

Module 53: Sources of Long-Run Economic Growth

Module 54: Productivity and Growth

Module 55: Long-Run Growth Policy

SECTION 17



Long-Run Economic Growth

TALL TALES



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 output per capita. 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.

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 the pace at which long-run growth takes place, examine how government policies can help or hinder growth, and address questions about the environmental sustainability of long-run growth.



Sources of Long-Run Economic Growth



WHAT YOU WILL LEARN

- 1 How to measure long-run economic growth
- 2 How real GDP has changed over time and how it varies across countries
- 3 The sources of 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 comparable growth. 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 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.

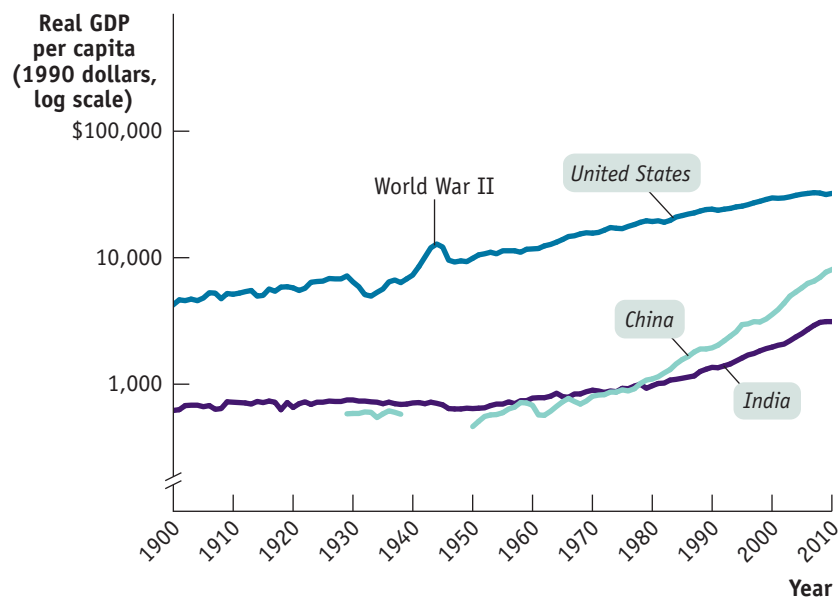
Although we also learned that growth in real GDP per capita should not be a policy goal in and of itself, it does serve as a very useful summary measure of a country's economic progress over time. Figure 53-1 shows real GDP per capita for the United States, India, and China, measured in 1990 dollars, from 1900 to 2010. 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.

FIGURE

53-1 Economic Growth in the United States, India, and China over the Past Century

Real GDP per capita from 1900 to 2010, 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. As the steeper slopes of the lines representing China and India show, since 1980 India and China had a much higher growth rate than the United States. In 2000, China attained the standard of living achieved in the United States in 1900. In 2010, India was still poorer than the United States was in 1900. (The break in the China data from 1940 to 1950 is due to war.)

Source: Maddison Project,
<http://www.ggdc.net/maddison>.



To give a sense of how much the U.S. economy grew during the last century, Table 53-1 shows real GDP per capita at selected years, expressed two ways: as a percentage of the 1900 level and as a percentage of the 2010 level. In 1920, the U.S. economy already produced 136% as much per person as it did in 1900. In 2010, it produced 745% as much per person as it did in 1900, a more than sevenfold increase. Alternatively, in 1900 the U.S. economy produced only 13% as much per person as it did in 2010.

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 2010, the median American household had an income of about \$50,000. Since Table 53-1 tells us that real GDP per capita in 1900 was only 13% of its 2010 level, a typical family in 1900 probably had a purchasing power only 13% as large as the purchasing power of a typical family in 2010. That's around \$6,100 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 1900, would feel quite a lot of deprivation.

Yet about 50% of the world's people live in countries with a lower standard of living than the United States had a century ago. That's the message about China and India in Figure 53-1: despite dramatic economic growth in China over the last three decades and the less dramatic acceleration of economic growth in India, China has only recently exceeded the standard of living that the United States enjoyed in the early twentieth century, while India is still poorer than the United States was at that time. 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 53-2, a map of the world in which countries are classified according to their 2010 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 \$3,976 per capita—and often much less.

TABLE 53-1

U.S. Real GDP per Capita

Year	Percentage of 1900 real GDP per capita	Percentage of 2010 real GDP per capita
1900	100%	13%
1920	136	18
1940	171	23
1980	454	61
2000	701	94
2010	745	100

Source: Maddison Project,
<http://www.ggdc.net/maddison>.

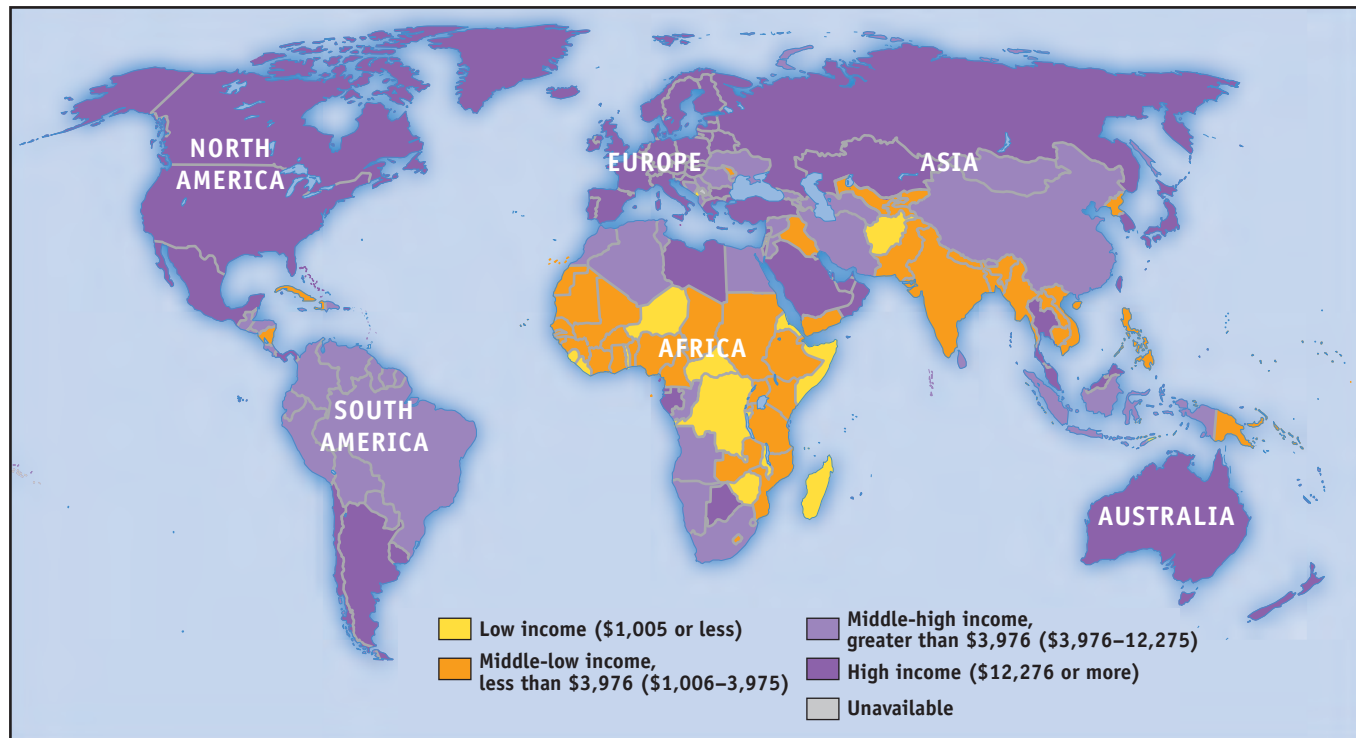


FIGURE 53-2 Per Capita Income Around the World, 2010 Although the countries of Europe and North America—along with a few in the Pacific—have high incomes, much of the world is still very poor. Today, about 50% of the world's population lives in countries with a lower standard of living than the United States had a century ago.
Source: International Monetary Fund.

Growth Rates

How did the United States manage to produce over seven times as much per person in 2010 than in 1900? The answer is 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 1900 to 2010, 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:

$$(53-1) \text{ Number of years for variable to double} = \frac{70}{\text{Annual growth rate of variable}}$$

(Note that the Rule of 70 can only be applied to 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.

In fact, U.S. real GDP per capita rose on average 1.9% per year over the last century. Applying the Rule of 70 to this information 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 1899 and 2010—a period of 111 years—real GDP per capita rose just about eightfold.

Figure 53-3 shows the average annual rate of growth of real GDP per capita for selected countries from 1980 to 2010. Some countries were notable success stories: for example, China, though still quite a poor country, has made spectacular progress. India, although not matching China's performance, has also achieved impressive growth, as discussed in the following Economics in Action.

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

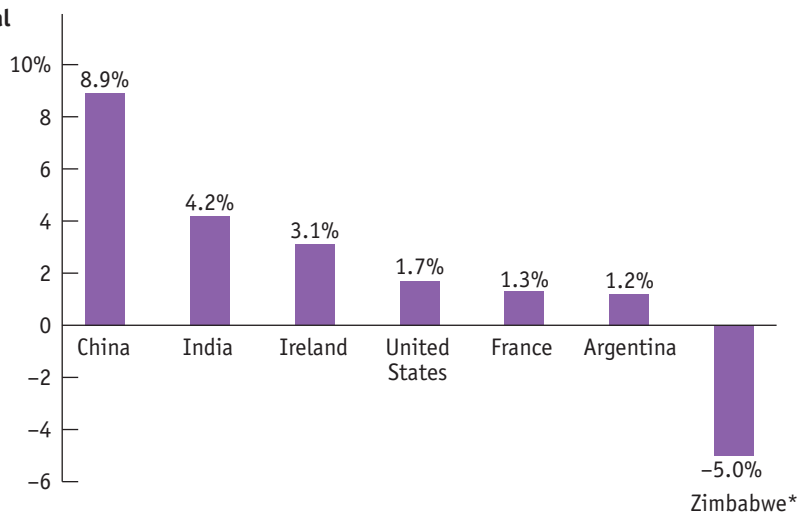
FIGURE 53-3 Comparing Recent Growth Rates

The average annual rate of growth of real GDP per capita from 1980 to 2010 is shown here for selected countries. China and, to a lesser extent, India and Ireland achieved impressive growth. The United States and France had moderate growth. Once considered an economically advanced country, Argentina had more sluggish growth. Still others, such as Zimbabwe, slid backward.

Source: International Monetary Fund.

*Data for Zimbabwe is average annual growth rate 2000–2010 due to data limitations.

Average annual growth rate of real GDP per capita, 1980–2010



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 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 economic growth.

ECONOMICS IN ACTION

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 53-3 shows, real GDP per capita has grown at an average rate of 4.2% a year, more than tripling between 1980 and 2010. 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.



Lionel Delormel/Alamy

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

The big question now is whether this growth can continue. Skeptics argue that there are bottlenecks in the Indian economy that may constrain future growth. They point to the still low education level of much of India's population and inadequate infrastructure—that is, the poor quality and limited capacity of the country's roads, railroads, power supplies, and so on. But India's economy has defied the skeptics for several decades and the hope is that it can continue doing so.

What Are 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 and then examine what affects it.

The Crucial Importance of Productivity

Sustained economic growth 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. 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 53-1.

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 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.

So increased productivity is the key to long-run economic growth. But what leads to higher productivity?

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 machinery 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.

INCREASE IN PHYSICAL CAPITAL Economists define **physical capital** as manufactured resources such as buildings and machines. Physical capital makes workers more productive. For example, a worker operating a backhoe can dig a lot more feet of trench per day than one equipped only with a shovel.

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

Physical capital consists of human-made resources such as buildings and machines.

The average U.S. private-sector worker today is backed up by more than \$150,000 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.

INCREASE IN 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 2010, the percentages were 87% and 30%, 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 in the next module, suggest that education—and its effect on productivity—is an even more important determinant of growth than increases in physical capital.

TECHNOLOGICAL PROGRESS Probably the most important driver of productivity growth is **technological progress**, which is broadly defined as an advance in the technical means of 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 Walmart rather than to high-technology companies.

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

Technological progress is an advance in the technical means of the production of goods and services.



MODULE 53 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 53.3 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.

Multiple-Choice Questions

- Which of the following is true regarding growth rates for countries around the world compared to the United States?
 - Fifty percent of the world's people live in countries with a lower standard of living than the U.S. in 1900.
 - The U.S. growth rate is six times the growth rate in the rest of the world.
 - China has only just attained the same standard of living the U.S. had in 1900.
 - I only
 - II only
 - III only
 - I and III only
 - I, II, and III
- Which of the following is the key statistic used to track economic growth?
 - GDP
 - real GDP
 - real GDP per capita
 - median real GDP
 - median real GDP per capita
- 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?
 - 3.5
 - 20
 - 35
 - 70
 - It will never double at that rate.
- 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?
 - 3.5%
 - 7%
 - 10%
 - 70%
 - 700%
- Long-run economic growth depends almost entirely on
 - technological change.
 - rising productivity.
 - increased labor force participation.
 - rising real GDP per capita.
 - population growth.

PITFALLS

CHANGE IN LEVEL VERSUS RATE OF CHANGE

? What's the difference between a *change in the level of real GDP* and a *change in the growth rate*?

> **WHEN YOU HEAR THAT REAL GDP "GREW," IT MEANS THAT THE LEVEL OF REAL GDP INCREASED. WHEN YOU HEAR STATEMENTS ABOUT ECONOMIC GROWTH OVER A PERIOD OF YEARS, YOU ARE ALMOST ALWAYS HEARING ABOUT CHANGES IN THE GROWTH RATE.** Consider this example. We might say that U.S. real GDP grew during 2010 by \$385 billion. If we knew the level of U.S. real GDP in 2009, we could also represent the amount of 2010 growth in terms of a rate of change. So, if U.S. real GDP in 2009 was \$12,703 billion, then U.S. real GDP in 2010 was \$12,703 billion + \$385 billion = \$13,088 billion. We could calculate the rate of change, or the growth rate, of U.S. real GDP during 2010 as: $(\$13,088 \text{ billion} - \$12,703 \text{ billion}) / \$12,703 \text{ billion} \times 100 = (\$385 \text{ billion} / \$12,703 \text{ billion}) \times 100 = 3.03\%$.

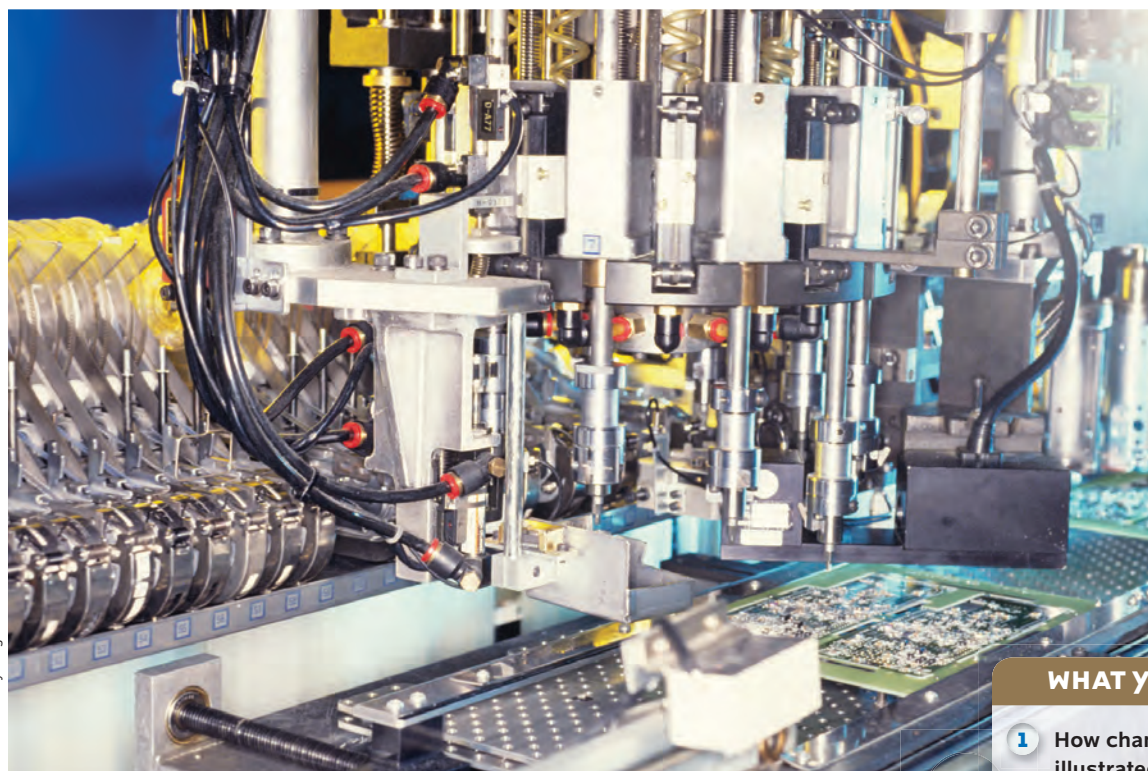
When talking about growth or growth rates, economists often use phrases that appear to mix the two concepts. Admittedly, this can be confusing. For example, when economists say that "U.S. growth fell during the 1970s," they are really saying that the U.S. growth rate of real GDP was lower in the 1970s in comparison to the 1960s. When they say that "growth accelerated during the early 1990s," what they mean is that the growth rate increased year after year in the early 1990s—for example, going from 3% to 3.5% to 4%.

To learn more, see pages 546 and 547.

Critical-Thinking Question

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?

Productivity and Growth



Kim Steele/Getty Images

WHAT YOU WILL LEARN

- 1 How changes in productivity are illustrated using an aggregate production function
- 2 About challenges to growth posed by limited natural resources and efforts to make growth sustainable

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 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.

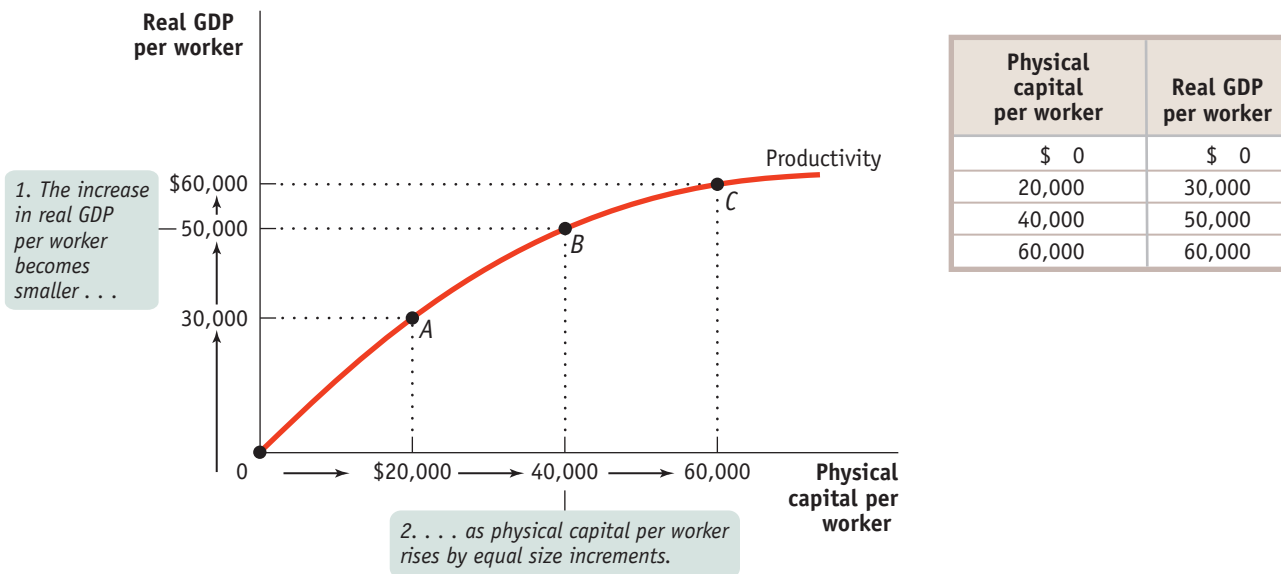
In analyzing historical economic growth, economists have discovered a crucial fact about the estimated aggregate production function: it exhibits **diminishing returns to physical capital**. That is, when the amount of human capital per worker and the state of technology are held fixed, each successive increase in the amount of physical capital per worker leads to a smaller increase in productivity. Figure 54-1 and the accompanying table give a hypothetical example of how the level of physical capital per worker might affect the level of 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 dollars.

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 farmworkers. 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 \$40,000 tractor will normally be able to cultivate more farmland in a given amount of time than a worker with a \$20,000 tractor because the more expensive machine will be more powerful, perform more tasks, or both.

The **aggregate production function** is a hypothetical function that shows how productivity (real GDP 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.

FIGURE 54-1 Physical Capital and Productivity



The aggregate production function shows how, in this case holding human capital per worker and technology fixed, productivity increases as physical capital per worker rises. 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 the origin, 0,

a \$20,000 increase in physical capital per worker leads to an increase in real GDP per worker of \$30,000, indicated by point A. Starting from point A, another \$20,000 increase in physical capital per worker leads to an increase in real GDP per worker but only of \$20,000, indicated by point B. Finally, a third \$20,000 increase in physical capital per worker leads to only a \$10,000 increase in real GDP per worker, indicated by point C.

But will a worker with a \$40,000 tractor, holding human capital and technology constant, be twice as productive as a worker with a \$20,000 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 \$200,000 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.

Diminishing returns to physical capital imply a relationship between physical capital per worker and output per worker like the one shown in Figure 54-1. As the productivity curve for physical capital and the accompanying table illustrate, more physical capital per worker leads to more output per worker. But each \$20,000 increment in physical capital per worker adds less to productivity.

As you can see from the table, there is a big payoff for the first \$20,000 of physical capital: real GDP per worker rises by \$30,000. The second \$20,000 of physical capital also raises productivity, but not by as much: real GDP per worker goes up by only \$20,000. The third \$20,000 of physical capital raises real GDP per worker by only \$10,000.

By comparing points along the curve you can also see that as physical capital per worker rises, output per worker also rises—but at a diminishing rate. Going from the origin at 0 to point A, a \$20,000 increase in physical capital per worker, leads to an increase of \$30,000 in real GDP per worker. Going from point A to point B, a second \$20,000 increase in physical capital per worker, leads to an increase of only \$20,000 in real GDP per worker. And from point B to point C, a \$20,000 increase in physical capital per worker increased real GDP per worker by only \$10,000.

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 at the same time the amount of physical capital per worker is increased.

For example, a worker with a \$40,000 tractor who has also been trained in the most advanced cultivation techniques may in fact be more than twice as productive as a worker with only a \$20,000 tractor and no additional human capital. But diminishing returns to any one input—regardless of whether it is physical capital, human capital, or number of workers—is a pervasive characteristic of production.

Growth Accounting

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**, which estimates 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.
- 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 $3\% \times 0.33 = 1$ percentage point 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 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.

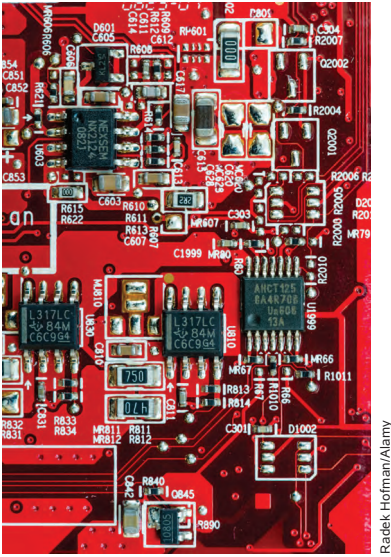
In Figure 54-2, the lower curve shows the same hypothetical relationship between physical capital per worker and output per worker shown in Figure 54-1. Let's assume that this was the relationship given the technology available in 1942. The upper curve also shows a relationship between physical capital per worker and productivity, but this time given the technology available in 2012. (We've chosen a 70-year stretch to allow us to use the Rule of 70.) The 2012 curve is shifted up compared to the 1942 curve because technologies developed over the previous 70 years made it possible to produce more output for a given amount of physical capital per worker than was possible with the technology available in 1942. (Note that the two curves are measured in constant dollars.)

Let's assume that between 1942 and 2012 the amount of physical capital per worker rose from \$20,000 to \$60,000. 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

Growth accounting estimates the contribution of each major factor in the aggregate production function to economic growth.

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

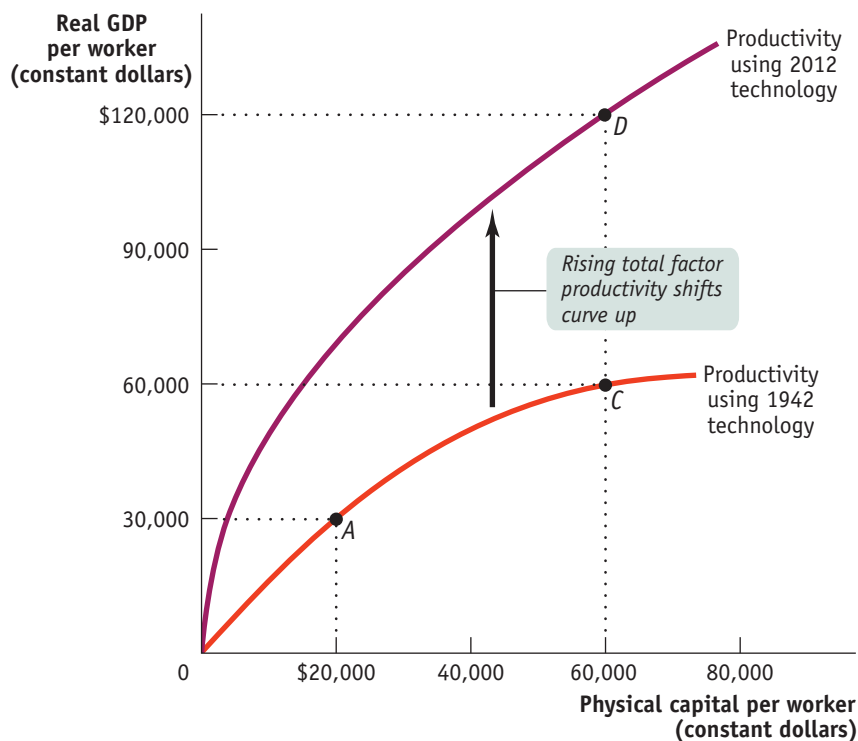


Technological progress is central to economic growth.

FIGURE

54-2 Technological Progress and Productivity Growth

Technological progress raises productivity at any given level of physical capital per worker, and therefore shifts the aggregate production function upward. Here we hold human capital per worker fixed. We assume that the lower curve (the same curve as in Figure 54-1) reflects technology in 1942 and the upper curve reflects technology in 2012. Holding technology and human capital fixed, tripling physical capital per worker from \$20,000 to \$60,000 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 raised productivity at any given level of physical capital—shown here by the upward shift of the curve—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.



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, during the past 70 years, only about half of the productivity in the economy 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.

ECONOMICS IN ACTION

THE INFORMATION TECHNOLOGY PARADOX

From the early 1970s through the mid-1990s, the United States went through a slump in total factor productivity growth. Figure 54-3 shows Bureau of Labor Statistics estimates of annual total factor productivity growth, averaged for each 10-year period from 1948 to 2010. As you can see, there was a large fall in the total factor 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: computers, the Internet, cell phones, and e-mail.

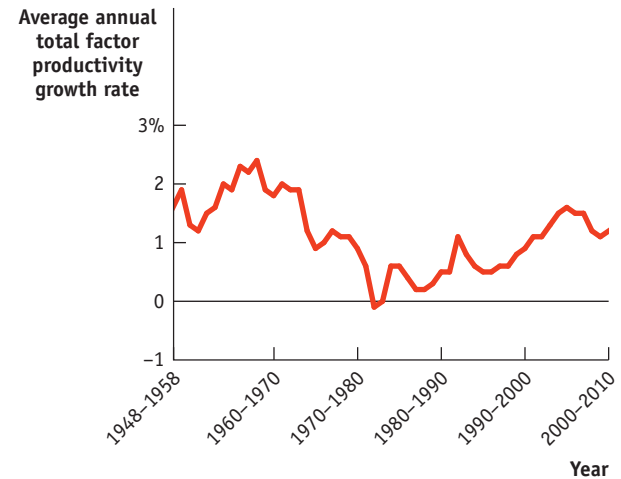
Yet the rate of growth of total factor productivity remained stagnant. In a famous remark, MIT economics professor and Nobel laureate Robert Solow, a pioneer in the analysis of economic growth, declared that the information technology revolution could be seen everywhere except in the economic statistics. 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 as companies discovered how to effectively use information technology. (The business case at the end of the section details Walmart's innovative practices.)

FIGURE 54-3 The U.S. Productivity Growth Slowdown and Recovery



Source: Bureau of Labor Statistics.

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 example, Kuwait has about the same level of real GDP per capita as Germany, but Kuwait's wealth is based on oil, not manufacturing, the source of Germany'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.

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.

Sustainable long-run economic growth is long-run growth that can continue in the face of the limited supply of natural resources and the impact of growth on the environment.

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.

Is World Growth Sustainable?

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

In 1972 a group of scientists 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 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 54-4 shows the real price of oil—the price of oil adjusted for inflation in the rest of the economy. The rise, fall, and rise of concern about resource-based limits to growth have more or less followed the rise, fall, and rise of oil prices shown in the figure.

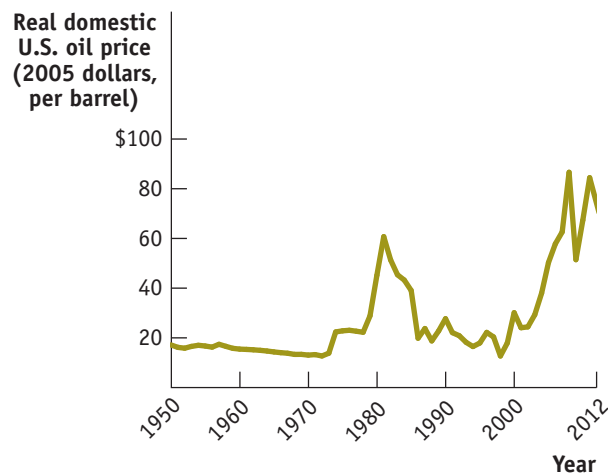
Differing views about the impact of limited natural resources on long-run economic growth turn on the answers to the following three questions:

1. HOW LARGE ARE THE SUPPLIES OF KEY NATURAL RESOURCES? It's mainly up to geologists to answer this question. And the response changes as new technologies, such as hydraulic fracking, are developed, allowing access to previously inaccessible oil and natural gas resources. Unfortunately, there's wide disagreement among the experts, especially about the prospects for future oil production.

Some analysts believe that there is enough 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.

2. HOW EFFECTIVE WILL TECHNOLOGY BE AT FINDING ALTERNATIVES TO NATURAL RESOURCES? This question will have to be answered by 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, oil extracted from

FIGURE 54-4 The Real Price of Oil, 1950–2012



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.

Sources: Energy Information Administration; Bureau of Labor Statistics.

Canadian tar sands is making a significant contribution to world oil supplies, and the amount of electricity generated by wind and solar power continues to grow.

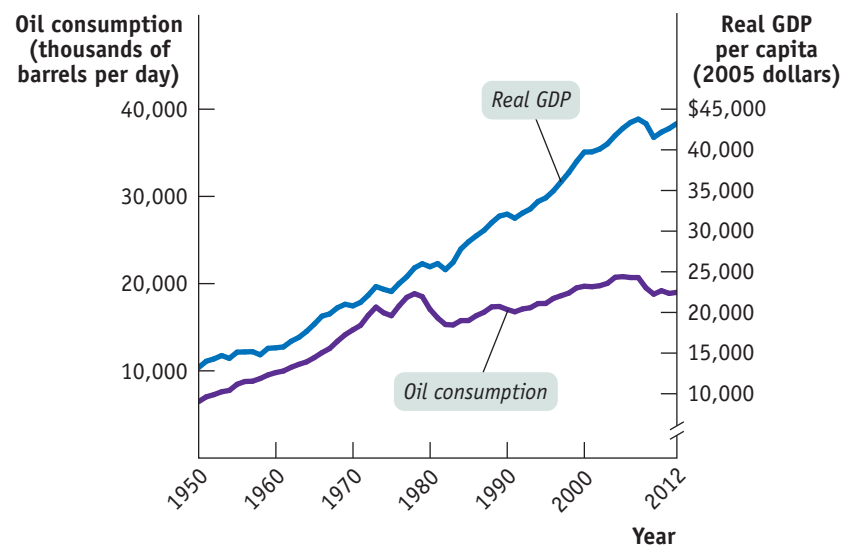
3. CAN LONG-RUN ECONOMIC GROWTH CONTINUE IN THE FACE OF RESOURCE SCARCITY? This is mainly a question for economists. And most, though not all, economists are optimistic: they believe that modern economies can find ways to work around limits in the supply of natural resources. One reason for this optimism 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.

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 54-5, which compares U.S. real GDP per capita and oil consumption before and after the 1970s energy crisis. In the United States before 1973, there seemed to be a more or less one-to-one relationship between economic growth and oil consumption.

FIGURE 54-5 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 deliver growth despite cutting back on oil consumption.

Sources: Energy Information Administration; Bureau of Economic Analysis.



However, after 1973 the U.S. economy continued to deliver growth in real GDP per capita even as it substantially reduced the use of oil. This move toward conservation paused after 1990, as low real oil prices encouraged consumers to shift back to gas-guzzling larger cars and SUVs. But a sharp rise in oil prices since 2005 encouraged renewed shifts toward oil conservation.

Given such responses to prices, economists generally tend to see resource scarcity as a problem that modern economies handle fairly well, and so not as 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. But again, other things aren't necessarily equal: countries can and do take action to protect their environments.



David Benton/Alamy

One response to resource scarcity.

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 more than 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 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 average 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.

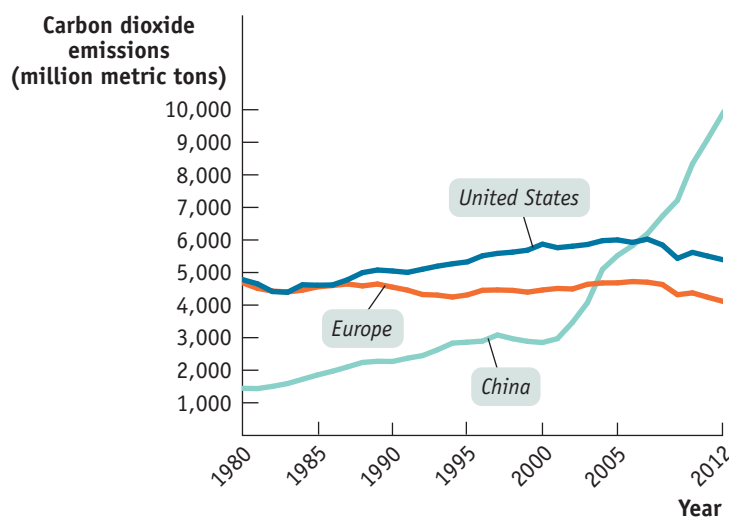
The problem of climate change is clearly linked to economic growth. Figure 54-6 shows carbon dioxide emissions from the United States, Europe, and China since 1980. Historically, the wealthy nations have been responsible for the bulk of these emissions because they have consumed far more energy per person 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.

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 capturing the carbon dioxide from power plants 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 big question 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.

FIGURE 54-6 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.

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 to proceed.

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 future generations.

There is also a difficult problem of international burden sharing. As Figure 54-6 shows, rich economies 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. At the same time, 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.

The general moral of this story is that it is possible to reconcile long-run economic growth with protecting the environment. The main question is one of getting political consensus around the necessary policies.



ChinaFotoPress/Getty Images

Emissions from coal-fired municipal heating systems contribute to the heavy smog that has become a problem in many Chinese cities.

MODULE 54 Review

Solutions appear at the back of the book.

Check Your Understanding

- Explain the effect of each of the following on the growth rate of productivity.
 - The amounts of physical and human capital per worker are unchanged, but there is significant technological progress.
 - The amount of physical capital per worker grows, but the level of human capital per worker and technology are unchanged.
- The economy of Erewhon 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%.
 - How fast has productivity in Erewhon grown?
 - How fast has physical capital per worker grown?
 - How much has growing physical capital per worker contributed to productivity growth? What percentage of total productivity growth is that?
 - How much has technological progress contributed to productivity growth? What percentage of total productivity growth is that?
- 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?
- 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?

Multiple-Choice Questions

- Which of the following is a source of increased productivity growth?
 - increased physical capital
 - increased human capital
 - technological progress
 - I only
 - II only
 - III only
 - I and II only
 - I, II, and III
- Which of the following is an example of physical capital?
 - machinery
 - healthcare
 - education
 - money
 - all of the above
- Which of the following is true of sustainable long-run economic growth?
 - Long-run growth can continue in the face of the limited supply of natural resources.
 - It was predicted by Thomas Malthus.
 - Modern economies handle resource scarcity problems poorly.
 - It is less likely when we find alternatives to natural resources.
 - All of the above are true.
- Which of the following statements is true of environmental quality?
 - It is typically not affected by government policy.
 - Other things equal, it tends to improve with economic growth.
 - There is broad scientific consensus that rising levels of carbon dioxide and other gases are raising the planet's overall temperature.
 - Most economists believe it is not possible to reduce greenhouse gas emissions while economic growth continues.
 - Most environmental success stories involve dealing with global, rather than local, impacts.
- When economists talk about *diminishing returns to physical capital*, they mean that
 - an increase in physical capital per worker will cause a reduction in real GDP per worker.
 - an increase in physical capital per worker will lead to smaller and smaller increases in real GDP per worker.
 - over time physical capital wears out.
 - increasing physical capital per worker has no effect on real GDP per worker.
 - increasing physical capital is not a source of economic growth.

Critical-Thinking Questions

Assume that between 1942 and 2012:

- 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 $\frac{1}{2}$ of a percent, or 0.5%.
 - There is no growth in human capital.
 - Real GDP per capita rises from \$30,000 to \$60,000.
- Growing physical capital per worker is responsible for how much productivity growth per year? Show your calculation.
 - By how much did total factor productivity grow over the time period? Explain.

PITFALLS

IT MAY BE DIMINISHED . . . BUT IT'S STILL POSITIVE

? If there are diminishing returns to physical capital per worker, does it mean that GDP per worker is falling?

> **NO, IT DOES NOT. AN INCREASE IN PHYSICAL CAPITAL PER WORKER WILL NEVER REDUCE PRODUCTIVITY. BUT DUE TO DIMINISHING RETURNS, AT SOME POINT INCREASING THE AMOUNT OF PHYSICAL CAPITAL PER WORKER WILL NO LONGER PRODUCE AN ECONOMIC PAYOFF: AT THAT POINT, THE INCREASE IN OUTPUT WILL BE SO SMALL THAT IT WON'T BE WORTH THE COST OF THE ADDITIONAL PHYSICAL CAPITAL.** To answer the question, keep in mind what diminishing returns to physical capital per worker means and what it doesn't mean. As we've seen, it is an "other things equal" statement: holding the amount of human capital per worker and the technology fixed, each successive increase in the amount of physical capital per worker results in a smaller increase in real GDP per worker. But this doesn't mean that real GDP per worker eventually falls as more and more physical capital is added. It's just that the increase in real GDP per worker gets smaller and smaller, while remaining at or above zero.

To learn more, see pages 551–553.

Long-Run Growth Policy



Focus Japan/Alamy

WHAT YOU WILL LEARN

- 1 Why growth rates vary in different regions of the world
- 2 What the convergence hypothesis predicts

Why Growth Rates Differ

In 1820, 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—since 1820—real GDP per capita grew at 1.9% per year in Japan but at only 1.3% 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?

Explaining Differences in Growth Rates

As one might expect, economies with rapid growth tend to 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:

1. Rapidly add to their physical capital through high savings and investment spending
2. Upgrade their educational level
3. Make fast technological progress.

Evidence also points to the importance of government policies, property rights, political stability, and good governance in fostering the sources of growth.

SAVINGS AND INVESTMENT SPENDING One reason for differences in growth rates between 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 did 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 2010, investment spending was 38% of China's GDP, compared with only 16% in the United States.

Where does the money for high investment spending come from? From savings. Investment spending must be paid for either out of savings from domestic households or by savings from foreign households—that is, an inflow of foreign capital.

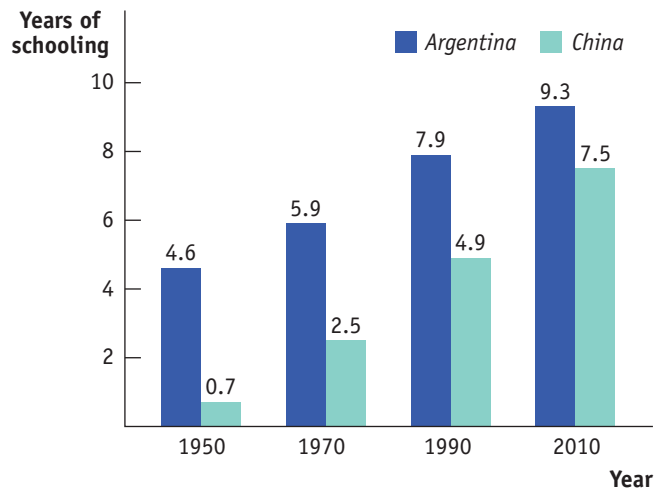
Foreign capital has played an important role in the long-run economic growth of some countries, including the United States, which relied heavily on foreign funds during its early industrialization. For the most part, however, countries that invest a large share of their GDP are able to do so because they have high domestic savings. In fact, China in 2012 saved an even higher percentage of its GDP than it invested at home. The extra savings were invested abroad, largely in the United States.

EDUCATION 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 Argentina and China. In both countries the average educational level has risen steadily over time, but it has risen much faster in China. Figure 55-1 shows the average years of education of adults in China, which we have highlighted as a spectacular example of long-run growth, and in Argentina, a country whose growth has been disappointing. Compared to China, sixty years ago, Argentina had a much more educated population, while many Chinese were still illiterate.

As of 2010, the average educational level in China was still slightly below that in Argentina—but that's mainly because there are still many elderly adults who never received basic education. In terms of secondary and tertiary education, China has outstripped once-rich Argentina.

FIGURE 55-1 China's Students Are Catching Up



In both China and Argentina, the average educational level—measured by the number of years the average adult aged 25 or older has spent in school—has risen over time. Although China is still lagging behind Argentina, it is catching up—and China's success at adding human capital is one key to its spectacular long-run growth.

Source: Robert Barro and Jong-Wha Lee, "A New Data Set of Educational Attainment in the World, 1950–2010," NBER Working Paper No. 15902 (April 2010).

Thomas Edison (shown here), is known as the inventor of R&D because he was first to form an organization devoted solely to creating new products and processes for business.



RESEARCH AND DEVELOPMENT The advance of technology is a key force behind economic growth. What drives technological progress?

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 apply them to practical use.

Although some research and development is conducted by governments, much R&D is paid for by the private sector. 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.

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

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

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. They can either affect growth directly through subsidies to factors that enhance growth, or by creating an environment that either fosters or hinders growth.

Government policies can increase the economy's growth rate through four main channels.

1. GOVERNMENT SUBSIDIES TO INFRASTRUCTURE Governments play an important direct role in building **infrastructure**: roads, power lines, ports, information networks, and other large-scale physical capital projects that provide a 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 offers an example of the importance of government-provided infrastructure. After the government invested in an excellent telecommunications infrastructure in the 1980s, Ireland became a favored location for high-technology companies from abroad and its economy took off in the 1990s.

Poor infrastructure, such as a power grid that frequently fails and cuts off electricity, is a major obstacle to economic growth in many countries. To provide good infrastructure, an economy must not only be able to afford it, but it must also have the political discipline to maintain it.

Perhaps the most crucial infrastructure is something we, in an advanced country, rarely think about: basic public health measures in the form of a clean water supply and disease control. Poor health infrastructure is a major obstacle to economic growth in poor countries, especially those in Africa.

2. GOVERNMENT SUBSIDIES TO EDUCATION In contrast to physical capital, which is mainly created by private investment spending, much of an economy's human capital is the result of government spending on education. Government pays for the great bulk of primary and secondary education. And it pays for a significant share of higher education: 75% of students attend public colleges and universities, and government significantly subsidizes research performed at private colleges and universities. As a result, differences in the rate at which countries add to their human capital largely reflect government policy. As we saw in Figure 55-1, educational levels in China are increasing much more rapidly than in Argentina. This isn't because China is richer than Argentina; until recently, China was, on average, poorer than Argentina. Instead, it reflects the fact that the Chinese government has made education a high priority.



Ingram Publishing/Thinkstock

Economic growth depends on an educated and skilled workforce.

3. GOVERNMENT SUBSIDIES TO R&D Technological progress is largely the result of private initiative. But in the more advanced countries, important R&D is done by government agencies as well. In the upcoming Economics in Action, we describe Brazil's

agricultural boom, which was made possible by government researchers who made discoveries that expanded the amount of arable land in Brazil, as well as developing new varieties of crops that flourish in Brazil's climate.

4. MAINTAINING A WELL-FUNCTIONING FINANCIAL SYSTEM Governments 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, especially its financial system. In particular, a well-regulated and well-functioning financial system is very important for economic growth because in most countries it is the principal way in which savings are channeled into 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 trust their banks, they will hoard gold or foreign currency, keeping their savings in safe deposit boxes or under the mattress, where it cannot be turned into productive investment spending. A well-functioning financial system requires appropriate government regulation to assure depositors that their funds are protected from loss.

Governments can also create an environment that fosters economic growth by providing the following.

PROTECTION OF PROPERTY RIGHTS *Property rights* are the rights of owners of valuable items to dispose of those items as they choose. A subset, *intellectual property rights*, are the rights of an innovator to accrue the rewards of her innovation.

The state of property rights generally, and intellectual property rights in particular, are important factors in explaining differences in growth rates across economies. Why? Because no one would bother to spend the effort and resources required to innovate if someone else could appropriate that innovation and capture the rewards. So, for innovation to flourish, intellectual property rights must receive protection.

Sometimes this is accomplished by the nature of the innovation: it may be too difficult or expensive to copy. But, generally, the government has to protect intellectual property rights. A *patent* is a government-created temporary monopoly given to an innovator for the use or sale of his or her innovation. It's a temporary rather than permanent monopoly because while it's in society's interests to give an innovator an incentive to invent, it's also in society's interests to eventually encourage competition.

POLITICAL STABILITY AND GOOD GOVERNANCE There's not much point in investing in a business if rioting mobs are likely to destroy it, or saving your money if someone with political connections can steal it. Political stability and good governance (including the protection of property rights) are essential ingredients in fostering economic growth in the long run.

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 state 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 laws don'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 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.

Even when the government isn'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, subject to unnecessary monopolization, or otherwise insulated from competition, productivity tends to suffer because of a lack of incentives.

ECONOMICS IN ACTION



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 as 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.

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.



Fandrade/Getty Images

In Brazil, government-funded R&D has resulted in crucial agricultural technologies that turn unusable land into profitable farmland.

Success, Disappointment, and Failure

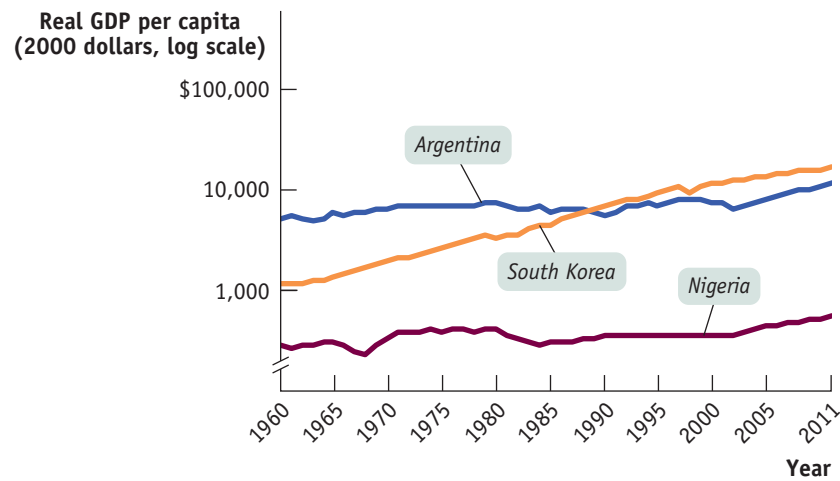
As we've seen, rates of long-run economic growth differ quite a lot around the world. Now let's look at three regions of the world that have had quite different experiences with economic growth over the last few decades.

Figure 55-2 shows trends since 1960 in real GDP per capita for three countries: Argentina, Nigeria, and South Korea. 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 broad “economic miracle” in East Asia. Argentina's slow progress, interrupted by repeated setbacks, is more or less typical of the disappointing growth that has characterized much of Latin America. And Nigeria's unhappy story until very recently—with little growth in real GDP until after 2000—was, unfortunately, an experience shared by many African countries.

FIGURE

55-2 Success and Disappointment



Real GDP per capita 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 barely budged

higher over the decades, an experience shared by many African countries. Neither Argentina nor Nigeria exhibited much growth over the period either, although both have had significantly higher growth in recent years.

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 55-2, 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, more than three times America's historical rate of growth.

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 didn't any economy achieve 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 on the convergence hypothesis in the Economics in Action at the end of this module.

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 demonstrate.

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

Latin America's Disappointment

In 1900, Latin America was not considered 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 55-2 shows in the case of Argentina, growth has been disappointing for many decades, until 2000 when it finally began to increase. The fact that South Korea is now much richer than Argentina would have seemed inconceivable a few generations ago.

Why did Latin America stagnate? 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.
- Political instability, leading to irresponsible economic policies, has taken a toll.

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 sustained rapid growth. It now seems that pulling off an economic miracle is harder than it looks. Although, in recent years Brazil and Argentina have seen their growth rates increase significantly as they exported large amounts of commodities to the advanced countries and rapidly developing China.

Africa's Troubles and Promise

Africa south of the Sahara is home to about 910 million people, more than 2 ½ 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



Jeanine Greenwald/Getty Images

Slow and uneven economic growth in sub-Saharan Africa has led to extreme and ongoing poverty for many of its people.

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% 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 story. What explains it?

Several factors are probably crucial. 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 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 major 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 very poor country.

But not all economists see political instability and government corruption as the leading causes of underdevelopment in Africa; some 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.

They also highlight 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 only be controlled with an effective public health infrastructure, something that is lacking in much of Africa.

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. As we noted in Figure 55-2, Nigeria's per capita GDP, after decades of stagnation, turned upward after 2000, achieving a 5.5% real GDP per capita growth rate in 2010. The same is true for sub-Saharan African economies as a whole.

In 2012, real GDP per capita growth rates averaged around 5.5% across sub-Saharan African countries and were projected to be nearly 6% in 2014. Rising prices for their exports are part of the reason for recent success, but there is growing optimism among development experts that a period of relative peace and better government is ushering in a new era for Africa's economies.

ECONOMICS IN ACTION



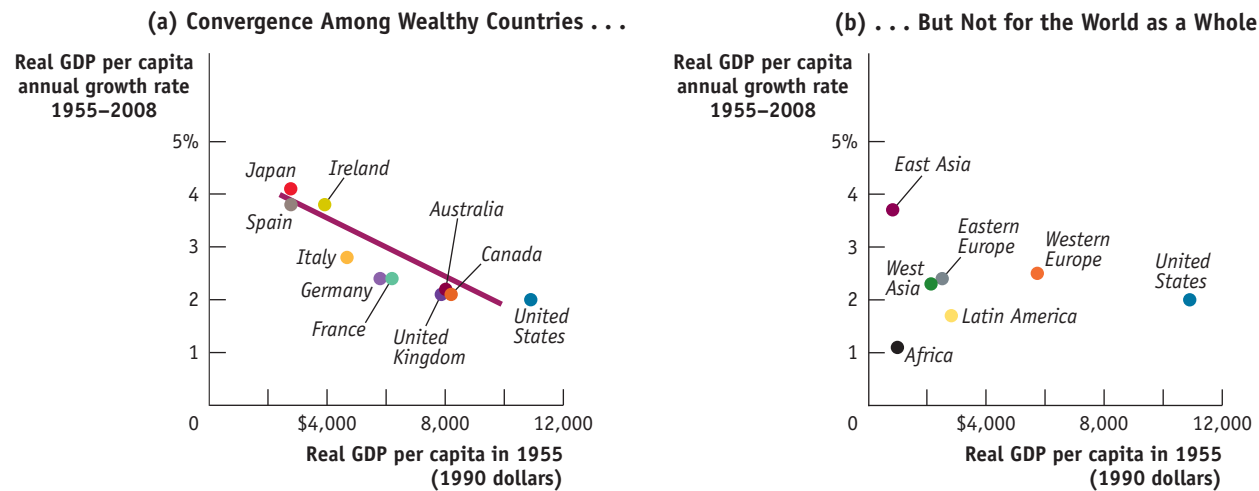
ARE ECONOMIES CONVERGING?

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.

FIGURE

55-3 Do Economies Converge?



Panel (a) of Figure 55-3 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 as can be seen from the line fitted through the points. 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 depend 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 largely converged in the last half-century. But looking across the world as a whole, including countries that remain poor, there is little evidence of convergence. Panel (b) of Figure 55-3 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. Likewise, 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, 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.

MODULE

55 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?

Multiple-Choice Questions

1. What explains the different growth rates economies experience?
 - I. savings and investment spending
 - II. research and development
 - III. government policies
 - 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. 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.

Critical-Thinking Question

Some economists think the high rates of growth of productivity achieved by many East Asian economies cannot be sustained. Why might they be right? What would have to happen for them to be wrong?

BUSINESS CASE • Big Box Boom



After 20 years of being sluggish, U.S. productivity growth accelerated sharply in the late 1990s; that is, productivity began to grow at a much faster rate than previously. What caused that acceleration? Was it the rise of the Internet?



AP Photo/Morry Gash

Not according to analysts at McKinsey and Co., the 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.

Other analysts agree. The accompanying figure shows the result of an analysis of total factor productivity growth in France, Germany, and the United States between 1995 and 2004, the decade of the U.S. productivity

surge. As you can see, the United States did considerably better than either European nation. The key to the surge was very fast growth in the productivity of the distribution sector, that is, in wholesale and retail trade.

Why did productivity surge in retailing in the United States? “The reason can be explained in just two syllables: Walmart,” wrote McKinsey.

Walmart is famed in the business world for its successful focus on the unglamorous but crucial area of *logistics*: getting stuff where it was needed, when it was needed. Walmart was one of the first companies to use computers to track inventory, to use bar-code scanners, to establish direct electronic links with suppliers, and so on. These practices gave it a huge advantage over competitors, leading to high profits and rapid expansion. Other firms, observing Walmart’s success, have emulated its business practices, spreading productivity gains through the economy as a whole.

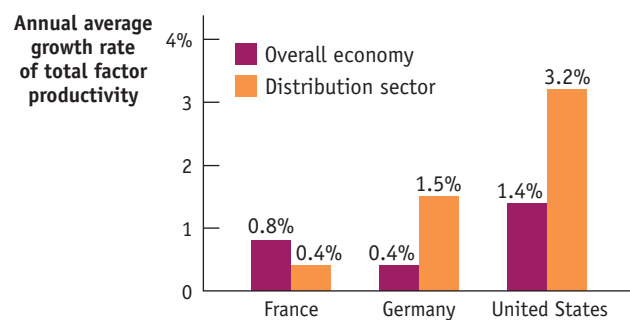
There are two lessons from the “Walmart effect,” as McKinsey calls it. One is that how you apply a technology makes all the difference: everyone in the retail business

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 flashy new technologies.

Questions for Thought

1. In this section we described several sources of productivity growth. Which of these sources corresponds to the “Walmart effect”?
2. How does the Walmart story relate to the “information technology paradox”?

U.S. and European Productivity Growth, 1995–2004



Source: Bart Van Ark, “Productivity, Sources of Growth and Potential Output in the Euro Area and the United States,” *Intereconomics* 45, no. 1 (2010). Brussels: Center for European Policy Studies.

SECTION 17 REVIEW

Summary

Sources of Long-Run Economic Growth

1. Growth is measured as changes in real GDP per capita in order to eliminate the effects of changes in the price level and changes in population size.
2. 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 1900. Over the course of the twentieth century, real GDP per capita in the United States increased more than fivefold.
3. 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.
4. 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 **technological progress**.

Productivity and Growth

5. 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. Equivalently, more physical capital per worker results in a lower, but still positive, increase in productivity.
6. **Growth accounting**, which estimates the contribution of each factor to a country's economic growth, has shown that rising **total factor productivity**, the amount of output produced from a given amount of factor inputs, is key to long-run growth. It is usually interpreted as the effect of technological progress.
7. In contrast to earlier times, natural resources are a less significant source of productivity growth in most countries today.
8. Economists generally believe that environmental issues pose a greater challenge to **sustainable long-run economic growth** than does natural resource scarcity.
9. The emission of greenhouse gases is clearly linked to growth, and limiting them 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.
10. 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.

Long-Run Growth Policy

11. 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. Although inflows of foreign savings from abroad help, a prime factor is differences in domestic savings and investment spending rates, since most countries that have high investment spending in physical capital finance it by high domestic savings.
12. Technological progress is largely a result of **research and development**, or **R&D**.
13. Governments can help or hinder growth. Government policies that directly foster growth are subsidies to **infrastructure**, particularly public health infrastructure, subsidies to education, subsidies to R&D, and maintenance of a well-functioning financial system that channels savings into investment spending, education, and R&D.
14. Governments can enhance the environment for growth by protecting property rights (particularly intellectual property rights through patents), by being politically stable, and by providing good governance. Poor governance includes corruption and excessive government intervention.
15. 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. The low growth rates of Latin American and African economies over many years led economists to believe that the **convergence hypothesis**, the claim that differences in real GDP per capita across countries narrow over time, fits the data only when factors that affect growth, such as education, infrastructure, and favorable government policies and institutions, are held equal across countries. In recent years, there has been an uptick in growth among some Latin American and sub-Saharan African countries, largely due to a boom in commodity exports.

Key Terms

Rule of 70, p. 546
Labor productivity, p. 548
Productivity, p. 548
Physical capital, p. 548
Human capital, p. 549

Technological progress, p. 549
Aggregate production function, p. 551
Diminishing returns to physical capital, p. 551

Growth accounting, p. 553
Total factor productivity, p. 553
Sustainable long-run economic growth, p. 556

Research and development (R&D), p. 563
Infrastructure, p. 563
Convergence hypothesis, p. 567

Problems

- The accompanying table shows data from the Penn World Table, Version 7.1, for real GDP per capita in 2005 U.S. dollars for Argentina, Ghana, South Korea, and the United States for 1960, 1970, 1980, 1990, 2000, and 2010.

Year	Argentina			Ghana			South Korea			United States		
	Real GDP per capita (2005 dollars)	Percentage of 1960 real GDP per capita	2010 real GDP per capita	Real GDP per capita (2005 dollars)	Percentage of 1960 real GDP per capita	2010 real GDP per capita	Real GDP per capita (2005 dollars)	Percentage of 1960 real GDP per capita	2010 real GDP per capita	Real GDP per capita (2005 dollars)	Percentage of 1960 real GDP per capita	2010 real GDP per capita
1960	\$6,043	?	?	\$1,286	?	?	\$1,656	?	?	\$15,398	?	?
1970	7,617	?	?	1,525	?	?	2,808	?	?	20,436	?	?
1980	8,496	?	?	1,295	?	?	5,179	?	?	24,952	?	?
1990	6,928	?	?	1,273	?	?	11,643	?	?	31,389	?	?
2000	8,909	?	?	1,478	?	?	18,729	?	?	36,669	?	?
2010	12,340	?	?	2,094	?	?	26,609	?	?	41,365	?	?

- Complete the table by expressing each year's real GDP per capita as a percentage of its 1960 and 2010 levels.
 - How does the growth in living standards from 1960 to 2010 compare across these four nations? What might account for these differences?
- The accompanying table shows the average annual growth rate in real GDP per capita for Argentina, Ghana, and South Korea using data from the Penn World Table, Version 7.1, for the past few decades.

Years	Average annual growth rate of real GDP per capita		
	Argentina	Ghana	South Korea
1960–1970	3.01%	2.08%	4.82%
1970–1980	1.21	0.68	6.35
1980–1990	–1.61	–0.47	7.19
1990–2000	2.41	1.49	5.51
2000–2010	2.97	3.66	4.00

- 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.
 - Suppose that the average annual growth rate that each country achieved over the period 2000–2010 continues indefinitely into the future. Starting from 2010, use the Rule of 70 to calculate the year in which a country will have doubled its real GDP per capita.
- The accompanying table provides approximate statistics on per capita income levels and growth rates for regions

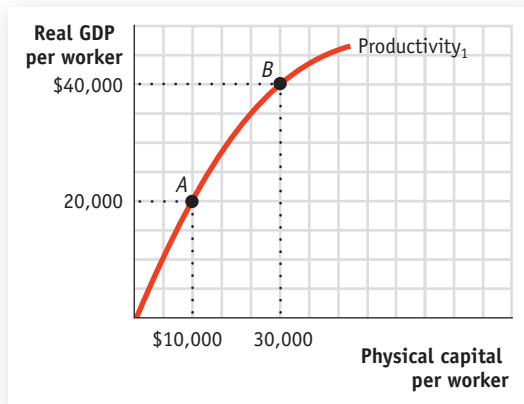
defined by income levels. According to the Rule of 70, starting in 2010 the high-income countries are projected to double their per capita GDP in approximately 78 years, in 2088. Throughout this question, assume constant growth rates for each of the regions that are equal to their average value between 2000 and 2010.

Region	GDP per capita (2010)	Average annual growth rate of real GDP per capita (2000–2010)
High-income countries	\$38,293	0.9%
Middle-income countries	3,980	4.8
Low-income countries	507	3.0

Source: World Bank.

- Calculate the ratio of per capita GDP in 2010 of the following:
 - Middle-income to high-income countries
 - Low-income to high-income countries
 - Low-income to middle-income countries
- Calculate the number of years it will take the low-income and middle-income countries to double their per capita GDP.
- Calculate the per capita GDP of each of the regions in 2088. (*Hint:* How many times does their per capita GDP double in 78 years, the number of years from 2010 to 2088?)
- Repeat part a with the projected per capita GDP in 2088.
- 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 Alberrnia and Brittania. Each country's current relationship between physical capital per worker and output per worker is given by the curve labeled "Productivity₁" in the accompanying diagram. Alberrnia is at point A and Brittania is at point B.



- In the relationship depicted by the curve Productivity₁, what factors are held fixed? Do these countries experience diminishing returns to physical capital per worker?
 - 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 Alberrnia?
 - How would your policy recommendation change if the amount of human capital per worker could be changed? Assume that an increase in human capital doubles the output per worker when physical capital per worker equals \$10,000. Draw a curve on the diagram that represents this policy for Alberrnia.
5. The country of Androde is currently using Method 1 for its production function. By chance, scientists stumble onto 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

- 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. In your figure, label that point A.
 - 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.
 - Now assume that, starting from point A, over the same period of 70 years, the amount of physical capital per worker in Androde rises to 400, but that during that time period, 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.
 - As the economy of Androde moves from point A to point C, what share 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, from the tab "Subject Areas," look under the head titled "Productivity," and select the link to "Labor Productivity & Costs"; then, from the heading "LPC News Releases," find the most recent "Productivity and Costs" report.) What was the percent change in nonfarm business sector labor productivity for the previous quarter? How does the percent change in that quarter's productivity compare to data from the previous quarter?
7. What roles do physical capital, human capital, technology, and natural resources play in influencing long-run economic growth of aggregate output per capita?
8. How have U.S. policies and institutions influenced the country's long-run economic growth?
9. 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 $\$x \times (1 + (y/100))^z$ in z years. We assume that $0 \leq y < 10$.]
10. The accompanying table shows data from the Penn World Table, Version 7.1, for real GDP per capita (2005 U.S. dollars) in France, Japan, the United Kingdom, and the United States in 1950 and 2010. Complete the table. Have these countries converged economically?

Country	1950		2010	
	Real GDP per capita (2005 dollars)	Percentage of U.S. real GDP per capita	Real GDP per capita (2005 dollars)	Percentage of U.S. real GDP per capita
France	\$7,084	?	\$31,299	?
Japan	2,787	?	31,447	?
United Kingdom	8,988	?	34,268	?
United States	13,069	?	41,365	?

11. The accompanying table shows data from the Penn World Table, Version 7.1, for real GDP per capita (2005 U.S. dollars) for Argentina, Ghana, South Korea, and the United States in 1960 and 2010. Complete the table. Have these countries converged economically?

Country	1960		2010	
	Real GDP per capita (2005 dollars)	Percentage of U.S. real GDP per capita	Real GDP per capita (2005 dollars)	Percentage of U.S. real GDP per capita
Argentina	\$6,043	?	\$12,340	?
Ghana	1,286	?	2,094	?
South Korea	1,656	?	26,609	?
United States	15,398	?	41,365	?

12. 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?
13. According to the *World Factbook*, published by the U.S. Central Intelligence Agency, the proven oil reserves existing in the world in 2012 consisted of 1,532 billion barrels. In that year, the U.S. Energy Information Administration reported that the world oil production was 88.97 million barrels a day.
- At this rate, for how many years will the proven oil reserves last? Discuss the Malthusian view in the context of the number you just calculated.
 - In order to do the calculations in part a, what did you assume about the total quantity of oil reserves over time? About oil prices over time? Are these assumptions consistent with the Malthusian view on resource limits?
 - 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.

14. The accompanying table shows the annual growth rate for the years 2000–2009 in per capita emissions of carbon dioxide (CO₂) and the annual growth rate in real GDP per capita for selected countries.

Country	2000–2009 average annual growth rate of:	
	Real GDP per capita	CO ₂ emissions per capita
Argentina	2.81%	1.01%
Bangladesh	4.17	5.47
Canada	0.68	–1.46
China	9.85	11.11
Germany	0.59	–1.23
Ireland	1.05	–2.10
Japan	0.29	–1.03
South Korea	3.48	1.68
Mexico	0.18	0.44
Nigeria	6.07	–2.46
Russia	5.22	0.52
South Africa	2.39	0.80
United Kingdom	0.88	–1.35
United States	0.58	–1.78

Sources: Energy Information Administration; International Monetary Fund.

- Rank the countries in terms of their growth in CO₂ emissions, from highest to lowest. What five countries have the highest growth rate in emissions? What five countries have the lowest growth rate in emissions?
- Now rank the countries in terms of their growth in real GDP per capita, from highest to lowest. What five countries have the highest growth rate? What five countries have the lowest growth rate?
- Would you infer from your results that CO₂ emissions are linked to growth in output per capita?
- Do high growth rates necessarily lead to high CO₂ emissions?