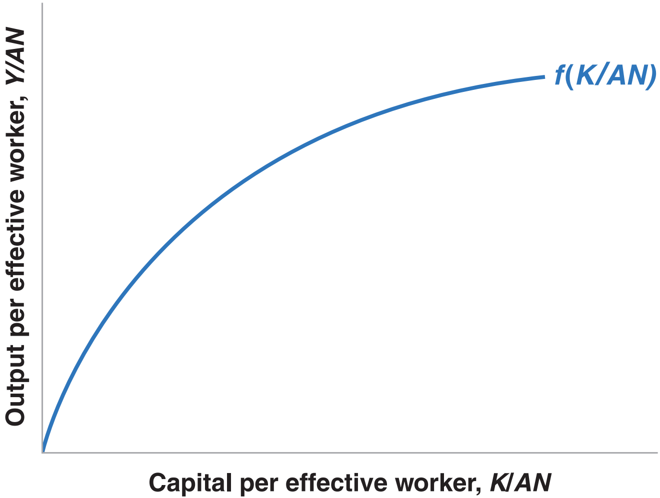
- If $x = 1/AN$, output per effective worker is a function of capital per effective worker:

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

- For example, you could think the following "double square root" function:

$$Y = F(K, AN) = \sqrt{K}\sqrt{AN} \quad \Rightarrow \quad \frac{Y}{AN} = \sqrt{\frac{K}{AN}}.$$

Output per Effective Worker versus Capital per Effective Worker



Interactions between output and capital

- Again, as for the Solow (1956) growth model, we shall assume that investment is just private saving, and that the saving rate is constant and equal to s. Therefore:

$$I = S = sY$$

  so this implies

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

- What is the level of investment per effective worker that is needed to maintain a given level of capital per effective worker?
- In Solow (1956), investment had to be equal to the depreciation of the existing capital stock.

Interactions between output and capital

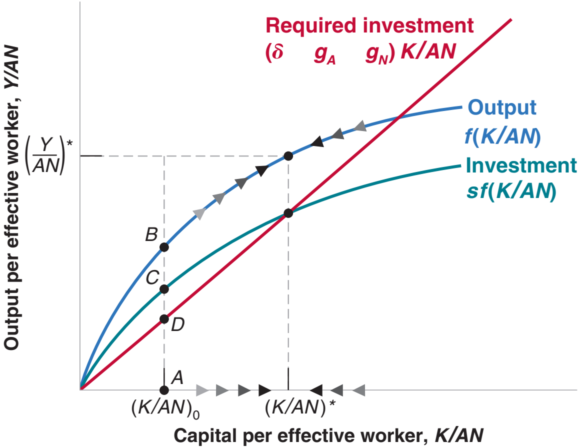
- Assume that the growth rate of A is equal to g_A, and since we are at it, that population also grows at g_N.
- To maintain the same level of K/AN, K must then clearly grow at rate $g_A + g_N$.
- The level of investment per effective worker needed to maintain a given level of capital per effective worker is therefore:

$$I = (\delta + g_A + g_N)\, K$$

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

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.



The Characteristics of Balanced Growth

Table 12-1 The Characteristics of Balanced Growth

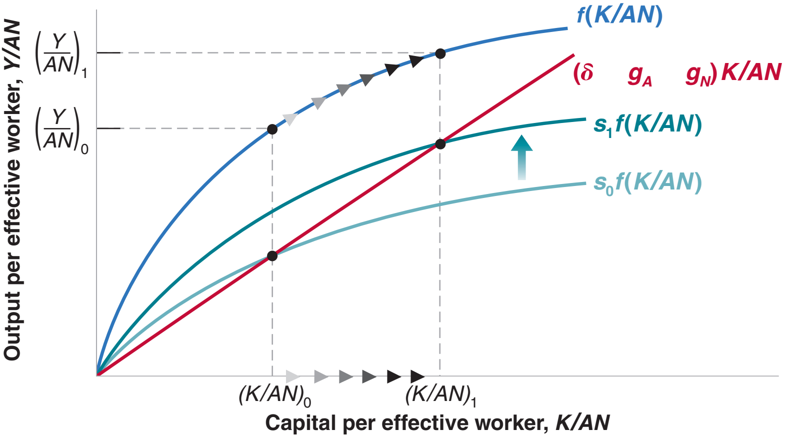
		Growth Rate:
1	Capital per effective worker	0
2	Output per effective worker	0
3	Capital per worker	g_A
4	Output per worker	g_A
5	Labor	g_N
6	Capital	$g_A + g_N$
7	Output	$g_A + g_N$

The Characteristics of Balanced Growth

- On the balanced growth path (steady state or long run):
  - Capital **per effective worker** and **output per effective 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.

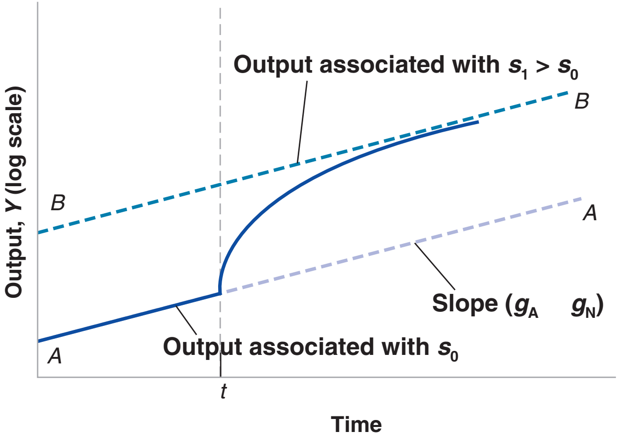
The Effects of an Increase in the Saving Rate 1/2

- 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.



The Effects of an Increase in the Saving Rate 2/2

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

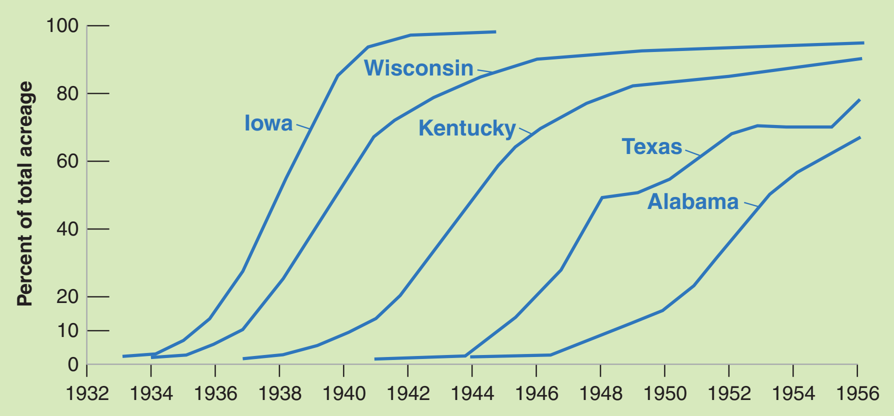


The Fertility of the Research Process

- 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. It is absolutely crucial to incentivize innovation, at the same time restricts access.

The Diffusion of New Technology: Hybrid Corn

Each state's speed of adopting hybrid corn, which increased the corn yield by up to 20%, was a function of its profitability: it was higher in Iowa, than in Alabama.

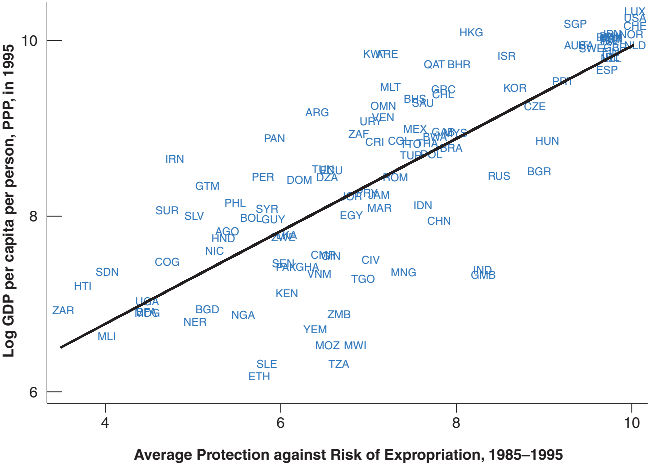


The Determinants of Technological Progress

- To sustain growth, advanced countries that are at the technology frontier must **innovate**.
- Poorer countries, which are further from the technology frontier, can instead grow largely by **imitating** rather than innovating, by importing and adapting existing technologies instead of developing new ones.
- This difference explains why countries that are less technologically advanced often have **poor patent protection**.

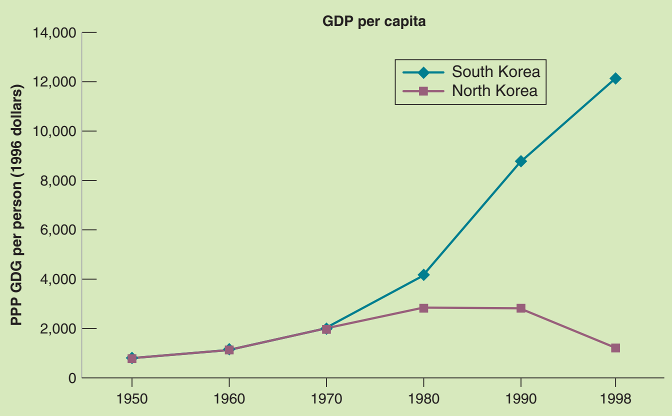
Protection from Expropriation and GDP per Person

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**.



The Importance of Institutions: North Korea and South Korea

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.



What Is Behind Chinese Growth?

- Average growth of output per worker in China has increased from 2.5% between 1952 and 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.

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.

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.

Readings

Chapters 12-13, *Macroeconomics*, 7th Edition, Olivier Blanchard.

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