

**Problem 1.** Match things.

(a) economic growth

(b) real GDP

(c) average labor productivity

(d) real GDP divided by the population

(e) technological progress

(f) human capital

(i) long-term increases in the aggregate level of output

(ii) the index economists use to represent the aggregate level of output

(iii) the amount of output produced by one unit of labor, on average

(iv) real GDP per capita

(v) increase in know-how related to the production of goods and services

(vi) knowledge and skills possessed by a person

**Answer 1.** Definitions are as follows:

- **economic growth:** long-term increases aggregate output
- **real GDP:** the index economists use to represent the aggregate level of output
- **average labor productivity:** the amount of output produced by one unit of labor, on average; mathematically given as  $Y/L$
- **real GDP divided by the population:** real GDP per capita, mathematically given as  $Y/N$
- **technological progress:** increase in know-how related to the production of goods and services
- **human capital:** knowledge and skills possessed by a person

**Problem 2.** Match more things.

- (a) knowledge capital
- (b) neoclassical theory
- (c) new growth theory
- (d) endogenous technological progress

- (i) total stock of knowledge possessed by the whole society
- (ii) growth theory in which technological progress is exogenous
- (iii) growth theory in which technological progress is endogenous
- (iv) technological progress that happens because of investments in research and development activities

**Answer 2.** Definitions are as follows:

- **knowledge capital:** total stock of knowledge possessed by the whole society
- **neoclassical theory:** growth theory in which technological progress is exogenous—it is left unexplained and is simply taken as a given
- **new growth theory:** growth theory in which technological progress is endogenous—it is explained within the model itself
- **endogenous technological progress:** technological progress that happens because of investments in research and development activities. This is the main feature of new growth theory. These models explain why technological progress takes place—in particular, because firms spend money on research and development.

**Problem 3.** *True or False.* One way to increase labor productivity is to increase the amount of capital per worker.

**Answer 3: True.** Labor productivity is output per worker,  $Y/L$ . If you give everyone more capital with which to work (e.g. more tools per worker), then those same people will produce more output and therefore will be more productive.

**Problem 4.** *True or False.* One way to increase capital per worker is to encourage saving by households.

**Answer 4: True.** When households save more money, that money becomes loanable funds. This amounts to an increase in the supply of loanable funds, which reduces the real interest rate. This means firms are willing to invest more, and therefore more capital will be accumulated with time. This is what the **Solow model** implies.

**Problem 5.** The difference between physical/human capital and knowledge capital is that

- (a) physical and human capital are nonrival and are subject to diminishing returns
- (b) physical and human capital are rival and not subject to diminishing returns
- (c) knowledge capital is rivalrous and not subject to diminishing returns
- (d) knowledge capital is nonrivalrous and not subject to diminishing returns
- (e) none of the above

**Answer 5: d.** Physical and human capital are

- **rivalrous.** Use by one agent prevents another agent from using it. For example, two farmers can't use the same tractor (physical capital) at the same time; an athlete can't play a game of football and a game of basketball at the same time (human capital).
- **subject to diminishing returns.** Every additional unit generates less new output than did the previous unit. Adding another tractor will make the farmer more productive, but not as much as the first tractor did.

Knowledge capital is

- **non-rivalrous.** Me using one idea does not prevent you from using the very same idea.
- **not subject to diminishing returns.** Me using an idea doesn't make the same idea less useful to someone else.

This means that knowledge capital has *positive spillover effects*. A good new idea discovered by one person or firm will eventually be used by others, which makes society as a whole more productive via the increase in knowledge capital.

**Problem 6.** Classical economic theory says that the per-worker production function should exhibit diminishing returns. What would a graph of this look like? What does the graph look like according to the data? How can we explain this shape?

**Answer 6.** As shown on the next page, the concave shape on the left is what theory suggests the per-worker production function should be. But the data shows a relatively straight line. According to new growth theory, there are no diminishing returns associated with knowledge capital at the national level due to technological progress and the fact that knowledge capital is not subject to diminishing returns. This is shown in the figure on the right.



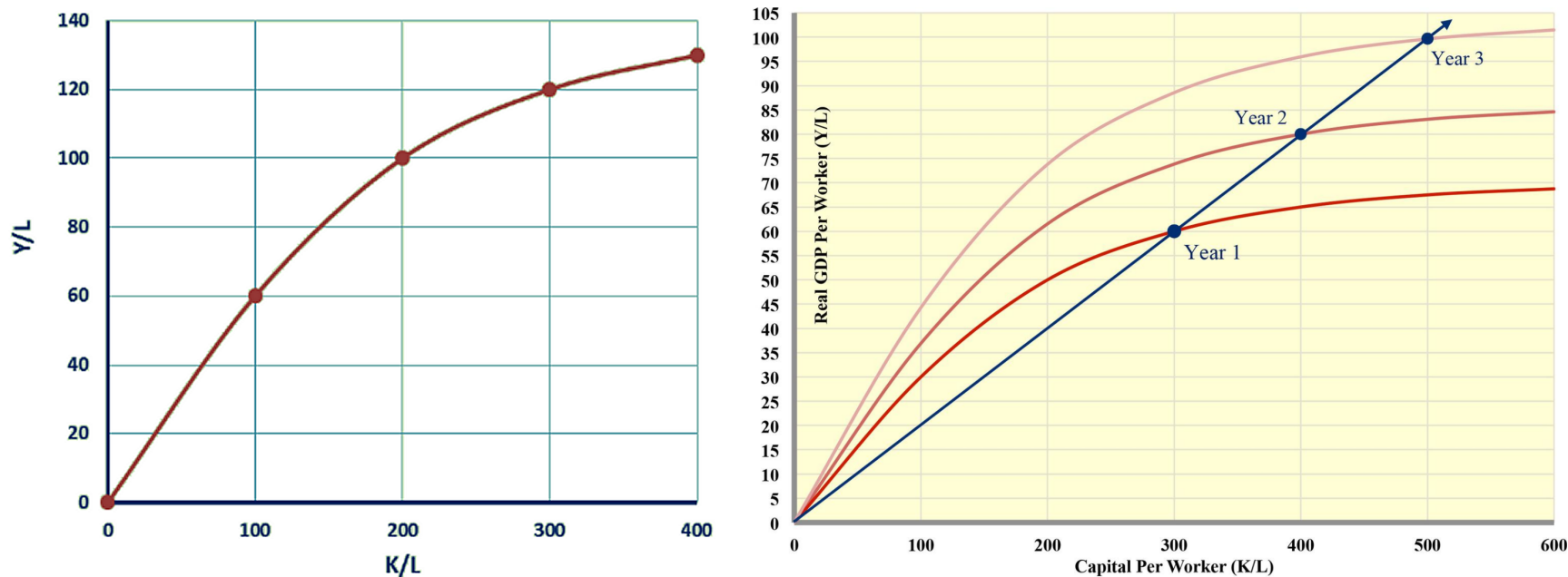


Figure 1: Improvement in technology skews the production function upwards over time, yielding constant returns to research and development in the aggregate.

**Problem 7.** Which of the following are long-run factors of growth?

- (a) capital accumulation
- (b) technological progress
- (c) population growth
- (d) amount of natural resources
- (e) all of the above
- (f) none of the above

**Answer 7: e.** Factors of long-run economic growth are:

- (a) capital accumulation—more machines, more production.
- (b) technological progress—better machines, more production.
- (c) population growth—more population, more workers, more production.
- (d) amount of natural resources—more raw materials, more machines, more production.

Note that it is a combination of these things that is important for growth. Hong Kong, for instance, does not have much in natural resources, but it has good institutions, has accumulated both physical and human capital, and is technologically advanced.

Governments can try to increase capital per worker by offering tax incentives to firms to invest in more R&D, like patent laws; or by giving households incentives to save more, which also results in more investment. An efficient financial system helps funnel funds to productive endeavors.

New growth theory economists argue that differences in growth and wealth are rooted in differences in **economic institutions**.

- Without proper protection of your private property, you will not have much incentive to save in order to accumulate wealth. This could happen from lack of legal enforcement or from government tyranny.
- Low quality institutions reduce the incentive to invest in new capital. If property rights are lacking, firms don't want to invest because another firm can just come and take their stuff. If the government is tyrannical, they could also just take your stuff or profits.

Comparing South to North Korea; Hong Kong to mainland China; and West to East Germany are all illustrative. (Also note that all comparisons here are capitalist democracies versus centrally-planned regimes.)

**Problem 8.** Consider an economy with the following data:

civilian population: 100,  
labor force: 80,  
employed: 60,  
real GDP: 24,000.

Find the following:

- (a) labor force participation rate
- (b) employment rate
- (c) average labor productivity
- (d) real GDP per capita

**Answer 8.** The relevant calculations are:

**(a)** Labor force participation rate is

$$\frac{LF}{N} = \frac{80}{100} = 80\%.$$

**(b)** Employment rate is

$$\frac{L}{LF} = \frac{60}{80} = 75\%.$$

**(c)** Average labor productivity is real GDP divided by workers:

$$\frac{Y}{L} = \frac{24,000}{60} = 400.$$

**(d)** Real GDP per capita is real GDP divided by the civilian population:

$$\frac{Y}{N} = \frac{24,000}{100} = 240.$$

**Problem 9.** In a country, the labor force participation rate is 75%, the employment rate is 90%, and the average labor productivity is 40,000 units of output. In this country, the output per capita equals what?

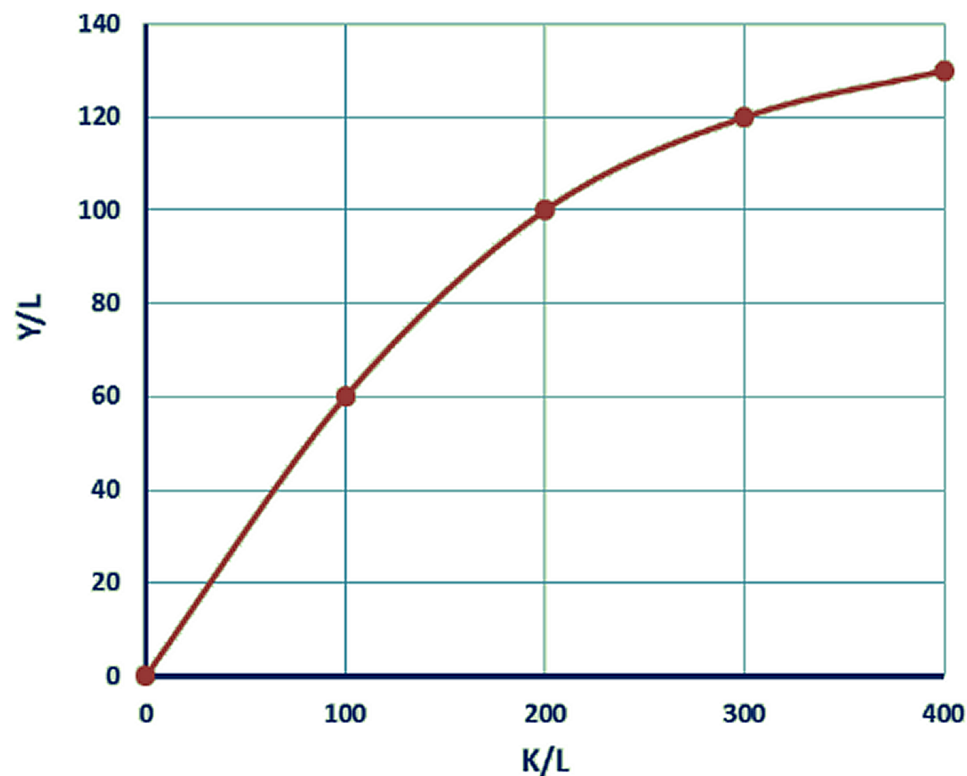
**Answer 9.** The relevant formulas are

labor force participation rate:  $\frac{LF}{N}$ , employment rate:  $\frac{L}{LF}$ ,

average labor productivity:  $\frac{Y}{L}$ , output per capita:  $\frac{Y}{N}$ .

Per-capita GDP can be decomposed into the following product:

$$\begin{aligned}\frac{Y}{N} &= \frac{Y}{L} \times \frac{L}{LF} \times \frac{LF}{N} \\ &= 40,000 \times 0.90 \times 0.75 \\ &= 27,000 \text{ output per civilian.}\end{aligned}$$

**Problem 10.**

LFPR: 50%

employment rate: 90%

physical capital  $K$ : 300,000

employed people  $L$ : 1,500

What is the average labor productivity? What is GDP per capita?

**Answer 10.**  $K/L$  is  $300,000/1,500 = 200$ . And therefore average labor productivity is  $Y/L = 100$ .

GDP per capita, again, can be decomposed as follows:

$$\begin{aligned}\frac{Y}{N} &= \frac{Y}{L} \times \frac{L}{LF} \times \frac{LF}{N} \\ &= 100 \times 0.90 \times 0.50 \\ &= 45.\end{aligned}$$