CHAPTER 4

Growth and Policy

CHAPTER HIGHLIGHTS

- Rates of economic growth vary widely across countries and across time.
- Endogenous growth theory attempts to explain growth rates as functions of societal decisions, in particular saving rates.
- Income in poor countries appears to be converging toward income levels of rich countries, but at extraordinarily slow rates.

Can we grow faster? The previous chapter explained how GDP and GDP growth are determined by the saving rate, the rate of population growth, and the rate of technical progress. How do society's choices affect these parameters? In countries on the leading edge of technology, the advance of knowledge is a key determinant of growth. Invention of new technology is much less important for poorer countries, because poorer countries can grow by "borrowing" technology, as well as by investing in physical and human capital. In the first part of this chapter we look at how society's choices lead to technical progress—the subject called *endogenous growth theory.* Paul Romer and Robert Lucas are responsible for much of the early development of this concept.[1] In the second part of the chapter we turn to an examination of a variety of social policies affecting growth.[2]

4-1
GROWTH THEORY: ENDOGENOUS GROWTH

Neoclassical growth theory dominated economic thought for three decades because it does a good job of explaining much of what we observe in the world and because it is mathematically elegant. Nonetheless, by the late 1980s dissatisfaction with the theory had arisen on both theoretical and empirical grounds.[3] Neoclassical growth theory attributes long-run growth to technological progress but leaves unexplained the economic determinants of that technological progress. Empirical dissatisfaction developed over the prediction that economic growth and saving rates should be uncorrelated in the steady state. The data make it clear that saving rates and growth are positively correlated across countries.[4]

[1]Robert E. Lucas, Jr., "On the Mechanics of Economic Development," *Journal of Monetary Economics,* July 1988; Paul Romer, "Increasing Returns and Long-Run Growth," *Journal of Political Economy,* October 1986. The volume edited by Alwyn Young, *Readings in Endogenous Growth* (Cambridge, MA: MIT Press, 1993), contains many of the key papers.

[2]N. Gregory Mankiw provides an accessible overview of issues of growth in "The Growth of Nations," *Brookings Papers on Economic Activity, No. 1* (1995). The best state-of-the-art examination of the theory of growth is the graduate-level text by Robert J. Barro and Xavier Sala-i-Martin, *Economic Growth* (New York: McGraw-Hill, 1995). Jonathan Temple presents a thoughtful examination of the empirical evidence on growth in "The New Growth Evidence," *Journal of Economic Literature,* March 1999. Xavier Sala-i-Martin links empirical evidence and the intellectual development of new growth theory in a very readable article, "15 Years of New Growth Economics: What Have We Learnt?" Universitat Pompeu Fabra, Department of Economics and Business working paper no. 620, June 2002.

[3]For an especially readable discussion, see Paul Romer, "The Origins of Endogenous Growth," *Journal of Economic Perspectives,* Winter 1994. Two other excellent references are Mancur Olson, "Big Bills on the Sidewalk: Why Are Some Nations Rich and Others Poor?" *Journal of Economic Perspectives,* Spring 1996, and Bennett McCallum, "Neoclassical versus Endogenous Growth: An Overview," Federal Reserve Bank of Atlanta *Economic Quarterly,* Fall 1996. Empirical growth theory has been influenced remarkably by an amazing set of data put together by Alan Heston and Robert Summers of the University of Pennsylvania. You can find the data, called the Penn World Tables, online at http://pwt.econ.upenn.edu.

[4]More recent work raises questions as to whether this observation is really an important argument against the neoclassical model. Mankiw ("Growth of Nations") writes, "The inability of saving to affect steady-state growth . . . might appear inconsistent with the strong correlation between growth and saving across countries. But this correlation could reflect the transitional dynamics that arise as economies approach their steady states."

BOX 4-1 A Nobel Laureate's Words

> I do not see how one can look at figures like these without seeing them as *possibilities.* Is there some action a government of India could take that would lead the Indian economy to grow like Indonesia's or Egypt's? If so, *what,* exactly? If not, what is it about the "nature of India" that makes it so? The consequences for human welfare involved in questions like these are simply staggering: Once one starts to think about them, it is hard to think about anything else.*

The opening quote was published in 1988. As you can see in Table 1, in the next ten years India succeeded in dramatically increasing its growth rate, although still not to the level of South Korea or China.

TABLE 1 GDP Per Capita

	1990 DOLLARS			AVERAGE ANNUAL GROWTH, %	
	1950	1988	1998	1950–1988	1988–1998
United States	9,561	22,499	27,331	1.8	2.0
Afghanistan	645	644	514	0.0	−2.2
Bangladesh	540	608	813	0.2	2.9
China	439	1,816	3,117	3.0	5.6
Egypt	718	2,001	2,128	2.2	0.6
Ghana	1,122	1,048	1,244	−0.1	1.7
India	619	1,216	1,746	1.4	3.7
Indonesia	840	2,196	3,070	2.0	3.4
Mexico	2,365	5,797	6,655	1.9	1.4
Somalia	1,057	1,067	883	0.0	−1.9
South Korea	770	7,621	12,152	4.9	4.8
Taiwan	936	9,714	15,012	5.0	4.4
Tanzania	377	549	553	0.8	0.1
Thailand	817	3,828	6,205	3.3	4.9
Former U.S.S.R.	2,834	7,032	3,893	1.9	−5.7

Source: Angus Maddison, *The World Economy: A Millennial Perspective* (Paris: Organization for Economic Cooperation and Development, 2001).

*Robert E. Lucas, Jr., "On the Mechanics of Economic Development," *Journal of Monetary Economics,* July 1988.

THE MECHANICS OF ENDOGENOUS GROWTH

The solution to both the theoretical and the empirical problems with neoclassical theory lies in modifying the production function in a way that allows for self-sustaining—*endogenous*—growth. In this section we look at the difference between endogenous growth and the previous chapter's neoclassical theory in a bit of a mechanical way. With the mechanical part under our belt, we flesh out the economics in the section following.

Figure 4-1*a* reproduces the basic Solow growth diagram from Chapter 3. You will remember that the steady state occurs at point *C*, where the saving and investment requirement lines cross. Anywhere the saving line is above the investment requirement line, the economy is growing because capital is being added. Starting at point *A*, for example, the economy moves, over time, to the right. How do we know that this process eventually comes to a halt (i.e., reaches a steady state)? Because of the *diminishing marginal product of capital,* the production function and the parallel saving curve eventually flatten out. Since the investment requirement line has a constant positive slope, the investment requirement line and saving curve are guaranteed to cross.

Contrast Figure 4-1*b*, where we have changed the assumed shape of the production function to show a *constant marginal product of capital*. The production function, like the parallel saving curve, is now a *straight line*. Since the saving curve no longer flattens out, saving is everywhere greater than required investment. The higher the saving rate, the bigger the gap of saving above required investment and the faster is growth.

The economy described in Figure 4-1*b* can be illustrated with a simple algebraic model leading to endogenous growth. Assume a production function with a constant marginal product of capital and with capital as the only factor. Specifically, let

$$Y = aK \tag{1}$$

That is, output is proportional to the capital stock. The marginal product of capital is simply the constant a.

Assume that the saving rate is constant at s and that there is neither population growth nor depreciation of capital. Then all saving goes to increase the capital stock. Accordingly,

$$\Delta K = sY = saK \tag{2}$$

or

$$\Delta K/K = sa$$

The growth rate of capital is proportional to the saving rate. Further, since output is proportional to capital, the growth rate of output is

$$\Delta Y/Y = sa \tag{3}$$

In this example, the higher the saving rate, the higher the growth rate of output.

THE DEEPER ECONOMICS OF ENDOGENOUS GROWTH

If a simple change to the assumed shape of the production function provides a satisfactory, albeit oversimplified, solution to the problems with neoclassical growth theory, what took 30 years to figure out? It turns out that eliminating diminishing marginal returns violates deep microeconomic principles. The changed assumption implies constant returns to scale for capital; in other words, a firm with twice as much machinery will produce twice as much output. But if doubling capital doubles output, then doubling all factors of production—that is, labor as well as capital—will more than double output. If there are constant returns to scale to capital alone, there will be

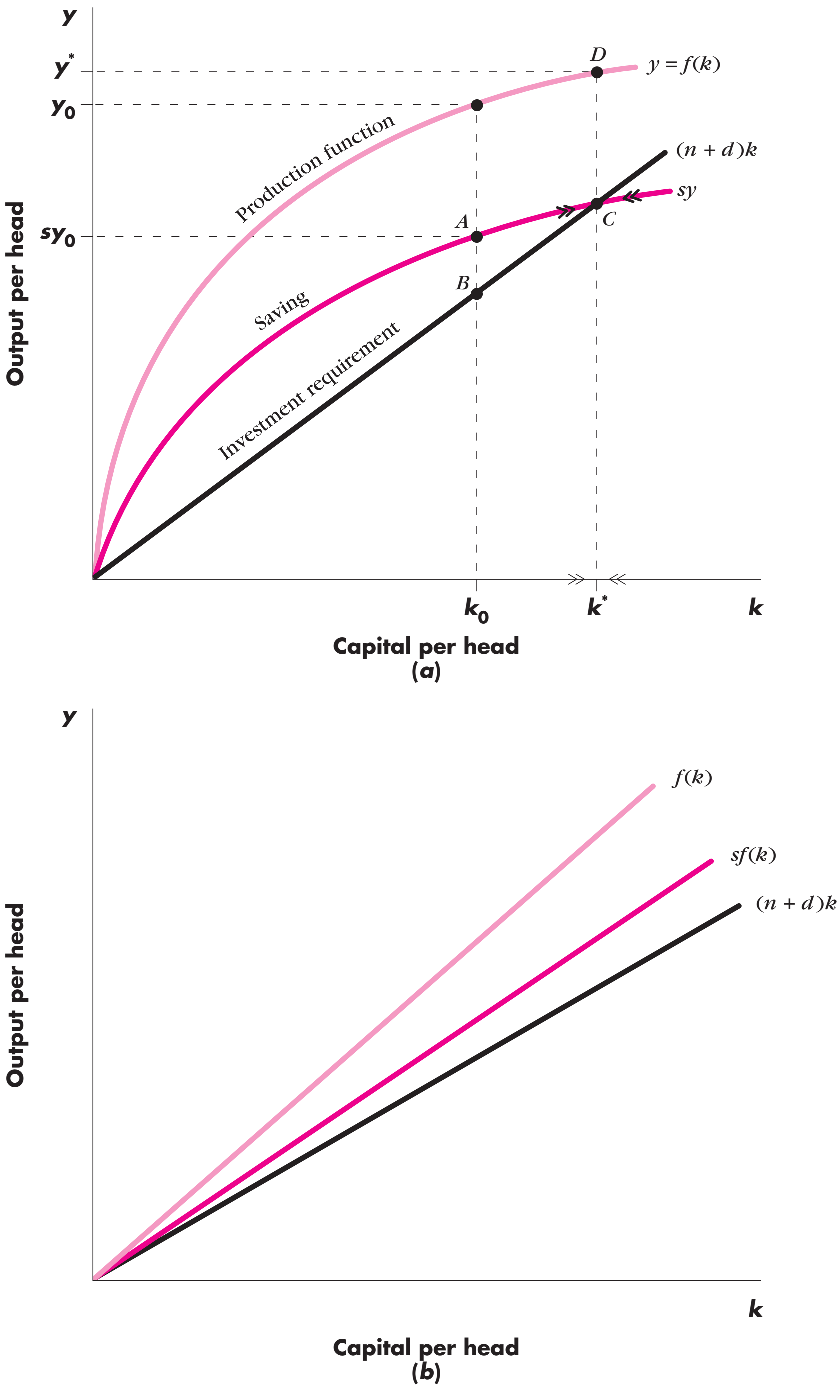

FIGURE 4-1 (*a*) SOLOW GROWTH MODEL VS. (*b*) ENDOGENOUS GROWTH.

increasing returns to scale to all factors taken together. This suggests that larger and larger firms are ever more efficient, so we should see a single firm come to dominate the entire economy. Since nothing remotely like this happens, we ought to rule out the possibility of increasing returns to scale to all factors and constant returns to a single factor, at least for a single firm.

Suppose, however, that an individual firm doesn't capture all the benefits of capital: Some of the benefits are *external* to the firm. In this case, when a firm increases capital, the firm's production rises but so does the productivity of other firms. As long as the *private* return has constant returns to all factors, there will be no tendency to monopolization.

Paul Romer's intellectual breakthrough was to partially separate private returns to capital from social returns.[5] Investment produces not only new machines but new ways of doing things as well—sometimes because of deliberate investment in research and sometimes because of serendipitous spin-offs. While firms do capture the production benefits of new machines, it is much harder to capture the benefits of new methods and new ideas because methods and ideas are easy to copy.

Endogenous growth theory hinges on the notion that there are substantial *external* returns to capital. Is this reasonable? If capital is physical machinery, probably not. After all, the benefits of a drill press are pretty much captured by the owner of the drill press. In contrast, consider the role of *human capital,* particularly investment knowledge. It is expensive to create a new drill press or a new idea. However, a copy of a drill press costs as much as the first one, while an idea can be copied at little or no expense. Since the contribution of new knowledge—new inventions and discoveries—is only partially captured by the creator, there can be substantial external benefits. Further, each new idea makes the next idea possible, so knowledge can grow indefinitely. Thus, economists think that investment in human capital in general and research and development specifically is the key to understanding long-run growth.

◆ OPTIONAL ◆

We turn now to a more fully developed endogenous growth model, a model with labor as well as capital. The key assumption is that better technology is produced as a by-product of capital investment. Specifically, assume that technology is proportional to the level of capital per worker in the economy overall, $A = \alpha K/N = \alpha k$, and that technology is labor-augmenting, so the production function can be written as $Y = F(K, AN)$.[6] The growth equations are like those of Chapter 3, except that technology growth, instead of being exogenously specified, now depends on capital growth, $\Delta A/A = \Delta K/K - \Delta N/N$.

Working through the algebra requires two steps. First, we show that output and capital grow at equal rates, implying that y/k is a constant. Then we use this fact to work backward to the growth rates.

[5]See Romer, "Increasing Returns and Long-Run Growth."

[6]To be clear about notation, note that a is the marginal product of capital and that α governs the way capital and labor combine to produce technology, A.

The GDP growth equation from Chapter 3 was

$$\Delta y/y = \theta \times \Delta k/k + (1 - \theta) \times \Delta A/A$$

Now we substitute the technology growth formula, $\Delta A/A = \Delta K/K - \Delta N/N = \Delta k/k$, into the growth equation to show that output and capital grow at the same rate:

$$\Delta y/y = \theta \times \Delta k/k + (1 - \theta) \times \Delta k/k$$
$$\Delta y/y = \Delta k/k$$

Since the numerator and denominator of y/k grow at an equal rate, y/k is constant. We find this constant by dividing the production function by K and simplifying:

$$y/k = F(K, AN)/K = F(K/K, AN/K) = F(1, \alpha) \equiv a$$

From Chapter 3 we know that the equation for capital accumulation can be written $\Delta k/k = sy/k - (n + d)$. Making the substitution for y/k, we have

$$\Delta y/y = \Delta k/k = g = sy/k - (n + d) = sa - (n + d)$$

The growth rate of GDP per capita is $sa - (n + d)$. A high saving rate generates a high growth rate. High rates of population growth and depreciation lead to a low growth rate.

CONVERGENCE

The question of "convergence" centers on whether economies with different initial levels of output eventually grow to equal standards of living.

Neoclassical growth theory predicts *absolute convergence* for economies with equal rates of saving and population growth and with access to the same technology. In other words, they should all reach the same steady-state income. (If Figure 4-1*a* is the same for two economies, they eventually reach the same steady state even if one economy begins farther to the left.) *Conditional convergence* is predicted for economies with different rates of saving or population growth; that is, steady-state incomes will differ as predicted by the Solow growth diagram, but *growth rates* will eventually equalize.

Contrast conditional convergence with the prediction of endogenous growth theory that a high saving rate leads to a high growth rate. In a series of papers, Robert Barro has shown that while countries that invest more tend to grow faster, the impact of higher investment on growth seems to be transitory:[7] Countries with higher investment will end in a steady state with higher per capita income but not with a higher growth rate. This suggests that countries do converge *conditionally,* and thus endogenous growth theory is not very important for explaining international differences in

[7]See, for example, Robert Barro's "Economic Growth in a Cross Section of Countries," *Quarterly Journal of Economics,* May 1991, and his *Determinants of Economic Growth: A Cross-Country Empirical Study,* (Cambridge, MA: MIT Press, 1997).

BOX 4-2 One Idea Leads to the Next

Paul Samuelson, winner of the Nobel Prize in economics in 1970, wrote in his classic book *Foundations of Economic Analysis,** "And most college graduates in physics know more than Isaac Newton: for as Newton himself said, a scientist sees further than his predecessors because he stands on the shoulders of earlier giants." The source of Samuelson's famous dictum is, "If I have seen further it is by standing on the shoulders of Giants" (Newton to Hooke, February 5, 1676).

*Cambridge, MA: Harvard University Press, 1947.

growth rates, although it may be quite important for explaining growth in countries on the leading edge of technology.

Barro's evidence suggests that conditional convergence is taking place at a rate of 2 percent per year. For instance, if India's income level is now 5 percent of that of the United States, in 35 years it would be approximately 10 percent of the U.S. level[8]—provided that the other variables that affect the level of income, such as the saving rate, are the same between the two countries. This convergence is very slow; it means that people in India today cannot look forward to catching up anytime soon with the United States merely by relying on the "natural" neoclassical force of convergence.

RECAP

- Endogenous growth theory relies on constant returns to scale to accumulable factors to generate ongoing growth.
- The microeconomics underlying endogenous growth theory emphasizes the difference between social and private returns when firms are unable to capture some of the benefits of investment.
- Current empirical evidence suggests that endogenous growth theory is not very important for explaining international differences in growth rates.

◆ OPTIONAL ◆

GROWTH TRAPS AND TWO-SECTOR MODELS

Explaining high or low growth isn't the same as explaining *no* growth. Little or no growth is the most accurate description of Ghana since 1900—and of most of humankind for most of history. To explain a world with both no-growth and high-growth countries, we would like a model in which there is a possibility of both a no-growth,

[8]It takes 35 years for an economy growing at 2 percent to double its size. In this case the doubling is relative to another economy.

low-income equilibrium and a positive-growth, high-income equilibrium. In other words, something that combines elements of neoclassical and endogenous growth theories.

Suppose there are two kinds of investment opportunities: those with diminishing marginal product (as in the neoclassical growth model) at low income levels, and those with constant marginal product (as in the endogenous growth model) at higher income levels. The production function will begin with a curved section (as in Figure 4-1*a*) and end with an upward-sloping line (as in Figure 4-1*b*).

Figure 4-2 shows an example. This model has a "neoclassical growth equilibrium" at point *A* but acts like an endogenous growth model to the right of point *B*. At low income and capital, the capital requirement line strikes the saving line in the neoclassical region (point *A*), leading to a no-growth steady state. At high income and capital (past point *B*), the saving line is above the capital requirement line, leading to ongoing growth.

One remaining piece is omitted from Figure 4-2. With two outlets for investment, society must choose not only total investment but also the division between the two kinds. Societies that direct investment toward research and development will have ongoing growth. Societies that direct investment toward physical capital may have higher output in the short run at the cost of lower long-run growth.

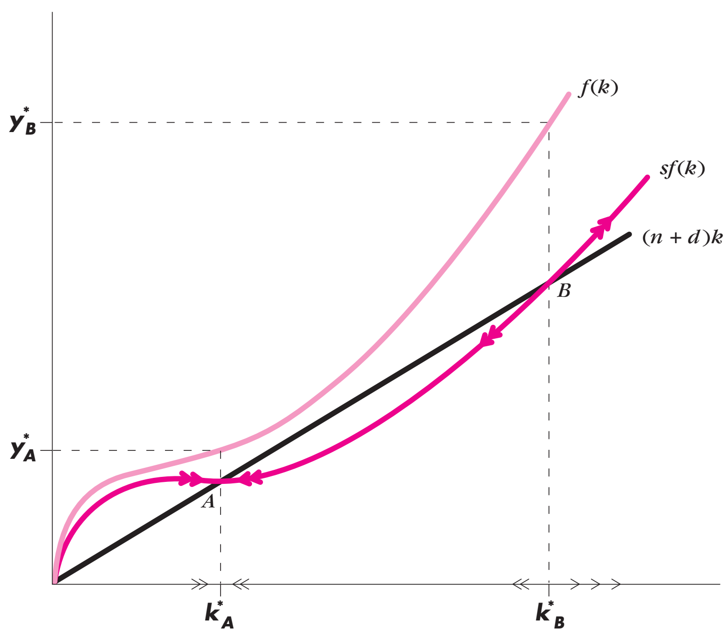

FIGURE 4-2 A CHOICE BETWEEN A STEADY STATE AND CONTINUED GROWTH.

A production function such as this could explain a world with both no-growth and high-growth countries.

4-2
GROWTH POLICY

The previous section focused on the determinants of the rate of technical progress, a problem of most interest to countries on the cutting edge of new technology. In this section we focus on the problems of population growth and the process by which some countries move from underdeveloped to developed status.

POPULATION GROWTH AND MALTHUS

One of the oldest ideas in economics is that population growth works against the achievement of high incomes.[9] The Solow growth model predicts that high population growth, n, means lower steady-state income because each worker will have less capital to work with. However, over a wide range of incomes, population growth itself depends on income. Extremely poor countries in modern times have very high birth rates and very high death rates, resulting in moderately high population growth. As incomes rise, death rates fall (especially through reductions in infant mortality) and population growth rises. At very high incomes, birth rates fall. Indeed, many of the wealthier countries in the world are approaching zero population growth (ZPG).

◆ OPTIONAL ◆

A simple version of a Solow model with endogenous population growth can be shown graphically. If we were to graph n against y, it would rise, fall, and then level off near zero. The slope of the investment requirement line depends on n, but since n is no longer constant, the investment requirement line becomes a curve. Modifying the investment requirement line on the Solow diagram to account for changing n gives a picture that looks something like Figure 4-3.

The investment requirement line with variable population growth in Figure 4-3, $[n(y) + d]k$, rises slowly, then sharply, and eventually flattens out. As shown, the investment requirement line crosses the saving curve at points A, B, and C. Point A is a

[9] For the original work by Malthus, see Thomas R. Malthus, "An Essay on the Principle of Population; or, A View of its Past and Present Effects on Human Happiness," 6th ed., first published in 1826, London, John Murray, Albermarle Street. Robert Lucas presents a very readable account of the interaction between technological growth and population in "The Industrial Revolution: Past and Future," University of Chicago working paper, February 1998. See also Oded Galor and David Weil, "From Malthusian Stagnation to Modern Growth," *American Economic Review,* May 1999. Growth, fertility, and economic inequality are tied together in Michael Kremer and Daniel Chen, "Income Distribution Dynamics with Endogenous Fertility," Harvard University working paper, 1999. (By the way, some of the origins of the paper lie in Chen's *undergraduate* senior thesis!) Growth, population, and intellectual property rights are tied together in Charles Jones, "Was an Industrial Revolution Inevitable? Economic Growth over the Very Long Run," *Advances in Macroeconomics* 1, no. 2 (2001).

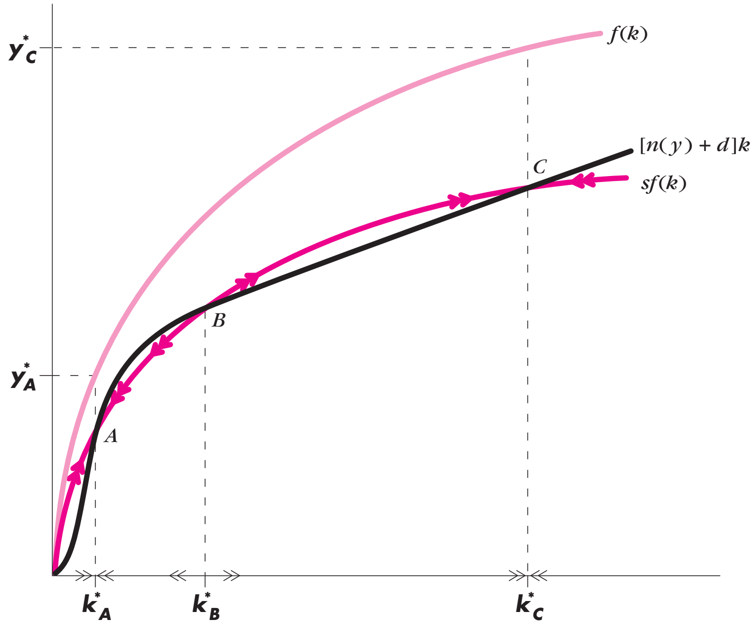

FIGURE 4-3 THE POVERTY TRAP.

In this model with two steady-state equilibria, a high rate of population growth results in a low level of per capita income.

poverty trap with high population growth and low income. The equilibrium at *C* has low population growth and high income. Note the arrows showing the direction of movement toward the steady state. Points *A* and *C* are said to be *stable equilibria* because the economy moves toward these points. *B* is an *unstable equilibrium* since the economy tends to move away from *B*.

How can an economy escape from the low-level equilibrium? There are two possibilities. If a country can put on a "big push" that raises income past point *B*, the economy will continue on its own the rest of the way to the high-level point *C*. Alternatively, a nation can effectively eliminate the low-level trap by moving the saving curve up or the investment requirement line down so that they no longer touch at *A* and *B*. Raising productivity or raising the saving rate raises the saving line. Population control policies lower the investment requirement line.

Some governments are beginning to recognize the need to reduce population growth—in some countries, the government tries to persuade people to use contraceptives; in other countries, the government institutes policies that have even included forced sterilization. But it is often difficult to reduce the rate of population growth in very poor countries, where large families may serve as a social security system, since having children ensures that the parents are taken care of in their old age.

TABLE 4-1 Growth in the Asian Tigers
(Percent)

	HONG KONG (1966–1991)	SINGAPORE (1966–1990)	SOUTH KOREA (1966–1990)	TAIWAN (1966–1990)
GDP per capita growth	5.7	6.8	6.8	6.7
TFP growth	2.3	0.2	1.7	2.6
Δ % labor force participation	38 → 49	27 → 51	27 → 36	28 → 37
Δ % secondary education or higher	27.2 → 71.4	15.8 → 66.3	26.5 → 75.0	25.8 → 67.6

Source: Alwyn Young, "The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience," *Quarterly Journal of Economics,* August 1995.

LESSONS FROM THE ASIAN TIGERS

Growth in Hong Kong, Singapore, South Korea, and Taiwan has been so remarkable that the four nations are sometimes called the "Asian Tigers." They have been held up as examples of effective development to the rest of the world. It has been argued—especially by some political leaders from these nations—that they have learned a special trick worthy of emulation. However, the best current evidence is that the principal "special trick" is old-fashioned hard work and sacrifice. In other words, these countries have not had remarkable increases in total factor productivity, A; they've saved and invested, put more people to work, and concentrated on education in order to raise human capital. What can we learn by examining the experience of the Asian Tigers?

Table 4-1 is taken from a very careful study of East Asian growth by Alwyn Young. All four countries have remarkably high growth, but their growth is mostly explained by increased input, not by higher productivity. Growth in total factor productivity, a measure of output per unit of input, is high, but not remarkable, in Hong Kong, South Korea, and Taiwan. Singapore's *TFP* growth is notably small. All four countries have had a drastic increase in the fraction of the population that works, largely due to increased labor force participation by women. Each country also greatly increased its human capital, moving educational attainment to levels close to those of the leading industrialized nations.

The Asian Tigers have several other characteristics in common. All four have relatively stable governments. The four share an outward-looking economic policy, encouraging their industries to export, compete, and learn to survive in the world market.

The near-zero productivity growth in Singapore is nonetheless noteworthy. In an influential article comparing Singapore and Hong Kong, Alwyn Young draws attention to the fact that Hong Kong has had an essentially laissez-faire, free-market government while Singapore's government maintains more control over the economy, with most of the economy's investments being indirectly directed by the government.[10] He argues

[10] A. Young, "A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore," *NBER Macroeconomics Annual,* 1992.

BOX 4-3 Is High Income Good? The Golden Rule

If this seems a strange question, remember that we're interested in high income insofar as it leads to high *consumption*. The higher the saving rate chosen by a society, the higher the steady-state capital and income. But the higher is k, the greater the investment required just to maintain the capital-labor ratio, as opposed to being used for current consumption. So too high a saving rate can lead to high income but low consumption.

Steady-state consumption, c^*, equals steady-state income, $y^* = f(k^*)$, minus steady-state investment, $(n + d)k^*$:

$$c^* = f(k^*) - (n + d)k^*$$

Steady-state consumption is maximized at the point where a marginal increase in capital produces just enough extra output to cover the increased investment requirement, $MPK(k^{**}) = (n + d)$. Capital k^{**}, the *golden-rule capital stock,* corresponds to the highest permanently sustainable level of consumption, the level at which we can "do unto future generations as we hope previous generations did unto us." Above the golden-rule level, we can cut back on saving and consume more both now and later. Below this level, we can increase future consumption only by making the choice to consume less today. The empirical evidence is that we are below the golden-rule level of saving.

that the government of Singapore has tried to force the pace of development, relying on foreign investment to bring in new technologies, but has moved on too rapidly to ever more sophisticated goods before local entrepreneurs and workers have mastered the current technology.

The fact remains that the Tigers have achieved something extraordinary in human history: They have been growing at rates that will transform them from being among the poorest of countries to having income levels that—already in Singapore, soon in the others—match those of the rich industrial countries. It is reassuring to see that this can be done the old-fashioned way, through saving, hard work, and competition.

THE TRULY POOR COUNTRIES

The growth line for Ghana (see Figure 3-1) and the nation's GDP data (see the table in Box 4-1) illustrate a striking problem. Compared with the rest of the world, Ghana has had very little economic growth! (Ghana is used as an example. The same holds true for a number of other countries.) Income is so low that much of the population lives at the border of subsistence.

Have we explained Ghana? In part yes. Saving in Ghana is quite low. According to the *World Development Indicators* CD-ROM, between 1960 and 1985 gross domestic savings in Ghana averaged 9.3 percent of GDP, as compared to 34.3 percent and

19.4 percent in Japan and the United States, respectively.[11] Population growth in Ghana, and other extremely poor countries, was also much higher than in Japan or the United States. So the effect of both saving and population growth is as theory would predict. The poorest countries are hard-pressed to invest in human capital. Many of the poorest countries also have hostile climates for foreign investment, either because of deliberate policies that attempt to encourage domestic production instead or simply because the economic and legal environment is uncertain and the nations are unwilling or unable to guarantee investors the ability to repatriate profits.

NATURAL RESOURCES: LIMITS TO GROWTH?

Production uses up natural resources, in particular energy. Is it true, as is sometimes alleged, that exponential growth in the economy will eventually use up the fixed stock of resources? Well yes, it is true in the limited sense that current theories suggest the universe will one day run down. However, this seems more of a concern for a course in astrophysics, or perhaps theology, than for a course in economics. Over any interesting horizon, the economy is protected from resource-depletion disasters by two factors. First, technical progress permits us to produce more using fewer resources. For example, the energy efficiency of room lighting has increased by a factor of 4,500 since Neolithic times.[12] Second, as specific resources come into short supply, their prices rise, leading producers to shift toward substitutes.

Environmental protection is important, however. Even here, technology can be directed to assist us. For example, the conversion of urban transportation systems from horses to internal combustion engines has eliminated most of the pollution associated with transportation.[13] As incomes rise and populations move away from the edge of survival, people and governments choose to spend more on protecting the environment. Unlike other consumption choices, environmental protection is often "bought" through political choices rather than in the marketplace. Because the benefits of environmental protection flow across property boundaries, there is greater reason for the government to intervene on environmental issues than there is with respect to purely private goods.

SOCIAL INFRASTRUCTURE AND OUTPUT

Our study of growth has identified a number of factors that help explain why some countries become rich while others do not, the accumulation of physical and human capital being primary examples. Two deep questions remain. The first is, Why do some countries have more capital than others? At one level the answer is that countries that save and invest more have more capital. But this answer suggests that we next ask, Why

[11] *World Development Indicators 2002,* CD-ROM, The World Bank.

[12] Actually, people in Neolithic times probably didn't have "rooms" per se. For a more recent benchmark, the energy efficiency of room lighting has improved by a factor of 20 since 1900. See William D. Nordhaus, "Do Real Output and Real Wage Measures Capture Reality? The History of Lighting Suggests Not," in Robert J. Gordon and Timothy F. Bresnahan (eds.), *The Economics of New Goods* (Chicago: University of Chicago Press, 1997), pp. 29–66.

[13] Think about it for a minute.

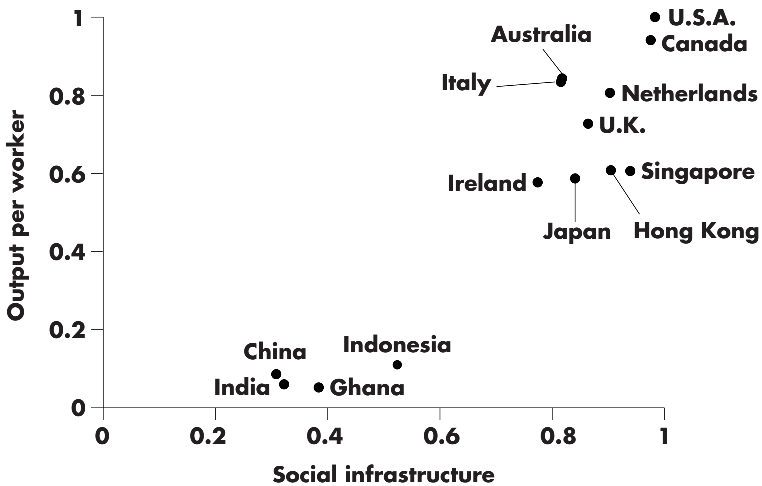

FIGURE 4-4 THE EFFECT OF SOCIAL INFRASTRUCTURE.

do some countries save and invest more than others? We are trying to determine whether, after accounting for identifiable factors of production, we can explain the remaining productivity differences. Table 1 in Box 3-3 shows that such unexplained productivity differences can account for a ratio of 4 or 5 to 1 in output between rich and poor countries. A number of macroeconomists are now investigating differences in *social infrastructure* as a potential answer to both questions.

In the United States or Ireland, you can open a small business and if it succeeds you keep most of the profits (although the government will take some of your gains in the form of taxes). You probably won't need to pay any bribes, the government will usually be able to protect you from being robbed, and the legal system is available to help enforce contracts and resolve disputes. In some other parts of the world, opening a business makes you a target for expropriation by other private parties, and maybe by the government as well. Unsurprisingly, people are more likely to be entrepreneurial and to save and invest in countries where they can reap the benefits.

All the things that go into making individuals and businesses productive—a good legal system, stable taxes, limits on government bureaucracy—are part of social infrastructure. Hall and Jones define social infrastructure as "the institutions and government policies that determine the economic environment."[14] Although social infrastructure is difficult to define precisely and even harder to measure, we use data put together by Hall and Jones in Figure 4-4 to show output per worker plotted against a measure of social infrastructure. The evidence supports the idea that social infrastructure does play an important role in determining output.[15]

[14]Robert E. Hall and Charles I. Jones, "Why Do Some Countries Produce So Much More Output per Worker than Others?" *Quarterly Journal of Economics,* February 1999, pp. 83–116.

[15]For an accessible, indeed delightful, read on this topic, see William Easterly, *The Elusive Quest for Growth: Economists' Adventures and Misadventures in the Tropics,* (Cambridge: MIT Press, 2002).

SUMMARY

1. Economic growth in the most developed countries depends on the rate of technological progress. According to endogenous growth models, technological progress depends on saving, particularly investment directed toward human capital.
2. International comparisons support conditional convergence. Adjusting for differences in saving and population growth rates, developing countries advance toward the income levels of the most industrialized countries.
3. There are extraordinarily different growth experiences in different countries. High saving, low population growth, outward-looking orientation, and a predictable economic environment are all important progrowth factors.

KEY TERMS

absolute convergence
conditional convergence
endogenous growth theory
golden-rule capital stock
increasing returns to scale
social infrastructure
stable equilibrium
unstable equilibrium

PROBLEMS

Conceptual

1. What is endogenous growth? How do endogenous growth models differ from the neoclassical models of growth presented in Chapter 3?
2. Why doesn't the constant marginal product of capital assumed in this chapter's simple model of endogenous growth create a situation in which a single large firm dominates the economy, as traditional microeconomic reasoning would suggest?
3. How do the implications of an increase in saving with regard to both the level and the growth rate of output differ between the neoclassical growth model outlined in Chapter 3 and the basic endogenous growth model outlined in this chapter?
4. *(Optional)*
   - **a.** What sorts of capital investment does this chapter suggest are most useful for explaining long-run equilibrium growth?
   - **b.** Discuss the long-run growth potential of each of the following government programs:
     - **i.** Investment tax credits
     - **ii.** R&D subsidies and grants
     - **iii.** Policies intended to increase saving
     - **iv.** Increased funding for primary education
5. What is the difference between absolute and conditional convergence, as predicted by the neoclassical growth model? Which seems to be occurring, empirically?
6. Can endogenous growth theory help explain international differences in growth rates? If so, how? If not, what can it help explain?
7. Suppose a society can invest in two types of capital—physical and human. How can its choice regarding the distribution of investment affect its long-term growth potential?
8. **a.** Consider once more the neoclassical model with a steady-state level of per capita output. Suppose a society can choose its rate of population growth. How can this choice affect the steady-state per capita output? Could such a policy help the country avoid falling into a poverty trap?

b. Now suppose we have an endogenous growth model. How will a lower population growth rate affect the society's long-term growth potential?

9. What elements of neoclassical and endogenous growth models can help us explain the remarkable growth of the group of countries known as the Asian Tigers?

10. Does growth in per capita output, among both more and less industrialized countries, have the potential to increase indefinitely? Explain.

Technical

(All optional)

1. Consider a two-sector model of growth, with two kinds of investment opportunities—one with a diminishing marginal product and one with a constant marginal product. (*Hint:* See Figure 4-2.)

a. What does the production function for this problem look like?

b. Characterize the set of equilibria for this model. Does output in any of the equilibria have nonzero per capita growth?

c. What can this model help us explain that strict endogenous and neoclassical growth models cannot?

2. Now suppose we have a one-sector model with a variable rate of population growth. (*Hint:* See Figure 4-3.)

a. What does the investment requirement line look like for this model?

b. Characterize the set of equilibria, being sure to discuss their stability or lack thereof. Does output in any of these equilibria have nonzero per capita growth?

c. Suppose your country is in a "poverty trap"—at the equilibrium with the very lowest level of output per person. What could the country do to move toward a point with higher income?

3. **Suppose you add a variable rate of population growth to a two-sector model of growth. (*Hint:* Combine Figures 4-2 and 4-3.)

a. What do the production function, investment requirement line, and saving line look like?

b. Characterize the set of equilibria for this model. Does output in any of the equilibria have nonzero per capita growth?

c. Does the addition of the variable rate of population growth to this model help you explain anything that a simpler two-sector model with a fixed rate of growth, or a one-sector model with variable population growth, cannot?

4. *Consider an economy whose production function is $Y = K^{\theta}(AN)^{1-\theta}$, with $A = 4\,K/N$. Suppose that it has a saving rate of .1, a population growth rate of .02, and an average depreciation rate of .03 and that $\theta = .5$.

a. Reduce the production function to the form $y = ak$. What is a?

b. What are the growth rates of output and capital in this model?

c. Interpret a. What are we really saying when we assume that the labor-augmenting technology, A, is proportional to the level of capital per worker?

d. What makes this an endogenous growth model?

5. Consider an economy in which production is characterized by the neoclassical function $Y = K^{.5}N^{.5}$. Suppose, again, that it has a saving rate of .1, a population growth rate of .02, and an average depreciation rate of .03.

*One asterisk denotes a more difficult problem. Two asterisks means the problem is *really* hard.

a. Write this production function in per capita form, and find the steady-state values of k and y.

b. At the steady-state value of k, is there more or less capital than at the golden-rule level?

c. Determine what saving rate would yield the golden-rule level of capital in this model.

d. In the context of this neoclassical growth model, can a country have *too much* saving?

Empirical

1. The www.economagic.com website gives the possibility of browsing data by source. Under the heading "Bureau of Labor Statistics," choose the link "International Employment and Prices." Scroll down the page, until you get to data for the United Kingdom.

a. Set up an EXCEL file in which you download the following four indicators for the United Kingdom for the period 1950–2001:

Manufacturing Output Index
Manufacturing Average Hours Index
Manufacturing Employment Index
Manufacturing Output per Hour Index

These indexes give us the evolution of output, hours, and employment in the manufacturing sector. For example, if the manufacturing output index decreased from 113.3 in 2000 to 110.7 in 2001, one can conclude that manufacturing output fell by 2.3 percent in 2001 $[(110.7 - 113.3)/113.3 \times 100]$.

b. What happened to manufacturing output, employment, and average hours worked by an employee in the period 1950–2001? What factors could lead to an increase in total manufacturing output, while employment and average hours worked fell considerably?