

Answers to Questions: Chapter 11

1. The great question of economic growth is, why is there such a great and growing gap between the standards of living in rich and poor nations? In the context of that question, when we consider a country as being rich or poor, we ask how well off is the average person in the country, not how much is produced in the country. To make this clear, consider Country A, which has a total output that is twice as large as that of Country B, but has a population that is 20 times greater than Country B. Note the average income of a person in Country B is 10 times greater than that of a person in Country A. Therefore, the average person in Country B is much better off than the average person in Country A, even though the total output of Country A exceeds that of Country B.

The second important question is why economic growth varies over time. If that variation is simply due to rises and falls in population growth as opposed to how quickly output per person is rising, very few people will care because the increase in the average standard of living has not changed. On the other hand, when there is a slowdown or speedup in output per person, as happened during the periods 1973–95 and 1995–2005, respectively, then those changes and why they occur become topics of great interest not only to economists but also to policymakers and the general public.

Therefore, the two great questions of economic growth require theories to explain what causes output per person, as opposed to total output, to grow over time.

2. If the production function has constant returns to scale, real GDP will double when labor and capital inputs double; because output and inputs all double, capital per person, the ratio of output to capital, and output per person do not change. When capital and labor inputs double and the autonomous growth factor also doubles, however, real GDP increases fourfold. In this situation, there is still no change in capital per person, but now the output-capital ratio and output per person both double.
3. In the steady state, output, capital input, and labor input grow at identical rates, so that capital per person and output per person remain constant. In Solow's model, the economy automatically adjusts toward steady-state capital per person (K/N) and output per person (Y/N). These adjustments occur when the level of saving and investment per person do not equal the level of steady-state investment per person needed to replace old capital and to provide new capital sufficient to keep K/N constant as the labor force grows. The higher is K/N , the greater is the required steady-state investment. Whether this level of investment per person is forthcoming depends on the amount of saving per person, which in turn depends on Y/N . Suppose that at initial values of K/N and Y/N ,

saving and investment per person exceed the required steady-state investment per person. As a result, K/N and Y/N both increase. Initially, the increase in saving per person that accompanies the growth in Y/N allows the economy to meet or exceed the rising steady-state investment per person required by the increased K/N . However, because saving per person grows more slowly than steady-state investment per person (to see this, compare the slopes of the saving line and the steady-state investment line in Figure 11-3), increases in K/N eventually require all of the economy's saving just to maintain K/N at its current level. This level is the steady-state level at which K/N remains constant, because at this level there is no excess saving to allow any further increase in K/N . If the initial position is one in which saving and investment per person are insufficient to maintain K/N , then both it and Y/N decline. Saving and investment per person both fall, but because K/N is dropping, the required steady-state investment per person is falling more sharply than is saving per person. Again, eventually K/N reaches a steady-state level at which saving and investment per person is sufficient to maintain the now lower K/N .

4. An increase in the depreciation rate means that a larger proportion of the capital stock wears out or becomes obsolete in a year. Therefore, a greater percentage of the capital stock needs to be replaced in order to keep the capital stock constant.

An increase in the depreciation rate makes the slope of the steady-state investment line, $n + d$, steeper. Therefore, the savings line and the steady-state investment line intersect at a lower capital-labor ratio, resulting in declines in both the capital-labor ratio and output per person.

If an increase in the depreciation rate is to have no effect on the capital-labor ratio and output per person, then the savings rate must increase at the same time that the depreciation rate increases. Graphically, the saving rate must increase enough so that the new savings line intersects the steeper steady-state investment line at the original combination of the capital-labor ratio and savings per person, and therefore output per person.

Both of these explanations are intuitively appealing. If the capital stock wears out faster or becomes obsolete more quickly, then for a given level of total savings, a larger percentage of it is needed to replace the exiting capital stock, leaving less savings available to provide new capital for the growing work force. Therefore, the capital-labor ratio falls, resulting in a decline in output per person. On the other hand, if the savings rate increases, then there is enough additional total savings to finance both the more rapid replacement of the existing capital stock and the increase in the capital stock needed for the growing work force, allowing the capital-labor ratio and output per person to remain at their exiting levels.

5. In the absence of changes in autonomous factors, the economy moves along a fixed production function characterized by diminishing returns. Continual increases in the level of per-person stock of capital (K/N) yields less and less of an increase in per-person output (Y/N). The reason is explained by the fact that the average productivity of capital (Y/K) falls as we move outward along the production function. As K/N grows in response to investment, the assumed diminishing returns imply that K/N grows faster than Y/N . And as the capital stock grows more, more and more of the national saving must be used to replace worn-out machines. Furthermore, if there is a positive rate of growth in the labor force, more and more investment is required to equip each of the new persons with a level of capital equal to that of the initial members of the labor force.
6. Solow showed that an increase in the national saving rate will not *permanently* increase the rate of economic growth. But, growth does increase temporarily until such time that all of the extra saving is required to maintain steady state investment. In the meantime, however, the standard of living, as measured by Y/N , has been increased. Moreover, on the reasonable assumption that increases in capital per person are accompanied by changes in technology and improvements in labor quality (i.e., that the autonomous factor A is *not* independent of changes in the capital stock), then society will become better off and may experience an increase in its permanent growth rate even though the growth in capital per person will eventually come to an end. This is pointed out by the examples of Germany and Japan which, although they lost tremendous amounts of capital during World War II, were able to retain and use the embodied “knowledge” and “technology.”
7. The two main sources of per-capita GDP growth are the autonomous factor and the growth of capital per person. Further, the growth in capital per person depends on the average saving rate, the output-capital ratio, the depreciation rate, and the population growth rate. Of these four factors, only the saving rate can be affected by policy. Thus, the average saving rate becomes the primary policy variable in determining the economy’s growth rate. Moreover, the evidence from other industrialized countries suggests that the higher the rate of saving, the higher the rate of economic growth. The explanation for this outcome does not lay in the analysis of steady state economies, but rather in the impact that changes in capital may play in improving labor productivity and technology through improvements in education, skills, and other components of “effective” labor input. There is also an element of hope involved, since empirical results of studies that disaggregate the growth factors into numerous independent components leave economists with little to say about ways to stimulate economic growth in the event that saving rates don’t matter at all. The author concludes that the

relationship between saving and growth are simply not captured by the Solow growth model.

8. Although the Solow model demonstrates that in the steady state $y = k = n$, and therefore the saving rate does not influence the *rate* of economic growth, it does show that the *levels* of capital per person and output per person do depend on the saving rate. (Also, as Question 6 suggests, the effects of increases in saving and investment on the autonomous growth factor are ignored in the steady state growth model.) The real concern of those who wish to promote more saving is that a low saving rate at present means future living standards will be lower than they would be if we saved more now. Policies to reduce the federal budget deficit and to reward household saving, such as moving to a consumption tax or providing tax incentives for saving, might be implemented to increase the saving rate.

9. Labor-augmenting technological change states that improvements in technology are confined to the productivity of workers. Neutral technological change states that technological advances improve the productivity of both capital and labor.

The new microprocessor improves the productivity of capital (the computers are faster) and labor (architects are now able to design building in less time). Therefore, it is an example of neutral technological change. On the other hand, the new operating system improves the productivity of programmers without any need for them to get new computers. Therefore, the new operating system is an example of labor-augmenting technological change.

10. The “Solow residual,” a , is referred to as the autonomous growth factor. It measures the portion of the long-term growth in output per person that cannot be explained by the growth of capital and labor inputs, or other identifiable sources of economic growth. The problem that the “Solow residual” presents for economic growth theory is that it is so large in the sense that much of the growth in output per person in the leading industrialized countries cannot be explained by such factors as the growth of capital and labor inputs. For example, in Solow’s initial study of economic growth, only one-eighth of the increase in output per person is accounted for by an increase in the capital–labor ratio; the remaining seven-eighths is due to the autonomous growth factor. Therefore, new theories of economic growth must come up with factors that account for most of the long-term growth in output per person and reduce Solow’s residual to a level that can be easily be interpreted as an unexplainable random factor.
11. Productivity as defined on page 2 in Chapter 1 refers to output per hour worked, whereas multifactor productivity examines the increases in output not due to increases in labor, capital, and other measurable inputs. One way of thinking of multifactor productivity is that it represents the increase in output, when labor, capital, and other measurable inputs

are held constant. Given that interpretation of multifactor productivity, an increase in it must result in an increase in output per hour worked since the number of hours worked is held constant.

12. The Solow growth model assumes that the same technology is available to both rich and poor countries. Therefore, it predicts that differences in per capita income are due to differences in capital–labor ratios, as illustrated by Points *P* and *R* in Figure 11-5 on page 374. The rate of return on capital in the Solow model (measured by the marginal product of capital), is given by the slope of the production function. The fact that the production function at Point *P* is steeper than at Point *R*, in Figure 11-5, the model predicts that the rate of return should be higher in poor countries than in rich countries. Furthermore, the prediction of higher rates of return in poor countries than in rich countries implies that capital should flow from rich countries to poor countries in order to earn those higher rates of return. Those capital flows would cause the capital–labor ratios to rise faster in poor countries than in rich countries, resulting in a narrowing of per capita income between poor and rich countries. Therefore, the facts that (1) poor countries do not seem to have higher rates of return on capital, and (2) the gaps between the per capita income of rich and poor countries have not narrowed significantly are puzzles for the Solow growth model in that these facts are inconsistent with the predictions of the model.

On the other hand, output per hour worked could increase with no change in multifactor productivity if other inputs increased enough to cause labor productivity to rise. An example is shown in Figure 11-1 where a rise in the capital–labor ratio results in an increase in output per person.

13. Endogenous growth theory attempts to improve upon explanations of economic growth that rely heavily on exogenous factors like labor input growth n , the saving rate s , and the residual a by explaining these factors as endogenously determined outcomes of economic incentives and behavior. It arose as a result of dissatisfaction with the exogeneity and vagueness of Solow's residual and with conflicts between the Solow model's predictions and real-world observations about growth. Chief among these are the model's inability to explain the wide variation across countries in output per person and capital per person and the failure of living standards in poorer countries to catch up to richer ones.
14. Human capital consists of people's acquired knowledge and skills. Physical capital, on the other hand, consists of the stock of actual capital, such as structures, equipment, and infrastructure, with which people have to work or which, in the case of infrastructure, facilitates their work. Both represent factors of production, with human capital being embodied in the labor input. Human capital helps explain why poor countries cannot

rapidly increase their economic growth rates even if they had immediate access to the newest technology. It takes many years of investment in human capital before the benefits of technology can benefit poor countries.

15. Endogenous growth theory is the theory of economic growth which attempts to explain not only why economic growth occurs but also what causes technological change to take place. Given that it attempts to explain why technological change occurs, it attempts to explain the economic forces that determine the size of the “Solow residual.” Furthermore, if endogenous growth theory can explain what causes technological change, it might be able to explain why technologies that are available in rich countries might not be available in poor countries. That could solve such “Solow puzzles” as why the incomes between rich and poor countries vary so much, or why rates of returns on capital do not vary systematically between rich and poor countries or why the gaps between rich and poor countries have not narrowed.
16. By indicating how technological change depends on the production of ideas for new goods and developing new methods of producing existing goods, endogenous growth theory emphasizes the role that governments have in making sure that people have an incentive to engage in such activities. Empirical studies have looked at how growth rates in rich and poor countries have been influenced by factors that governments have some control over such as the levels of private and government investment expenditures, government consumption spending, school enrollment rates, political stability, and fertility rates.

These studies suggest that governments have the ability to increase the rate of growth of income in poor countries, say, for example by increasing educational levels through higher enrollment rates or by cutting government consumption and increasing government investment expenditures. However, it is difficult to do so in poor countries because these are all expensive, and poor countries are not likely to have the resources to do so, precisely because they are poor. Furthermore, cutting government consumption programs is likely to be politically unpopular and therefore may not be in the best self-interest of those in government. (*Note*: the political difficulties associated with cutting government consumption spending are a problem in rich countries as well as poor countries, as is so clearly illustrated by the debate over what to do, if anything, about Social Security and Medicare in this country.)