C H A P T E R 5

Capital Accumulation and Economic Growth

Overview

In this chapter we examine the relationship between increases in the capital stock and economic growth. We first discuss whether an economy can always grow if it increases only its capital stock. Under certain plausible assumptions, we show this is not possible, and that poorer countries should therefore grow faster than wealthy ones, whose economies will depend more on technological progress than capital accumulation. We then discuss why countries with high investment rates also have high standards of living. We show that to have a high standard of living a country must, over the long run, have a high level of savings and investment. We then examine why some countries have such low savings rates and whether governments can alter this. Finally we consider the rapid growth of the Southeast Asian economies and the extent to which they have relied on capital accumulation.

5.1 Introduction: What Is the Capital Stock?

THE LINK BETWEEN CAPITAL AND OUTPUT

As we outlined at the end of Chapter 4, increases in the capital stock are a major factor in explaining growth in industrialized countries over the last 100 years and in accounting for differences in the standard of living among countries. Figure 5.1*a* plots

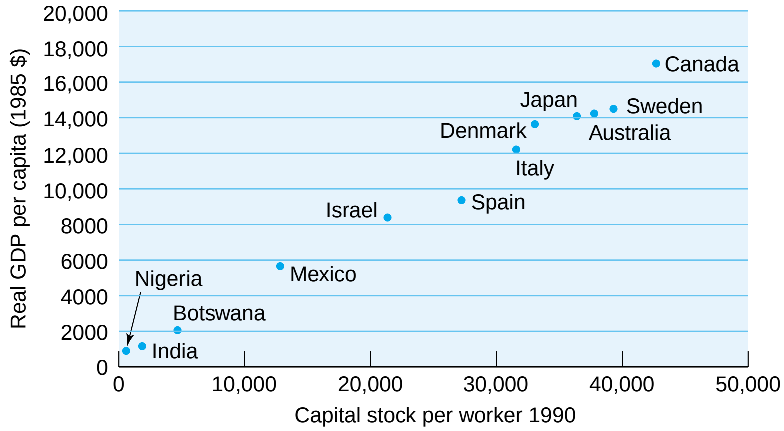

FIGURE 5.1a GDP per capita versus capital stock per worker in 1990. *Source*: Summers and Heston dataset, Penn World Tables 5.5, http:/www.nber.org

per capita real gross domestic product (GDP) and the per capita capital stock for a group of industrialized and developing countries. Figure 5.1*b* focuses on the growth in GDP and the growth in the capital stock between 1965 and 1990 for the same group of countries. Countries that have had large increases in their capital stock have also seen large increases in their GDP. For instance, Botswana during this period has seen a near 20-fold increase in its capital stock, and largely as a consequence, its GDP per capita has more than quadrupled. This represents both the largest increase in capital and the largest increase in GDP per capita of all of these countries. Similarly Japan had both the second highest proportional increase in its capital stock and the second highest percentage increase in GDP. Evidently capital accumulation matters greatly for both a country's standard of living and its rate of growth.

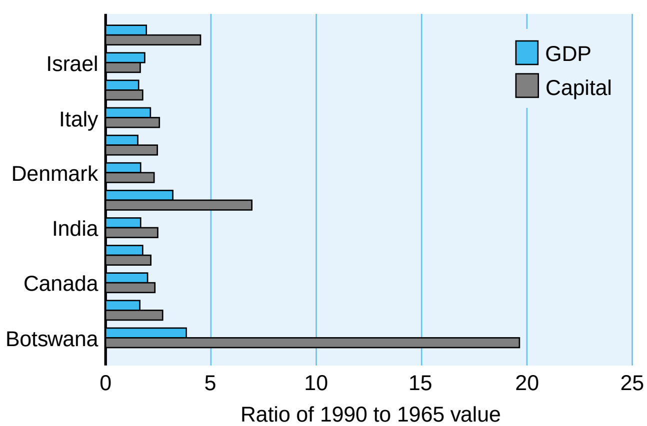

FIGURE 5.1b Capital growth and GDP growth 1965–90. Countries that have accumulated substantial stocks of productive capital have reached higher standards of living. *Source*: Summers and Heston, Penn World Table 5.5, http:/www.nber.org

TABLE 5.1 Average Length of Life of Physical Capital

	USA	UK	Germany	France	Japan
Equipment	15	23	14	15	10
Structures	40	66	57	34	42

Source: O'Mahoney, "Measures Of Fixed Capital Stocks in the Post-War Period: A Five Country Study," in van Ark and Crafts (eds.), *Quantitative Aspects of Post-War European Economic Growth* (Cambridge: Cambridge University Press, 1996).

WHAT IS CAPITAL?

Before considering how capital accumulation boosts output, we have to be more precise about what we mean by capital. Broadly speaking, there are two categories of capital: machines and buildings (sometimes also called equipment and structures, respectively). Production requires both types of capital—car firms could not operate without a site that protected machines and workers from the elements, and even service sector firms need machinery (telephones, computers, etc.) to produce their output.

Capital is long lasting—it provides a flow of services over several time periods, often lasting decades. A firm invests in more capital to produce more output in the future, not just today. By contrast, when a firm hires a worker or uses raw materials in the production process, the services provided are instantaneous. Table 5.1 indicates how long lasting equipment and buildings are for five industrialized nations. For instance, in the United States a new machine can be expected to boost production for 15 years, while a building provides 40 years of productive services. This durability is an essential element of capital.

Our interest is in the ability of the capital stock to boost output. Therefore we *exclude* from our measures of the capital stock factors that do not boost GDP. We also exclude most of the capital stock of the household sector, which consists of a vast array of consumer durables found in households, such as refrigerators, microwaves, and televi-

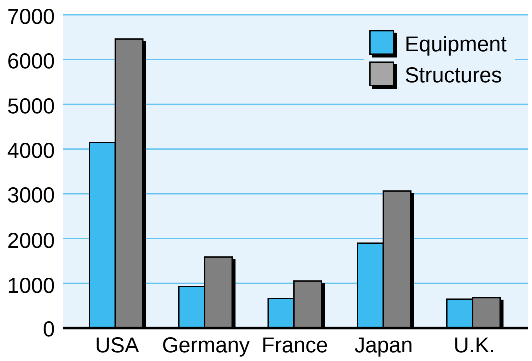

FIGURE 5.2 Relative importance of structures and equipment in capital stock. Buildings and structures have been somewhat more important than equipment in the overall capital stocks of developed countries. *Source*: O'Mahoney, "Measures of Fixed Capital Stocks in the Post-War Period: A Five Country Study" in van Ark and Crafts (eds.), *Quantitative Aspects of Post-War European Economic Growth* (Cambridge: Cambridge University Press, 1996).

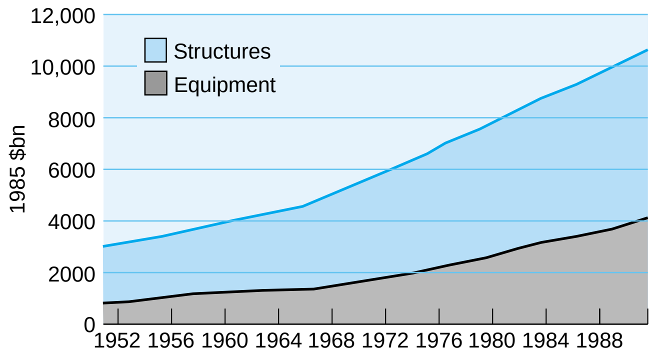

FIGURE 5.3 U.S. capital stock 1948–89. In the period since the Second World War, U.S. stocks of equipment and of buildings and other structures have grown broadly in line. *Source*: O'Mahoney. "Measures Of Fixed Capital Stocks In The Post-War Period: A Five Country Study," in van Ark and Crafts (eds.), *Quantative Aspects of Post-War European Economic Growth* (Cambridge: Cambridge University Press, 1996).

sions. These commodities should last (hopefully!) for years and provide a flow of services, but these services are not recorded in GDP.[1]

We should therefore think of our measure of the capital stock as the machines and buildings used in the production of GDP. This raises the issue of which form of capital—machines or buildings—is more important. Figure 5.2 shows that for industrialized nations buildings account for around 60% of the capital stock. Figure 5.3 illustrates (for the United States) that the trend in both forms of capital is the same. Economic growth comes about through increases in *both* equipment and structures.

HOW LARGE IS THE CAPITAL STOCK?

The other important fact to note about the capital stock is its size relative to the economy. Table 5.2 shows the ratio of the capital stock to GDP for a range of industrial countries. The capital stock is generally between two and three times the size of GDP (it would be much larger if we included the residential housing stock). We would expect this given the

TABLE 5.2 Capital Stock Divided by GDP, 1992

	USA	France	Germany	Netherlands	UK	Japan
Machinery and Equipment	0.86	0.74	0.70	0.78	0.65	1.07
Nonresidential Structures	1.57	1.52	1.63	1.53	1.17	1.95
Total	2.43	2.26	2.33	2.31	1.82	3.02

Source: Table 2.1 Maddison, *Monitoring the World Economy: 1820–1992* (Paris: OECD, 1995).

[1]GDP does include the rental services of residential property. However, our focus is on the production process, so unless we state otherwise, our capital stock measures will also exclude the residential housing stock.

durability of capital. Annual GDP measures the flow of output produced from the stock of capital over a given year. But capital is long lasting so that the flow (GDP) is small relative to the stock (capital), and hence the capital–output ratio is substantially greater than 1.

5.2 Capital Accumulation and Output Growth

HOW MUCH EXTRA OUTPUT DOES A NEW MACHINE PRODUCE?

We now discuss how increases in the capital stock lead to increases in output, our first step in constructing a model of economic growth. First we consider a purely technological question about the production function, namely, *what happens to output when a country increases its capital stock*? The answer will strongly affect how we view the process of economic growth.

As we discussed in Chapter 4, this technological question is about the marginal product of capital—how does output increase when a country increases its capital stock? Remember that the marginal product of capital is about what happens to output when *only* the capital stock changes: in other words, when a country invests in capital but leaves unchanged the amount of labor employed and the technology in use. Note that we are not taking any account of whether there will be demand for the additional output created—our sole concern is the technological relationship between increased capital input and increased output.

The key question is how the marginal product of capital varies. In particular, how does the extra output that *another* unit of capital produces compare with the output that the last unit of capital installed produced? Consider the case of a firm that publishes textbooks and has four printing presses. The introduction of the fourth printing press enabled the firm to increase its production by 500 books per week. Will a fifth machine increase production by more than 500 books, by less than 500 books, or just 500 more books? If the fifth machine leads to an increase in production of more than 500 books (the increase the fourth machine generated), then we have an *increasing marginal product of capital*. If the increased production is less than 500 books, then we have a *decreasing marginal product*, and if the increase equals 500, then we have a *constant marginal product*.

Answering this question is about technology, not economics. It is a question about what the world is actually like, and we can answer by observing what happens in particular firms or industries. Marginal product may be increasing in some industries and decreasing in others. Over some range of capital, an industry may face an increasing marginal product, but beyond a certain stage of development, the marginal product may begin to fall.

DECREASING MARGINAL PRODUCT, OR IT DOESN'T GET ANY EASIER

In this chapter we shall assume that the marginal product of capital is decreasing for the aggregate economy and discuss what this implies for economic growth. In Chapter 7 we consider alternative assumptions and the empirical evidence for them.

Why might the marginal product of capital be decreasing? Consider again the publishing company and assume that it has 10 employees, each working a fixed shift. With four machines, there are already two and a half employees per machine. But as we increase the number of machines but hold fixed the technology and hours worked, we are going to encounter problems. There will be fewer and fewer operator hours to monitor the machines, so each machine will probably be less productive. Even if each new machine produces extra output, that the boost in output will probably not be as high as from the previous machine. Note the importance of assuming that labor input and technology remain unchanged.

Obviously not all technologies will be characterized by decreasing marginal product. Consider the case of a telephone. When a country has only one telephone, the marginal product of that investment is zero—there is no one to telephone! Investment in a second telephone has a positive boost to output; there is now one channel of communication. Investment in a third telephone substantially increases communications—there are now three communication links, and so the investment increases the marginal product of capital. Adding more and more telephones increases even further the number of potential communication links.[2] Telephones are an example of a technology that benefits from network effects, as is the case with information technology generally (see Chapter 6). Network effects operate when the benefits of being part of a network increase with the number of people using the network. Therefore not all technologies have to have decreasing marginal product.

Figure 5.4 shows the case of diminishing marginal product of capital. At point A the country has little capital, so new investment leads to a big boost in output. At point B the capital stock is so large that each new machine generates little extra output. Note that we have assumed that new machines always increase output—albeit by small amounts—when the capital stock is high.

Figure 5.4*a* shows how the capital stock is related to increases in output (the marginal product of capital), but we can also use this relationship to draw a production function summarizing how the stock of capital is linked to the *level* of output. This is shown in Figure 5.4*b*. At low levels of capital, the marginal product is high, so that small increases in the capital stock lead to a big jump in output, and the production function is steeply sloped. Thus point A in Figure 5.4*b* corresponds to the same point in Figure

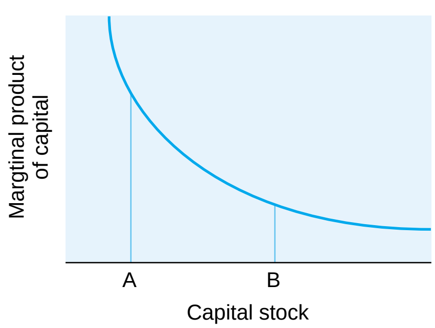

FIGURE 5.4a Marginal product of capital.

[2]If the number of telephone lines is n, then addition of a new line creates n new potential connections.

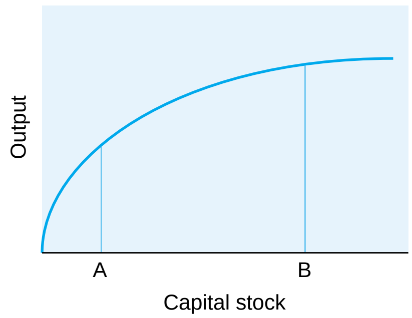

FIGURE 5.4b The production function. A concave production function implies a declining marginal product of capital.

5.4*a*. However, at high levels of capital (such as point B), each new machine generates only a small increase in output, so that the production function starts to flatten out—output changes little in this range even for large changes in the capital stock. Figure 5.4*b* will feature prominently in the rest of this chapter as we discuss how much a country can grow through capital accumulation.

5.3 Capital Stock and Interest Rates

CHOOSING THE CAPITAL STOCK

The marginal product of capital is crucial for determining how much capital a firm or a country should accumulate.[3] The extra revenue a new machine contributes is the price at which output is sold (p) multiplied by the marginal product of capital (MPK). If this amount is greater than the cost of a new machine (which we shall denote r) then it is profitable for a firm to install the machinery. So if MPK$>r/p$ it is profitable to add to the capital stock. Therefore in Figure 5.5 at A, the marginal product of capital is higher

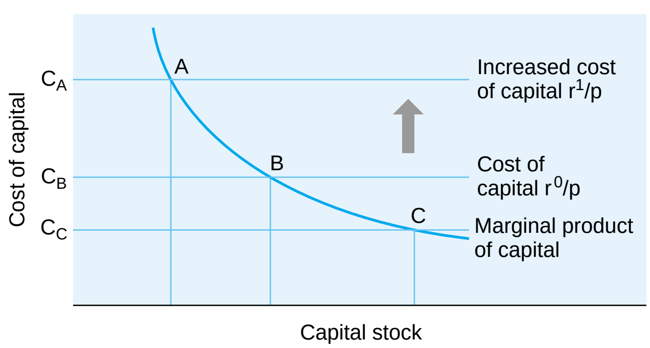

FIGURE 5.5 Investment and the cost of capital. Increases in the cost of capital reduce the optimal capital stock.

[3]Note once again that what we mean by investment here are increases in the capital stock rather than the more common usage in newspapers where investment refers to the purchase of financial assets.

than the cost of an additional machine (given by the horizontal line r^0/p), so the firm increases its capital stock until it reaches B, where the last machine contributes just as much to revenues as it does to cost. By contrast, at C each new machine loses money, so the capital stock should be reduced.

This discussion raises the issue of what determines the cost of capital. For the moment we shall consider just one element: the interest rate.[4] We can think of the cost of the machine as the interest rate (r) that would need to be paid on a loan used to buy it. If we assume that it costs 1 to buy a unit of capital (so we measure everything in terms of the price of a machine) then the interest cost is just r. An alternative way of seeing the point is to note that rather than purchase a new machine, a firm could invest the funds in a bank account and earn interest. Therefore to be profitable, the investment project must produce at least the rate of interest. If the marginal product of capital is above the interest rate, then firms will continue to invest in more machines until, because of decreasing marginal product, there is no additional advantage from doing so—the marginal product equals the interest rate. As the interest rate changes, so does the desired level of capital—if the interest rate increases, then the cost of capital shifts to r^1/p (as in Figure 5.6) and the firm desires less capital, while if the interest rate falls, investment demands will be high. Therefore the relationship between investment and the interest rate is negative, as shown in Figure 5.6.

DETERMINING INTEREST RATES

However, while a firm may wish to increase its capital stock, given the level of interest rates, it has to finance this increase. Either the firm has to use its own savings or borrow those of other economic agents. We assume that as interest rates increase, so does the level of savings. In other words, as banks or financial markets offer higher rates of return on savings, individuals and firms respond by spending less and saving more. Therefore the relationship between savings and the interest rate is positive. Figure 5.6 shows this relationships among savings, investment, and the interest rate.

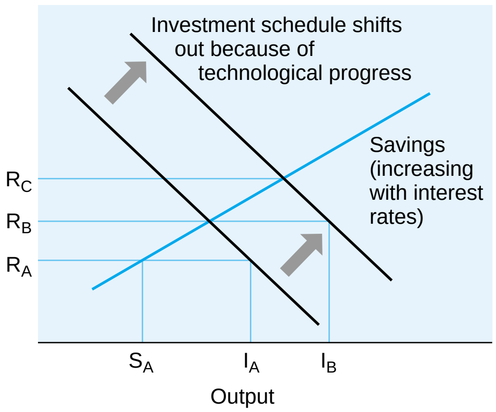

FIGURE 5.6 **Investment, savings, and interest rates.** Technical progress increases investment and may also drive rates of return (interest rates) up.

[4]Chapter 14 considers in far more detail the investment decision and shows that the cost of capital must also include allowance for depreciation, changes in the price of capital goods, and taxes.

Consider the case where the interest rate is R_A. At this level interest rates are so low that savers are not prepared to save much, and savings are at S_A. However, low interest rates make capital investment attractive as the marginal product of capital is higher than the interest rate. As a result, firms are keen to borrow and desire investment I_A. There are not enough savings to finance this desired level of investment, which frustrates some firms' investment plans. Because of the gap between the marginal product of capital and the interest rate, firms are prepared to pay a higher interest rate to raise funds for investment. This puts upward pressure on interest rates, which in turn leads to increases in savings, which can be used to finance the desired investment. This additional savings will in turn help alleviate the imbalance between savings and investment. This process will continue—with interest rates increasing—until savings equal investment at the interest rate R_B. At this point firms will not be demanding more loan finance because the interest rate is such that additional investment is not profitable. At this point the cost of capital just matches the value of the extra output produced; with decreasing MPK any extra investment will generate a lower value of extra output than the extra cost involved.

5.4 Why Poor Countries Catch Up with the Rich

We return now to our discussion of the marginal product of capital. From the technological assumption of a decreasing marginal product of capital, we can derive strong implications about economic growth. Consider two economies that have similar levels of unemployment and access to similar technologies. This means that we can think of both economies as sharing the same marginal product curve of Figure 5.4*a* or equivalently the same production function as in Figure 5.4*b*. However, one economy has a much higher capital stock. Figure 5.7 shows these two economies as being at K_A and K_B. Diminishing marginal product implies that the economy at K_A will find it easier to grow through investment than the economy at K_B. Assume both countries increase their capital stock by the same amount. The low capital stock country increases capital from K_A to K_B while the wealthier economy moves from K_B to K_C. The result is that output in

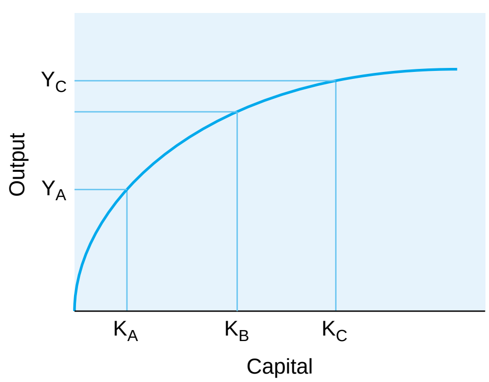

FIGURE 5.7 Poor countries grow faster than wealthier countries. A given increase in the capital stock generates more extra output for a country with relatively low capital.

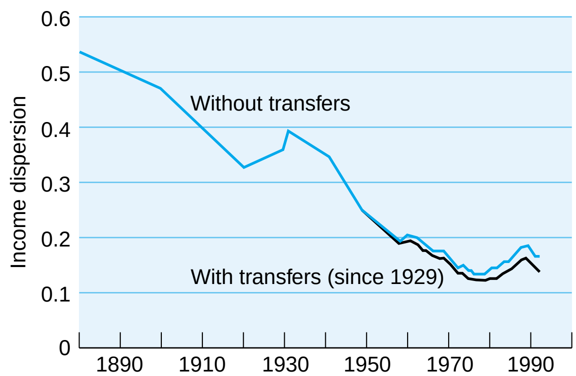

FIGURE 5.8 Income dispersion across U.S. states. Income inequality between states in the Untied States has declined greatly since the end of the nineteenth century. *Source*: Baro and Sala-I-Martin, *Economic Growth* (New York: McGraw Hill, 1995). (Transfers are government transfers of income.)

the low capital country rises from Y_A to Y_B and in the richer economy from Y_B to Y_C. Therefore, the *same* investment will bring forth a *bigger* increase in output in the poorer economy than the richer one. In other words, because of decreasing marginal product, growth from capital accumulation becomes more and more difficult the higher the capital stock of a country becomes. This "catch-up" result implies a process of convergence among countries and regions—for the same investment poorer countries will grow faster than wealthier ones, so wealth inequalities across countries should decrease over time.

Figure 5.8, which displays the dispersion (as measured by the standard deviation) of income per head across U.S. states, shows some evidence for this. Since 1900 the inequalities of income across states have been dramatically reduced as poorer states, such as Maine and Arkansas, have grown faster than wealthier ones, such as Massachusetts and New York. This is entirely consistent with the assumption of decreasing marginal product and its implication of catch up.

Comparing income across U.S. states is a good test of the theoretical predictions of catch-up because our analysis depends on countries or regions sharing the same production function (i.e., similar unemployment rates and access to similar technology). This is likely to be the case comparing across U.S. states. But finding other examples of countries that satisfy these conditions is not easy—low capital countries like India or Botswana also tend to have access to lower levels of technology than countries such as Japan or Australia. However, the circumstances of war and subsequent economic recovery offer some further support for assuming decreasing marginal product. Figure 5.9 shows that between 1945 and 1946, just after World War II, West German capital stock and output both fell. However, between 1947 and 1952, the German economy grew far more rapidly than over the previous decade. It achieved this rapid growth with only small increases in the capital stock—the ratio of output growth to capital growth during this period was extremely high. In other words, small levels of investment produced high levels of output growth compared to the years before 1945—exactly what decreasing marginal product would predict. The large drop in the capital stock between 1944 and 1947, the result of Germany's losing the war, meant that investment in 1947 would benefit from a much higher marginal product of capital compared to 1943. Table 5.3 shows a similarly sharp bounce back in output after WWII for other European nations.

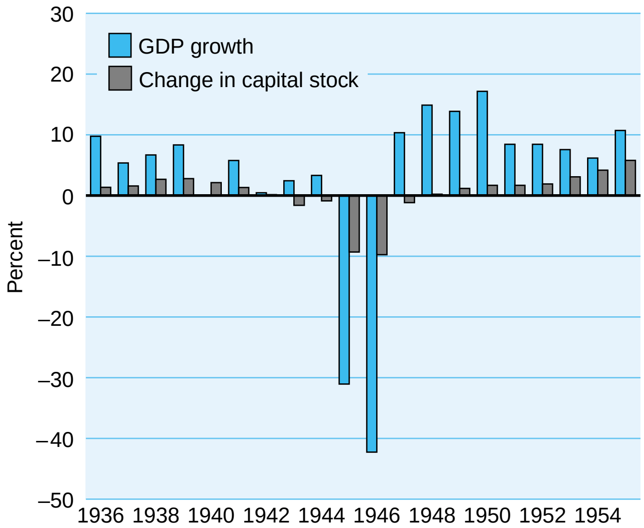

FIGURE 5.9 West German GDP and capital growth 1936–55. West German GDP grew rapidly in the 1950s as the capital stock was rebuilt after the war. *Source*: Stock from Maddison, "Macroeconomics Accounts for European Countries," in van Ark and Crafts (eds.), *Quantitative Aspects of Post-War European Economic Growth* (Cambridge: Cambridge University Press: 1996).

As a consequence of the war, European output declined: by the end of the war, GDP and the capital stock had fallen to the level they had been at several decades earlier. However, within a few years these countries had regained the lost output as the depressed level of capital meant that investment benefited from high marginal product of capital.

TABLE 5.3 Post-War Reconstruction in Europe

	Pre-War Year GDP Same as 1945	Year Reached Pre-War High
Austria	1886	1951
Belgium	1924	1948
Denmark	1936	1946
Finland	1938	1945
France	1891	1949
Germany	1908	1951
Italy	1909	1950
Netherlands	1912	1947
Norway	1937	1946

Source: Crafts and Toniolo, "Postwar Growth: An Overview," in Crafts and Toniolo (eds.), *Economic Growth in Europe Since 1945*, (Cambridge: Cambridge University Press, 1996).

5.5 Growing Importance of Total Factor Productivity

The previous section showed that due to diminishing marginal product of capital, wealthier countries find it hard to maintain fast growth through capital accumulation *alone*. In this section we show a further implication of diminishing marginal product—total factor productivity (TFP) is more important for wealthier economies than poorer ones.

To see the intuition behind this result, imagine two publishing firms each with 10 employees. One firm has three printing presses, while the other has ten. Consider the impact one more machine will have for each firm compared to the introduction of new software that improves the productivity of all machines. For the firm with only three machines, the technological progress (the new software) will have only a limited effect—with only three machines, the software will not improve productivity a lot. However, this firm gains significantly from the introduction of a new machine because its capital stock is so low that its marginal product of capital is high. By contrast, the other firm already has as many machines as employees, so it will benefit very little from an additional printing press. However, with ten machines to operate, the technological progress will have a more substantial impact. Therefore we can expect capital accumulation to be more important for growth relative to TFP for poorer nations, whereas for capital rich countries we expect the opposite. This is exactly what we saw in Figure 4.12 in Chapter 4 for the more mature industrialized nations and emerging markets.

To show this argument graphically, consider the production function in Figure 5.10. In Year 0 the production function is the solid line, but because of technological progress, the production function shifts up—for a given level of capital, the improved technology increases output. Now consider two economies—A and B—both of which increase their capital stock by the same amount. For country A the capital stock has risen from K_0^A to K_1^A. Without technological progress, the increase in output would have been Y_0^A to Y_*^A However, because of technological developments more output can be

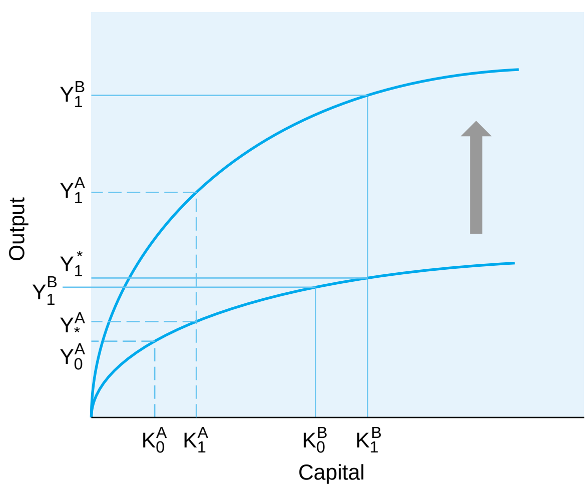

FIGURE 5.10 The impact of technological progress and economic maturity. Technological progress is more valuable the greater is the capital stock.

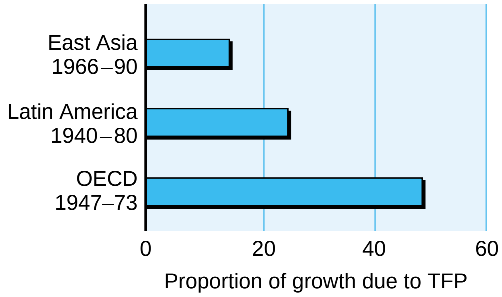

FIGURE 5.11 Importance of TFP in growth.
Source: Crafts, "Productivity Growth Reconsidered" *Economic Policy* (1992) vol. 15, pp. 388–426.

produced for any given level of capital, so that with a capital stock K_1^A country A can produce Y_1^A in Year 1.

In Figure 5.10 we see that output has increased by a total of $Y_1^A - Y_0^A$, of which $(Y_*^A - Y_0^A)$ is due to the addition of extra capital and $(Y_1^A - Y_*^A)$ to technological progress. We can use the same argument for country B and show that capital accumulation (without technological progress) leads to an increase in output of $(Y_*^B - Y_0^B)$, whereas at this new higher level of capital (K_1^B), the improved technology increases output $(Y_1^B - Y_*^B)$. As the diagram shows, the proportion of growth that TFP explains is higher in country B than country A—technological progress has a bigger impact for capital rich countries. This implies that wealthier economies, such as those belonging to the OECD, will have a much greater dependence on TFP for producing economic growth than less developed nations. By contrast, emerging economies will be more reliant on capital accumulation than they will on TFP, a conjecture that Figure 5.11 supports. For the periods considered in the figures, we suggest that the OECD countries were high capital stock countries, the Asian economies low capital stock countries, and Latin American economies in the middle. Clearly TFP has been much more important for growth among the more developed nations.

5.6 The End of Growth through Capital Accumulation

THE STEADY STATE—A POINT OF REST

We have just shown how the relative importance of capital accumulation declines as the capital stock increases. In this section we go further and show how countries *always* reach a point where they cannot grow any more from capital accumulation alone. Crucial to this section is the notion of a "steady state":

A **steady state** is a point where capital accumulation alone will not increase output any further.

As this definition makes clear the steady state is the point at which the economy ceases to grow because of capital accumulations alone.[5] The steady state is a point of rest for the capital stock—efforts to raise or lower the capital stock are futile, and it will always return to this equilibrium level. Why is this so?

INVESTMENT AND DEPRECIATION

Two factors cause the capital stock to change over time. The first is that firms invest in new machinery and structures, so that the capital stock is increasing. But another factor, “depreciation,” reduces the capital stock. Whenever they are used machines are subject to wear and tear and breakdown. This means that over time machines become less effective in production unless they are repaired or maintained. Economists call this process of deterioration *depreciation*—the reduction over time in the productive capabilities of capital. Note that economists use the term “depreciation” in a different sense than accountants do. In accounting, “depreciation” refers to the writing down of the book value of an asset, which may bear little relation to the physical ability of a machine to produce output.

Because of depreciation, we need to distinguish between different measures of investment. In Chapter 2 we discussed investment as a part of the national accounts of a country. This is often called *gross fixed capital formation*, where gross means that no allowance is made for the loss of capital through depreciation. Gross investment is the amount of new capital being added to an economy and includes both the repair and replacement of the existing capital stock as well as new additions to it. Net investment is equal to gross investment less depreciation and represents the increase in the net capital stock—in other words, it deducts repairs and replacements from the new capital stock being added to an economy. Net investment is therefore equivalent to the increase in the capital stock from one year to another. Figure 5.12 shows, for a sample of developed economies, gross investment and depreciation as a percentage of GDP and suggests that net investment is about 5–10% of GDP.

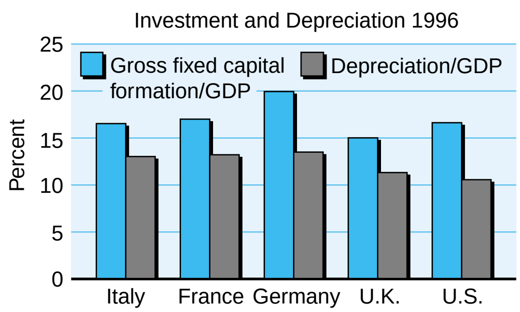

FIGURE 5.12 Investment and depreciation in selected OECD countries. Gross investment is substantially higher than net investment for developed countries because their stocks of capital are high. *Source*: OECD Main Economic Indicators.

[5] Although, as we shall see in Chapter 6, technological progress will provide incentives for further capital accumulation. This section shows that without technological progress the capital stock does not change.

Allowing for gross investment and depreciation, the capital stock evolves over time as

$$K(t) = K(t-1) + I(t) - D(t)$$

where $K(t)$ is the capital stock at time t, $I(t)$ is gross investment, and $D(t)$ is depreciation: $I(t) - D(t)$ is net investment. The steady state is the point where the capital stock does not change, so that $K(t) = K(t-1)$, which can only occur when $I(t) = D(t)$ or where gross investment equals depreciation. The country purchases just enough machinery each period to make good depreciation.

CONVERGENCE

So far our analysis has been based on only a technological assumption about the marginal product of capital. But to complete our model of growth, we need to make some economic assumptions. The first concerns gross investment, which we assume equals a fixed proportion of output, e.g., $I(t) = bY(t)$, where $Y(t)$ is current GDP. How much of GDP is invested varies across countries, but for simplicity we assume that 20% of output is invested, i.e., $b = 0.2$. In Figure 5.13 we show the production function of the economy and the investment function this implies. Because investment equals 20% of output, the investment line is just a scaled-down version of the production function. The other assumption we make concerns depreciation. We assume this occurs at a rate of 5% per year—in other words, each period around 5% of the capital stock is retired or needs to be repaired. Therefore $D(t) = \delta K(t)$, where $\delta = 0.05$. Note that while investment is a proportion of output and thus is related to the production function, depreciation is linked to the capital stock. Figure 5.13 shows depreciation as a straight line—if you double the capital stock, you double depreciation.

Consider point A in Figure 5.13. At this level of capital stock, I_A—20% of the output produced—gives the amount of investment that can be financed. At this level of capital, depreciation is only D_A, so that gross investment exceeds depreciation, net investment is positive, and the capital stock is increasing. As the capital stock increases, the gap between investment and depreciation narrows. Decreasing marginal

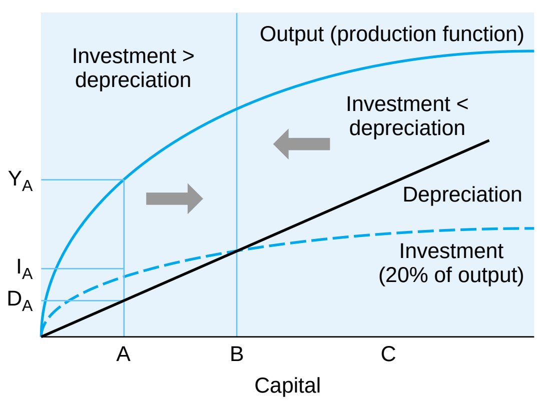

FIGURE 5.13 The steady state. If the stock of capital is below B, net investment is positive and the capital stock is growing. If the capital stock is above B, depreciation exceeds gross investment and the capital stock declines.

product implies that each new machine leads to a smaller boost in output than the previous one. Because investment is a constant proportion of output, this means each new machine produces ever smaller amounts of new investment. However, depreciation is at a constant rate—each new machine adds 5% of its own value to the depreciation bill. Therefore the gap between investment and depreciation narrows. At point B the depreciation and investment lines intersect. This defines the steady state capital stock where gross investment equals depreciation. At this point the last machine adds just enough extra output to provide enough investment to make good the extra depreciation it brings. At this point the capital stock is neither rising nor falling but stays constant.

Imagine instead that the economy starts with a capital stock of C. At this point depreciation is above investment, net investment is negative, and the capital stock is declining. The country has so much capital that the marginal product of capital is low. As a consequence, each machine cannot produce enough output to provide the investment to cover its own depreciation, and so the capital stock moves back to the steady state at B.

Therefore when the capital stock is below its steady state level, it is increasing, and if it is above the steady state level, then capital declines. In other words, *growth in the capital stock* is declining with the size of the capital stock, as Figure 5.14 shows.

Growth in the capital stock slows down purely because of the decreasing marginal product of capital. The change in the capital stock is simply net investment, which under our assumptions equals $bY(t) - \delta K(t)$. Every unit change in the capital stock increases output by MPK, investment by $b \times$ MPK, and depreciation by δ. Therefore net investment changes by $b \times$ MPK $- \delta$. Under the assumption of decreasing marginal product, this expression gets smaller as the capital stock increases. Therefore diminishing marginal product implies that countries play economic catch-up—countries that start richer than others will grow more slowly because of decreasing marginal product.

You can see evidence supporting this catch-up phenomenon in Figure 5.15 which shows real GDP per capita between 1870 and 1999 for four major European countries. In 1870 the UK was substantially wealthier than other European nations. Its GDP per capita was 71% higher than in France, 76% higher than in Germany, and 122% higher than in Italy. However, by 1999 these large gaps in the standard of living had been substantially reduced: the gap between the richest and poorest countries was only 13%, relatively small by historical comparison.

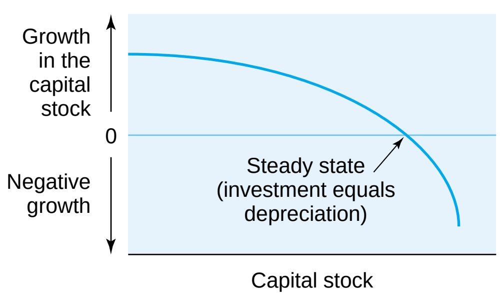

FIGURE 5.14 **Capital growth declines with capital stock.** With a constant rate of investment and of depreciation the growth of the capital stock declines the more capital is in place.

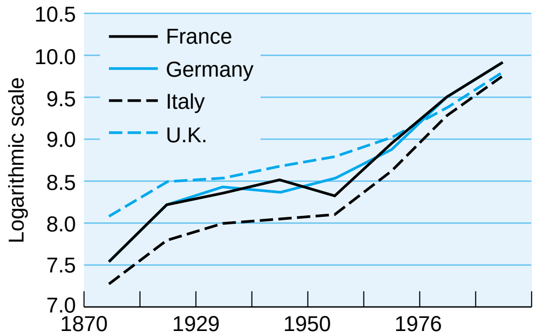

FIGURE 5.15 **Convergence in GDP per capita in Europe.** Levels of output in the major four European industrial countries have converged since the end of the nineteenth century. *Source*: Maddison, *Monitoring the World Economy, 1820–1992* (Paris: OECD, 1995). Updated to 1999 from 1994 by author using IMF data.

5.7 Why Bother Saving?

INVESTMENT AND THE STANDARD OF LIVING

Because the steady state is the point at which there is no growth through capital accumulation, growth at the steady state must be due either to increases in labor input or to improvements in TFP. Assuming that countries cannot continually reduce their unemployment rate, and that all countries eventually have access to the same technology, this implies that at the steady state countries will all grow at the same rate. In particular whether one country is investing more than another does not matter—*at the steady state, capital accumulation does not influence the growth rate*. Why then should countries encourage high levels of investment if such investment makes no difference to the long run growth rate?

The answer to this question is simple. While the amount of investment makes no difference to the *growth* of the economy, it strongly influences the *level* of capital in steady state. In other words, while the growth of output in the steady state does not depend on investment, the level of output does. **The more investment a country does, the higher its steady state standard of living.**

To see this, imagine two countries, one of which invests 20% of its output and the other which invests 30%, as in Figure 5.16. Otherwise both countries are identical—they have access to the same production function, have the same population and the same depreciation rate. For both countries their steady state occurs at the point at which investment equals depreciation—K_L for the low investment rate country and K_H for the high investment country. Therefore the level of output in the low investment country is Y_L, substantially below Y_H. Countries with low investment rates will therefore have a lower standard of living (measured by GDP per capita) than countries with high investment rates. Low investment rates can only fund a low level of maintenance, so the steady state occurs at a low capital stock and, via the production function, at a low output level.

However, at the steady state, both countries will be growing at the same rate—the rate at which technological improvements lead to improvements in the production function.

Therefore, while long-term growth rates are independent of the investment rate, the *level* of GDP per capita is definitely related to the amount of investment. High investment countries are wealthier than low investment countries, as Figure 5.17 shows.

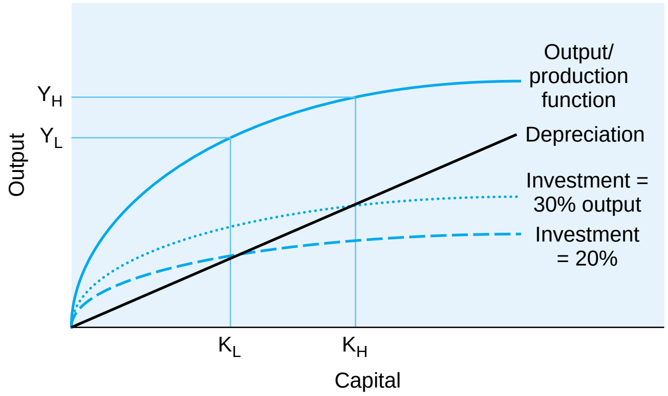

FIGURE 5.16 Steady state depends on investment rate. The higher is the rate of investment the greater is the steady state capital stock.

We can also show the dependence of the standard of living on the investment rate algebraically. At the steady state, gross investment equals depreciation or $bY(t) = \delta K(t)$. Simple rearrangement leads to $K(t)/Y(t) = b/\delta$, so that the higher the investment rate (b) and the lower the depreciation rate (δ), the more capital intensive the economy and, via the production function, the higher the level of output will be. Figure 5.17 shows that the evidence is consistent with this.

THE LONG RUN IS A LONG TIME COMING

As discussed above, decreasing marginal product of capital and the concept of a steady state suggest that in the long run a country's growth rate is independent of its investment. But the experience of Asia (see Figure 5.18) over the last 20 years is hard to square with this—countries with the highest investment rates have had the fastest GDP growth.

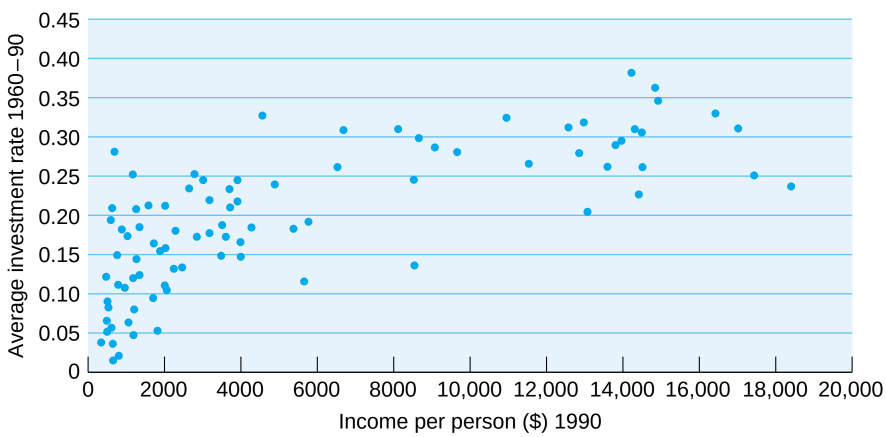

FIGURE 5.17 Output and investment in the world economy. Higher investment countries tend to have higher incomes—each point represents the income level in 1990 of a country mapped against its average investment rate from the previous 30 years. *Source:* Summers and Heston, Penn World Table 5.5, http:/www.nber.org

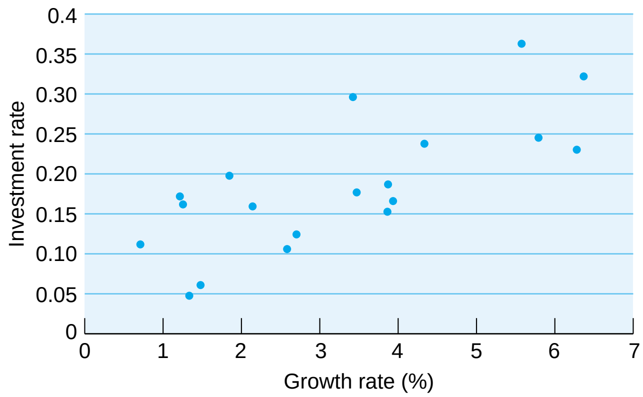

FIGURE 5.18 Growth and investment in 19 Asian countries, 1960–95. In developing Asian countries there has been a positive link between investment and growth. *Source*: Summers and Heston, Penn World Table 5.5, http:/www.nber.org

To reconcile Figure 5.18 with the implications of decreasing marginal product of capital, we must stress that only in the steady state is growth independent of the investment rate. Consider the high and low investment countries of Figure 5.16. At K_L the low investment country has no more scope for growth through capital accumulation—it is already at its steady state. However, also at K_L, the high investment country still has gross investment in excess of depreciation, so its capital stock will continue to rise until it reaches its steady state at K_H. Therefore while the low investment rate country shows zero growth, the high investment rate country shows continual growth *while it is moving towards its steady state*. If the transition from K_L to K_H takes a long time (e.g., more than 25 years), then our model can still explain why investment and growth are strongly correlated, as in Figure 5.17.

Examining our model and using plausible numbers for investment rates and other key economic parameters shows that the movement from K_L to K_H does indeed take a long time. For instance, after 10 years only 40% of the distance between K_L and K_H has been traveled; after 20 years just under two-thirds of the gap has been reduced. Therefore decreasing marginal product of capital can explain sustained correlations between investment rates and economic growth over long periods.

5.8 How Much Should a Country Invest?

The previous section showed that countries with high levels of investment will also have high levels of GDP per capita (other things being equal). Does this mean that countries should seek to maximize their investment rate?

THE GOLDEN RULE AND OPTIMAL LEVEL OF INVESTMENT

The answer to this question is no. Output per head is an imperfect measure of the standard of living. We are really interested in consumption. The trouble with investment is that for a given level of output, the more a country invests the less it can consume. For instance, an economy with an investment rate of 100% would have an enormous level of GDP per capita, but it would only produce investment goods. However, at the opposite extreme, an economy with an investment rate of zero would have high consumption today but low consumption in the future because depreciation would cause its capital stock to continually decline leading to lower levels of future output. The situation is like that in the fishing industry. Overfishing reduces the stock of fish and diminishes the ability of the fish to breed making future catches, and thus also future consumption, of fish low. However, catching no fish at all would lead to a rapid increase in fish stocks but none to eat. Ideally we want to catch enough fish every day to sustain a constant stock of fish but also enable us to consume a lot of fish.

Economists have a similar concept in mind when they consider the ideal rate of investment. This ideal rate is called the "Golden Rule" rate of investment—the investment rate that produces the steady state with the highest level of consumption. We have shown that countries with different levels of investment will have different steady states and thus different levels of consumption. The Golden Rule compares all of these different steady states (e.g., examines different investment rates) and chooses the investment rate that delivers the highest consumption in the steady state.

If for simplicity we ignore the government sector and assume no trade, then consumption must equal output less investment ($C = Y - I$). In the steady state, investment also equals depreciation ($I = \delta K$), so steady state consumption must also equal output less depreciation ($C^{ss} = Y - \delta K$). According to the Golden Rule, the capital stock should be increased so long as steady consumption also rises. Using our expression for steady state consumption, we can see that increases in capital boost consumption as they lead to higher output. Each extra unit of capital boosts output by the marginal product, so that steady state consumption—other things being equal—is increased by MPK. But other things are not equal because the addition of an extra unit of capital also increases depreciation by δ, which tends to lower steady state consumption. Therefore the overall effect on steady state consumption from an increase in capital is

change in steady state consumption from increase in capital = marginal product of capital $- \delta$

For low levels of capital, the MPK exceeds δ and steady state consumption increases with the capital stock and higher investment. But as the capital stock increases, the marginal product of capital declines until eventually $MPK = \delta$. At this point steady state consumption cannot be raised through higher investment. Further increases in the capital stock would decrease MPK to less than δ—steady state consumption would be declining. Therefore the Golden Rule says that to maximize steady state consumption the marginal product of capital should equal the depreciation rate.

What level of investment does the Golden Rule suggest is optimal? To answer this question, we need to make an assumption about the production function. We shall assume, as previously, that output is related to inputs via a Cobb-Douglas production function. In Chapter 4 we stated that this leads to :

$$MPK = aY/K$$

so that the Golden Rule implies that steady state consumption is maximized when

$$MPK = aY/K = \delta$$

TABLE 5.4 Investment as Percentage of GDP, 1965–90

Country	Investment Rate	Country	Investment Rate	Country	Investment Rate
Algeria	23.2	Chile	14.7	Germany	30.9
Cameroon	7.9	Venezuela	19.2	Italy	31.4
Egypt	5.2	India	17.2	Netherlands	27.9
South Africa	21.8	Israel	29.9	Norway	34.9
Canada	25.4	Japan	36.6	Spain	28.2
Mexico	18.3	Singapore	32.6	Sweden	26.4
USA	24	Austria	28.3	UK	20.7
Argentina	14.8	Denmark	29.2	Australia	31.3
Brazil	21.7	France	29.7	New Zealand	26.8

Source: Summers and Heston, Penn World Table 5.5, http:\www.nber.org

However, we also know that in the steady state investment equals depreciation, or using our earlier assumptions

$$\text{I} = b\text{Y} = \delta\text{K} = \text{depreciation}$$

or

$$b\text{Y/K} = \delta$$

Comparing the Golden Rule condition and this steady state definition, we can see they can only both be true when $a = b$. That is, the term that influences the productivity of capital in the production function (a) equals the investment rate (b). When we discussed the Cobb-Douglas production function in Chapter 4, we showed how a was equal to the share of capital income in GDP, which empirically was around 30–35%. Therefore the Golden Rule suggests that the optimal investment rate is 30–35% of GDP.

Table 5.4 shows average investment rates for a wide range of countries. Singapore and Japan stand out as having high investment rates, and Germany fares reasonably well, but the United States and the UK score poorly according to this test.[6] The United States and the United Kingdom are underinvesting relative to the Golden Rule, and if this continues will eventually have a much lower future level of consumption than if they invested more (all other things being equal).

HOW TO BOOST SAVINGS

Because investment rates in most countries are lower than the prescription of the Golden Rule, governments often to try to boost savings and investment. Thus many countries create special tax-favored savings accounts, e.g., in the United States, IRAs

[6]Of course, the financial sector must use savings efficiently and allocate it to high productivity investment projects. We return to this issue in Chapter 20 when we discuss the Asian crisis of 1998.

and 401ks, in the UK, ISAs. The idea is to provide tax incentives for savings, which can then be used to finance a higher investment rate. However, this approach only boosts savings if individuals are responsive to changes in rates of return. Assume investors are taxed at the rate of 25% on their investment income and the interest rate is currently 4% or 3% after tax. If savings become tax exempt, the net interest rate increases from 3% to 4% for taxpayers. However, many empirical studies show that individuals only increase their savings by a small amount in response to such a tax benefit. As a result, these schemes probably only have a modest impact on national savings.

Another approach is to make high levels of savings compulsory—a policy pursued successfully in Singapore where the government has operated a compulsory pension scheme. Both employers and employees have to pay a percentage of the worker's salary into a pension scheme. The pension scheme is in the name of the worker and cannot be used to fund anyone else's pension. The government uses these pension funds to invest in the economy. While many countries operate similar systems, contributions in Singapore have been extremely high. At certain times in the 1980s contributions reached nearly 50% of a worker's gross salary. This has helped support the high levels of investment in Singapore that we examine later in this chapter.

Why don't all countries levy a similar high contribution rate into a compulsory pension scheme? The answer is in part political. The Golden Rule gives the level of investment that would maximize the level of consumption in the steady state. But it takes decades for a country to reach a new steady state. For instance, if the United States were to increase its investment rate by 10%, it would take more than 40 years to move only two-thirds of the way to this higher steady state. Therefore several generations of voters would not benefit from the eventual higher consumption but would suffer from lower consumption during the transition to the new steady state because of the higher investment rate. The generations that suffer would be the current working generation, and those that would benefit are as yet unborn. This creates a problem at election times.

The problem is that different groups experience the costs and benefits of higher investment. But even if we assume that all individuals receive the future benefits of higher consumption, we might still not abide by the simple Golden Rule. Because of discounting, individuals prefer current consumption to future consumption. Therefore if consumers discount the benefits they will get from future consumption at a sufficiently high rate, the eventual outcome of higher consumption may not compensate them for the displeasure they incur during the transitional period of high investment and low consumption.

ARE ECONOMIES EFFICIENT?

The Golden Rule suggests that an economy can have too much capital—the investment rate can be so high that maintaining the capital stock becomes a drain on consumption. A simple test determines whether economies are efficient, e.g., whether they have too much capital.[7] If an economy is capital efficient, the operating profits of the corporate sector should be large enough to cover investment. If they are, then the corporate sector has

[7]This test is explained in detail in "Assessing Dynamic Efficiency" by Abel, Mankiw, Summers, and Zeckhauser, *Review of Economic Studies*, (1989), vol. 56, pp. 1–20.

TABLE 5.5 Contribution of Capital Sector to Consumption

Year	USA	UK	South Korea	Germany	France
1984	8.8	5.3	14.6		5.3
1985	7.6	6	15.2		5.6
1986	7.1	5.4	16		8.1
1987	8.3	5.8	13.8		7.9
1988	8.6	5.5	12.9		7.8
1989	9	3.9	9.3		8.1
1990	8.3	2.5	3.6		7.5
1991	8.3	2.9	2.9	4.1	6.6
1992	8.3	6	2.8	3.2	6.8
1993	8.8	9	3.2	4.1	6.6
1994	10	10.7	4	6.9	9.2
1995	9.7	10.2	2.5	8.3	9.4
1996	9.9	10.3	0.6	9.6	9

Source: OECD *National Accounts Volume II 1998*.

Cashflow less investment (less depreciation less residential investment) expressed as a percentage of GDP.

been a provider of funds for consumption. But if investment exceeds profits, then the capital stock has been financed at the expense of consumption. Table 5.5 shows, for a sample of OECD countries, the value of profits less investment relative to GDP. In every case the number is positive, suggesting that these countries' stock of capital is not too high. However, the South Korean numbers are particularly interesting. By the end of the sample period, the South Korean capital stock was close to becoming a drain on the corporate sector—a point we shall return to when we consider the Asian crisis in Chapter 20.

5.9 The Asian Miracle—A Case Study in Capital Accumulation?

RAPID SOUTH ASIAN GROWTH

This chapter has focused only on the contribution capital accumulation makes to economic growth. It is useful to see how much this framework helps explain the dramatic economic growth in Southeast Asia since 1960. Figure 5.19 shows average GDP growth

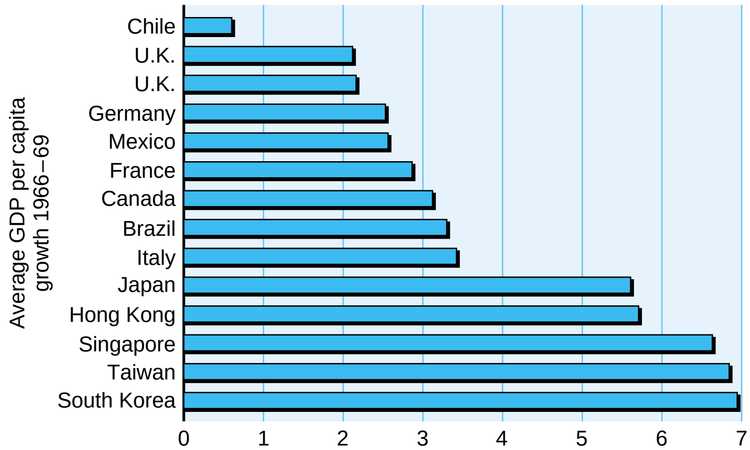

FIGURE 5.19 Growth in GDP per capita, 1966–90. The growth record of the Asian Tigers in the 25 years from the mid 1960s was exceptional. *Source*: Summers and Heston, Penn World Table 5.5, http:/www.nber.org

rate between 1966 and 1990 for a selection of countries. The performance of the Asian Tigers over this period—Japan, Hong Kong, Singapore, Taiwan, and South Korea—was exceptional, with average growth rates in excess of 6% per annum.

Such rapid increases in GDP have transformed the standard of living in these economies. Table 5.6 lists real GDP per capita for a variety of OECD and Asian economies. In 1950 the wealthiest Asian country was Singapore, which was ranked seventeenth amongst our sample—slightly richer than the poorest European nation, Greece. Between 1950 and 1976, the European nations approximately doubled their level of GDP per capita, but the Asian economies performed substantially better. The most impressive growth occurred during 1973–1996. When the level of GDP per capita rose almost fourfold in Singapore, in less than one generation its standard of living quadrupled. Most of the Asian economies experienced similar large increases in the standard of living. By contrast, OECD nations saw relatively little growth—although Ireland and Norway both doubled their standard of living, most other European countries had only a 20–40% improvement. This “Asian miracle” and what the OECD nations could learn from it were much discussed by academics and by the media.

As Table 5.7 shows, the performance of these Asian countries really was exceptional. In 1960 South Korea and Taiwan had a similar standard of living as Senegal, Ghana, and Mozambique. Between 1960 and 1990, these African countries had static or declining standards of living, whereas the Asian standards of living increased 6- or 7-fold. What made these Asian Tigers grow so fast, or alternatively, why didn’t growth like this occur in Africa?

INCREASE THE INPUTS AND INCREASE THE OUTPUT

The production function implies that to increase output it is necessary to increase either factor inputs, e.g., labor and capital, or the efficiency with which the production process

TABLE 5.6 Real GDP per Person in 1950, 1973, and 1996 (Constant Prices, 1990 $)

Country	1950	Country	1973	Country	1996
USA	9573	Switzerland	17593	USA	23719
Switzerland	8939	USA	16607	Norway	22256
UK	6847	Sweden	13494	Hong Kong	21201
Sweden	6738	Denmark	13416	Singapore	20983
Denmark	6683	West Germany	13152	Switzerland	20252
Netherlands	5850	France	12940	Denmark	19803
Norway	5403	Netherlands	12763	West Germany	19622
Belgium	5346	UK	11992	Japan	19582
France	5221	Belgium	11905	Netherlands	18504
West Germany	4281	Austria	11308	France	18207
Finland	4131	Japan	11017	Austria	17951
Austria	3731	Finland	10768	Belgium	17756
Italy	3425	Italy	10409	Sweden	17566
Ireland	3325	Norway	10229	UK	17326
Spain	2397	Spain	8739	Italy	16814
Portugal	2132	Greece	7779	Finland	15864
Singapore	2038	Portugal	7568	Ireland	15820
Hong Kong	1962	Ireland	7023	Taiwan	14222
Greece	1951	Hong Kong	6768	Spain	13132
Japan	1873	Singapore	5412	Korea	12874
Malaysia	1696	Taiwan	3669	Portugal	12015
Philippines	1293	Malaysia	3167	Greece	10950
Taiwan	922	Korea	2840	Malaysia	7764
Korea	876	Philippines	1956	Thailand	6112
Indonesia	874	Thailand	1750	China	4551
Thailand	848	Indonesia	1538	Indonesia	3464
China	614	China	1186	Philippines	2369

Source: Crafts, "East Asian Growth Before and After the Crisis," IMF Working Paper 98/137, 1996.

combines capital and labor, e.g., growth in TFP. Because the OECD countries are probably at or near their steady state, they are unlikely to grow much through capital accumulation and depend instead on improvements in TFP. By contrast, countries with low capital stocks can grow rapidly and catch up with economically more mature nations by increasing the capital stock and labor used in the production process.[8]

[8]The work of Alwyn Young suggests that most economic growth in East Asia is the result of a dramatic increase in the factors of production. Paul Krugman further elaborated this point in a seminal article, "The Myth of the Asian Miracle" in *Foreign Affairs* (1994).

TABLE 5.7 Asia and Africa in 1960

Country	GDP per Capita 1960	GDP per Capita 1990
South Korea	883	6206
Taiwan	1359	6207
Ghana	873	815
Senegal	1017	1082
Mozambique	1128	756

Source: Summers and Heston, Penn World Table 5.5, http:/www.nber.org

The data supports this idea. For instance, Table 5.8 shows the higher average investment rate in East Asian economies over 1981–1996 compared to the OECD numbers in Table 5.4. Therefore we would expect more rapid growth in these Southeast Asian economies for two reasons. First, they began with lower levels of capital, so as a result of diminishing marginal product of capital, they should catch up with wealthier nations. Second, high investment rates mean the steady state level of capital is high. Therefore, as in Figure 5.16, the East Asian economies have further to grow before they reach their steady state.

Increases in capital are not the only explanation for this rapid Southeast Asian growth—other factors of production also increased. For instance, while OECD countries were experiencing a declining birth rate and sometimes falling populations, the proportion of the Southeast Asian population aged between 15 and 64 years—the crucial working age population—was increasing rapidly. Average hours worked also rose—see Table 5.9.

In a controversial study, Alwyn Young claimed that a growth accounting exercise for these fast growing Southeast Asian economies suggests that growth was almost entirely due to capital accumulation and increased labor input (see Figure 5.20). For each country the most important factor behind economic growth has been capital accumulation. TFP only contributed a substantial amount to economic growth in Hong Kong. In Singapore, Young calculates that TFP growth has actually been negative. In other words, Singapore should have witnessed an even larger increase in GDP given the extraordinary increase in capital and labor that occurred there. Young suggests this negative TFP growth is a result of Singapore's ambitious development plans. The government intervened in many facets of the economy—from the provision of compulsory savings via the pension scheme to choosing which industries to develop. As a result, the industrial structure has frequently changed, with the economy moving from

TABLE 5.8 Asian Investment Rates, 1981–96

China	Hong Kong	Indonesia	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
35.5	28.4	32.0	33.5	35.8	22.3	39.1	22.8	35.4

Source: Crafts, "East Asian Growth Before and After the Crisis," IMF Working Paper 98/137, 1996.

TABLE 5.9 Employment Growth

Country	Average Growth	Country	Average Growth
Austria	−2.15	Switzerland	−10.99
Belgium	−17.36	UK	−11.26
Denmark	−5.34	West Germany	−19.09
Finland	−18.67	Hong Kong	11.80
France	−23.37	Indonesia	19.76
Greece	−11.46	Japan	−8.35
Ireland	−18.47	Korea	37.71
Italy	−17.92	Philippines	−12.5
Netherlands	−14.45	Singapore	36.81
Norway	−5.76	Taiwan	6.23
Portugal	11.06	Thailand	13.14
Spain	−31.66	USA	19.05
Sweden	−7.47		

Percentage change in hours worked per person between 1973 and 1996.

Source: Crafts, "East Asian Growth Before and After the Crisis," IMF Working Paper 98/137, 1996.

textiles to electrical goods to financial services and currently to the IT and communications industry. Young argues that this frequent reorientation of the economy has been a source of inefficiency. Rather than learn how to optimally exploit the technology of the existing industrial structure, Singapore has grown through massive investment in new industries. As a result, it has had minimal TFP growth.

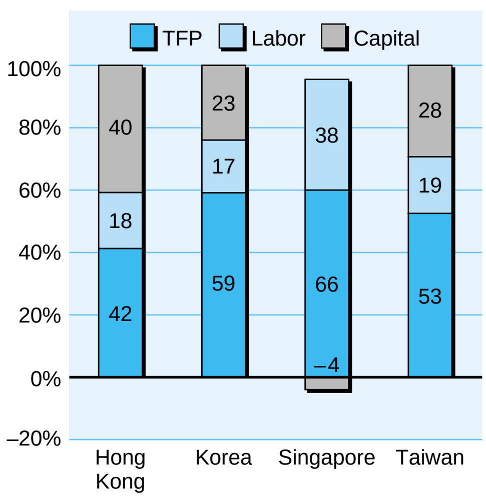

FIGURE 5.20 Growth accounting for Asian Tigers, 1966–90. Increases in inputs of labor and capital accounted for most of the growth of the Asian Tigers over the period when they increased output most rapidly. *Source*: Young, "Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience," *Quarterly Journal of Economics* (1985) vol. 110, pp. 641–680.

WHERE'S THE MIRACLE?

Surprisingly Young's findings have not generated much debate. Subsequent studies argued that Young's calculations were incorrect and that TFP growth had actually been far more substantial for Singaporean growth.[9] Whether TFP growth in Singapore has been significant remains contentious. If true, this result puts the Asian growth "miracle" in a different perspective. For mature industrialized economies at their steady state, the important source of growth now is TFP—these nations have already achieved their growth through capital accumulation. If anything is mysterious about economic growth, it surely relates to this TFP category. Increasing output by increasing factor inputs via capital accumulation or increases in employment is not miraculous. However, growth through TFP means that economies can produce more output even without using extra factor inputs. Young's calculations suggest that as far as TFP growth is concerned the world may not have much to learn from the Asian Tigers.

While East Asian growth has come mainly from increases in factor inputs, the sheer scale of these increases is impressive. Figure 5.21 shows that investment rates in Hong Kong and Singapore are higher than in most other nations. Therefore other economies could benefit from studying how the Asian economies achieved such high savings rates. The increase in labor input has also been impressive although there may be less to learn from this aspect of Asian growth. The Asian economies have benefited from large increases in the working age population combined with a shift in the working population away from low productivity agriculture to higher productivity industrial activities. This has been combined with either a constant or increasing level of hours worked per worker, which have declined in many OECD economies (see Table 5.9). Such increases in employment are either no longer physically possible in OECD nations or politically infeasible.

DOES IT MATTER? Does it matter if increases in factor inputs drove Southeast Asian economic growth? At a basic level, the answer is no—the huge increases in the standard of living these economies attained cannot be denied. That Singapore now has

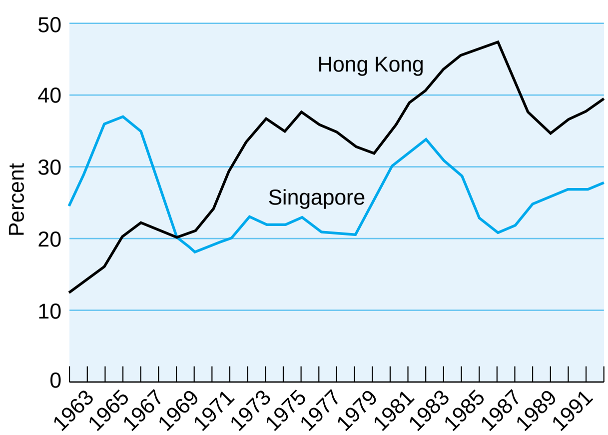

FIGURE 5.21 **Investment rates for Hong Kong and Singapore.** Starting at the beginning of the 1960s, for 30 years Hong Kong and Singapore invested an unusually high proportion of GDP. *Source*: IMF *Financial Statistics*.

[9]Collins and Bosworth, "Economic Growth in East Asia: Accumulation versus Assimilation," Brookings Papers in Economic Activity, (1996) vol. 2, pp. 135–191 and Sarel, "Growth and Productivity in ASEAN Countries," IMF Working Paper 97/97 1997.

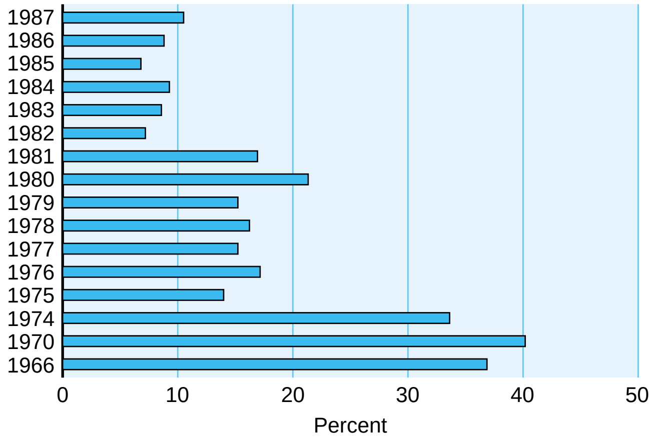

FIGURE 5.22 Real return on capital in Singapore. As the capital stock grew, the rate of return on capital in Singapore trended down. *Source*: Young, "Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience," *Quarterly Journal of Economics*, (1985) vol. 110, pp. 641–680.

one of the highest standards of living in the world is not a statistical mirage. On the other hand, it does matter, for two reasons. The first is to emphasize that this growth has not been miraculous but has required sacrifices. Singapore has such high levels of capital today because it had high investment rates in previous decades. Lower consumption in previous decades paid for current prosperity. The current generation of Singaporeans are benefiting from these sacrifices, but their high standard of living has come at a cost.

The second reason for concern is the implications that decreasing marginal product of capital have for future economic growth in the region. If technology is characterized by decreasing marginal product of capital, then the Asian Tigers will eventually reach their steady state, if they are not already there. Figure 5.22 shows Young's calculations of the marginal product of capital and suggests that by the end of the 1980s decreasing marginal product had already set in. Because of their high investment rates, this steady state will be at high levels of output per head. However, once at this steady state the economy will cease to grow very fast through capital accumulation, and instead these countries will have to pay attention to the factors that drive TFP. Just because Singapore, according to Young's calculations, has no history of strong TFP growth does not mean that it cannot produce strong TFP growth in the future. However, our analysis suggests that at some point the development strategy of Singapore and the Asian Tigers will have to turn away from just boosting factor inputs and focus on TFP improvements. For instance, between 1966 and 1990 Singapore saw employment rise from 27% to 51% of the population, and investment as a proportion of GDP rose from 11% to 40%; in 1966 half the population had no formal education, but by 1990 more than two thirds had completed secondary education. As a result of this huge improvement in factor inputs, the country witnessed remarkable growth. But a similar increase in factor inputs over the next 30 years is impossible.

5.10 China—A Big Tiger

The previous section suggested that Southeast Asia grew rapidly because of a substantial increase in factor inputs based around high investment rates and a fast-growing

TABLE 5.10 Chinese Employment Growth

Year	Percentage Growth
1980–85	17.7
1986–90	28.1
1990–95	6.3
1996–97	2.4

Source: Chinese Statistical Agency.

population. The result has been a huge increase in the standard of living of these countries. However, while these economies have grown substantially, they remain small-to-medium-sized economies due to the size of their population. For instance, South Korea has a population of around 50 million, while Hong Kong and Singapore have only about 6.5 million and 3.8 million, respectively. Therefore the rapid growth in these countries has not substantially affected the world's economy. However, the same cannot be said of China with its enormous population of 1.3 billion. China seems to be embarking on the same growth pattern as East Asia 30 years ago, with a huge increase in population and employment (see Table 5.10), high levels of investment (see Figure 5.23*a*), and a substantial shift of resources from agriculture into industry. The result has been rapid rates of growth (see Figure 5.23*b*) suggesting that China may be able to repeat a similarly rapid economic transformation as the other East Asian economies.

But China faces difficulties. In particular the need to shift an enormous part of the economy from state-controlled means of production and distribution to more market-oriented systems. Moreover, tensions over the weakness of China's financial system, in particular its banks, and the conflict between economic reform and the political status quo are growing. Pollution is also a major problem. All this means that Chinese economic growth is not guaranteed and that future economic growth may be volatile. However, China is pursuing a similar path to the East Asian Tigers of 30 years ago—large capital accumulation and increases in employment. Our analysis suggests that China

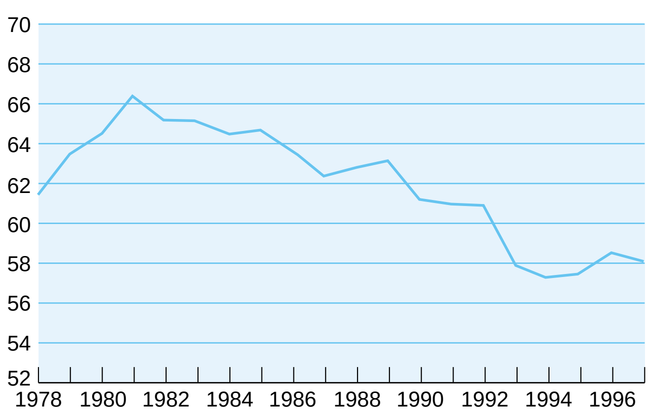

FIGURE 5.23a Chinese investment as proportion of GDP. China invests a very high proportion of GDP and its growth rate in the 1990s was very rapid. *Source*: IMF.

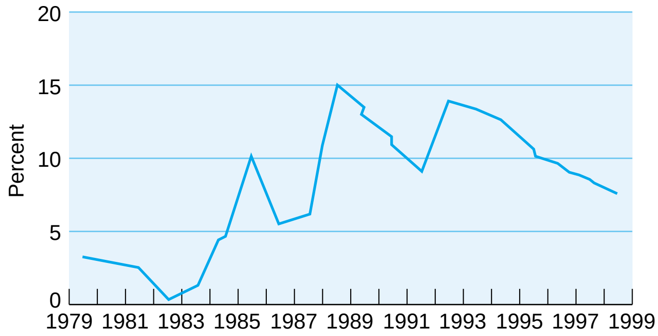

FIGURE 5.23b Chinese real GDP growth 1979–98.
Source: IMF.

can produce decades of fast growth based solely on high capital accumulation rather than reliance on technological progress. China will not need to focus on improving TFP to improve its standard of living for many years.

SUMMARY

This chapter has examined the link between the capital stock and the standard of living and economic growth. Central to our discussion was the concept of the marginal product of capital—the additional output that investment in a new machine brings. We discussed the consequences of assuming decreasing marginal product of capital whereby each new machine leads to a smaller increase in output than the last machine. We showed how this assumption implies that capital poor countries will grow faster than capital rich ones, so that countries or regions will show convergence. Decreasing marginal product also implies that wealthier countries will depend more on TFP improvements than on capital accumulation. Eventually, under decreasing marginal product, countries will arrive at a steady state—where for a given investment rate, a country cannot grow any further through capital accumulation. The steady state level of capital depends crucially on the investment rate—the higher the investment rate is, the larger the steady state capital stock and the higher the level of output are. Compared to the investment rate, which maximizes consumption in the steady state, most countries invest relatively little. We then considered the dramatic growth of East Asia between 1960 and 1995 and argued that this was mostly due to factor accumulation, in particular, high investment rates.

CONCEPTUAL QUESTIONS

1. Using Figure 5.6 show what happens to interest rates, investment, and savings when the economy experiences a wave of technological progress?
2. Should we include washing machines and irons in measures of the nation's capital stock?

3. What technologies might experience increasing marginal product of capital? Do they experience increasing marginal product over all ranges?
4. What influences your savings decisions? How responsive would you be to tax incentives?
5. What can mature industrialized nations learn from the rapid growth of Southeast Asian nations?
6. A nation wishes to have a capital output ratio of 2 and has a depreciation rate of 10%. What investment rate should it aim for?

ANALYTICAL QUESTIONS

1. Gross investment in an economy (I) is a fixed proportion, λ, of output (Y). Depreciation (D) is a fixed proportion, α, of the capital stock (K). What is the long-run impact of a rise in λ from 0.15 to 0.20 if α is 0.05? What happens to the rate of return on capital if output is produced with the Cobb-Douglas production function: $Y = A.\, L^{0.7}\, K^{0.3}$?
2. The steady state level of consumption in an economy (Css) is equal to steady state output (Y^{ss}) minus steady state depreciation. The latter is the depreciation rate (α) times the steady state capital stock (K^{ss}). We assume here that there is no technological progress. Thus

   $$C^{ss} = Y^{ss} - \alpha\, K^{ss}$$

   What is the impact on steady state consumption of a small increase in the steady state capital stock? What level of the capital stock maximizes the steady state rate of consumption?
3. The simple Golden Rule says that the optimal level of capital is one where the marginal product of capital equals the depreciation rate. If people attach less weight to the enjoyment they get from consumption in the future than consumption today, then does it make sense to abide by the Golden Rule? Is there a better rule? If such an economy ever found itself with the Golden Rule level of capital should it preserve the capital stock by setting gross investment equal to depreciation?
4. Consider an economy where output (Y) is produced by labor (L) and capital (K) according to

   $$Y = A.\, L^{0.7}\, K^{0.3}$$

   Investment is always 25% of output and the depreciation rate is 6%. If $A = 10$ and $L = 100$, what is the steady state level of K?
5. Suppose that the economy described in Question 4 enters the twenty-first century with a capital stock of 15,000. Assume that the labor force in year 2000 is 100 and remains constant and there is no technical progress. Calculate output and investment in 2000 and derive the capital stock in 2001. Use the relation

   $$K_{t=1} = K_t + I_t - \alpha K_t \qquad \text{where } \alpha \text{ is the depreciation rate } (= 0.06).$$

   Then calculate output, investment, and the capital stock for each year up to 2005. Plot the evolution of the capital stock on a graph and show the steady state that you calculated in Question 4 on the same figure.