section 7

Economic Growth and Productivity

China is growing—and so are the Chinese. According to official statistics, children in China are almost 2½ inches taller now than they were 30 years ago. The average Chinese citizen is still a lot shorter than the average American, but at the current rate of growth the difference may be largely gone in a couple of generations.

If that does happen, China will be following in Japan's footsteps. Older Americans tend to think of the Japanese as short, but today young Japanese men are more than 5 inches taller on average than they were in 1900, which makes them almost as tall as their American counterparts.

There's no mystery about why the Japanese grew taller—it's because they grew richer. In the early twentieth century, Japan was a relatively poor country in which many families couldn't afford to give their children adequate nutrition. As a result, their children grew up to be short adults. However, since World War II, Japan has become an economic powerhouse in which food is ample and young adults are much taller than before.

The same phenomenon is now happening in China. Although it continues to be a relatively poor country, China has made great economic strides over the past 30 years. Its recent history is probably the world's most dramatic example of economic growth—a sustained increase in the productive capacity of an economy. Yet despite its impressive performance, China is currently playing catch-up with economically advanced countries like the United States and Japan. It's still relatively poor because these other nations began their own processes of economic growth many decades ago—and in the case of the United States and European countries, more than a century ago.

Unlike a short-run increase in real GDP caused by an increase in aggregate demand or short-run aggregate supply, we'll see that economic growth pushes the production possibilities curve outward and shifts the long-run aggregate supply curve to the right. Because economic growth is a long-run concept, we often refer to it as *long-run economic growth* for clarity. Many economists have argued that long-run economic growth—why it happens and how to achieve it—is the single most important issue in macroeconomics. In this section, we present some facts about long-run growth, look at the factors that economists believe determine its pace, examine how government policies can help or hinder growth, and address questions about the environmental sustainability of growth.

AP Photo/EyePress

What you will learn in this Module:

- How we measure long-run economic growth
- How real GDP has changed over time
- How real GDP varies across countries
- The sources of long-run economic growth
- How productivity is driven by physical capital, human capital, and technological progress

Module 37 Long-run Economic Growth

Comparing Economies Across Time and Space

Before we analyze the sources of long-run economic growth, it's useful to have a sense of just how much the U.S. economy has grown over time and how large the gaps are between wealthy countries like the United States and countries that have yet to achieve a comparable standard of living. So let's take a look at the numbers.

Real GDP per Capita

The key statistic used to track economic growth is *real GDP per capita*—real GDP divided by the population size. We focus on GDP because, as we have learned, GDP measures the total value of an economy's production of final goods and services as well as the income earned in that economy in a given year. We use *real* GDP because we want to separate changes in the quantity of goods and services from the effects of a rising price level. We focus on real GDP *per capita* because we want to isolate the effect of changes in the population. For example, other things equal, an increase in the population lowers the standard of living for the average person—there are now more people to share a given amount of real GDP. An increase in real GDP that only matches an increase in population leaves the average standard of living unchanged.

Although we learned that growth in real GDP per capita should not be a policy goal in and of itself, it does serve as a very useful summary measure of a country's economic progress over time. Figure 37.1 shows real GDP per capita for the United States, India, and China, measured in 1990 dollars, from 1908 to 2008. (We'll talk about India and China in a moment.) The vertical axis is drawn on a logarithmic scale so that equal percent changes in real GDP per capita across countries are the same size in the graph.

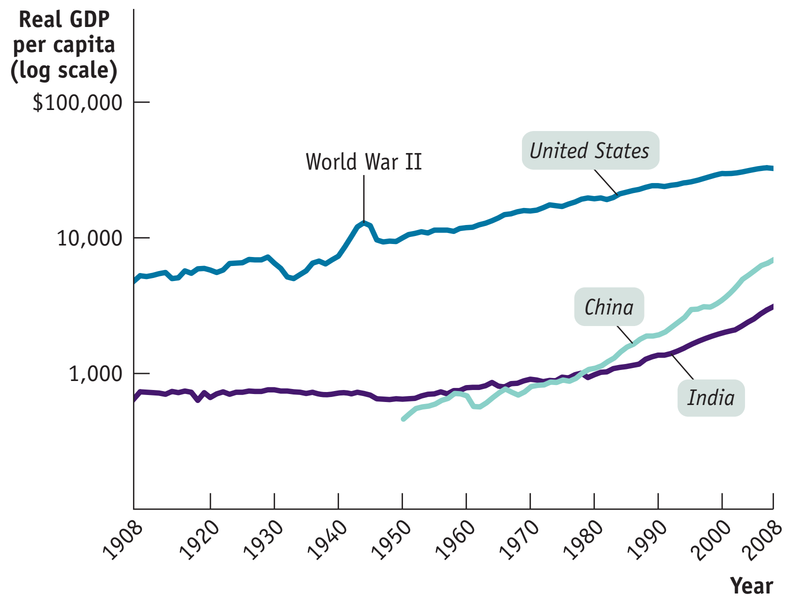
To give a sense of how much the U.S. economy grew during the last century, Table 37.1 shows real GDP per capita at 20-year intervals, expressed two ways: as a percentage of the 1908 level and as a percentage of the 2008 level. In 1928, the U.S. economy already produced 144% as much per person as it did in 1908. In 2008, it produced 684% as much per

figure 37.1

Economic Growth in the United States, India, and China over the Past Century

Real GDP per capita from 1908 to 2008, measured in 1990 dollars, is shown for the United States, India, and China. Equal percent changes in real GDP per capita are drawn the same size. India and China currently have a much higher growth rate than the United States. However, China has only just attained the standard of living achieved in the United States in 1908, while India is still poorer than the United States was in 1908.

Sources: Angus Maddison, *Statistics on World Population, GDP, and Per Capita GDP, 1–2008AD,* http://www.ggdc.net/maddison.



person as it did in 1908. Alternatively, in 1908, the U.S. economy produced only 15% as much per person as it did in 2008.

The income of the typical family normally grows more or less in proportion to per capita income. For example, a 1% increase in real GDP per capita corresponds, roughly, to a 1% increase in the income of the median or typical family—a family at the center of the income distribution. In 2008, the median American household had an income of about $50,000. Since Table 37.1 tells us that real GDP per capita in 1908 was only 15% of its 2008 level, a typical family in 1908 probably had purchasing power only 15% as large as the purchasing power of a typical family in 2008. That's around $8,000 in today's dollars, representing a standard of living that we would now consider severe poverty. Today's typical American family, if transported back to the United States of 1908, would feel quite a lot of deprivation.

Yet many people in the world have a standard of living equal to or lower than that of the United States a century ago. That's the message about China and India in Figure 37.1: despite dramatic economic growth in China over the last three decades and the less dramatic acceleration of economic growth in India, China has only just attained the standard of living that the United States enjoyed in 1908, while India is still poorer than the United States was in 1908. And much of the world today is poorer than China or India.

You can get a sense of how poor much of the world remains by looking at Figure 37.2 on the next page, a map of the world in which countries are classified according to their 2008 levels of GDP per capita, in U.S. dollars. As you can see, large parts of the world have very low incomes. Generally speaking, the countries of Europe and North America, as well as a few in the Pacific, have high incomes. The rest of the world, containing most of its population, is dominated by countries with GDP less than $5,000 per capita—and often much less. In fact, today more than 50% of the world's people live in countries with a lower standard of living than the United States had a century ago.

table 37.1

U.S. Real GDP per Capita

Year	Percentage of 1908 real GDP per capita	Percentage of 2008 real GDP per capita
1908	100%	15%
1928	144	21
1948	199	29
1968	326	48
1988	493	72
2008	684	100

Source: Angus Maddison, *Statistics on World Population, GDP, and Per Capita GDP, 1–2008AD,* http://www.ggdc.net/maddison.

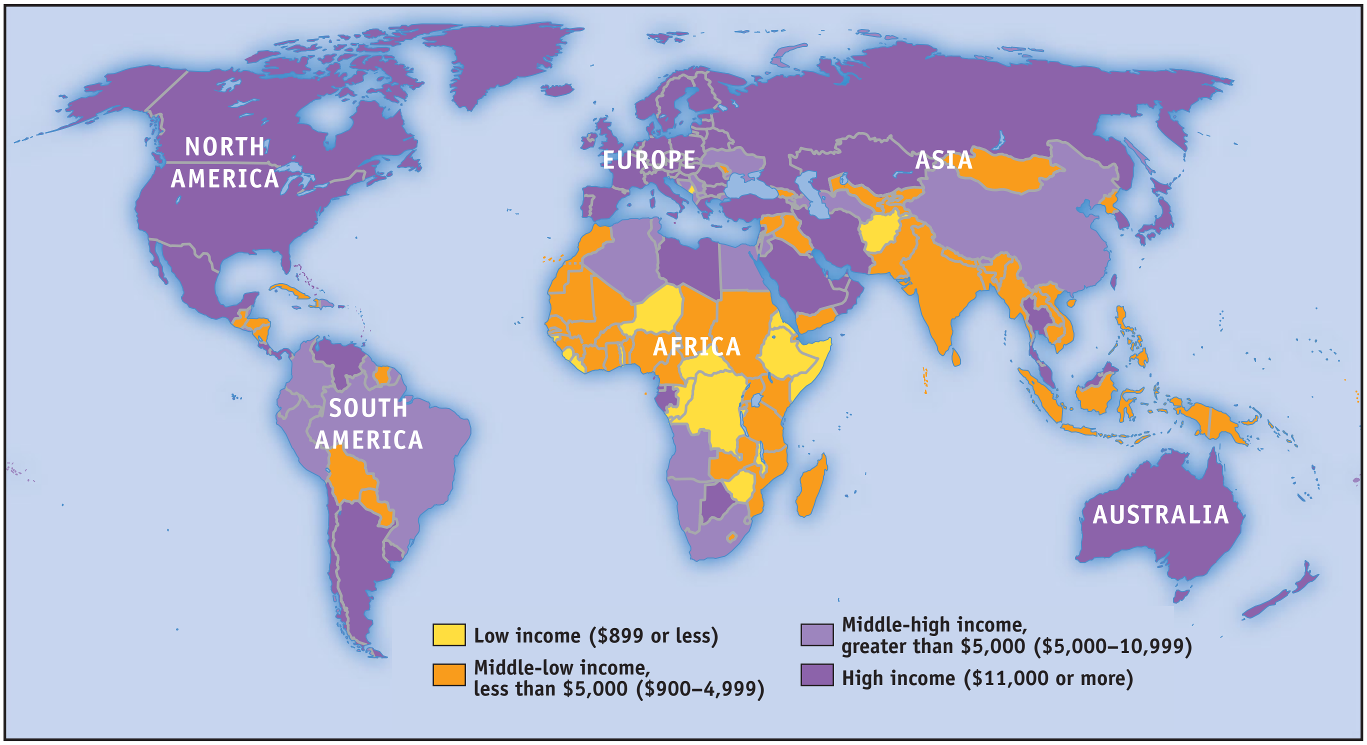


figure 37.2

Incomes Around the World, 2008

Although the countries of Europe and North America—along with a few in East Asia—have high incomes, much of the world is still very poor. Today, more than 50% of the world's population lives in countries with a lower standard of living than the United States had a century ago.

Source: International Monetary Fund.

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India Takes Off

India achieved independence from Great Britain in 1947, becoming the world's most populous democracy—a status it has maintained to this day. For more than three decades after independence, however, this happy political story was partly overshadowed by economic disappointment. Despite ambitious economic development plans, India's performance was consistently sluggish. In 1980, India's real GDP per capita was only about 50% higher than it had been in 1947; the gap between Indian living standards and those in wealthy countries like the United States had been growing rather than shrinking.

Since then, however, India has done much better. As Figure 37.3 shows, real GDP per capita has grown at an average rate of 4.1% a year, tripling between 1980 and 2008. India now has a large and rapidly growing middle class. And yes, the well-fed children of that middle class are much taller than their parents.

What went right in India after 1980? Many economists point to policy reforms. For decades after independence, India had a tightly controlled, highly regulated economy. Today, things are very different: a series of reforms opened the economy to international trade and freed up domestic competition. Some economists, however, argue that this can't be the main story because the big policy reforms weren't adopted until 1991, yet growth accelerated around 1980.

Regardless of the explanation, India's economic rise has transformed it into a major new economic power—and allowed hundreds of millions of people to have a much better life, better than their grandparents could have dreamed.

Verity Steel/Alamy

India's high rate of economic growth since 1980 has raised living standards and led to the emergence of a rapidly growing middle class.

Growth Rates

How did the United States manage to produce nearly seven times more per person in 2008 than in 1908? A little bit at a time. Long-run economic growth is normally a gradual process in which real GDP per capita grows at most a few percent per year. From 1908 to 2008, real GDP per capita in the United States increased an average of 1.9% each year.

To have a sense of the relationship between the annual growth rate of real GDP per capita and the long-run change in real GDP per capita, it's helpful to keep in mind the **Rule of 70,** a mathematical formula that tells us how long it takes real GDP per capita, or any other variable that grows gradually over time, to double. The approximate answer is:

The **Rule of 70** tells us that the time it takes a variable that grows gradually over time to double is approximately 70 divided by that variable's annual growth rate.

$$\textbf{(37-1)}\quad \text{Number of years for variable to double} = \frac{70}{\text{Annual growth rate of variable}}$$

(Note that the Rule of 70 can be applied to only a positive growth rate.) So if real GDP per capita grows at 1% per year, it will take 70 years to double. If it grows at 2% per year, it will take only 35 years to double. Applying the Rule of 70 to the 1.9% average growth rate in the United States implies that it should have taken 37 years for real GDP per capita to double; it would have taken 111 years—three periods of 37 years each—for U.S. real GDP per capita to double three times. That is, the Rule of 70 implies that over the course of 111 years, U.S. real GDP per capita should have increased by a factor of $2 \times 2 \times 2 = 8$. And this does turn out to be a pretty good approximation of reality. Between 1890 and 2008—a period of 118 years—real GDP per capita rose just about eightfold.

Figure 37.3 shows the average annual rate of growth of real GDP per capita for selected countries from 1980 to 2008. Some countries were notable success stories: we've already mentioned China, which has made spectacular progress. India, although not matching China's performance, has also achieved impressive growth.

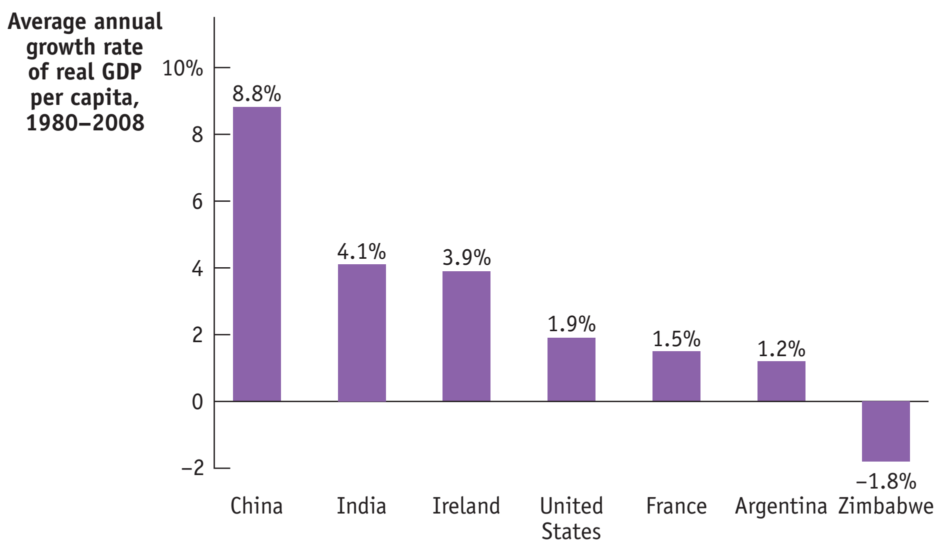
Some countries, though, have had very disappointing growth. Argentina was once considered a wealthy nation. In the early years of the twentieth century, it was in the same league as the United States and Canada. But since then it has

figure 37.3

Comparing Recent Growth Rates

Here the average annual rate of growth of real GDP per capita from 1980 to 2008 is shown for selected countries. China and, to a lesser extent, India and Ireland have achieved impressive growth. The United States and France have had moderate growth. Despite having once been considered an economically advanced country, Argentina has had sluggish growth. Still others, such as Zimbabwe, have slid backward.

Source: International Monetary Fund.



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The Walmart Effect

After 20 years of being sluggish, U.S. productivity growth accelerated sharply in the late 1990s. What caused that acceleration? Was it the rise of the Internet?

Not according to analysts at McKinsey and Co., a famous business consulting firm. They found that a major source of productivity improvement after 1995 was a surge in output per worker in retailing—stores were selling much more merchandise per worker. And why did productivity surge in retailing in the United States? "The reason can be explained in just two syllables: Walmart," wrote McKinsey.

Walmart has been a pioneer in using modern technology to improve productivity. For example, it was one of the first companies to use computers to track inventory, to use barcode scanners, to establish direct electronic links with suppliers, and so on. It continued to set the pace in the 1990s, but, increasingly, other companies have imitated Walmart's business practices.

There are two lessons from the "Walmart effect," as McKinsey calls it. One is that how you apply a technology makes all the difference: everyone in the retail business knew about computers, but Walmart figured out what to do with them. The other is that a lot of economic growth comes from everyday improvements rather than glamorous new technologies.

PAUL J. RICHARDS/AFP/Getty Images

lagged far behind more dynamic economies. And still others, like Zimbabwe, have slid backward.

What explains these differences in growth rates? To answer that question, we need to examine the sources of long-run growth.

The Sources of Long-run Growth

Long-run economic growth depends almost entirely on one ingredient: rising *productivity*. However, a number of factors affect the growth of productivity. Let's look first at why productivity is the key ingredient. After that, we'll examine what affects it.

The Crucial Importance of Productivity

Sustained growth in real GDP per capita occurs only when the amount of output produced by the average worker increases steadily. The term **labor productivity,** or **productivity** for short, is used to refer either to output per worker or, in some cases, to output per hour (the number of hours worked by an average worker differs to some extent across countries, although this isn't an important factor in the difference between living standards in, say, India and the United States). In this book we'll focus on output per worker. For the economy as a whole, productivity—output per worker—is simply real GDP divided by the number of people working.

You might wonder why we say that higher productivity is the only source of long-run growth in real GDP per capita. Can't an economy also increase its real GDP per capita by putting more of the population to work? The answer is, yes, but . . . . For short periods of time, an economy can experience a burst of growth in output per capita by putting a higher percentage of the population to work. That happened in the United States during World War II, when millions of women who previously worked only in the home entered the paid workforce. The percentage of adult civilians employed outside the home rose from 50% in 1941 to 58% in 1944, and you can see the resulting bump in real GDP per capita during those years in Figure 37.1.

Over the longer run, however, the rate of employment growth is never very different from the rate of population growth. Over the course of the twentieth century, for example, the population of the United States rose at an average rate of 1.3% per year and employment

Labor productivity, often referred to simply as **productivity,** is output per worker.

rose 1.5% per year. Real GDP per capita rose 1.9% per year; of that, 1.7%—that is, almost 90% of the total—was the result of rising productivity. In general, overall real GDP can grow because of population growth, but any large increase in real GDP *per capita* must be the result of increased output *per worker.* That is, it must be due to higher productivity.

We have just seen that increased productivity is the key to long-run economic growth. But what leads to higher productivity?

Physical capital consists of human-made goods such as buildings and machines used to produce other goods and services.

Human capital is the improvement in labor created by the education and knowledge of members of the workforce.

Technology is the technical means for the production of goods and services.

Explaining Growth in Productivity

There are three main reasons why the average U.S. worker today produces far more than his or her counterpart a century ago. First, the modern worker has far more *physical capital,* such as tools and office space, to work with. Second, the modern worker is much better educated and so possesses much more *human capital.* Finally, modern firms have the advantage of a century's accumulation of technical advancements reflecting a great deal of *technological progress.*

Let's look at each of these factors in turn.

Physical Capital

Module 22 explained that capital—manufactured goods used to produce other goods and services—is often described as **physical capital** to distinguish it from human capital and other types of capital. Physical capital such as buildings and machinery makes workers more productive. For example, a worker operating a backhoe can dig a lot more feet of trench per day than one equipped with only a shovel.

The average U.S. private-sector worker today makes use of around $130,000 worth of physical capital—far more than a U.S. worker had 100 years ago and far more than the average worker in most other countries has today.

Human Capital

It's not enough for a worker to have good equipment—he or she must also know what to do with it. **Human capital** refers to the improvement in labor created by the education and knowledge embodied in the workforce.

The human capital of the United States has increased dramatically over the past century. A century ago, although most Americans were able to read and write, very few had an extensive education. In 1910, only 13.5% of Americans over 25 had graduated from high school and only 3% had four-year college degrees. By 2008, the percentages were 86% and 27%, respectively. It would be impossible to run today's economy with a population as poorly educated as that of a century ago.

Analyses based on *growth accounting,* described later in this section, suggest that education—and its effect on productivity—is an even more important determinant of growth than increases in physical capital.

Jon Feingersch/Corbis

If you've ever had doubts about attending college, consider this: factory workers with only high school degrees will make much less than college grads. The present discounted value of the difference in lifetime earnings is as much as $300,000.

Technology

Probably the most important driver of productivity growth is progress in **technology,** which is broadly defined as the technical means for the production of goods and services. We'll see shortly how economists measure the impact of technology on growth.

Workers today are able to produce more than those in the past, even with the same amount of physical and human capital, because technology has advanced over time. It's important to realize that economically important technological progress need not be flashy or rely on cutting-edge science. Historians have noted that past economic growth has been driven not only by major inventions, such as the railroad or the semiconductor chip, but also by thousands of modest innovations, such as the flat-bottomed paper bag, patented in 1870, which made packing groceries and many other goods much easier, and the Post-it note, introduced in 1981, which has had surprisingly large benefits for office productivity. Experts attribute much of the productivity surge that took place in the United States late in the twentieth century to new technology adopted by retail companies like Wal-mart rather than to high-technology companies.

Corbis Super RF/Alamy

Module 37 AP Review

Solutions appear at the back of the book.

Check Your Understanding

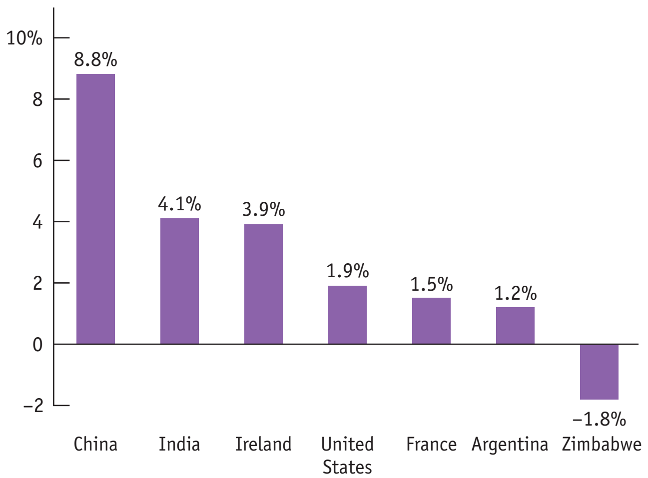
1. Why do economists focus on real GDP per capita as a measure of economic progress rather than on some other measure, such as nominal GDP per capita or real GDP?
2. Apply the Rule of 70 to the data in Figure 37.3 to determine how long it will take each of the countries listed there to double its real GDP per capita. Would India's real GDP per capita exceed that of the United States in the future if growth rates remained the same? Why or why not?
3. Although China and India currently have growth rates much higher than the U.S. growth rate, the typical Chinese or Indian household is far poorer than the typical American household. Explain why.

Tackle the Test: Multiple-Choice Questions

1. Which of the following is true regarding growth rates for countries around the world compared to the United States?
   I. Fifty percent of the world's people live in countries with a lower standard of living than the U.S. in 1908.
   II. The U.S. growth rate is six times the growth rate in the rest of the world.
   III. China has only just attained the same standard of living the U.S. had in 1908.
   a. I only
   b. II only
   c. III only
   d. I and III only
   e. I, II, and III
2. Which of the following is the key statistic used to track economic growth?
   a. GDP
   b. real GDP
   c. real GDP per capita
   d. median real GDP
   e. median real GDP per capita
3. According to the "Rule of 70," if a country's real GDP per capita grows at a rate of 2% per year, it will take how many years for real GDP per capita to double?
   a. 3.5
   b. 20
   c. 35
   d. 70
   e. It will never double at that rate.
4. If a country's real GDP per capita doubles in 10 years, what was its average annual rate of growth of real GDP per capita?
   a. 3.5%
   b. 7%
   c. 10%
   d. 70%
   e. 700%
5. Long-run economic growth depends almost entirely on
   a. technological change.
   b. rising productivity.
   c. increased labor force participation.
   d. rising real GDP per capita.
   e. population growth.

Tackle the Test: Free-Response Questions

1. Refer to Figure 37.3.



   a. If growth continues at the rates shown in Figure 37.3, which of the seven countries will have a lower real GDP per capita in 2009 than in 2008? Explain.
   b. If growth continues at the rates shown in Figure 37.3, which of the seven countries will have the highest real GDP per capita in 2009? Explain.
   c. If growth continues at the rates shown in Figure 37.3, real GDP per capita for which of the seven countries will at least double over the next 10 years? Explain.

Answer (6 points)

1 point: Zimbabwe

1 point: It has a negative average annual growth rate of real GDP per capita.

1 point: It cannot be determined.

1 point: The figure provides data for growth rates, but not for the level of real GDP per capita. Higher growth rates do not indicate higher levels.

1 point: China

1 point: A country has to have an average annual growth rate of 7% or higher for real GDP to at least double in 10 years. China has a growth rate of 8.8%.

2. Increases in real GDP per capita result mostly from changes in what variable? Define that variable. What other factor could also lead to increased real GDP per capita? Why is this other factor not as significant?

What you will learn in this **Module:**

- How changes in productivity are illustrated using an aggregate production function
- How growth has varied among several important regions of the world and why the convergence hypothesis applies to economically advanced countries

Module 38 Productivity and Growth

Accounting for Growth: The Aggregate Production Function

Productivity is higher, other things equal, when workers are equipped with more physical capital, more human capital, better technology, or any combination of the three. But can we put numbers to these effects? To do this, economists make use of estimates of the **aggregate production function,** which shows how productivity depends on the quantities of physical capital per worker and human capital per worker as well as the state of technology. In general, all three factors tend to rise over time, as workers are equipped with more machinery, receive more education, and benefit from technological advances. What the aggregate production function does is allow economists to disentangle the effects of these three factors on overall productivity.

A recent example of an aggregate production function applied to real data comes from a comparative study of Chinese and Indian economic growth conducted by the economists Barry Bosworth and Susan Collins of the Brookings Institution. They used the following aggregate production function:

$$\text{GDP per worker} = T \times (\text{physical capital per worker})^{0.4} \times (\text{human capital per worker})^{0.6}$$

where T represented an estimate of the level of technology and they assumed that each year of education raised workers' human capital by 7%. Using this function, they tried to explain why China grew faster than India between 1978 and 2004. About half the difference, they found, was due to China's higher levels of investment spending, which raised its level of physical capital per worker faster than India's. The other half was due to faster Chinese technological progress.

In analyzing historical economic growth, economists have discovered a crucial fact about the estimated aggregate production function: it exhibits **diminishing returns to physical capital.** That is, when the amount of human capital per worker and the state of technology are held fixed, each successive increase in the amount of physical capital per worker leads to a smaller increase in productivity. Table 38.1 gives a hypothetical example of how the level of physical capital per worker might affect the level of

The **aggregate production function** is a hypothetical function that shows how productivity (output per worker) depends on the quantities of physical capital per worker and human capital per worker as well as the state of technology.

An aggregate production function exhibits **diminishing returns to physical capital** when, holding the amount of human capital per worker and the state of technology fixed, each successive increase in the amount of physical capital per worker leads to a smaller increase in productivity.

table 38.1

A Hypothetical Example: How Physical Capital per Worker Affects Productivity, Holding Human Capital and Technology Fixed

Physical capital investment per worker	Real GDP per worker
$0	$0
15,000	30,000
30,000	45,000
45,000	55,000

real GDP per worker, holding human capital per worker and the state of technology fixed. In this example, we measure the quantity of physical capital in terms of the dollars worth of investment.

As you can see from the table, there is a big payoff from the first $15,000 invested in physical capital: real GDP per worker rises by $30,000. The second $15,000 worth of physical capital also raises productivity, but not by as much: real GDP per worker goes up by only $15,000. The third $15,000 worth of physical capital raises real GDP per worker by only $10,000.

To see why the relationship between physical capital per worker and productivity exhibits diminishing returns, think about how having farm equipment affects the productivity of farm workers. A little bit of equipment makes a big difference: a worker equipped with a tractor can do much more than a worker without one. And a worker using more expensive equipment will, other things equal, be more productive: a worker with a $30,000 tractor will normally be able to cultivate more farmland in a given amount of time than a worker with a $15,000 tractor because the more expensive machine will be more powerful, perform more tasks, or both.

But will a worker with a $30,000 tractor, holding human capital and technology constant, be twice as productive as a worker with a $15,000 tractor? Probably not: there's a huge difference between not having a tractor at all and having even an inexpensive tractor; there's much less difference between having an inexpensive tractor and having a better tractor. And we can be sure that a worker with a $150,000 tractor won't be 10 times as productive: a tractor can be improved only so much. Because the same is true of other kinds of equipment, the aggregate production function shows diminishing returns to physical capital.

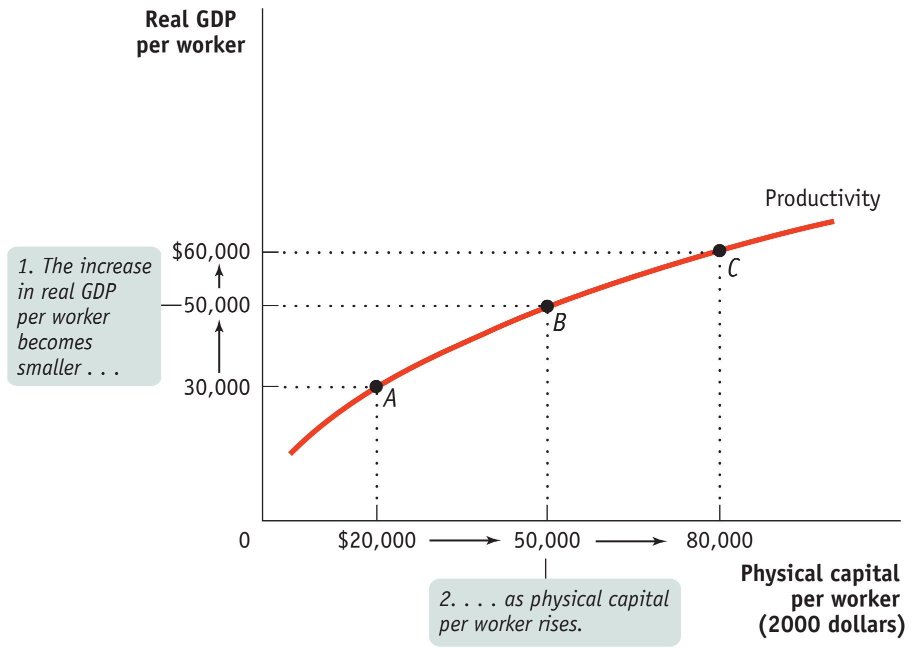
Figure 38.1 on the next page is a graphical representation of the aggregate production function with diminishing returns to physical capital. As the *productivity curve* illustrates, more physical capital per worker leads to more output per worker. But each $30,000 increment in physical capital per worker adds less to productivity. By comparing points *A, B,* and *C,* you can also see that as physical capital per worker rises, output per worker also rises—but at a diminishing rate. Going from point *A* to point *B,* representing a $30,000 increase in physical capital per worker, leads to an increase of $20,000 in real GDP per worker. Going from point *B* to point *C,* a second $30,000 increase in physical capital per worker, leads to an increase of only $10,000 in real GDP per worker.

It's important to realize that diminishing returns to physical capital is an "other things equal" phenomenon: additional amounts of physical capital are less productive *when the amount of human capital per worker and the technology are held fixed.* Diminishing returns may disappear if we increase the amount of human capital per worker, or improve the technology, or both when the amount of physical capital per worker is increased. For example, a worker with a $30,000 tractor who has also been trained in the most advanced cultivation techniques may in fact be more than twice

figure 38.1

Physical Capital and Productivity

Other things equal, a greater quantity of physical capital per worker leads to higher real GDP per worker but is subject to diminishing returns: each successive addition to physical capital per worker produces a smaller increase in productivity. Starting at point *A,* with \$20,000 in physical capital per worker, a \$30,000 increase in physical capital per worker leads to an increase of \$20,000 in real GDP per worker. At point *B,* with \$50,000 in physical capital per worker, a \$30,000 increase in physical capital per worker leads to an increase of only \$10,000 in real GDP per worker.



Economists use **growth accounting** to estimate the contribution of each major factor in the aggregate production function to economic growth.

as productive as a worker with only a \$15,000 tractor and no additional human capital. But diminishing returns to any one input—regardless of whether it is physical capital, human capital, or labor—is a pervasive characteristic of production. Typical estimates suggest that, in practice, a 1% increase in the quantity of physical capital per worker increases output per worker by only one-third of 1%, or 0.33%.

In practice, all the factors contributing to higher productivity rise during the course of economic growth: both physical capital and human capital per worker increase, and technology advances as well. To disentangle the effects of these factors, economists use **growth accounting** to estimate the contribution of each major factor in the aggregate production function to economic growth. For example, suppose the following are true:

- The amount of physical capital per worker grows 3% a year.
- According to estimates of the aggregate production function, each 1% rise in physical capital per worker, holding human capital and technology constant, raises output per worker by one-third of 1%, or 0.33%.

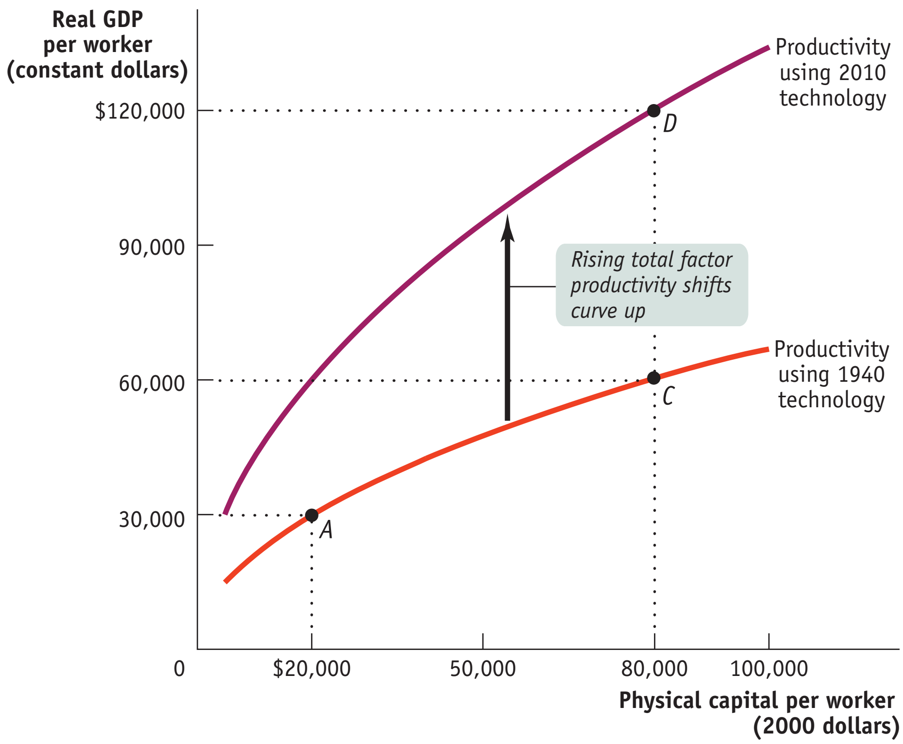
In that case, we would estimate that growing physical capital per worker is responsible for 1 percentage point (3% × 0.33) of productivity growth per year. A similar but more complex procedure is used to estimate the effects of growing human capital. The procedure is more complex because there aren't simple dollar measures of the quantity of human capital.

Growth accounting allows us to calculate the effects of greater physical and human capital on economic growth. But how can we estimate the effects of technological progress? We can do so by estimating what is left over after the effects of physical and human capital have been taken into account. For example, let's imagine that there was no increase in human capital per worker so that we can focus on changes in physical capital and in technology. In Figure 38.2, the lower curve shows the same hypothetical relationship between physical capital per worker and output per worker shown in Figure 38.1. Let's assume that this was the relationship given the technology available in 1940. The upper curve also shows a relationship between physical capital per worker

figure 38.2

Technological Progress and Productivity Growth

Technological progress shifts the productivity curve upward. Here we hold human capital per worker fixed. We assume that the lower curve (the same curve as in Figure 38.1) reflects technology in 1940 and the upper curve reflects technology in 2010. Holding technology and human capital fixed, quadrupling physical capital per worker from $20,000 to $80,000 leads to a doubling of real GDP per worker, from $30,000 to $60,000. This is shown by the movement from point *A* to point *C*, reflecting an approximately 1% per year rise in real GDP per worker. In reality, technological progress shifted the productivity curve upward and the actual rise in real GDP per worker is shown by the movement from point *A* to point *D*. Real GDP per worker grew 2% per year, leading to a quadrupling during the period. The extra 1% in growth of real GDP per worker is due to higher total factor productivity.



and productivity, but this time given the technology available in 2010. (We've chosen a 70-year stretch to allow us to use the Rule of 70.) The 2010 curve is shifted up compared to the 1940 curve because technologies developed over the previous 70 years make it possible to produce more output for a given amount of physical capital per worker than was possible with the technology available in 1940. (Note that the two curves are measured in constant dollars.)

Total factor productivity is the amount of output that can be achieved with a given amount of factor inputs.

Let's assume that between 1940 and 2010 the amount of physical capital per worker rose from $20,000 to $80,000. If this increase in physical capital per worker had taken place without any technological progress, the economy would have moved from *A* to *C:* output per worker would have risen, but only from $30,000 to $60,000, or 1% per year (using the Rule of 70 tells us that a 1% growth rate over 70 years doubles output). In fact, however, the economy moved from *A* to *D:* output rose from $30,000 to $120,000, or 2% per year. There was an increase in both physical capital per worker and technological progress, which shifted the aggregate production function.

In this case, 50% of the annual 2% increase in productivity—that is, 1% in annual productivity growth—is due to higher **total factor productivity,** the amount of output that can be produced with a given amount of factor inputs. So when total factor productivity increases, the economy can produce more output with the same quantity of physical capital, human capital, and labor.

Most estimates find that increases in total factor productivity are central to a country's economic growth. We believe that observed increases in total factor productivity in fact measure the economic effects of technological progress. All of this implies that technological change is crucial to economic growth. The Bureau of Labor Statistics estimates the growth rate of both labor productivity and total factor productivity for nonfarm business in the United States. According to the Bureau's estimates, over the period from 1948 to 2008 American labor productivity rose 2.6% per year. Only 46% of that rise is explained by increases in physical and human capital per worker; the rest is explained by rising total factor productivity—that is, by technological progress.

What About Natural Resources?

In our discussion so far, we haven't mentioned natural resources, which certainly have an effect on productivity. Other things equal, countries that are abundant in valuable natural resources, such as highly fertile land or rich mineral deposits, have higher real GDP per capita than less fortunate countries. The most obvious modern example is the Middle East, where enormous oil deposits have made a few sparsely populated countries very rich. For instance, Kuwait has about the same level of real GDP per capita as South Korea, but Kuwait's wealth is based on oil, not manufacturing, the source of South Korea's high output per worker.

But other things are often not equal. In the modern world, natural resources are a much less important determinant of productivity than human or physical capital for the great majority of countries. For example, some nations with very high real GDP per capita, such as Japan, have very few natural resources. Some resource-rich nations, such as Nigeria (which has sizable oil deposits), are very poor.

Mark Shenley/Alamy

The offerings at markets such as this one in Lagos, Nigeria, are shaped by the available natural resources, human and physical capital, and technology.

Historically, natural resources played a much more prominent role in determining productivity. In the nineteenth century, the countries with the highest real GDP per capita were those abundant in rich farmland and mineral deposits: the United States, Canada, Argentina, and Australia. As a consequence, natural resources figured prominently in the development of economic thought. In a famous book published in 1798, *An Essay on the Principle of Population,* the English economist Thomas Malthus made the fixed quantity of land in the world the basis of a pessimistic prediction about future productivity. As population grew, he pointed out, the amount of land per worker would decline. And this, other things equal, would cause productivity to fall. His view, in fact, was that improvements in technology or increases in physical capital would lead only to temporary improvements in productivity because they would always be offset by the pressure of rising population and more workers on the supply of land. In the long run, he concluded, the great majority of people were condemned to living on the edge of starvation. Only then would death rates be high enough and birth rates low enough to prevent rapid population growth from outstripping productivity growth.

It hasn't turned out that way, although many historians believe that Malthus's prediction of falling or stagnant productivity was valid for much of human history. Population pressure probably did prevent large productivity increases until the eighteenth century. But in the time since Malthus wrote his book, any negative effects on productivity from population growth have been far outweighed by other, positive factors—advances in technology, increases in human and physical capital, and the opening up of enormous amounts of cultivatable land in the New World.

It remains true, however, that we live on a finite planet, with limited supplies of resources such as oil and limited ability to absorb environmental damage. We address the concerns these limitations pose for economic growth later in this section.

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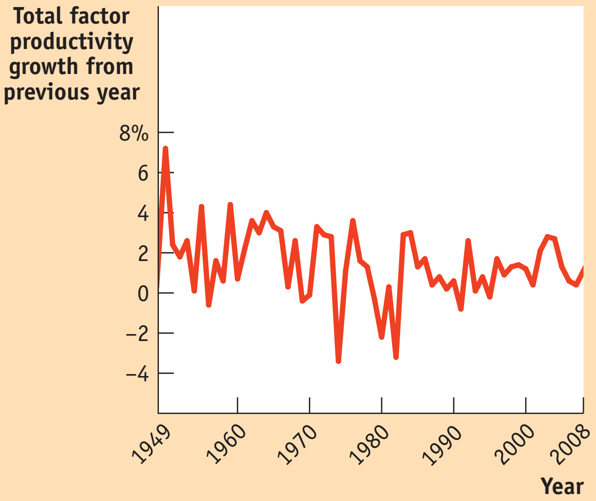
The Information Technology Paradox

From the early 1970s through the mid-1990s, the United States went through a slump in total factor productivity growth. The figure shows Bureau of Labor Statistics estimates of annual total factor productivity growth since 1949. As you can see, there was a large fall in the productivity growth rate beginning in the early 1970s. Because higher total factor productivity plays such a key role in long-run growth, the economy's overall growth was also disappointing, leading to a widespread sense that economic progress had ground to a halt.

Many economists were puzzled by the slowdown in total factor productivity growth after 1973, since in other ways the era seemed to be one of rapid technological progress. Modern information technology really began with the development of the first microprocessor—a computer on a chip—in 1971. In the 25 years that followed, a series of inventions that seemed revolutionary became standard equipment in the business world: fax machines, desktop computers, cell phones, and e-mail. Yet the rate of growth of productivity remained stagnant. In a famous remark, MIT economics professor and Nobel laureate Robert Solow, a pioneer in the analysis of economic growth, declared that the information technology revolution could be seen everywhere except in the economic statistics.

Why didn't information technology show large rewards? Paul David, a Stanford University economic historian, offered a theory and a prediction. He pointed out that 100 years earlier another miracle technology—electric power—had spread through the economy, again with surprisingly little impact on productivity growth at first. The reason, he suggested, was that a new technology doesn't yield its full potential if you use it in old ways.



For example, a traditional factory around 1900 was a multistory building, with the machinery tightly crowded together and designed to be powered by a steam engine in the basement. This design had problems: it was very difficult to move people and materials around. Yet owners who electrified their factories initially maintained the multistory, tightly packed layout. Only with the switch to spread-out, one-story factories that took advantage of the flexibility of electric power—most famously Henry Ford's auto assembly line—did productivity take off.

David suggested that the same phenomenon was happening with information technology. Productivity, he predicted, would take off when people really changed their way of doing business to take advantage of the new technology—such as replacing letters and phone calls with e-mail. Sure enough, productivity growth accelerated dramatically in the second half of the 1990s. And, a lot of that may have been due to the discovery by companies like Walmart of how to effectively use information technology.

Success, Disappointment, and Failure

Rates of long-run economic growth differ markedly around the world. Let's look at three regions that have had quite different experiences with economic growth over the last few decades.

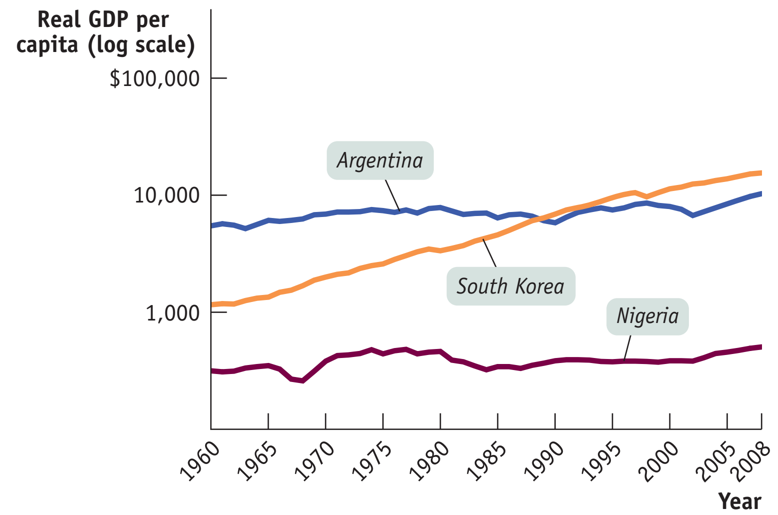
Figure 38.3 on the next page shows trends since 1960 in real GDP per capita in 2000 dollars for three countries: Argentina, Nigeria, and South Korea. (As in Figure 37.1, the vertical axis is drawn in logarithmic scale.) We have chosen these countries because each is a particularly striking example of what has happened in its region. South Korea's amazing rise is part of a larger success story in East Asia. Argentina's slow progress, interrupted by repeated setbacks, is more or less typical of the disappointment that has characterized Latin America. And Nigeria's unhappy story—real GDP per capita is barely higher now than it was in 1960—is, unfortunately, an experience shared by many African countries.

figure 38.3

Success and Disappointment

Real GDP per capita from 1960 to 2008, measured in 2000 dollars, is shown for Argentina, South Korea, and Nigeria, using a logarithmic scale. South Korea and some other East Asian countries have been highly successful at achieving economic growth. Argentina, like much of Latin America, has had several setbacks, slowing its growth. Nigeria's standard of living in 2008 was only barely higher than it had been in 1960, an experience shared by many African countries.

Source: World Bank.



East Asia's Miracle

In 1960, South Korea was a very poor country. In fact, in 1960 its real GDP per capita was lower than that of India today. But, as you can see from Figure 38.3, beginning in the early 1960s, South Korea began an extremely rapid economic ascent: real GDP per capita grew about 7% per year for more than 30 years. Today South Korea, though still somewhat poorer than Europe or the United States, looks very much like an economically advanced country.

South Korea's economic growth is unprecedented in history: it took the country only 35 years to achieve growth that required centuries elsewhere. Yet South Korea is only part of a broader phenomenon, often referred to as the East Asian economic miracle. High growth rates first appeared in South Korea, Taiwan, Hong Kong, and Singapore but then spread across the region, most notably to China. Since 1975, the whole region has increased real GDP per capita by 6% per year, three times America's historical rate of growth.

amana images inc./Alamy

Countries in East Asia have enjoyed unprecedented growth since the 1970s, thanks largely to the adoption of modern technology and the accumulation of human capital.

How have the Asian countries achieved such high growth rates? The answer is that all of the sources of productivity growth have been firing on all cylinders. Very high savings rates, the percentage of GDP that is saved nationally in any given year, have allowed the countries to significantly increase the amount of physical capital per worker. Very good basic education has permitted a rapid improvement in human capital. And these countries have experienced substantial technological progress.

Why hasn't any economy achieved this kind of growth in the past? Most economic analysts think that East Asia's growth spurt was possible because of its *relative* backwardness. That is, by the time that East Asian economies began to move into the modern world, they could benefit from adopting the technological advances that had been generated in technologically advanced countries such as the United States. In 1900, the United States could not have moved quickly to a modern level of productivity because much of the technology that powers the modern economy, from jet planes to computers, hadn't been invented yet. In 1970, South Korea probably still had lower labor productivity than the United States had in 1900, but it could rapidly upgrade its productivity by adopting technology that had been developed in the United States, Europe, and Japan over the previous century. This was aided by a huge investment in human capital through widespread schooling.

The East Asian experience demonstrates that economic growth can be especially fast in countries that are playing catch-up to other countries with higher GDP per capita. On this basis, many economists have suggested a general principle known as the **convergence hypothesis.** It says that differences in real GDP per capita among countries tend to narrow over time because countries that start with lower real GDP per capita tend to have higher growth rates. We'll look at the evidence for the convergence hypothesis later in this section.

According to the **convergence hypothesis,** international differences in real GDP per capita tend to narrow over time.

Even before we get to that evidence, however, we can say right away that starting with a relatively low level of real GDP per capita is no guarantee of rapid growth, as the examples of Latin America and Africa both demonstrate.

Latin America's Disappointment

In 1900, Latin America was not regarded as an economically backward region. Natural resources, including both minerals and cultivatable land, were abundant. Some countries, notably Argentina, attracted millions of immigrants from Europe in search of a better life. Measures of real GDP per capita in Argentina, Uruguay, and southern Brazil were comparable to those in economically advanced countries.

Since about 1920, however, growth in Latin America has been disappointing. As Figure 38.3 shows in the case of Argentina, it has remained disappointing to this day. The fact that South Korea is now much richer than Argentina would have seemed inconceivable a few generations ago.

Why has Latin America stagnated? Comparisons with East Asian success stories suggest several factors. The rates of savings and investment spending in Latin America have been much lower than in East Asia, partly as a result of irresponsible government policy that has eroded savings through high inflation, bank failures, and other disruptions. Education—especially broad basic education—has been underemphasized: even Latin American nations rich in natural resources often failed to channel that wealth into their educational systems. And political instability, leading to irresponsible economic policies, has taken a toll.

David R. Frazier Photolibrary, Inc./Alamy

Relatively low rates of savings, investment spending, and education, along with political instability, have hampered economic growth in Latin America.

In the 1980s, many economists came to believe that Latin America was suffering from excessive government intervention in markets. They recommended opening the economies to imports, selling off government-owned companies, and, in general, freeing up individual initiative. The hope was that this would produce an East Asian–type economic surge. So far, however, only one Latin American nation, Chile, has achieved rapid growth. It now seems that pulling off an economic miracle is harder than it looks.

Africa's Troubles

Africa south of the Sahara is home to about 780 million people, more than 2½ times the population of the United States. On average, they are very poor, nowhere close to U.S. living standards 100 or even 200 years ago. And economic progress has been both slow and uneven, as the example of Nigeria, the most populous nation in the region, suggests. In fact, real GDP per capita in sub-Saharan Africa actually fell 13 percent from 1980 to 1994, although it has recovered since then. The consequence of this poor growth performance has been intense and continuing poverty.

This is a very disheartening picture. What explains it?

Perhaps first and foremost is the problem of political instability. In the years since 1975, large parts of Africa have experienced savage civil wars (often with outside powers fyi

Are Economies Converging?

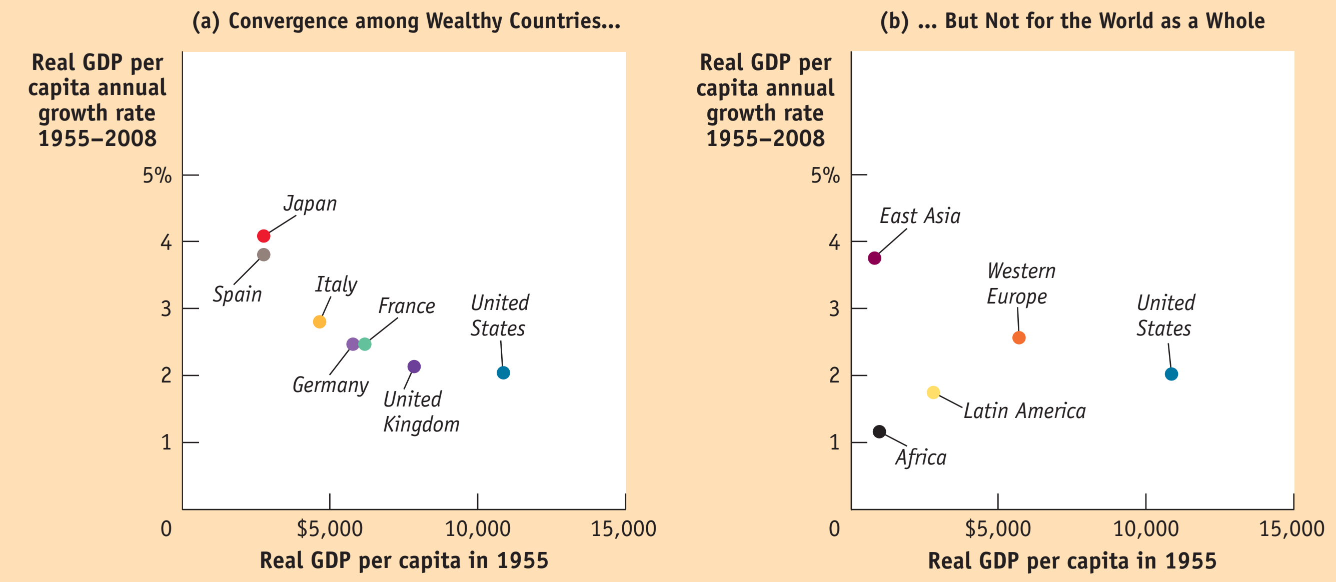
In the 1950s, much of Europe seemed quaint and backward to American visitors, and Japan seemed very poor. Today, a visitor to Paris or Tokyo sees a city that looks about as rich as New York. Although real GDP per capita is still somewhat higher in the United States, the differences in the standards of living among the United States, Europe, and Japan are relatively small.

Many economists have argued that this convergence in living standards is normal; the convergence hypothesis says that relatively poor countries should have higher rates of growth of real GDP per capita than relatively rich countries. And if we look at today's relatively well-off countries, the convergence hypothesis seems to be true. Panel (a) of the figure shows data for a number of today's wealthy economies measured in 1990 dollars. On the horizontal axis is real GDP per capita in 1955; on the vertical axis is the average annual growth rate of real GDP per capita from 1955 to 2008. There is a clear negative relationship. The United States was the richest country in this group in 1955 and had the slowest rate of growth. Japan and Spain were the poorest countries in 1955 and had the fastest rates of growth. These data suggest that the convergence hypothesis is true.

But economists who looked at similar data realized that these results depended on the countries selected. If you look at successful economies that have a high standard of living today, you find that real GDP per capita has converged. But looking across the world as a whole, including countries that remain poor, there is little evidence of convergence. Panel (b) of the figure illustrates this point using data for regions rather than individual countries (other than the United States). In 1955, East Asia and Africa were both very poor regions. Over the next 53 years, the East Asian regional economy grew quickly, as the convergence hypothesis would have predicted, but the African regional economy grew very slowly. In 1955, Western Europe had substantially higher real GDP per capita than Latin America. But, contrary to the convergence hypothesis, the Western European regional economy grew more quickly over the next 53 years, widening the gap between the regions.

So is the convergence hypothesis all wrong? No: economists still believe that countries with relatively low real GDP per capita tend to have higher rates of growth than countries with relatively high real GDP per capita, *other things equal.* But other things—education, infrastructure, rule of law, and so on—are often not equal. Statistical studies find that when you adjust for differences in these other factors, poorer countries do tend to have higher growth rates. This result is known as *conditional convergence.*

Because other factors differ, however, there is no clear tendency toward convergence in the world economy as a whole. Western Europe, North America, and parts of Asia are becoming more similar in real GDP per capita, but the gap between these regions and the rest of the world is growing.



backing rival sides) that have killed millions of people and made productive investment spending impossible. The threat of war and general anarchy has also inhibited other important preconditions for growth, such as education and provision of necessary infrastructure.

Property rights are also a problem. The lack of legal safeguards means that property owners are often subject to extortion because of government corruption, making them averse to owning property or improving it. This is especially damaging in a country that is very poor.

While many economists see political instability and government corruption as the leading causes of underdevelopment in Africa, some—most notably Jeffrey Sachs of Columbia University and the United Nations—believe the opposite. They argue that Africa is politically unstable because Africa is poor. And Africa's poverty, they go on to claim, stems from its extremely unfavorable geographic conditions—much of the continent is landlocked, hot, infested with tropical diseases, and cursed with poor soil.

Sachs, along with economists from the World Health Organization, has highlighted the importance of health problems in Africa. In poor countries, worker productivity is often severely hampered by malnutrition and disease. In particular, tropical diseases such as malaria can be controlled only with an effective public health infrastructure, something that is lacking in much of Africa. At the time of this writing, economists are studying certain regions of Africa to determine whether modest amounts of aid given directly to residents for the purposes of increasing crop yields, reducing malaria, and increasing school attendance can produce self-sustaining gains in living standards.

Although the example of African countries represents a warning that long-run economic growth cannot be taken for granted, there are some signs of hope. Mauritius has developed a successful textile industry. Several African countries that are dependent on exporting commodities such as coffee and oil have benefited from the higher prices of those commodities. And Africa's economic performance since the mid-1990s has been generally much better than it was in preceding decades.

Module 38 AP Review

Solutions appear at the back of the book.

Check Your Understanding

1. Explain the effect of each of the following on the growth rate of productivity.
   a. The amounts of physical and human capital per worker are unchanged, but there is significant technological progress.
   b. The amount of physical capital per worker grows, but the level of human capital per worker and technology are unchanged.
2. The economy of Erehwon has grown 3% per year over the past 30 years. The labor force has grown at 1% per year, and the quantity of physical capital has grown at 4% per year. The average education level hasn't changed. Estimates by economists say that each 1% increase in physical capital per worker, other things equal, raises productivity by 0.3%.
   a. How fast has productivity in Erehwon grown?
   b. How fast has physical capital per worker grown?
   c. How much has growing physical capital per worker contributed to productivity growth? What percentage of total productivity growth is that?
   d. How much has technological progress contributed to productivity growth? What percentage of total productivity growth is that?
3. Multinomics, Inc., is a large company with many offices around the country. It has just adopted a new computer system that will affect virtually every function performed within the company. Why might a period of time pass before employees' productivity is improved by the new computer system? Why might there be a temporary decrease in employees' productivity?

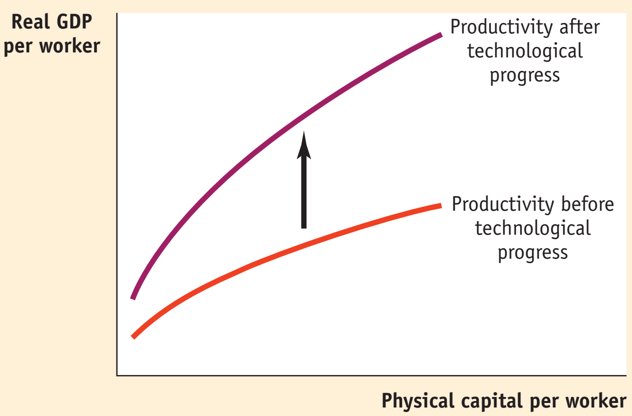
Tackle the Test: Multiple-Choice Questions

1. Which of the following is a source of increased productivity growth?
   I. increased physical capital
   II. increased human capital
   III. technological progress
   a. I only
   b. II only
   c. III only
   d. I and II only
   e. I, II, and III
2. Which of the following is an example of physical capital?
   a. machinery
   b. healthcare
   c. education
   d. money
   e. all of the above
3. The following statement describes which area of the world? "This area has experienced growth rates unprecedented in history and now looks like an economically advanced country."
   a. North America
   b. Latin America
   c. Europe
   d. East Asia
   e. Africa
4. Which of the following is cited as an important factor preventing long-run economic growth in Africa?
   a. political instability
   b. lack of property rights
   c. unfavorable geographic conditions
   d. poor health
   e. all of the above
5. The "convergence hypothesis"
   a. states that differences in real GDP per capita among countries widen over time.
   b. states that low levels of real GDP per capita are associated with higher growth rates.
   c. states that low levels of real GDP per capita are associated with lower growth rates.
   d. contradicts the "Rule of 70."
   e. has been proven by evidence from around the world.

Tackle the Test: Free-Response Questions

1. a. Draw a correctly labeled graph of an aggregate production function that illustrates diminishing returns to physical capital.
   b. Explain how your aggregate production function illustrates diminishing returns to physical capital.
   c. On your graph, illustrate the effect of technological progress.
   d. How is the level of human capital per worker addressed on your graph?

Answer (7 points)



1 point: Vertical axis is labeled "Real GDP per worker."

1 point: Horizontal axis is labeled physical capital per worker.

1 point: Upward-sloping curve is labeled "Aggregate production function" or "Productivity."

1 point: Curve increases at a decreasing rate (the slope is positive and decreasing).

1 point: Equal increases in physical capital per worker lead to smaller increases in real GDP per worker.

1 point: Upward shift of production function is labeled to indicate technological progress.

1 point: Human capital per worker is held constant.

2. Assume that between 1940 and 2010:
   The amount of physical capital per worker grows at 2% per year.
   Each 1% rise in physical capital per worker (holding human capital and technology constant) raises output per worker by ½ of a percent, or 0.5%.
   There is no growth in human capital.
   Real GDP per capita rises from $30,000 to $60,000.
   a. Growing physical capital per worker is responsible for how much productivity growth per year? Show your calculation.
   b. By how much did total factor productivity grow over the time period? Explain.

What you will learn in this Module:

- The factors that explain why long-run growth rates differ so much among countries
- The challenges to growth posed by scarcity of natural resources, environmental degradation, and efforts to make growth sustainable

Module 39 Growth Policy: Why Economic Growth Rates Differ

Why Growth Rates Differ

In 1820, according to estimates by the economic historian Angus Maddison, Mexico had somewhat higher real GDP per capita than Japan. Today, Japan has higher real GDP per capita than most European nations and Mexico is a poor country, though by no means among the poorest. The difference? Over the long run, real GDP per capita grew at 1.9% per year in Japan but at only 1.2% per year in Mexico.

As this example illustrates, even small differences in growth rates have large consequences over the long run. So why do growth rates differ across countries and across periods of time?

Capital, Technology, and Growth Differences

As one might expect, economies with rapid growth tend to be economies that add physical capital, increase their human capital, or experience rapid technological progress. Striking economic success stories, like Japan in the 1950s and 1960s or China today, tend to be countries that do all three: that rapidly add to their physical capital, upgrade their educational level, and make fast technological progress.

Adding to Physical Capital One reason for differences in growth rates among countries is that some countries are increasing their stock of physical capital much more rapidly than others, through high rates of investment spending. In the 1960s, Japan was the fastest-growing major economy; it also spent a much higher share of its GDP on investment goods than other major economies. Today, China is the fastest-growing major economy, and it similarly spends a very large share of its GDP on investment goods. In 2009, investment spending was 44% of China's GDP, compared with only 18% in the United States.

Research and development, or **R & D,** is spending to create and implement new technologies.

Where does the money for high investment spending come from? We have already analyzed how financial markets channel savings into investment spending. The key point is that investment spending must be paid for either out of savings from domestic households or by an inflow of foreign capital—that is, savings from foreign households. Foreign capital has played an important role in the long-run economic growth of some countries, including the United States, which relied heavily on foreign funds during its early industrialization. For the most part, however, countries that invest a large share of their GDP are able to do so because they have high domestic savings. One reason for differences in growth rates, then, is that countries have different rates of savings and investment spending.

Adding to Human Capital Just as countries differ substantially in the rate at which they add to their physical capital, there have been large differences in the rate at which countries add to their human capital through education.

A case in point is the comparison between Latin America and East Asia. In both regions the average educational level has risen steadily over time, but it has risen much faster in East Asia. As shown in Table 39.1, East Asia had a significantly less educated population than Latin America in 1960. By 2000, that gap had been closed: East Asia still had a slightly higher fraction of adults with no education—almost all of them elderly—but had moved well past Latin America in terms of secondary and higher education.

table **39.1**

Human Capital in Latin America and East Asia

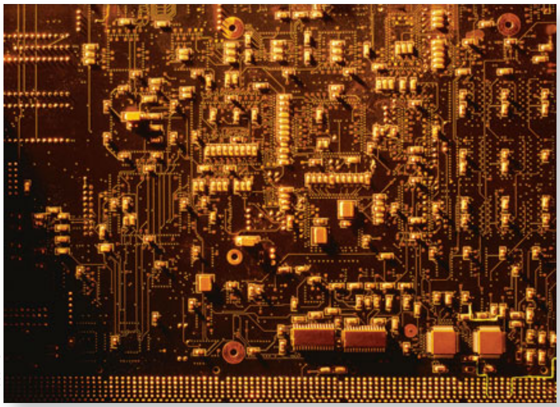
	Latin America		East Asia	
	1960	2000	1960	2000
Percentage of population with no schooling	37.9%	14.6%	52.5%	19.8%
Percentage of population with high school or above	5.9	19.5	4.4	26.5

Source: Barro, Robert J. and Lee, Jong-Wha (2001) "International Data on Educational Attainment: Updates and Implications," *Oxford Economic Papers* vol. 53(3), p. 541–563.

Technological Progress The advance of technology is a key force behind economic growth. What drives technology?

Scientific advances make new technologies possible. To take the most spectacular example in today's world, the semiconductor chip—which is the basis for all modern information technology—could not have been developed without the theory of quantum mechanics in physics.

But science alone is not enough: scientific knowledge must be translated into useful products and processes. And that often requires devoting a lot of resources to **research and development,** or **R&D,** spending to create new technologies and prepare them for practical use.



Photodisc

Although some research and development is conducted by governments, much R&D is paid for by the private sector, as discussed below. The United States became the world's leading economy in large part because American businesses were among the first to make systematic research and development a part of their operations.

Developing new technology is one thing; applying it is another. There have often been notable differences in the pace at which different countries take advantage of new technologies. America's surge in productivity growth after 1995, as firms learned to make use of information technology, was at least initially not matched in Europe.

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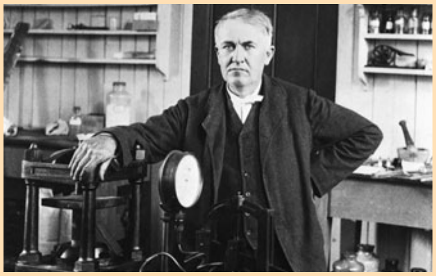
Inventing R&D

Thomas Edison is best known as the inventor of the light bulb and the phonograph. But his biggest invention may surprise you: he invented research and development.

Before Edison's time, there had, of course, been many inventors. Some of them worked in teams. But in 1875 Edison created something new: his Menlo Park, New Jersey, laboratory. It employed 25 men full-time to generate new products and processes for business. In other words, he did not set out to pursue a particular idea and then cash in. He created an organization whose purpose was to create new ideas year after year.

Edison's Menlo Park lab is now a museum. "To name a few of the products that were developed in Menlo Park," says the museum's website, "we can list the following: the carbon button mouthpiece for the telephone, the phonograph, the incandescent light bulb and the electrical distribution system, the electric train, ore separation, the Edison effect bulb, early experiments in wireless, the grasshopper telegraph, and improvements in telegraphic transmission."

You could say that before Edison's lab, technology just sort of happened: people came up with ideas, but businesses didn't plan to make continuous technological progress. Now R&D operations, often much bigger than Edison's original team, are standard practice throughout the business world.



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Thomas Alva Edison in his laboratory in East Orange, New Jersey, in 1901.

The Role of Government in Promoting Economic Growth

Governments can play an important role in promoting—or blocking—all three sources of long-term economic growth: physical capital, human capital, and technological progress.

Roads, power lines, ports, information networks, and other underpinnings for economic activity are known as **infrastructure.**

Governments and Physical Capital Governments play an important direct role in building **infrastructure:** roads, power lines, ports, information networks, and other parts of an economy's physical capital that provide an underpinning, or foundation, for economic activity. Although some infrastructure is provided by private companies, much of it is either provided by the government or requires a great deal of government regulation and support. Ireland, whose economy really took off in the 1990s, is often cited as an example of the importance of government-provided infrastructure: the government invested in an excellent telecommunications infrastructure in the 1980s, and this helped make Ireland a favored location for high-technology companies.

Poor infrastructure—for example, a power grid that often fails, cutting off electricity to homes and businesses—is a major obstacle to economic growth in some countries. To provide good infrastructure, an economy must be able to afford it, but it must also have the political discipline to maintain it and provide for the future.

Perhaps the most crucial infrastructure is something we rarely think about: basic public health measures in the form of a clean water supply and disease control. As we'll see in the next section, poor health infrastructure is a major obstacle to economic growth in poor countries, especially those in Africa.

Governments also play an important indirect role in making high rates of private investment spending possible. Both the amount of savings and the ability of an economy to direct savings into productive investment spending depend on the economy's institutions, notably its financial system. In particular, a well-functioning banking system is very important for economic growth because in most countries it is the principal way in which savings are channeled into business investment spending. If a country's citizens trust their banks, they will place their savings in bank deposits, which the banks will then lend to their business customers. But if people don't

ED OUDENAARDEN/AFP/Getty Images

Governments play a vital role in health maintenance. A child is vaccinated against the influenza A (H_1N_1) virus during a mass vaccination in Schiedam, Netherlands, in late 2009.

trust their banks, they will hoard gold or foreign currency, keeping their savings in safe deposit boxes or under their mattresses, where it cannot be turned into productive investment spending. A well-functioning financial system requires appropriate government regulation that assures depositors that their funds are protected.

Governments and Human Capital An economy's physical capital is created mainly through investment spending by individuals and private companies. Much of an economy's human capital, in contrast, is the result of government spending on education. Governments pay for the great bulk of primary and secondary education, although individuals pay a significant share of the costs of higher education.

As a result, differences in the rate at which countries add to their human capital largely reflect government policy. As we saw in Table 39.1, East Asia now has a more educated population than Latin America. This isn't because East Asia is richer than Latin America and so can afford to spend more on education. Until very recently, East Asia was, on average, poorer than Latin America. Instead, it reflects the fact that Asian governments made broad education of the population a higher priority.

Governments and Technology Technological progress is largely the result of private initiative. But much important R&D is done by government agencies. For example, Brazil's agricultural boom was made possible by government researchers who discovered that adding crucial nutrients to the soil would allow crops to be grown on previously unusable land. They also developed new varieties of soybeans and breeds of cattle that flourish in Brazil's tropical climate.

Political Stability, Property Rights, and Excessive Government Intervention There's not much point in investing in a business if rioting mobs are likely to destroy it. And why save your money if someone with political connections can steal it? Political stability and protection of property rights are crucial ingredients in long-run economic growth.

Long-run economic growth in successful economies, like that of the United States, has been possible because there are good laws, institutions that enforce those laws, and a stable political system that maintains those institutions. The law must say that your property is really yours so that someone else can't take it away. The courts and the police must be honest so that they can't be bribed to ignore the law. And the political system must be stable so that the law doesn't change capriciously.

Americans take these preconditions for granted, but they are by no means guaranteed. Aside from the disruption caused by war or revolution, many countries find that

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The Brazilian Breadbasket

A wry Brazilian joke says that "Brazil is the country of the future—and always will be." The world's fifth most populous country has often been considered a possible major economic power yet has never fulfilled that promise.

In recent years, however, Brazil's economy has made a better showing, especially in agriculture. This success depends on exploiting a natural resource, the tropical savanna land known as the *cerrado.* Until a quarter century ago, the land was considered unsuitable for farming. A combination of three factors changed that: technological progress due to research and development, improved economic policies, and greater physical capital.

The Brazilian Enterprise for Agricultural and Livestock Research, a government-run agency, developed the crucial technologies. It showed that adding lime and phosphorus made *cerrado* land productive, and it developed breeds of cattle and varieties of soybeans suited for the climate. (Now they're working on wheat.) Also, until the 1980s, Brazilian international trade policies discouraged exports, as did an overvalued exchange rate that made the country's goods more expensive to foreigners. After economic reform, investing in Brazilian agriculture became much more profitable and companies began putting in place the farm machinery, buildings, and other forms of physical capital needed to exploit the land.

What still limits Brazil's growth? Infrastructure. According to a report in the *New York Times,* Brazilian farmers are "concerned about the lack of reliable highways, railways and barge routes, which adds to the cost of doing business." Recognizing this, the Brazilian government is investing in infrastructure, and Brazilian agriculture is continuing to expand. The country has already overtaken the United States as the world's largest beef exporter and may not be far behind in soybeans.

their economic growth suffers due to corruption among the government officials who should be enforcing the law. For example, until 1991 the Indian government imposed many bureaucratic restrictions on businesses, which often had to bribe government officials to get approval for even routine activities—a tax on business, in effect. Economists have argued that a reduction in this burden of corruption is one reason Indian growth has been much faster in recent years than it was in the first 40 years after India gained independence in 1947.

Even when governments aren't corrupt, excessive government intervention can be a brake on economic growth. If large parts of the economy are supported by government subsidies, protected from imports, or otherwise insulated from competition, productivity tends to suffer because of a lack of incentives. As we saw in Module 38, excessive government intervention is one often-cited explanation for slow growth in Latin America.

Long-run economic growth is **sustainable** if it can continue in the face of the limited supply of natural resources and the impact of growth on the environment.

Is World Growth Sustainable?

Earlier we described the views of Thomas Malthus, the nineteenth-century economist who warned that the pressure of population growth would tend to limit the standard of living. Malthus was right—about the past: for around 58 centuries, from the origins of civilization until his own time, limited land supplies effectively prevented any large rise in real incomes per capita. Since then, however, technological progress and rapid accumulation of physical and human capital have allowed the world to defy Malthusian pessimism.

But will this always be the case? Some skeptics have expressed doubt about whether long-run economic growth is **sustainable**—whether it can continue in the face of the limited supply of natural resources and the impact of growth on the environment.

Natural Resources and Growth, Revisited

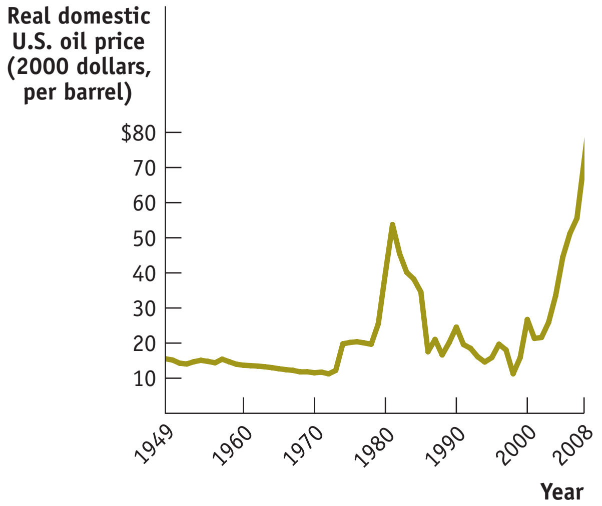
In 1972, a group of scientists called the Club of Rome made a big splash with a book titled *The Limits to Growth,* which argued that long-run economic growth wasn't sustainable due to limited supplies of nonrenewable resources such as oil and natural gas. These "neo-Malthusian" concerns at first seemed to be validated by a sharp rise in resource prices in the 1970s, then came to seem foolish when resource prices fell sharply in the 1980s. After 2005, however, resource prices rose sharply again, leading to renewed concern about resource limitations to growth. Figure 39.1 shows the real price

figure 39.1

The Real Price of Oil, 1949–2008

The real price of natural resources, like oil, rose dramatically in the 1970s and then fell just as dramatically in the 1980s. Since 2005, however, the real prices of natural resources have soared.

Source: Energy Information Administration.



of oil—the price of oil adjusted for inflation in the rest of the economy. The rise and fall of concerns about resource-based limits to growth have more or less followed the rise and fall of oil prices shown in the figure.

Differing views about the impact of limited natural resources on long-run economic growth turn on the answers to three questions:

- How large are the supplies of key natural resources?
- How effective will technology be at finding alternatives to natural resources?
- Can long-run economic growth continue in the face of resource scarcity?

It's mainly up to geologists to answer the first question. Unfortunately, there's wide disagreement among the experts, especially about the prospects for future oil production. Some analysts believe that there is so much untapped oil in the ground that world oil production can continue to rise for several decades. Others—including a number of oil company executives—believe that the growing difficulty of finding new oil fields will cause oil production to plateau—that is, stop growing and eventually begin a gradual decline—in the fairly near future. Some analysts believe that we have already reached that plateau.

The answer to the second question, whether there are alternatives to certain natural resources, will come from engineers. There's no question that there are many alternatives to the natural resources currently being depleted, some of which are already being exploited. For example, "unconventional" oil extracted from Canadian tar sands is already making a significant contribution to world oil supplies, and electricity generated by wind turbines is rapidly becoming big business in the United States—a development highlighted by the fact that in 2009 the United States surpassed Germany to become the world's largest producer of wind energy.

The third question, whether economies can continue to grow in the face of resource scarcity, is mainly a question for economists. And most, though not all, economists are optimistic: they believe that modern economies can find ways to work around limits on the supply of natural resources. One reason for this optimism is the fact that resource scarcity leads to high resource prices. These high prices in turn provide strong incentives to conserve the scarce resource and to find alternatives.

Photodisc/Getty Images

The Tehachapi Wind Farm, in Tehachapi, California, is the second largest collection of wind generators in the world. The turbines are operated by several private companies and collectively produce enough electricity to meet the needs of 350,000 people every year.

For example, after the sharp oil price increases of the 1970s, American consumers turned to smaller, more fuel-efficient cars, and U.S. industry also greatly intensified its efforts to reduce energy bills. The result is shown in Figure 39.2, which compares the growth rates of real GDP per capita and oil consumption before and after the 1970s energy crisis. Before 1973, there seemed to be a more or less one-to-one relationship between economic growth and oil consumption, but after 1973 the U.S. economy continued to deliver growth in real GDP per capita even as it substantially reduced its use of oil. This move toward conservation paused after 1990, as low real oil prices encouraged consumers to shift back to gas-greedy larger cars and SUVs. A sharp rise in oil prices from 2005 to 2008 encouraged renewed shifts toward oil conservation, although these shifts lost some steam as prices started falling again in late 2008.

Given such responses to prices, economists generally tend to see resource scarcity as a problem that modern economies handle fairly well, and so not a fundamental limit to long-run economic growth. Environmental issues, however, pose a more difficult problem because dealing with them requires effective political action.

Economic Growth and the Environment

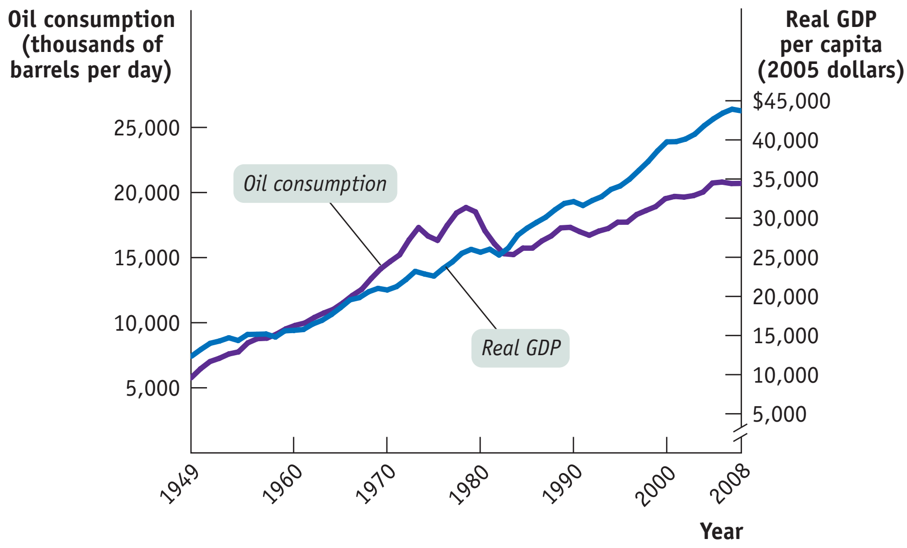
Economic growth, other things equal, tends to increase the human impact on the environment. For example, China's spectacular economic growth has also brought a spectacular increase in air pollution in that nation's cities. It's important to realize,

figure 39.2

U.S. Oil Consumption and Growth over Time

Until 1973, the real price of oil was relatively cheap and there was a more or less one-to-one relationship between economic growth and oil consumption. Conservation efforts increased sharply after the spike in the real price of oil in the mid-1970s. Yet the U.S. economy was still able to grow despite cutting back on oil consumption.

Sources: Energy Information Administration; Bureau of Economic Analysis.



however, that other things aren't necessarily equal: countries can and do take action to protect their environments. In fact, air and water quality in today's advanced countries is generally much better than it was a few decades ago. London's famous "fog"—actually a form of air pollution, which killed 4,000 people during a two-week episode in 1952—is gone, thanks to regulations that virtually eliminated the use of coal heat. The equally famous smog of Los Angeles, although not extinguished, is far less severe than it was in the 1960s and early 1970s, again thanks to pollution regulations.

Despite these past environmental success stories, there is widespread concern today about the environmental impacts of continuing economic growth, reflecting a change in the scale of the problem. Environmental success stories have mainly involved dealing with *local* impacts of economic growth, such as the effect of widespread car ownership on air quality in the Los Angeles basin. Today, however, we are faced with *global* environmental issues—the adverse impacts on the environment of the Earth as a whole by

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Coal Comfort on Resources

Those who worry that exhaustion of natural resources will bring an end to economic growth can take some comfort from the story of William Stanley Jevons, a nineteenth-century British economist best known today for his role in the development of marginal analysis. In addition to his work in economic theory, Jevons worked on the real-world economic problems of the day, and in 1865 he published an influential book, *The Coal Question,* that foreshadowed many modern concerns about resources and growth. But his pessimism was proved wrong.

The Industrial Revolution was launched in Britain, and in 1865 Britain still had the world's richest major economy. But Jevons argued that Britain's economic success had depended on the availability of cheap coal and that the gradual exhaustion of Britain's coal resources, as miners were forced to dig ever deeper, would threaten the nation's long-run prosperity.

He was right about the exhaustion of Britain's coal: production peaked in 1913, and today the British coal industry is a shadow of its former self. But Britain was able to turn to alternative sources of energy, including imported coal and oil. And economic growth did not collapse: real GDP per capita in Britain today is about seven times its level in 1865.

worldwide economic growth. The biggest of these issues involves the impact of fossil-fuel consumption on the world's climate.

Burning coal and oil releases carbon dioxide into the atmosphere. There is broad scientific consensus that rising levels of carbon dioxide and other gases are causing a greenhouse effect on the Earth, trapping more of the sun's energy and raising the planet's overall temperature. And rising temperatures may impose high human and economic costs: rising sea levels may flood coastal areas; changing climate may disrupt agriculture, especially in poor countries; and so on.

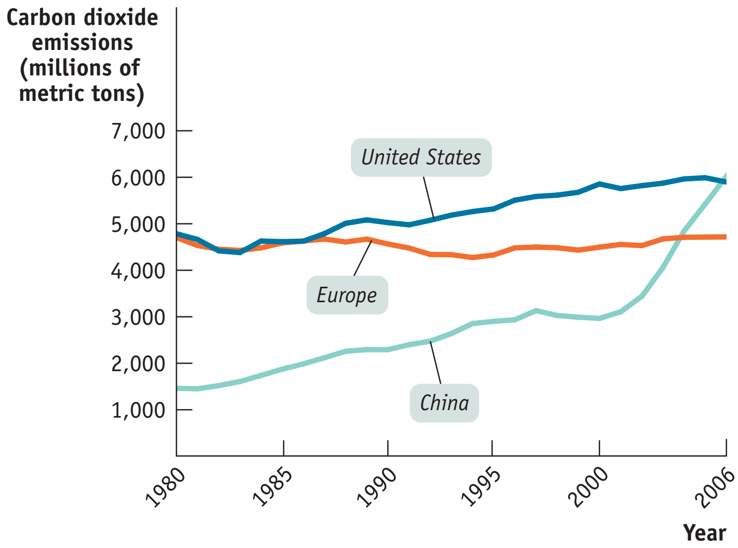
The problem of climate change is clearly linked to economic growth. Figure 39.3 shows carbon dioxide emissions from the United States, Europe, and China since 1980. Historically, the wealthy nations have been responsible for the bulk of these emissions because they have consumed far more energy per person than poorer countries. As China and other emerging economies have grown, however, they have begun to consume much more energy and emit much more carbon dioxide.

figure 39.3

Climate Change and Growth

Greenhouse gas emissions are positively related to growth. As shown here by the United States and Europe, wealthy countries have historically been responsible for the great bulk of greenhouse gas emissions because of their richer and faster-growing economies. As China and other emerging economies have grown, they have begun to emit much more carbon dioxide.

Source: Energy Information Administration.



Is it possible to continue long-run economic growth while curbing the emissions of greenhouse gases? The answer, according to most economists who have studied the issue, is yes. It should be possible to reduce greenhouse gas emissions in a wide variety of ways, ranging from the use of non-fossil-fuel energy sources such as wind, solar, and nuclear power; to preventive measures such as carbon sequestration (capturing carbon dioxide and storing it); to simpler things like designing buildings so that they're easier to keep warm in winter and cool in summer. Such measures would impose costs on the economy, but the best available estimates suggest that even a large reduction in greenhouse gas emissions over the next few decades would only modestly dent the long-term rise in real GDP per capita.

The problem is how to make all of this happen. Unlike resource scarcity, environmental problems don't automatically provide incentives for changed behavior. Pollution is an example of a *negative externality,* a cost that individuals or firms impose on others without having to offer compensation. In the absence of government intervention, individuals and firms have no incentive to reduce negative externalities, which is why it took regulation to reduce air pollution in America's cities. And as Nicholas Stern, the author of an influential report on climate change, put it, greenhouse gas emissions are "the mother of all externalities."

So there is a broad consensus among economists—although there are some dissenters—that government action is needed to deal with climate change. There is also broad consensus that this action should take the form of market-based incentives, either in the form of a carbon tax—a tax per unit of carbon emitted—or a cap and trade system in which the total amount of emissions is capped, and producers must buy licenses to emit greenhouse gases. There is, however, considerable dispute about how much action is appropriate, reflecting both uncertainty about the costs and benefits and scientific uncertainty about the pace and extent of climate change.

There are also several aspects of the climate change problem that make it much more difficult to deal with than, say, smog in Los Angeles. One is the problem of taking the long view. The impact of greenhouse gas emissions on the climate is very gradual: carbon dioxide put into the atmosphere today won't have its full effect on the climate for several generations. As a result, there is the political problem of persuading voters to accept pain today in return for gains that will benefit their children, grandchildren, or even great-grandchildren.

The added problem of international burden sharing presents a stumbling block for consensus, as it did at the United Nations Climate Change Conference in 2009. As Figure 39.3 shows, today's rich countries have historically been responsible for most greenhouse gas emissions, but newly emerging economies like China are responsible for most of the recent growth. Inevitably, rich countries are reluctant to pay the price of reducing emissions only to have their efforts frustrated by rapidly growing emissions from new players. On the other hand, countries like China, which are still relatively poor, consider it unfair that they should be expected to bear the burden of protecting an environment threatened by the past actions of rich nations.

Despite political issues and the need for compromise, the general moral of this story is that it is possible to reconcile long-run economic growth with environmental protection. The main question is one of getting political consensus around the necessary policies.

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The Cost of Climate Protection

At the time of this writing, there were a number of bills before the U.S. Congress, some of them with bipartisan sponsorship, calling for ambitious, long-term efforts to reduce U.S. emissions of greenhouse gases. For example, a bill sponsored by Senators Joseph Lieberman and John McCain would use a cap and trade system to gradually reduce emissions over time, eventually—by 2050—reducing them to 60% below their 1990 level. Another bill, sponsored by Senators Barbara Boxer and Bernie Sanders, called for an 80% reduction by 2050.

Would implementing these bills put a stop to long-run economic growth? Not according to a comprehensive study by a team at MIT, which found that reducing emissions would impose significant but not overwhelming costs. Using an elaborate model of the interaction between environmental policy and the economy, the MIT group estimated that the Lieberman–McCain proposal would reduce real GDP per capita in 2050 by 1.11% and the more stringent Sanders–Boxer proposal would reduce real GDP per capita by 1.79%.

These may sound like big numbers—they would amount to between \$200 billion and \$250 billion today—but they would hardly make a dent in the economy's long-run growth rate. Remember that over the long run the U.S. economy has on average seen real GDP per capita rise by almost 2% a year. If the MIT group's estimates are correct, even a strong policy to avert climate change would, in effect, require that we give up less than one year's growth over the next four decades.

Module 39 AP Review

Solutions appear at the back of the book.

Check Your Understanding

1. Explain the link between a country's growth rate, its investment spending as a percent of GDP, and its domestic savings.
2. Which of the following is the better predictor of a future high long-run growth rate: a high standard of living today or high levels of savings and investment spending? Explain your answer.
3. Some economists think the best way to help African countries is for wealthier countries to provide more funds for basic infrastructure. Others think this policy will have no long-run effect unless African countries have the financial and political means to maintain this infrastructure. What policies would you suggest?
4. What is the link between greenhouse gas emissions and growth? What is the expected effect on growth from emissions reduction? Why is international burden sharing of greenhouse gas emissions reduction a contentious problem?

Tackle the Test: Multiple-Choice Questions

1. Economies experience more rapid economic growth when they do which of the following?
   I. add physical capital
   II. promote technological progress
   III. limit human capital
   a. I only
   b. II only
   c. III only
   d. I and II only
   e. I, II, and III
2. Which of the following can lead to increases in physical capital in an economy?
   a. increased investment spending
   b. increased savings by domestic households
   c. increased savings from foreign households
   d. an inflow of foreign capital
   e. all of the above
3. Which of the following is true of sustainable long-run economic growth?
   a. Long-run growth can continue in the face of the limited supply of natural resources.
   b. It was predicted by Thomas Malthus.
   c. Modern economies handle resource scarcity problems poorly.
   d. It is less likely when we find alternatives to natural resources.
   e. All of the above are true.
4. Which of the following statements is true of environmental quality?
   a. It is typically not affected by government policy.
   b. Other things equal, it tends to improve with economic growth.
   c. There is broad scientific consensus that rising levels of carbon dioxide and other gases are raising the planet's overall temperature.
   d. Most economists believe it is not possible to reduce greenhouse gas emissions while economic growth continues.
   e. Most environmental success stories involve dealing with global, rather than local impacts.
5. According to the MIT study discussed in the module, a cap and trade system to reduce greenhouse gas emissions in the United States would lead to
   a. no significant costs.
   b. significant but not overwhelming costs.
   c. a loss of roughly three year's real GDP over the next 40 years.
   d. a reduction in real GDP per capita of over 10%.
   e. a loss of 5 years' worth of economic growth over the next 40 years.

Tackle the Test: Free-Response Questions

1. List and explain five different actions the government can take to promote long-run economic growth.

Answer (10 points)—10 points for 5 of the 6 possible actions/descriptions

1 point: Build infrastructure.

1 point: The government can provide roads, power lines, ports, rail lines, and related systems to support economic activity.

1 point: Invest in human capital.

1 point: The government can improve access to quality education.

1 point: Invest in research and development.

1 point: The government can promote technological progress by having government agencies support and participate in R&D.

1 point: Provide political stability.

1 point: The government can create and maintain institutions that make and enforce laws that promote stability.

1 point: Establish and protect property rights.

1 point: Growth is promoted by laws that define what property belongs to whom and by institutions that defend those property rights.

1 point: Minimize government intervention.

1 point: The government can limit its intervention in the economy and promote competition.

2. What roles do physical capital, human capital, technology, and natural resources play in influencing long-run economic growth of aggregate output per capita?

What you will learn in this Module:

- How long-run economic growth is represented in macroeconomic models
- How to model the effects of economic growth policies

Module 40 Economic Growth in Macroeconomic Models

Long-run economic growth is fundamental to solving many of today's most pressing economic problems. It is even more critical in poorer, less developed countries. But the policies we have studied in earlier sections to address short-run fluctuations and the business cycle may not encourage long-run economic growth. For example, an increase in household consumption can help an economy to recover from a recession. However, when households increase consumption, they decrease their savings, which leads to decreased investment spending and slows long-run economic growth.

In addition to understanding short-run stabilization policies, we need to understand the factors that influence economic growth and how choices by governments and individuals can promote or retard that growth in the long-run.

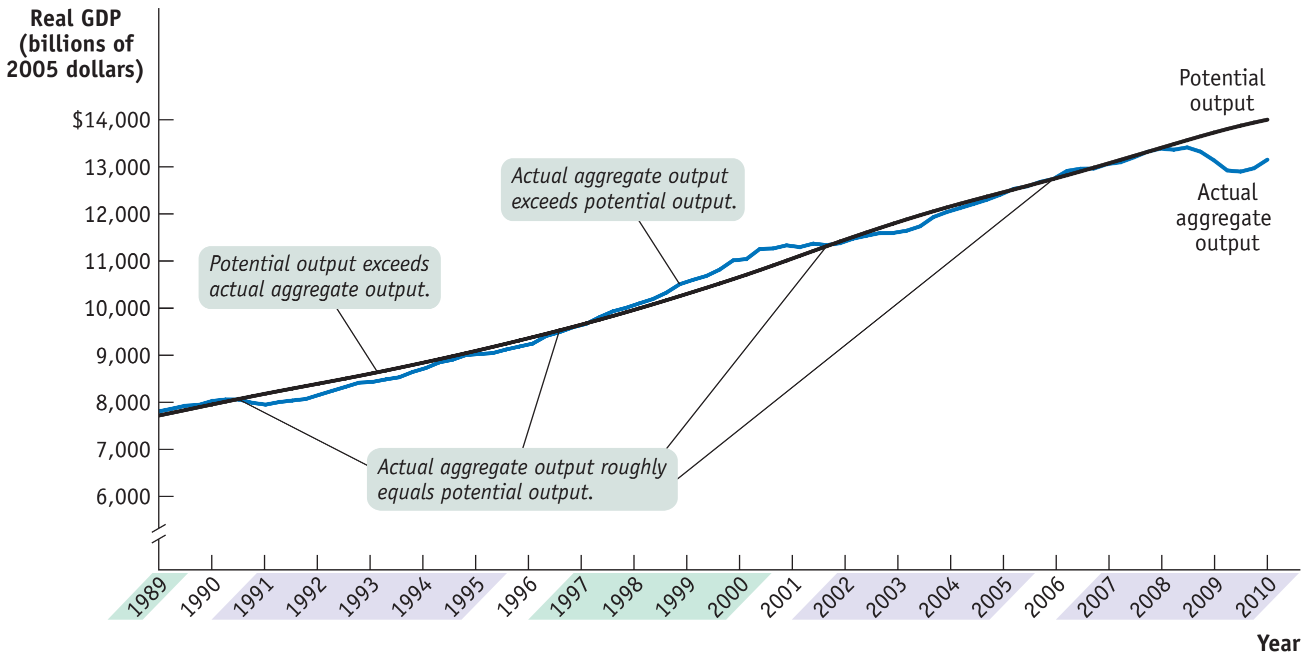
Long-run economic growth is the sustained rise in the quantity of goods and services the economy produces, as opposed to the short-run ups and downs of the business cycle. In Module 18, we looked at actual and potential output in the United States from 1989 to 2009. As shown in Figure 40.1, increases in potential output during that time represent long-run economic growth in the economy. The fluctuations of actual output compared to potential output are the result of the business cycle.

As we have seen throughout this section, long-run economic growth depends almost entirely on rising productivity. Good macroeconomic policy strives to foster increases in productivity, which in turn leads to long-run economic growth. In this module, we will learn how to evaluate the effects of long-run growth policies using the production possibilities curve and the aggregate demand and supply model.

Long-run Economic Growth and the Production Possibilities Curve

Recall from Section 1 that we defined the production possibilities curve as a graph that illustrates the trade-offs facing an economy that produces only two goods. In our example, we developed the production possibilities curve for Tom, a castaway facing a

figure 40.1 Actual and Potential Output from 1989 to 2009



This figure shows the performance of actual and potential output in the United States from 1989 to 2009. The black line shows estimates, produced by the Congressional Budget Office, of U.S. potential output. The blue line shows actual aggregate output. The purple-shaded years are periods in which actual aggregate output fell below potential output, and the green shaded years are periods in which actual aggregate output exceeded potential output. As shown, significant shortfalls occurred in the recessions of the early 1990s and after 2000. Actual aggregate output was significantly above potential output in the boom of the late 1990s.

Sources: Congressional Budget Office, Bureau of Economic Analysis.

trade-off between producing fish and coconuts. Looking at Figure 40.2 on the next page, we see that economic growth is shown as an outward shift of the production possibilities curve. Now let's return to the production possibilities curve model and use a different example to illustrate how economic growth policies can lead to long-run economic growth.

Figure 40.3 on the next page shows a hypothetical production possibilities curve for a fictional country we'll call Kyland. In our previous production possibilities examples, the trade-off was between producing quantities of two different goods. In this example, our production possibilities curve illustrates Kyland's trade-off between two different *categories* of goods. The production possibilities curve shows the alternative combinations of investment goods and consumer goods that Kyland can produce. The consumer goods category includes everything purchased for consumption by households, such as food, clothing, and sporting goods. Investment goods include all forms of physical capital. That is, goods that are used to produce other goods. Kyland's production possibilities curve shows the trade-off between the production of consumer goods and the production of investment goods. Recall that the bowed-out shape of the production possibilities curve reflects increasing opportunity cost.

Kyland's production possibilities curve shows all possible combinations of consumer and investment goods that can be produced with full and efficient use of all of Kyland's resources. However, the production possibilities curve model does not tell us which of the possible points Kyland *should* select.

figure 40.2

Economic Growth

Economic growth results in an *outward shift* of the production possibilities curve because production possibilities are expanded. The economy can now produce more of everything. For example, if production is initially at point *A* (20 fish and 25 coconuts), it could move to point *E* (25 fish and 30 coconuts).

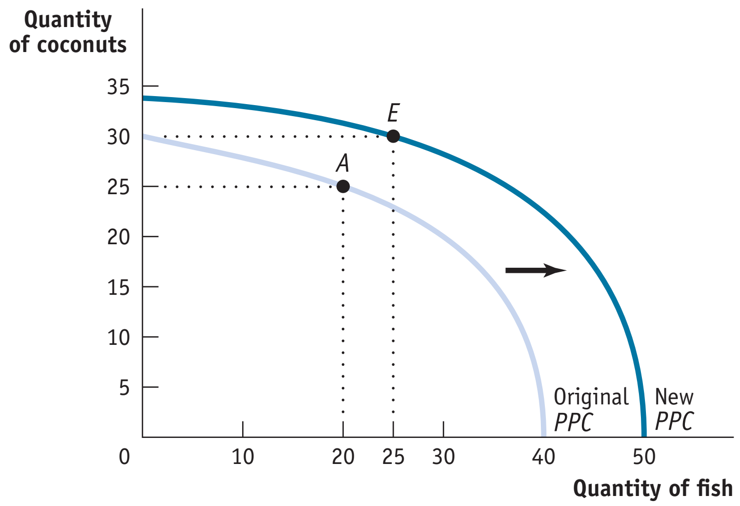


Figure 40.3 illustrates four points on Kyland's production possibilities curve. At point *A,* Kyland is producing all investment goods and no consumer goods. Investment in physical capital, one of the economy's factors of production, causes the production possibilities curve to shift outward. Choosing to produce at a point on the production possibilities curve that creates more capital for the economy will result in greater production possibilities in the future. Note that at point *A,* there are no consumer goods being produced, a situation which the economy cannot survive.

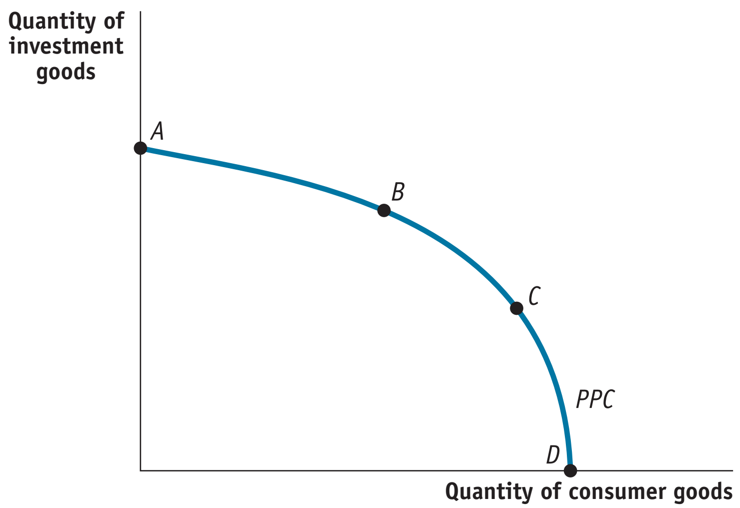
At point *D,* Kyland is producing all consumer goods and no investment goods. While this point provides goods and services for consumers in Kyland, it does not include the production of any physical capital. Over time, as an economy produces more goods and services, some of its capital is used up in that production. A loss in the value of physical capital due to wear, age, or obsolescence is called **depreciation.** If Kyland were to produce at point *D* year after year, it would soon find its stock of physical

Depreciation occurs when the value of an asset is reduced by wear, age, or obsolescence.

figure 40.3

The Trade-off Between Investment and Consumer Goods

This production possibilities curve illustrates Kyland's trade-off between the production of investment goods and consumer goods. At point *A,* Kyland produces all investment goods and no consumer goods. At point *D,* Kyland produces all consumer goods and no investment goods.



capital depreciating and its production possibilities curve would shift inward over time, indicating a decrease in production possibilities. Points *B* and *C* represent a mix of consumer and investment goods for the economy. While we can see that points *A* and *D* would not be acceptable choices over a long period of time, the choice between points *B* and *C* would depend on the values, politics, and other details related to the economy and people of Kyland. What we do know is that the choice made by Kyland each year will affect the position of the production possibilities curve in the future. An emphasis on the production of consumer goods will make consumers better off in the short run but will prevent the production possibilities curve from moving farther out in the future. An emphasis on investment goods will lead the production possibilities curve to shift out farther in the future but will decrease the quantity of consumer goods available in the short run.

So what does the production possibilities curve tell us about economic growth? Since long-run economic growth depends almost entirely on rising productivity, a country's decision regarding investment in physical capital, human capital, and technology affects its long-run economic growth. Governments can promote long-run economic growth, shifting the country's production possibilities curve outward over time, by investing in physical capital such as infrastructure. They can also encourage high rates of private investment in physical capital by promoting a well-functioning financial system, property rights, and political stability.

Investments in capital help the economy reach new heights of productivity.

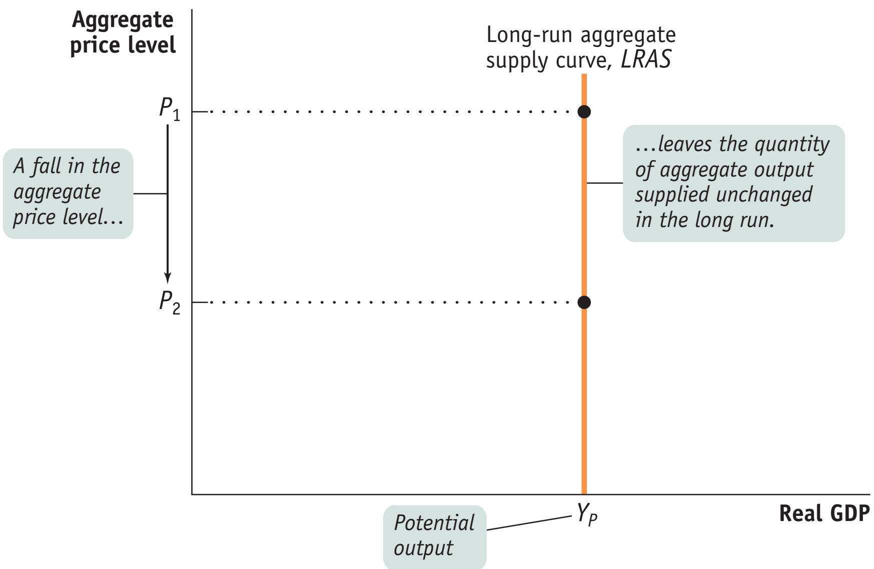
Long-run Economic Growth and the Aggregate Demand-Aggregate Supply Model

The aggregate demand and supply model we developed in Section 4 is another useful tool for understanding long-run economic growth. Recall that in the aggregate demand-aggregate supply model, the long-run aggregate supply curve shows the relationship between the aggregate price level and the quantity of aggregate output supplied when all prices, including nominal wages, are flexible. As shown in Figure 40.4, the

figure 40.4

The Long-run Aggregate Supply Curve

The long run aggregate supply curve shows the quantity of aggregate output supplied when all prices, including nominal wages, are flexible. It is vertical at potential output, Y_P, because in the long run a change in the aggregate price level has no effect on the quantity of aggregate supplied.

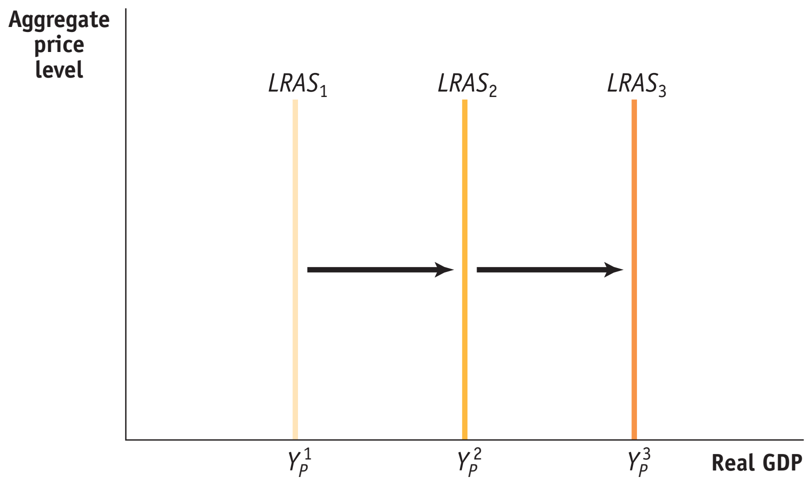


long-run aggregate supply curve is vertical at the level of potential output. While actual real GDP is almost always above or below potential output, reflecting the current phase of the business cycle, potential output is the level of output around which actual aggregate output fluctuates. Potential output in the United States has risen steadily over time. This corresponds to a rightward shift of the long-run aggregate supply curve, as shown in Figure 40.5. Thus, the same government policies that promote an outward shift of the production possibilities curve promote a rightward shift of the long-run aggregate supply curve.

figure 40.5

Long-run Growth and the LRAS Curve

The growth in potential output over time can be shown as a rightward shift of the long-run aggregate supply curve.



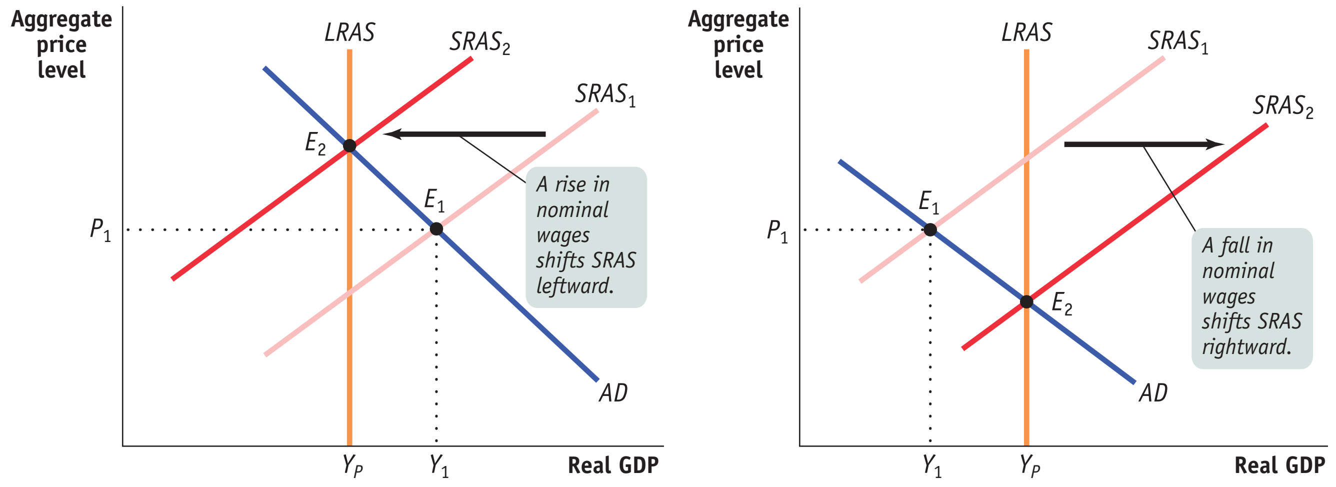
Distinguishing Between Long-run Growth and Short-run Fluctuations

When considering changes in real GDP, it is important to distinguish long-run growth from short-run fluctuations due to the business cycle. Both the production possibilities curve model and the aggregate demand-aggregate supply model can help us do this.

The points along a production possibilities curve are achievable if there is efficient use of the economy's resources. If the economy experiences a macroeconomic fluctuation due to the business cycle, such as unemployment due to a recession, production falls to a point inside the production possibilities curve. On the other hand, long-run growth will appear as an outward shift of the production possibilities curve.

In the aggregate demand-aggregate supply model, fluctuations of actual aggregate output around potential output are illustrated by shifts of aggregate demand or short-run aggregate supply that result in a short-run macroeconomic equilibrium above or below potential output. In both panels of Figure 40.6, E_1 indicates a short-run equilibrium that differs from long-run equilibrium due to the business cycle. In the case of short-run fluctuations like these, adjustments in nominal wages will eventually bring the equilibrium level of real GDP back to the potential level. By contrast, we saw in Figure 40.5 that long-run economic growth is represented by a rightward shift of the long-run aggregate supply curve and corresponds to an increase in the economy's level of potential output.

figure 40.6 From the Short Run to the Long Run



In panel (a), the initial equilibrium is E_1. At the aggregate price level, P_1, the quantity of aggregate output supplied, Y_1, exceeds potential output, Y_P. Eventually, low unemployment will cause nominal wages to rise, leading to a leftward shift of the short-run aggregate supply curve from $SRAS_1$ to $SRAS_2$ and a long-run equilibrium at E_2. In panel (b), the reverse happens: at the short-run equilibrium, E_1, the quantity of aggregate output supplied is less than potential output. High unemployment eventually leads to a fall in nominal wages over time and a rightward shift of the short-run aggregate supply curve. The end result is long-run equilibrium at E_2.

Module 40 AP Review

Solutions appear at the back of the book.

Check Your Understanding

1. How are long-run economic growth and short-run fluctuations during a business cycle represented using the production possibilities curve model?
2. How are long-run economic growth and short-run fluctuations during a business cycle represented using the aggregate demand-aggregate supply model?

Tackle the Test: Multiple-Choice Questions

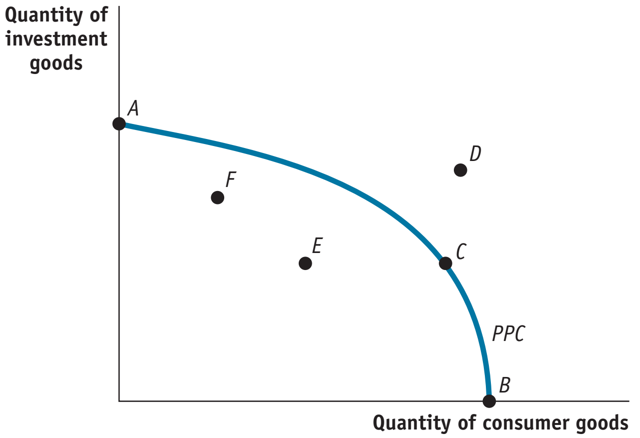
1. Which of the following will shift the production possibilities curve outward?
   I. an increase in the production of investment goods
   II. an increase in the production of consumer goods
   III. technological progress
   a. I only
   b. II only
   c. III only
   d. I and III only
   e. I, II, and III
2. In the production possibilities curve (PPC) model, long-run economic growth is shown by a(n)
   a. outward shift of the PPC.
   b. inward shift of the PPC.
   c. movement from a point below the PPC to a point on the PPC.
   d. movement from a point on the PPC to a point below the PPC.
   e. movement from a point on the PPC to a point beyond the PPC.
3. The reduction in the value of an asset due to wear and tear is known as
   a. depreciation.
   b. negative investment.
   c. economic decline.
   d. disinvestment.
   e. net investment.

4. In the aggregate demand-aggregate supply model, long-run economic growth is shown by a
   a. leftward shift of the aggregate demand curve.
   b. rightward shift of the aggregate demand curve.
   c. rightward shift of the long-run aggregate supply curve.
   d. rightward shift of the short-run aggregate supply curve.
   e. leftward shift of the short-run aggregate supply curve.

5. Which of the following is listed among the key sources of growth in potential output?
   a. expansionary fiscal policy
   b. expansionary monetary policy
   c. a rightward shift of the short-run aggregate supply curve
   d. investment in human capital
   e. both a and b

Tackle the Test: Free-Response Questions

1. Refer to the graph provided.



   a. Which point(s) could represent a downturn in the business cycle?
   b. Which point(s) represent efficient production?
   c. Which point(s) are attainable only after long-run economic growth?
   d. How would long-run economic growth be represented on this graph?
   e. Policy that results in an increase in the production of consumer goods without reducing the production of investment goods is represented by a movement from point ________ to point ________.
   f. Producing at which efficient point this year would lead to the most economic growth next year?

Answer (9 points)

2 points: A downturn could be represented by points *E* or *F*

3 points: Points *A, B,* and *C* represent efficient production.

1 point: Point *D* is attainable only after long-run economic growth.

1 point: Long-run economic growth would be represented by an outward shift of the curve.

1 point: Consumer goods increase and investment goods remain unchanged when moving from point *E* to point *C.*

1 point: Producing at point *A* would lead to the most economic growth.

2. Draw a separate, correctly labeled aggregate demand and supply graph to illustrate each of the following situations. On each of your graphs, include the short-run aggregate supply curve(s), long-run aggregate supply curve(s), and aggregate demand curve(s).
   a. Expansionary fiscal policy moves the economy out of a recession.
   b. Investment in infrastructure by the government leads to long-run economic growth.

Section 7 Review

Summary

1. Economic growth is a sustained increase in the productive capacity of an economy and can be measured as changes in real GDP per capita. This measurement eliminates the effects of changes in both the price level and population size. Levels of real GDP per capita vary greatly around the world: more than half of the world's population lives in countries that are still poorer than the United States was in 1908.

2. Growth rates of real GDP per capita also vary widely. According to the **Rule of 70,** the number of years it takes for real GDP per capita to double is equal to 70 divided by the annual growth rate of real GDP per capita.

3. The key to long-run economic growth is rising **labor productivity,** or just **productivity,** which is output per worker. Increases in productivity arise from increases in **physical capital** per worker and **human capital** per worker as well as advances in **technology.** The **aggregate production function** shows how real GDP per worker depends on these three factors. Other things equal, there are **diminishing returns to physical capital:** holding human capital per worker and technology fixed, each successive addition to physical capital per worker yields a smaller increase in productivity than the one before. Similarly, there are diminishing returns to human capital among other inputs. With **growth accounting,** which involves estimates of each factor's contribution to economic growth, economists have shown that rising **total factor productivity,** the amount of output produced from a given amount of factor inputs, is key to long-run growth. Rising total factor productivity is usually interpreted as the effect of technological progress. In most countries, natural resources are a less significant source of productivity growth today than in earlier times.
4. The world economy contains examples of success and failure in the effort to achieve long-run economic growth. East Asian economies have done many things right and achieved very high growth rates. In Latin America, where some important conditions are lacking, growth has generally been disappointing. In Africa, real GDP per capita declined for several decades, although there are recent signs of progress. The growth rates of economically advanced countries have converged, but the growth rates of countries across the world have not. This has led economists to believe that the **convergence hypothesis** fits the data only when factors that affect growth, such as education, infrastructure, and favorable policies and institutions, are held equal across countries.
5. The large differences in countries' growth rates are largely due to differences in their rates of accumulation of physical and human capital as well as differences in technological progress. A prime factor is differences in savings and investment rates, since most countries that have high investment in physical capital finance it by high domestic savings. Technological progress is largely a result of **research and development,** or **R&D.**
6. Government actions that contribute to growth include the building of **infrastructure,** particularly for transportation and public health; the creation and regulation of a well-functioning banking system that channels savings into investment spending; and the financing of both education and R&D. Government actions that slow growth are corruption, political instability, excessive government intervention, and the neglect or violation of property rights.
7. In regard to making economic growth **sustainable,** economists generally believe that environmental degradation poses a greater problem than natural resource scarcity does. Addressing environmental degradation requires effective governmental intervention, but the problem of natural resource scarcity is often well handled by the incentives created by market prices.
8. The emission of greenhouse gases is clearly linked to growth, and limiting emissions will require some reduction in growth. However, the best available estimates suggest that a large reduction in emissions would require only a modest reduction in the growth rate.
9. There is broad consensus that government action to address climate change and greenhouse gases should be in the form of market-based incentives, like a carbon tax or a cap and trade system. It will also require rich and poor countries to come to some agreement on how the cost of emissions reductions will be shared.
10. Long-run economic growth can be analyzed using the production possibilities curve and the aggregate demand-aggregate supply model. In these models, long-run economic growth is represented by an outward shift of the production possibilities curve and a rightward shift of the long-run aggregate supply curve.
11. Physical capital **depreciates** with use. Therefore, over time, the production possibilities curve will shift inward and the long-run aggregate supply curve will shift to the left if the stock of capital is not replaced.

Key Terms

Rule of 70, p. 371
Labor productivity (productivity), p. 372
Physical capital, p. 373
Human capital, p. 373
Technology, p. 373
Aggregate production function, p. 376
Diminishing returns to physical capital, p. 376
Growth accounting, p. 378
Total factor productivity, p. 379
Convergence hypothesis, p. 383
Research and development (R&D), p. 388
Infrastructure, p. 389
Sustainable, p. 391
Depreciation, p. 400

Problems

1. The accompanying table shows data on real GDP per capita for several countries between 1960 and 2000. (*Source:* The Penn World Table, Version 6.2.)

	Argentina			Ghana			South Korea			United States		
Year	Real GDP per capita (2000 dollars)	Percentage of 1960 real GDP per capita	Percentage of 2000 real GDP per capita	Real GDP per capita (2000 dollars)	Percentage of 1960 real GDP per capita	Percentage of 2000 real GDP per capita	Real GDP per capita (2000 dollars)	Percentage of 1960 real GDP per capita	Percentage of 2000 real GDP per capita	Real GDP per capita (2000 dollars)	Percentage of 1960 real GDP per capita	Percentage of 2000 real GDP per capita
1960	$7,838	?	?	$412	?	?	$1,458	?	?	$12,892	?	?
1970	9,821	?	?	1,052	?	?	2,552	?	?	17,321	?	?
1980	10,921	?	?	1,142	?	?	4,497	?	?	21,606	?	?
1990	8,195	?	?	1,153	?	?	9,593	?	?	27,097	?	?
2000	11,332	?	?	1,392	?	?	15,702	?	?	34,365	?	?

a. Complete the table by expressing each year's real GDP per capita as a percentage of its 1960 and 2000 levels.

b. How does the growth in living standards from 1960 to 2000 compare across these four nations? What might account for these differences?

2. The accompanying table shows the average annual growth rate in real GDP per capita for several countries between 1960 and 2000. (*Source:* The Penn World Table, Version 6.2)

	Average annual growth rate of real GDP per capita		
Years	Argentina	Ghana	South Korea
1960–1970	2.53%	15.54%	7.50%
1970–1980	1.12	0.85	7.62
1980–1990	–2.50	0.10	11.33
1990–2000	3.83	2.08	6.37

a. For each decade and for each country, use the Rule of 70 where possible to calculate how long it would take for that country's real GDP per capita to double.

b. Suppose that the average annual growth rate that each country achieved over the period 1990–2000 continues indefinitely into the future. Starting from 2000, use the Rule of 70 to calculate, where possible, the year in which a country will have doubled its real GDP per capita.

3. The accompanying table provides approximate statistics on per capita income levels and growth rates for regions defined by income levels. According to the Rule of 70, the high-income countries are projected to double their per capita GDP in approximately 37 years, in 2042. Throughout this question, assume constant growth rates for each of the regions that are fixed at their average value between 2000 and 2005.

Region	GDP per capita (2005)	Average GDP per capita growth (2000–2005)
High-income countries	$28,612	1.9%
Middle-income countries	2,196	5.7
Low-income countries	494	3.6

Source: World Bank.

a. Calculate the ratio of per capita GDP in 2005 for each of the following:
I. middle-income to high-income countries
II. low-income to high-income countries
III. low-income to middle-income countries

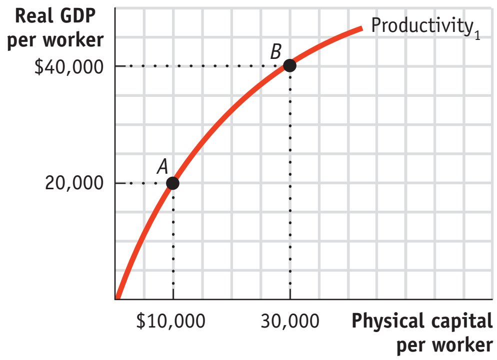
b. Calculate the number of years it will take the low-income and middle-income countries to double their per capita GDP.

c. Calculate the per capita GDP of each of the regions in 2042. (*Hint:* How many times does their per capita GDP double in 37 years?)

d. Repeat part a with the projected per capita GDP in 2042.

e. Compare your answers to parts a and d. Comment on the change in economic inequality between the regions.

4. You are hired as an economic consultant to the countries of Albernia and Brittania. Each country's current relationship between physical capital per worker and output per worker is given by the curve labeled Productivity$_1$ in the accompanying diagram. Albernia is at point *A* and Brittania is at point *B*.



a. In the relationship depicted by the curve Productivity$_1$, what factors are held fixed? Do these countries experience diminishing returns to physical capital per worker?

b. Assuming that the amount of human capital per worker and the technology are held fixed in each country, can you recommend a policy to generate a doubling of real GDP per capita in Albernia?

c. How would your policy recommendation change if the amount of human capital per worker and the technology were not fixed? Draw a curve on the diagram that represents this policy for Albernia.

5. The country of Androde is currently using Method 1 for its production function. By chance, scientists stumble on a technological breakthrough that will enhance Androde's productivity. This technological breakthrough is reflected in another production function, Method 2. The accompanying table shows combinations of physical capital per worker and output per worker for both methods, assuming that human capital per worker is fixed.

Method 1		Method 2	
Physical capital per worker	Real GDP per worker	Physical capital per worker	Real GDP per worker
0	0.00	0	0.00
50	35.36	50	70.71
100	50.00	100	100.00
150	61.24	150	122.47
200	70.71	200	141.42
250	79.06	250	158.11
300	86.60	300	173.21
350	93.54	350	187.08
400	100.00	400	200.00
450	106.07	450	212.13
500	111.80	500	223.61

a. Using the data in the accompanying table, draw the two production functions in one diagram. Androde's current amount of physical capital per worker is 100 using Method 1. In your figure, label that point *A*.

b. Starting from point *A*, over a period of 70 years, the amount of physical capital per worker in Androde rises to 400. Assuming Androde still uses Method 1, in your diagram, label the resulting point of production *B*. Using the Rule of 70, calculate by how many percent per year output per worker has grown.

c. Now assume that, starting from point *A*, over the same 70 years, the amount of physical capital per worker in Androde rises to 400, but that during that time, Androde switches to Method 2. In your diagram, label the resulting point of production *C*. Using the Rule of 70, calculate by how many percent per year output per worker has grown now.

d. As the economy of Androde moves from point *A* to point *C*, which percentage of the annual productivity growth is due to higher total factor productivity?

6. The Bureau of Labor Statistics regularly releases the "Productivity and Costs" report for the previous month. Go to www.bls.gov and find the latest report. (On the Bureau of Labor Statistics home page, under Latest Numbers, find "Productivity" and click on "News Release.") What were the percent changes in business and nonfarm business productivity for the previous quarter (on the basis of annualized rates for output per hour of all persons)? How does the percent change in that quarter's productivity compare to data from the previous quarter?

7. How have U.S. policies and institutions influenced the country's long-run economic growth?

8. Over the next 100 years, real GDP per capita in Groland is expected to grow at an average annual rate of 2.0%. In Sloland, however, growth is expected to be somewhat slower, at an average annual growth rate of 1.5%. If both countries have a real GDP per capita today of $20,000, how will their real GDP per capita differ in 100 years? [*Hint:* A country that has a real GDP today of $$x$ and grows at y% per year will achieve a real GDP of $$x \times (1 + 0.0y)^z$ in z years. We assume that $0 \leq y < 10$.]

9. The accompanying table shows data on real GDP per capita in 2000 U.S. dollars for several countries in 1950 and 2004. (*Source:* The Penn World Table, Version 6.2) Complete the table. Have these countries converged economically?

	1950		2004	
	Real GDP per capita (2000 dollars)	Percentage of U.S. real GDP per capita	Real GDP per capita (2000 dollars)	Percentage of U.S. real GDP per capita
France	$5,921	?	$26,168	?
Japan	2,188	?	24,661	?
United Kingdom	8,082	?	26,762	?
United States	11,233	?	36,098	?

10. The accompanying table shows data on real GDP per capita in 2000 U.S. dollars for several countries in 1960 and 2003. (*Source:* The Penn World Table, Version 6.2.) Complete the table. Have these countries converged economically?

	1960		2003	
	Real GDP per capita (2000 dollars)	Percentage of U.S. real GDP per capita	Real GDP per capita (2000 dollars)	Percentage of U.S. real GDP per capita
Argentina	\$7,838	?	\$10,170	?
Ghana	412	?	1,440	?
South Korea	1,458	?	17,597	?
United States	12,892	?	34,875	?

11. Why would you expect real GDP per capita in California and Pennsylvania to exhibit convergence but not in California and Baja California, a state of Mexico that borders the United States? What changes would allow California and Baja California to converge?

12. According to the *Oil & Gas Journal,* the proven oil reserves of the top 12 oil producers was 1,137 billion barrels of oil in 2007. In that year, the U.S. Energy Information Administration reported that the daily oil production from these nations was 48.2 million barrels a day.

a. At this rate, how many years will the proven oil reserves of the top 12 oil producers last? Discuss the Malthusian view in the context of the number you just calculated.

b. What are some important assumptions implicit in your calculations that challenge the Malthusian view on this issue?

c. Discuss how market forces may affect the amount of time the proven oil reserves will last, assuming that no new oil reserves are discovered and that the demand curve for oil remains unchanged.

13. The accompanying table shows the percent change in verified emissions of carbon dioxide (CO_2) and the percent change in real GDP per capita for selected EU countries.

Country	Percent change in real GDP per capita 2005–2007	Percent change in CO_2 emissions 2005–2007
Austria	6.30%	–4.90%
Belgium	4.19	–4.60
Cyprus	5.56	6.20
Finland	9.23	28.50
France	2.76	–3.50
Germany	5.79	2.50
Greece	8.09	2.00
Ireland	6.56	–5.30
Italy	2.28	0.20
Luxembourg	8.55	–1.40
Netherlands	4.61	–0.60
Portugal	2.67	–14.40
Slovenia	11.79	3.80
Spain	4.28	1.60

Sources: European Commission Press Release, May 23, 2008; International Monetary Fund, *World Factbook* 2008.

a. Rank the countries in terms of percentage increase in CO_2 emissions, from highest to lowest. What five countries have the highest percentage increase in emissions? What five countries have the lowest percentage increase in emissions?

b. Now rank the countries in terms of the percentage increase in real GDP per person, from highest to lowest. What five countries have the highest percentage increase? What five countries have the lowest percentage increase?

c. Would you infer from your results that CO_2 emissions are linked to growth in output per person?

d. Do high growth rates necessarily lead to high CO_2 emissions?