No one could have ever intended to deny that technological change is at least partially endogenous to the economy. Valuable resources are used in the pursuit of innovation, presumably with some rational hope of financial success.

Robert M. Solow

4.1 Overview

In Chapter 3, we identified three sources of economic growth: (1) increases in the working population, (2) capital accumulation, and (3) technological progress. Its message was that two countries with identical economic characteristics should have equal output and income per capita in the long run, regardless of their initial conditions. In effect, the Solow model predicts that countries as diverse as Algeria, Bangladesh, Paraguay, or Zambia can all hope to reach the living standards of the wealthiest nations of the world in reasonable time. Yet reality is not as clear-cut or encouraging. Rather than converging to a common growth path, we observe very different outcomes around the world—wealthy, middling, and poor—and they don't seem to be pulling together in the way theory predicts. While the Organization for Economic Cooperation and Development (OECD) countries continue to converge to a common (high) standard of living, other countries have diverged or congregated around common, stagnating regional averages.

To begin to understand the diverse growth experiences across the world, we need to recall that another conclusion of Chapter 3 was that technological progress—as measured by the Solow residual—is the only true engine of growth. The most convincing explanation of divergence of economic development in the modern world must therefore lie in explaining differences in levels and growth of total factor productivity. But what is total factor productivity? Can anything be done to better understand, harness, or even accelerate this formidable source of economic prosperity?

Chapter 4 delves into these fascinating and important questions. First, by extending our description of the aggregate production function to account for labour quality, we can explain a great deal of the differences in per capita income levels across countries. Labour is not homogeneous: some workers are highly skilled, others much less so. Human capital (skills acquired on the job or through investment in education, and kept in use through good health care) contributes a great deal to explaining why workers in wealthy countries are so productive. Second, countries have different levels of public capital or physical infrastructure—streets and highways, bridges, hospitals, airports, to name just a few examples. Third, intangible aspects such as law and order, efficient court systems, and transparent governmental administration also contribute to income differences around the world and cannot be ignored. Here it makes sense to speak of social as well as physical capital.

Yet to explain economic growth over many decades, we must return to technological progress. In Chapter 3, technological progress was the engine of growth because it never runs out of fuel. Productivity was assumed to increase exogenously, irrespective of economic and social circumstances. This is unsatisfactory for both intellectual and practical reasons. Technological progress is the result of costly efforts at research and development (R&D). R&D combines pure production of knowledge (research) and making that knowledge work for us (development). In fact, R&D represents an economic activity in its own right. Yet why doesn't R&D fall victim to decreasing returns, as is the case with other factors of production? The question of whether the evolution of technological progress itself could be endogenous is an open area of macroeconomics. It also raises the question of whether government policies can improve the long-run growth performance of nations.

4.2 The Convergence Hypothesis

4.2.1 The Boundless Optimism of the Solow Model

In Chapter 3, output per capita in the long run was explained by (1) the savings rate and (2) the state of technology as summarized by the vertical 'height' of the production function at any given level of capital per capita. All other things being equal, countries with higher savings rates and more productive technologies will have higher output per capita than those with lower saving rates and less productive technologies. Countries with similar savings rates and comparable technological sophistication should have the same income per capita in the long run. Moreover, even if countries have different savings rates, they should grow at the same rate, if they have access to the same technology as the leading economies—either by copying international best practice or by allowing foreign corporations to transfer their know-how by investing in or trading with the domestic economy.

The Solow growth model thus contains a fundamentally optimistic view of economic development. Given the similar underlying conditions, GDP or income per capita should converge in level and growth rate across countries. Furthermore, the more distant a country's GDP is from its steady state, the faster it will grow in subsequent years. These predictions are known as the **convergence hypothesis**.

Panel (*a*) of Figure 4.1 plots the average growth rate of 34 advanced countries over the period 1960–2009 against their real per capita GDP in 1960. The convergence hypothesis predicts that countries with low initial per capita GDP will grow faster than those that started richer, that is what catching up is all about. Under the assumption that these countries have more or less the same steady state value of GDP per capita, it makes sense to expect a negative relationship between initial conditions (per capita GDP in 1960) and the growth which followed. This does indeed appear to be the case. As Box 4.1 explains, among these countries, it takes about 35 years to eliminate half of the gap between any nation and the richest ones. While the optimistic message of the convergence hypothesis is that poorer countries should grow faster than average, practical experience teaches us that the process is slow, even under the best of circumstances.

4.2.2 Reality: Growth Clubs and Growth Traps

While panel (*a*) of Figure 4.1 shows that the convergence hypothesis does remarkably well among the club of richer nations, panel (*b*) shows that, for the world as a whole, there is little or no evidence of convergence. Evidently, per capita incomes differ considerably and that, for many poor countries, income differences persist or have even widened. While standards of living among the wealthier countries seem to be organized around **convergence clubs**, many poorer countries seem to be 'stuck' in **growth traps** with low per capita GDP and low or even negative growth. How can we explain this apparent contradiction with the principles laid out in Chapter 3?

One possibility is that countries with low income per capita suffer from insufficient capital accumulation because of inadequate saving or destruction by war or natural disaster. Yet low domestic savings alone cannot explain the situation. While we stressed in Chapter 3 that investment must equal savings, this need not be true out of the steady state. It is very possible for foreigners—either individuals or corporations—to invest in poor countries. In this case, investment could be financed through foreign borrowing. In fact, if capital is free to move, we should expect multinational firms, investors, and financiers to move capital to countries where capital–labour ratios are low and, therefore, returns on investment ought to be high. Over time, capital–labour ratios (k) should be equalized across countries. This process may take some time, of course, but a process of convergence towards similar capital–labour ratios, and therefore per capita GDPs should occur.

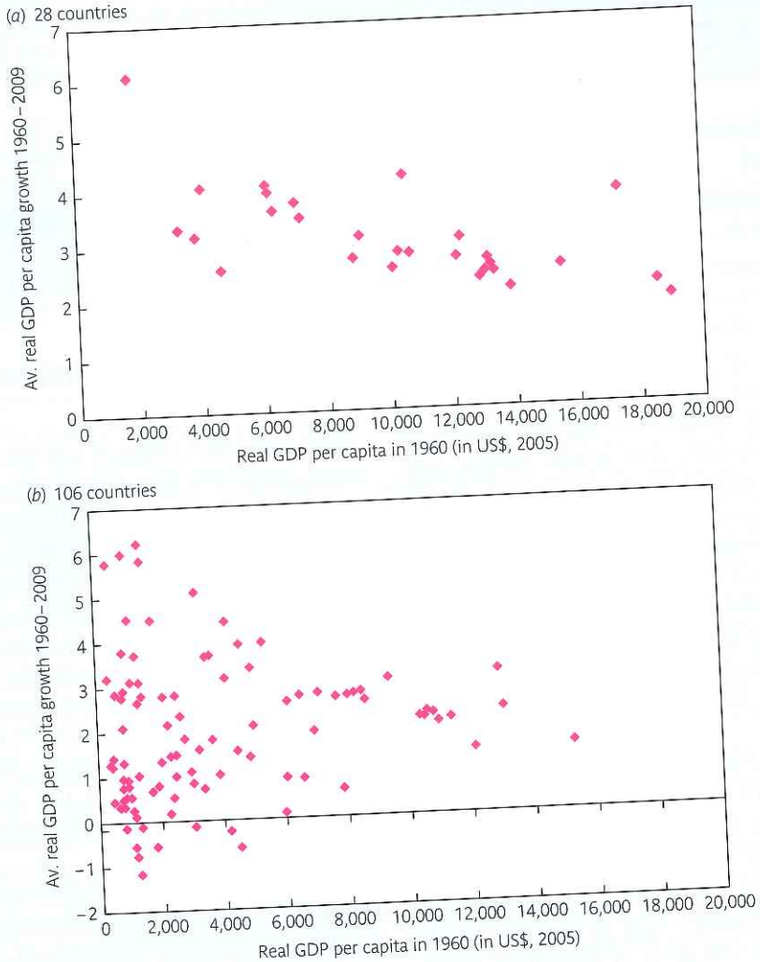

Fig. 4.1 The Convergence Hypothesis in Reality

All things equal, growth theory predicts that poorer countries should grow faster than richer ones. Panel (*a*), which plots the average growth rate for 28 advanced OECD countries over 1960–2009 against initial GDP per capita in 1960, lends strong support to the convergence hypothesis. Panel (*b*), which displays the experience of 106 countries over the same period, does not.

Sources: Heston, Summers, and Aten (2006); authors' calculations.

A second possibility is that chronically poor countries suffer from technological backwardness or a lack of a properly functioning economy. It must be that, for some reason, the poorest countries have not yet been able to reach a steady-state level attainable by rich countries—point *B* in Figure 3.5. In that case, when and if they eliminate the barriers that prevent them from moving towards their steady states, they should catch up and therefore grow faster than the wealthy economies, which can only grow at the speed of technological progress. A prominent example is China, which has grown by some 10% per year ever since it abandoned central planning in the 1980s. India is following, although not quite as fast.

Plainly, this process may have occurred in China and India recently, but it hasn't occurred in many

Box 4.1 A Snail's Pace: The 2% Convergence Rule

The convergence hypothesis can be expressed in the following way:[1]

$$\frac{\Delta Y_t}{Y_t} - a = \beta \frac{\bar{Y}_t - Y_t}{\bar{Y}_t}, \quad (4.1)$$

which asserts that the *growth rate* of an economy in period t, $\frac{\Delta Y_t}{Y_t}$ will be higher than its steady-state growth rate (a) when current GDP (Y_t) is less than the steady-state *level* ($\bar{Y}_t$) predicted by savings and technology. The parameter β captures the speed of convergence. The greater the distance is between the current GDP and its steady-state value, the faster the rate of growth. For the countries shown in Figure 4.1, Robert Barro of Harvard and Xavier Sala-i-Martin of Pompeu Fabra University[2] conclude that β is about 0.02, which means that about 2% of the gap in per capita income is closed per year. This implies that it takes roughly 35 years to eliminate 50% of the difference between a given region and the leading one.[3] As an example, consider the convergence of regions within the USA. In 1880, the US South had a GDP per capita of about one-third of the richer, north-eastern New England region. This very low initial condition reflected the destruction of capital and infrastructure during the Civil War. It has taken more than a century of convergence for GDP per capita of the two regions to move to within roughly 10% of each other. Similarly, the hopes and expectations that southern Italy, eastern Germany, or western Spain will converge quickly to the leading regions of their respective countries have not been entirely fulfilled. We will look at some reasons why convergence may be held in check, an issue of burning relevance to some countries of Eastern and Central Europe.

countries.[4] Poorer countries' inability to close the income gap represents a massive challenge to the international community and to economics as well. It calls into question the basic assumption that all benefit from free markets. It also casts doubt on the validity of the principles presented in Chapter 3. At the very least, it is suggestive of a systematic factor that we have not taken into account. Could our story just be too simple? Let us try to review what could be changed to better explain the facts.

4.3 Conditional Convergence and Missing Inputs

So far, we have implicitly assumed that all countries have access to the same technology, represented by the production function. What if they were to differ? Figure 4.2 shows an example of dissimilar production functions in two otherwise identical economies, in which households save the same fraction of their income and with the same capital-widening lines in both. The figure shows that two countries with dissimilar production functions will converge to

[1] Interested readers can see in the WebAppendix how this formulation is derived.

[2] See Barro and Sala-i-Martin (1991).

[3] This is the useful rule-of-thumb for computing doubling time or half-lives. Suppose a variable x grows at a constant positive rate of g% per annum, then it will double in roughly $70/g$ years. If it is shrinking at rate g, it will shrink to half its size in $70/g$ years. See the WebAppendix for a derivation of this rule.

[4] Nobel Laureate Robert E. Lucas, Jr of Chicago estimated that if India and the United States had the same production function, the marginal product of capital in the former would have to be about 58 times the marginal product in the latter! In his words, 'If this model were anywhere close to being accurate, and if world capital markets were anywhere close to being free and complete, it is clear that, in the face of return differentials of this magnitude, investment goods would flow rapidly from the United States and other wealthy countries to India and other poor countries. Indeed, one would expect *no* investment to occur in the wealthy countries in the face of return differentials of this magnitude.' (Lucas 1990: 92.)

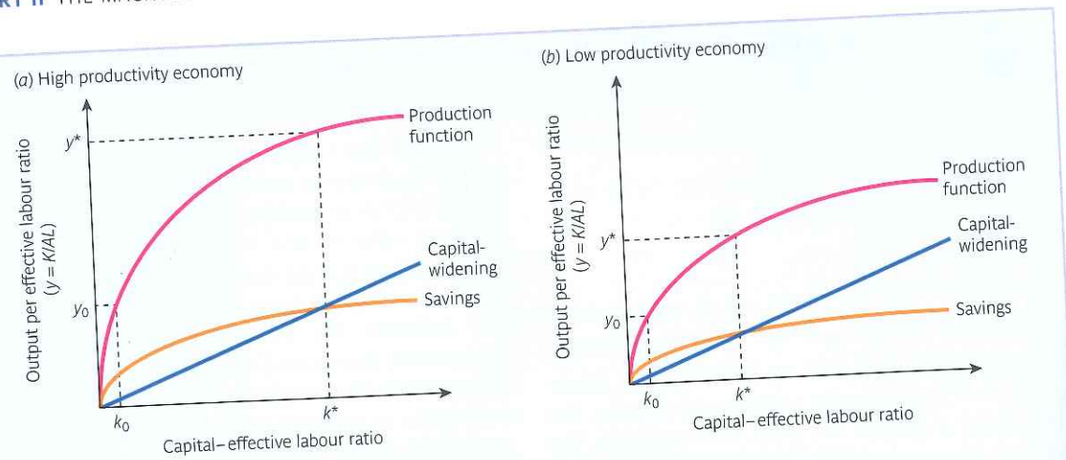

Fig. 4.2 Conditional Convergence
The economies depicted in the two panels are identical in all respects except that the available production technology is more productive at all levels of capital per capita in (*a*) compared with (*b*). In the steady state, the more productive economy is richer because it has a higher capital–effective labour ratio. For two countries with identical initial capital stock per effective labour (k_0), conditional convergence will occur to fundamentally different steady states. The richer economy at the outset will also grow faster along its path to the steady state, as predicted by equation (4.1). Conditional convergence means taking not only an economy's initial condition into account, but also its steady state.

different steady states. The notion that convergence occurs, but to steady states that depend on the individual attributes of an economy, nation, or region, is called **conditional convergence**.

But why should production functions differ across countries? International differences are unlikely due to technology in the strict sense. It is hard to see why knowledge or the mere availability of state-of-the-art methods can differ across countries for any period of time. Information is freely available, so producing clothing or electronic chips in an internationally competitive market will necessarily involve the same production techniques whether in Taiwan, Germany, India, or Zimbabwe. Yet, most experts would agree that productivity per head in these countries would be significantly different even if they had the same amount of capital per head to work with.

The most important reason why production functions are different is the existence of other observable inputs to the production function which make capital and labour more productive, just as technological progress does. Research has identified a long list of such influences. While they can be thought of as 'technology' in the broader sense, they are observable and often are quite evident features distinguishing rich, fast-growing countries from poor, stagnant ones. Which factors are they, exactly? We now examine a number of possible explanations.

4.3.1 Human Capital

Education and training

Just as firms acquire physical capital for producing goods and services, individuals expend time, energy, and money to acquire knowledge and learning how to use that knowledge. These activities range from going to school, learning a skill, or taking a training course. Acquisition of knowledge is an investment. It represents a sacrifice today—foregoing a paid job, or the costs of education—for gains in the future. Such sacrifices are generally made because future gains exceed the initial costs.[5] It is for this reason that one speaks of investment in **human capital**. Better-trained and educated workers are more productive, and more productive workers can earn higher wages. Beyond this, more educated workers tend to enhance the productivity of other factors. Skilled workers are

[5] In Chapters 7 and 8 the notion of an investment and the assessment of the desirability of investment will be made much more precise.

better at operating complex machines, and may be used to manage other labourers and organize the production process.

Thus, it makes sense to think of production as combining not only physical capital K and hours of work L, but also a third input, human capital H. The economy's production function becomes

$$Y = AF(K, L, H). \quad (4.2)$$
$$(+ \; + \; +)$$

Much of the reasoning in Chapter 3 can be repeated using this extended version of the production function. Like physical capital, human capital is accumulated over time and is subject to depreciation as knowledge progresses and people age. This implies that countries that invest more in education and training tend to be better off in the long run—they would tend to have a production function in panel (*a*) of Figure 4.2 rather than in panel (*b*).

Yet, this does not quite explain away all the puzzles. If the production function (4.2) exhibits constant returns to scale in all three factors—capital, pure labour, and human capital—then the marginal product of human capital must be decreasing, just as it was for capital in Chapter 3.[6] Then, again, it follows that, in the steady state, long-run growth rates in economies with low and high 'savings' rates in human capital will still be the same, determined by the rate of technological progress. Of course, the country that invests more in human capital will be richer and more productive.

Health

Human capital is not just education. It includes anything that raises labour productivity for a given capital stock. In particular, human capital also includes the state of health of workers. Freedom from disease and chronic illness as well as access to adequate medical care are considered by many to be fundamental human rights, but they also represent a critically important determinant of economic prosperity. Workers who are ill or must care for relatives cannot be available for productive activities. Furthermore, in places where health services are poor or access is limited to the richest segment of the population, life expectancy will be low. Reduced life expectancy reduces incentives for individuals to invest in education, and can lead to emigration of wealthy elites.

Poor health services, therefore, are a plausible further interpretation of growth traps. But does good health cause high income, or does high income cause good health, or both? Figure 4.3 shows that the relationship between income and life expectancy is positive, but by no means linear. Life expectancy increases dramatically with income. Not only is life expectancy shamefully low in the very poorest countries, but the growth benefits from improved health are likely to be shamefully high—because the marginal productivity of labour, and therefore of health, is likely to be decreasing. In large parts of the world, existing medicines could cure endemic sicknesses, but people cannot afford them. The AIDS disaster in Africa is a tragic example of a vicious circle in which poverty shortens life expectancy, which further cripples incentives to invest in human capital and future growth.

[6] In general, if the production function is subject to constant returns to scale in all inputs, it must be the case that the marginal productivity of each input taken individually is decreasing.

4.3.2 Public Infrastructure

A second important factor which is missing from the production function is **public infrastructure**. This includes streets, public transport, telecommunication, postal services, airports, systems of water distribution, electricity provision, and sewage treatment, etc. Like the private capital stock, public infrastructure are goods which contribute to general productivity and are widely available to all users, often at low or no cost, and are most often provided by the government. Firms use roads and telephone lines as much as they use their own computers, machines, and lorries. At the aggregate level, the production function can be further augmented to include the stock of public capital, which we will call K^G:

$$Y = AF(K, L, H, K^G). \quad (4.3)$$
$$(+ \; + \; + \; +)$$

The importance of public infrastructure raises a number of questions. Public infrastructure is often free to use, but it is definitely not costless. Like private physical capital, it must be financed. Governments are generally in charge of infrastructure spending, and use taxation or user fees to finance these expenditures.

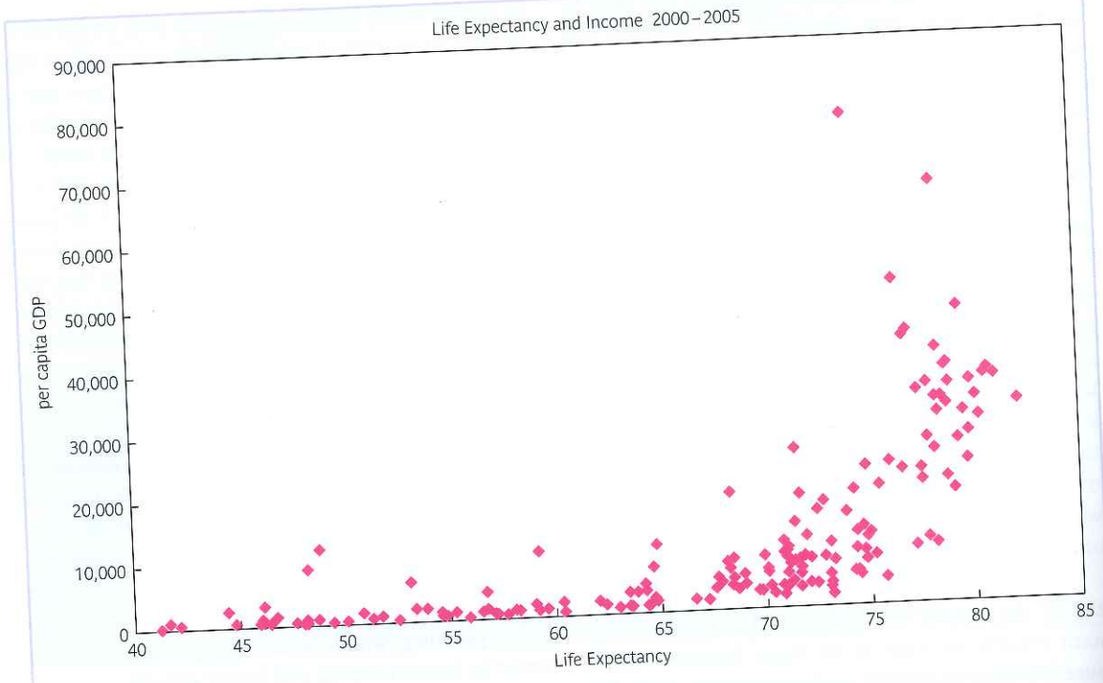

Fig. 4.3 Life Expectancy and Income

In a cross-section of nations, life expectancy declines dramatically at low to moderate income levels. It is difficult to believe that general health conditions do not influence investment decisions, especially in skills and education. At the same time, the demand for health depends on income.

Source: United Nations Population Division, Heston, Summers, and Aten (2006).

While private firms are under constant pressure from their owners to evaluate the balance of costs and benefits from acquiring more equipment, it is difficult, if not impossible, for the government to evaluate the benefits that accrue in millions of ways to millions of users. Furthermore, politicians rarely reap the benefits of infrastructure spending directly. At best, infrastructure enhances tax revenues in the future, and politicians may not be in power to claim credit for those future growth effects. Figure 4.4 shows the average amounts that European governments spent on public capital accumulation over the period 1995–2005. The wide variation across countries signals both needs to modernize their infrastructures (Ireland, Portugal, and Spain) and constraints of fiscal policy (Germany and the UK).

A number of difficulties arise in getting the level of spending on public infrastructure right. Some governments tend to underinvest because other uses of taxpayers' money are more politically rewarding, or because pressures to cut the budget force spending cuts. On the other hand, some other governments might spend too much on infrastructure because political lobbies for public works defend this budgetary item. Growth may be held back for lack of adequate infrastructure in the first case and because of excessive taxation in the second case. In order to reduce the risk of such slippage, a number of governments have increasingly decided to privatize these areas. Indeed, over the last decade, the production of electricity, telephone, water, railways, etc. has been increasingly turned over to the private sector. Yet, we must remember that there is no guarantee that public infrastructure will be adequately provided, an issue to which we return in Chapter 18.

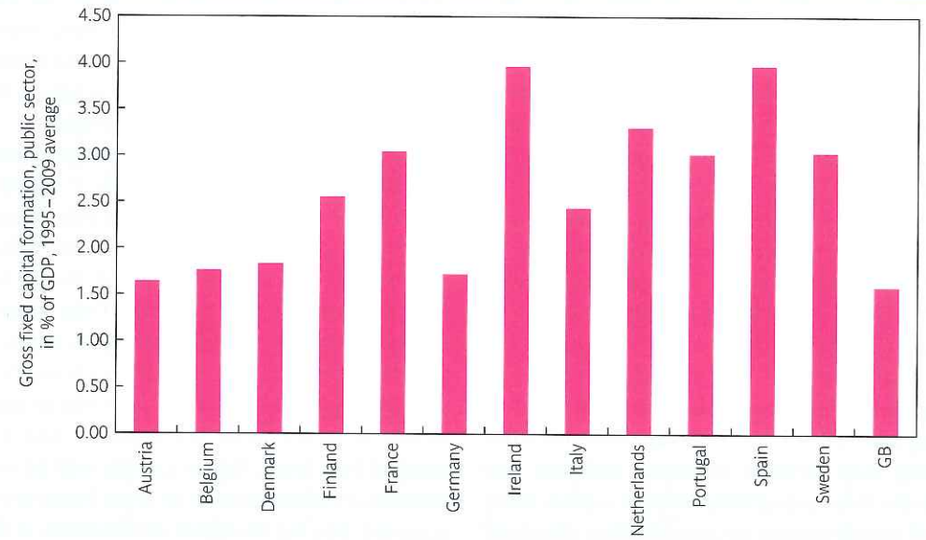

Fig. 4.4 Gross Fixed Capital Formation in the Public Sector, 1995–2009 (% of GDP)

On average, European countries spend 2–3% of GDP on public infrastructure. Yet the variation across countries is high.

Source: OECD

4.3.3 Social Infrastructure

Even accounting for 'hard factors' like education, health, and infrastructure, it remains difficult to account for the enormous differences in total factor productivity between the richest and the poorest nations of the world. For instance, the level of GDP per capita in the USA is roughly 35 times as high as in Niger in Africa. This means that an average US worker works 10 days to produce the *annual* output of a worker in Niger. Naturally, part of this difference is linked to the fact that US workers have better capital equipment, education and skills, and public infrastructure to work with. Yet even if these differences are taken into account, US workers are still almost eight times more productive in per capita terms. Economists attribute this wide gap to 'soft' factors which improve both directly and indirectly the effectiveness of workers.

The first of these is **property rights**. A recurrent theme of Chapters 3 and 4 is that growth is driven by investment. In Chapter 3, emphasis was placed on physical capital, while in this chapter we have seen that the concept of investment is flexible enough to include public infrastructure, health, and human capital. The common feature of an investment, spelled out in more detail in Chapters 7 and 8, is that it means spending now for uncertain benefits in the future. It is often taken for granted that ownership of capital will be unquestioned both today and in the future, and that individuals will be able to use the skills that they acquire. In both cases, we can speak of clearly defined rights of ownership, or property rights, which are respected by others and systematically enforced by the state. While property rights are well established in the richest countries of the world, they cannot be taken for granted universally.

Property rights require clear, credible, and enforceable legislation or constitutional provisions which guarantee that individuals and firms cannot be dispossessed of their belongings, except if they violate the law and even then, only after due process. The concept of property rights is not restricted to merely retaining one's belongings. In the extreme case, it would guarantee that one's possessions can always be used as intended and disposed of, under all circumstances. Such absolute property rights are rarely observed: landowners are seldom allowed to build 'the house of their dreams' without the implicit or explicit permission of their residential area. More relevant for economic growth, property rights are

denied if a firm is taken over by the state, say, to produce weaponry against the will of its owners. Such nationalizations, which occurred in France as recently as the early 1980s, similarly violate property rights, even if the owners are compensated, because they break the link between investment and its intended use. Nationalizations are an example of retroactive legislation, enacted after the original investment was carried out. They damage the fabric of trust between capital owners and the government, which depends on productive economic activity to finance its activities.

At the individual level, property rights should be extended to **human rights**. Being arbitrarily sent to jail, being barred from jobs, or being prevented from performing (non-harmful) economic activities prevents people from using their human capital. Mere threats of imprisonment or assassination also deny property and human rights. As long as individuals do not have basic freedoms of association, expression, and protection from violence—and these irrespective of sex, race, political opinions, or religious beliefs—their property rights are not established.

It is easy to see why property rights are a precondition for long-run economic growth. If investors cannot be sure that they will own their investments tomorrow, why bother to invest today? This would also explain why capital does not always seem to flow from rich to poor countries. Even if the rate of return on capital in poor countries is much higher, the risk of expropriation or arbitrary restriction of property rights may convince investors to keep their money in richer, more stable places. And if investment is held back, future growth will be too. This elementary proposition is far from being universally accepted. Box 4.2 examines communism, a doctrine

Box 4.2 Communism and Economic Growth in Communist Countries

In its unrecanted form, communism holds that private ownership of capital leads to the never-ending concentration of wealth in a few hands, while workers are subordinated and kept at the subsistence level of existence. A revolution would ultimately collectivize ownership of the capital stock ('the means of production' in Marxian terminology), by nationalizing large private firms, and in some countries even by banning small ones as well. In several countries, collective ownership was extended to land and housing. While communism or state socialism has been in decline since the mid-1980s, there are still a number of countries which adhere to its tenets (Cuba, Venezuela, North Korea). While undoubtedly one of the most dynamic market economies of the world today, China still claims to be a 'people's republic' and still carries the heavy baggage of decades of socialism in the thousands of state enterprises still in government ownership.

While driven by lofty aims of creating a better society, communism suffers from fundamental flaws. Most economists agree that incentives to work, invest, and innovate are severely attenuated in societies of collectivized ownership and centralized economic planning. To counteract this, communist regimes offered a combination of centrally organized carrots (rewards) and sticks (penalties). Firm managers negotiated production plans with the central planning office, and were provided with the necessary means, equipment, and salaries. Both managers and workers were also offered various incentives to produce more: more money, medals, better housing, and other benefits. Underperformance was punished, sometimes harshly so.

How did it work? Figure 4.5 shows that, up until the early 1970s, the growth performance was good, certainly on a par with Western Europe. Part of the reason was catch-up after the destruction of the Second World War, which affected both East and West. But then things turned sour, much worse than in Western Europe. Most centrally-planned countries experienced two decades of negative growth rates, an extraordinary failure. Central planning simply did not work, and brought the collapse of the communist regimes. The odd man out is China: a poor performance over the first period, followed by fast growth. The most plausible explanation of the Chinese success story is the gradual relaxation of central planning, accompanied by the introduction of private ownership and openness to trade. But another part of the story seems to be the tight control over human rights imposed by the regime; a puzzling observation.

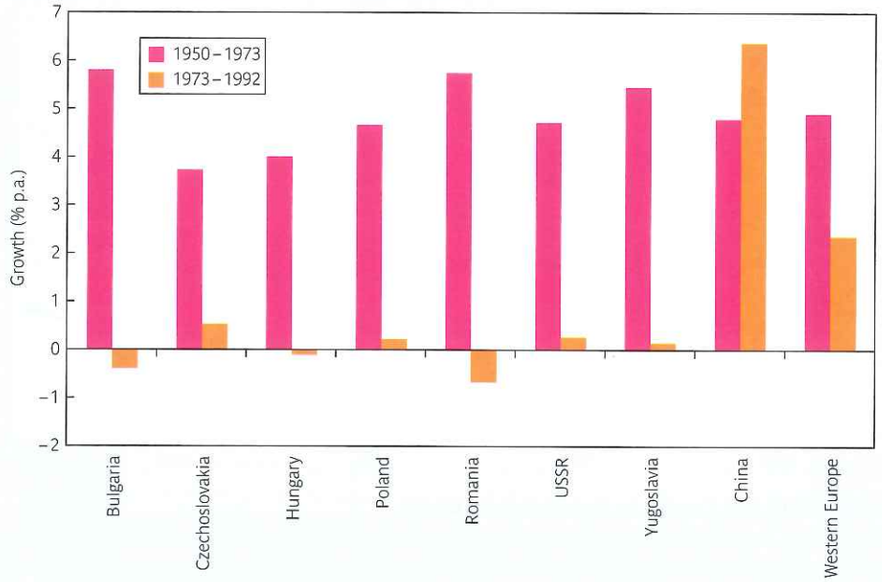

Fig. 4.5 Growth Performance under Central Planning

The impressive growth performance over the first 25 years in planned economies was followed by a catastrophic decline over the next two decades. China stands out as a different and puzzling story.

Source: Maddison (1995).

which explicitly rejected private ownership of means of production. More generally, property rights are routinely denied by arbitrary, undemocratic regimes and by wars, both civil and international.

The relationship between property rights, broadly defined, and growth is more complicated than meets the eye. There is powerful evidence that rich and fast-growing countries tend to be democratic, law-abiding, and peaceful, but it is not clear what comes first—economic well-being or property rights. One view is that property rights are a prerequisite for sustained economic growth. Another view is that affluence makes basic freedoms and property rights more desirable. It could well be that each aspect strengthens the other, generating either virtuous circles of growth and better-established rights, or vicious circles leading to poverty traps which combine economic stagnation and the absence of property (and human) rights.

Indeed, there are cases of countries which embarked on a stable, often fast growth path while enjoying limited property and human rights: the communist countries, Chile under Pinochet, or some countries of South-East Asia. Conversely, it can be argued that some countries visibly fail to grow because property rights are non-existent. A sobering example is Sub-Saharan Africa, which has grown by a mere 1.5% (GNI per capita) over the years 1965–1997, while the world's overall growth over the same period stood at 50.9%. As Figure 4.6 shows, this average performance conceals a wide disparity, depending on the policy regime.

Another main threat to property rights is armed conflict, which destroys both physical and human capital. If wars are occasional, a catch-up process sets in once they are over. This was the experience of Europe after 1945, which enjoyed rapid growth while building supra-national institutions (the common market, the European Court of Justice, monetary union) and peace-enhancing mechanisms (NATO, the Organization for Security and Cooperation in Europe) to reduce the risk of renewed conflict.

Civil wars can also pose an enormous hindrance to economic development. Africa has been devastated by

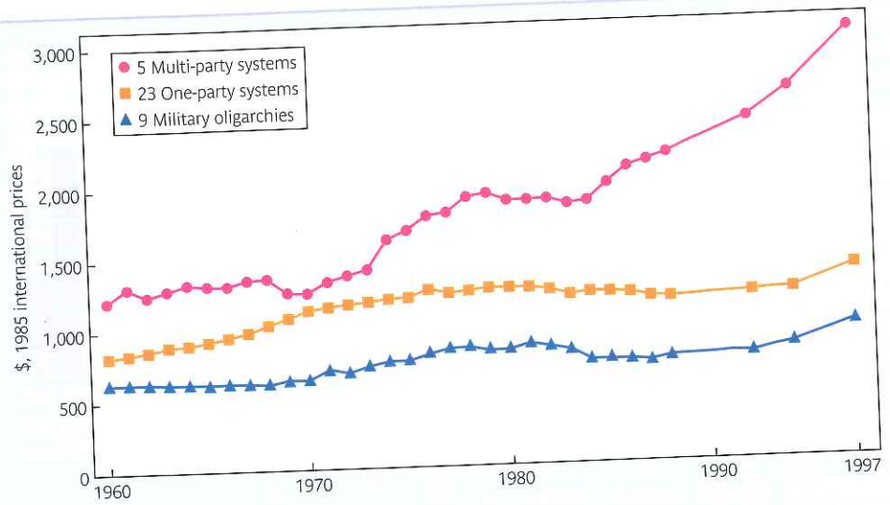

Fig. 4.6 Real GDP per Capita in Sub-Saharan Africa

Over the period 1960–1999, the five countries with democratic political regimes (Botswana, Gambia, Mauritius, Senegal, and Zimbabwe) display a much better growth performance than countries with one-party systems. Countries with military regimes have stagnated.

Source: Ndulu and O'Connell (1999).

civil conflict as states inherited from colonial times have tried to come to grips with ethnic diversity. For example, the index of ethnic fractionalization stands at 67.6% in Sub-Saharan Africa, and at 32.7% on average in other developing countries.[7] Besides the obvious material destruction, investment is held back and human capital declines through the emigration of wealthy and powerful elites. Figure 4.7 establishes an unmistakable link between growth and property rights, where the latter is measured by a legal index of the rule of law prevailing in the country.

4.3.4 Contributions of the Missing Inputs

Alongside capital and labour, human capital, public and private infrastructure should be taken as inputs of the production function. Although precision is obviously limited, most of the missing inputs can be quantified, or expressed in a readily comparable form. Do they account for average growth over a period of several decades, in a type of statistical 'horse race'? Table 4.1 presents estimates of their effects on average annual growth rates.

1 **Catch-up** (convergence). Starting far below its steady state, a country should be accumulating

Table 4.1 What Drives Growth? Some Estimates

Factor	Effect on annual growth rate
Initial per capita GDP (effect of 1% higher level)	–2.5
Education (effect of 1 more year)	0.4
Life expectancy (effect of 10% increase)	0.8
Fertility rate (effect of a 50% increase)	–0.6
Government consumption (effect of a 10% higher ratio)	–0.6
Rule of law (effect of an increase of 0.1)	0.2
Investment (effect of a 10% increase of ratio to GDP)	0.8

Source: Barro and Sala-i-Martin (2004).

[7] This index reports the probability that two people randomly chosen in a country belong to two different ethnic groups; Collier and Gunning (1999).

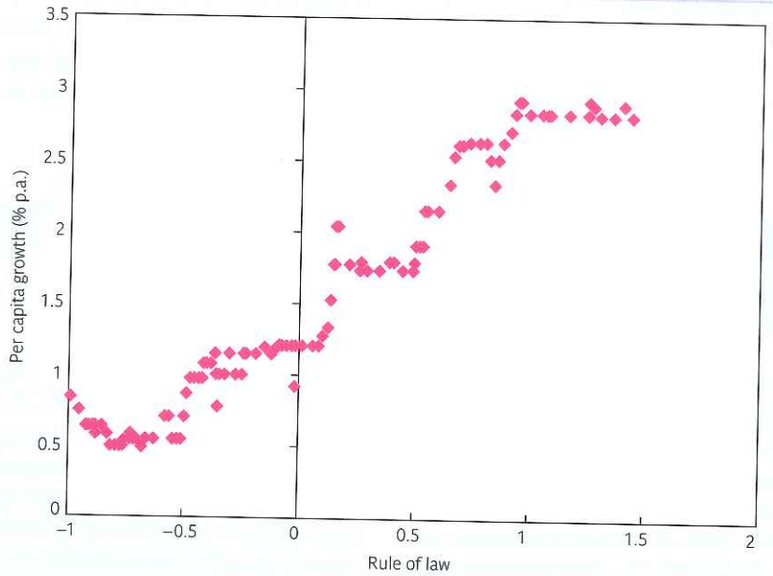

Fig. 4.7 Rule of Law and Growth, 1960–1998

Based on a large sample of countries, the figure relates average economic growth over nearly four decades with an index measuring how well the rule of law applies. The index ranges from –2.5 (complete breakdown) to +2.5 (perfect legal protection). It includes political corruption, likelihood of government repudiation of contracts, risk of government expropriation, quality of bureaucracy, and overall maintenance of law. The figure sends a very strong message: the stronger the rule of law, the faster a country grows. Note the beneficial effect only sets in after some minimal threshold.

Source: Easterly (1999).

capital, both physical and human, more rapidly, as well as adopting new technologies. The table indicates that the economic backwardness is closed at a rate of about 2.5% per year (the higher is initial GDP, the less it subsequently grows).

2 **Human capital**. People's knowledge, ranging from basic literacy to sophisticated skills, represents an additional factor of production. One common measure of investment in education is the average number of years spent in secondary or higher education by males.[8] Raising the population's average schooling by one year is found to speed up growth by 0.4% per year.

3 **Health**. A ten-year increase in life expectancy at birth raises average growth by 0.8%—a very large effect indeed. As stated already, the effect is likely to come through investment in human capital and, more generally, more effective labour input and greater work effort. This effect is unlikely to be important in rich countries where it is retirement that limits the length of active lifetime. It may be crucial in the poorest countries where few people ever reach retirement age.

4 **Fertility**. The negative effect of the rate of fertility (the average number of children per woman) seems related to two main effects: capital-widening and time spent by mothers in child rearing instead of economic activity.

5 **Public consumption**. Reducing public consumption by 10% of GDP raises growth by 0.6%. This measure excludes spending on public infrastructure. The

[8] This does not mean that female schooling is unimportant, even if the study reported here does not detect any clear *direct* effect. Female schooling is usually found to be more socially productive than male schooling, but this effect is more complex, and mostly *indirect*. In many developing countries, female school attendance is much lower than for males, so a little effort produces large effects. Also better-educated females make better mothers, with considerable impacts on children's education, health, and, more widely, approach to life. Female education also affects fertility.

negative effect probably reflects the fact that high public employment tends to be inefficient and invites corruption, as well as high tax collection, which acts as a disincentive to savings, investment, and innovative activity.

6 **Rule of law**. Lasting, credible property rights are a precondition for investment in both physical and human capital. Going the full way from the worst to the top ranking raises growth by a whopping 2% annually.

4.4 Possibility of Endogenous Growth[9]

The analysis of Chapter 3 showed that technological change is the ultimate engine that pushes the output–labour ratio—and GDP per capita—ever higher. While differences in human capital, public investments, and social infrastructure can explain differences in long-run levels of national prosperity, they do not change the bottom line. Per capita growth in the long run settles down to the rate of technological change, which is exogenous at rate a. Technological progress is the engine of growth because it is assumed never to run out of fuel; it increases exogenously, irrespective of what happens.

Can the growth process be as simple as that? Might not technological progress itself—or at least part of it—be driven by man-made decisions? Technological progress is related to investment in education and science, to efforts in R&D, and to millions of discoveries, small and large. Might not those discoveries be affected by what others do?

We will find that growth can only perpetuate itself when the marginal product of capital stops falling. As we explore the nature of technological progress, we open up the hunt for possible sources of non-decreasing marginal productivities. **Endogenous growth theory** attempts to explain how growth in the leading economies can vary in the long run—meaning over several decades at a time. Because it represents the boundary of economic research, it is not accepted by all, for reasons we discuss later.

4.4.1 A Sufficient Condition for Endogenous Growth

A hallmark of the analysis of Chapter 3 is that the capital–labour ratio will converge to a steady-state value which is predetermined by the economy's individual characteristics. Declining marginal productivity is responsible for this result. Graphically, this feature is captured by the gradual flattening out of the aggregate production function shown in Figure 3.5. As the capital stock in an economy increases, the marginal product of additional investments and additions to the capital stock declines, as do their contribution to generating new income. As the marginal income from investment falls, savings and investment decline and the economy grows more slowly.

But suppose that marginal productivity did not decline enough, and that the slope of the production function schedule always exceeded the slope of the capital-widening line. This would mean that, for sufficiently high levels of the capital–effective labour ratio, the production function schedule would become a straight line. This would remain consistent with output increasing at the same rate as new capital is being accumulated, one of the stylized facts discussed in Chapter 3.

Figure 4.8 shows how things change radically. If the capital–labour ratio is initially at k_1, savings and investment correspond to point A and lie above the capital-widening line (point B). The ratio of capital to effective labour ratio $k = K/AL$ will thus increase by the distance AB. As this ratio grows to reach the level k_2, saving is determined by point C and the capital–effective labour ratio keeps rising even faster as indicated by the distance CD.

Because the marginal productivity of capital does not decline, more of it produces more income and therefore more saving. The striking consequence is that the output–labour and capital–labour ratios never stop growing.[10] This contrasts sharply with the case of declining marginal productivity in Figure 3.13, in which a unique steady state is always reached with $y = Y/AL$ constant, and GDP per capita Y/L growing at the constant rate a. Now y itself is rising secularly, while Y/L is rising even faster.[11] Another implication of non-declining marginal productivity of capital is that an increase in the saving rate makes the saving schedule rotate upwards, leading to faster accumulation of the capital stock and permanent growth in GDP per capita.

[9] The material in this section is somewhat more advanced.

[10] A simple example: suppose the production function in intensive form is simply $y = Ak$ where A is a positive constant. Then the capital accumulation equation is $\Delta k = sAk - (\delta + a + n)k$, which implies a growth rate of k given by $\Delta k/k = sA - (\delta + a + n)$. Furthermore, $\Delta y/y = \Delta k/k$, so a higher growth rate of capital per capita (k) forever implies a higher growth rate of output per capita (y) forever.

[11] Note that, in this case, the saving line must lie above the capital accumulation line ($sA > \delta + a + n$). If this were not the case, the capital–effective labour ratio would instead shrink to zero over time, because savings would never be sufficient to make up for depreciation and capital-widening.

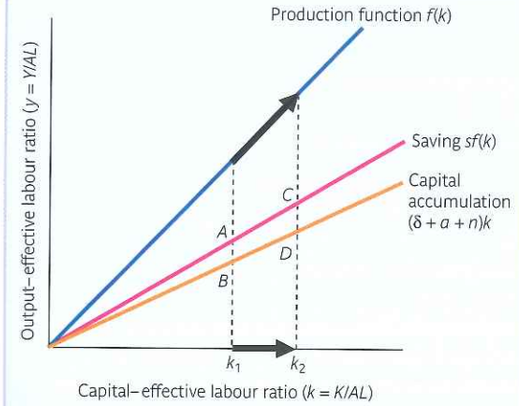

Fig. 4.8 Endogenous Growth with Non-Declining Marginal Productivity

When the marginal productivity of capital is constant, the production function is a straight line. If saving is large enough to exceed depreciation and the need for capital-widening, the capital stock will increase without bound. For example, starting from per capita capital stock k_1, AB represents new capital being installed, which takes the economy to k_2. There, CD corresponds to a further increase in the capital stock, and so on.

We have thus found a sufficient condition for endogenous growth: the marginal product of capital must stop declining. The question is whether this condition is reasonable and whether it occurs in reality. The next two sections outline some possible economic mechanisms which could give rise to endogenous growth.

4.4.2 Externalities and Constant Returns in Accumulated Factors

One important reason that the marginal product of capital ceases to decline is because the law of diminishing returns no longer holds. For some reason, the accumulation of capital—physical as well as human or infrastructural capital—no longer diminishes its marginal product *from the perspective of the aggregate economy*. The English economist Alfred Marshall hypothesized that the perceived effect of an individual's actions can differ substantially from the factual outcome if others act in the same way. In particular, while each individual perceives diminishing marginal returns to investment, it could well be that, when *everyone* engages in the same activity, effective marginal productivity does not fall, but remains constant. Marshall, in fact, was introducing a new concept—economic externality.

An externality occurs when the actions of individuals affect the welfare or productivity of others in ways which are not mediated by the market. For example, someone listening to loud music may disturb those around him; he imposes a cost on others but one for which there is no market. There is no market because a property right is not assigned: it is not clear whether one owns the 'right' to quiet surroundings or to listen to music in an unrestricted way. This is an example of a negative externality, because one's action imposes a cost on others. Externalities can also be positive. For instance, working alongside skilled and educated people may increase your own productivity as they give you tips and provide advice.

That individual activities could increase aggregate productivity, even if the individual does not perceive any effect of his own actions, is an example of **Marshallian externality**. If the Marshallian externality creates conditions of constant returns to scale with respect to accumulated factors *only*—physical capital,

Box 4.3 Constant Returns in Accumulated Factors: Some Mathematical Examples

Using the Cobb–Douglas production function,[12] it is easy to see how constant returns in accumulated factors could arise and lead to the production function shown in Figure 4.8.

The simplest example involves human capital. Suppose that aggregate output of an economy is given by the function $Y = K^{\alpha}(AL)^{1-\alpha}$, and that $A = H$, that is, human capital is the same thing as labour augmenting technical progress. A doubling of human and physical capital will lead to a doubling of output, holding labour input constant. If agents save constant fractions s_K and s_H of their income in physical and human capital, respectively, then K and H will grow along a steady-state growth path at the same rate as Y. In addition, this rate will depend on the savings rates s_K and s_H.

A second example of constant returns in the accumulated factors involves infrastructure. Let K^G be the stock of infrastructure capital described in Section 4.2.2, and is financed by taxation on output at the rate τ: $\Delta K^G = \tau Y$. Let the production function be $Y = AK^{\alpha}L^{1-\alpha}$. Finally, let $A = (K^G)^{\gamma}$, meaning that total factor productivity is increasing in infrastructure, but at a decreasing rate ($\gamma < 1$). Under these conditions, the economy's production function is given by $Y = (K^G)^{\gamma}K^{\alpha}L^{1-\alpha}$. If $\gamma = 1-\alpha$, the economy has constant returns in K and K^G, the two factors which can be accumulated by saving out of current income, and will behave exactly as in Figure 4.8. Here the tax rate τ acts like the savings rate. Note that a similar argument could be made for human capital, substituting H for K^G throughout the example. This would lend support to the case for government-financed education.

A third example is a Marshallian externality. Suppose an economy consists of a very large number of identical firms, each producing with the same production function $Y_i = AK_i^{\alpha}L_i^{1-\alpha}$. But now suppose that A depends on the sum of what all the producers are doing, but no single producer can perceive her individual effect on A. To make the point, let $A = Z^{\gamma}$ where Z is an indicator of the sum of all the capital inputs of the individual firms: $Z = \Sigma_i K_i$ and assume that $\gamma < 1$. Again, if $\gamma = 1-\alpha$, this economy will have constant returns in capital alone, even though no individual producer perceives this to be the case.

All these examples require restrictive assumptions on the parameters of the model. In the first, human capital acts as labour-augmenting technical progress without any slippage (loss of marginal productivity). The second two cases require the 'knife-edge' condition $\gamma = 1-\alpha$. These assumptions led Robert Solow, the intellectual father of growth theory, to criticize models of endogenous growth precisely because they lack robustness, i.e. they are sensitive to such assumptions. If there is little reason to believe that these conditions hold exactly, the overall plausibility of the conclusions is easy to challenge.

human capital, or infrastructure—then the marginal product of capital need not decline with growth, and endogenous growth is possible. In Box 4.3, the mathematics of such conditions is spelled out in more detail.

4.4.3 Knowledge

The term A has been defined as 'the state of technology', but what is it exactly? A very particular feature of knowledge is that it is a **public good**. Two features characterize public goods. First, they are **non-excludable**, meaning that the consumer of a good cannot legally or physically prevent others from consuming it at the same time. Second, they are **non-rivalrous** to the extent that the consumption of a good by one person does not affect others' ability to enjoy it. Table 4.2 shows how goods and services we encounter in our economic life can be classified according to their excludability or the rival nature of their use. Knowledge turns out to be both non-excludable and non-rival. It is non-excludable because, once produced, it tends to be freely available. In the form of education, internet, or TV and radio programmes, knowledge is also non-rival; the consumption by one person does not preclude someone else from consuming (or using) it at the same time.

[12] The Cobb–Douglas production function was introduced in Box 3.2.

Table 4.2 Non-rivalrousness and Excludability: A Taxonomy of Goods

	Rivalrous	Non-rivalrous
Excludable	Most conventionally marketed private goods	Police protection, patented inventions, copyrighted material, subscription cable television programming
Non-excludable	Parking spaces, public tennis courts, beaches, park benches, congested highways	National defence, good weather, radio/television programming, internet, knowledge

Because knowledge can be used over and over again, it cannot be characterized by diminishing returns. Some mathematical formulae from ancient times (e.g. the area of a circle) have been put to such extensive use since their discovery that they could well be among the most productive investments ever made! Yet, as Box 4.4 shows, the ultimate discoverers are frequently underpaid for their efforts. This crucial observation implies that, under intuitive and plausible conditions, knowledge can be the secret to endless growth.

Innovation and knowledge creation represent a clear case of a positive externality. Social gains resulting from the activities of creative, inventive thinkers generally exceed their private return. But the creation of new knowledge does not come free. Innovators work hard and invest lots of their own money in their ideas, blueprints, and inventions—as well as money of investors. It is hard to know whether these contributions to economic activity will be remunerated sufficiently. Will the inventors of the next wonder drug or telecommunication device reap rewards for their hard work, or will copycats or 'intellectual pirates' steal the idea? And because they do, will the inventors and investors expend less effort than they should to achieve their goals? Later we discuss how societies encourage this engine of growth by establishing property rights over ideas for some limited time, enforcing them with judicial systems, and thereby seeking to encourage entrepreneurial activity essential to research and development.

Box 4.4 The Origins of Icons

Because it is easy to borrow, copy, or steal new ideas or basic research results, innovative activity frequently yields far greater gains to society than to the clever individuals who first came up with them. A striking new example is the 'technology' of icons, cursors/pointers, double-clicking, and windows. This paradigm for working with information was developed by the Xerox Corporation in their Palo Alto research facility in the 1970s, before personal computers and the mouse were even invented. Apple was able to convert the technology into a usable system and Microsoft, Intel, and other companies were able to make enormous amounts of money on what was essentially a free technology.

Describing the invention, Professor DeLong of Berkeley writes:

The net result? Large benefits to the economy and the society in terms of expanded productivity growth from the work carried on at Xerox's Palo Alto Research Center in the 1970s. But barely a cent returned in revenues to Xerox from this particular drain on its cash flow. Companies that are in business to make money will not long spend a great time and effort on such research projects that do not boost productivity and revenues, even if they boost industry productivity and revenues manifold. Thus there is every reason to believe that the private sector tends to underinvest in research and development.

4.4.4 Evidence for Endogenous Growth: Long Waves

Innovations add to our stock of knowledge but they come in many forms and shapes: new ideas (e.g. Newton's discovery of gravity), new techniques (electricity, the steam and combustion engines, computers), new processes (float glass, household appliances, the internet), or new consumer brands, designs, and products. How do these major discoveries really occur?

One view is that discoveries appear more or less randomly. R&D produces innovations, some big, some small, continuously restarting growth by boosting the existing technology. Another view, initially proposed by Harvard economist Joseph Schumpeter, is that big discoveries tend to be associated with long-term waves in economic activity, because they are followed by a number of subsequent, related secondary innovations. Figure 4.9 shows the average annual rate of increase in total factor productivity. We see a sharp acceleration in the UK and the USA early on in the twentieth century, which continues until the early 1970s. This wave is often associated with a succession of great inventions in the latter part of the nineteenth century: electricity, engines, petro-chemistry, pharmaceuticals, telephone, radio, etc. According to Schumpeter's vision of innovations, major innovations were bunched in their occurrence but required decades to diffuse across the economy.

To explain why innovation came in long waves, Schumpeter puts the entrepreneur at centre stage. When growth slows, some enterprising managers react by investing more in risky R&D projects. More research effort eventually pays off, producing a number of innovations that emerge more or less simultaneously, all within a decade or two. As profits rise spectacularly, fierce competition sets in. Competition takes two forms: improvements and **imitation**. Both erode monopoly power of the original innovators, eating into their profits and reducing their ability and desire to pursue vigorous R&D. Technological progress slows down, ending the big wave of accelerated growth. As profits gradually decline, a new generation of entrepreneurs emerge and prepare the next long wave.

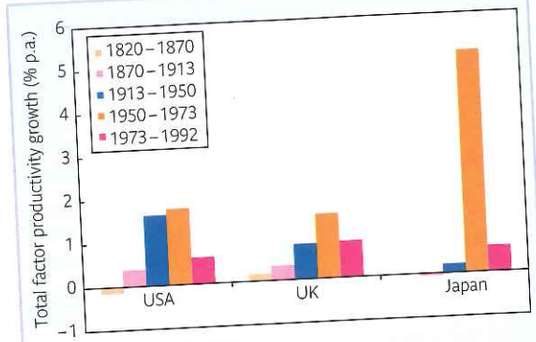

Fig. 4.9 Long Waves
Sustained increases in technological changes seem to come in long-lasting waves.
Source: Maddison (1995).

The **Schumpeterian theory of innovation** represents one of the most compelling accounts of the evolution of growth of advanced economies over the past two centuries. Although we still lack sufficient data to firmly establish its validity, the Schumpeter account is supported by the fact that long waves in growth occur across countries together, and that leading nations do tend to grow in a synchronous way. This supports the notion that innovations involve ideas and knowledge which travel rather well across national boundaries, even if they require some time. The leading nations tend to be those which innovate frequently, pushing out the frontiers of technological possibilities, while follower nations adopt later and adapt or perfect the technologies.

4.5 Growth Policy

What can governments do to increase long-run economic growth? When the issue of policy arises it is usually a good idea to follow the rule 'if it ain't broke, don't fix it'. In properly functioning economies, it is best to let the interplay of households and firms run its course, unless a convincing case for government policy can be made. A good example is the savings rate. According to the Solow model of Chapter 3, nations which save a greater fraction of their income will have a higher level of GDP per capita, but this certainly does not imply that the government should increase the national savings rate. The golden rule (Section 3.3.5) made it clear that a higher savings rate does not necessarily mean more consumption per capita, or more welfare for that matter.

Much of the discussion of Sections 4.3 and 4.4 centred around missing and possibly non-marketed factors in the production function and externalities. Here it is possible to make a convincing case for government intervention. Among other things, it may pay off to subsidize education, research and development, other innovative activities, and even certain types of investment spending. It may be worth improving the rewards to entrepreneurial activity, but it may also make sense to increase protection of innovators from copycat activity. It is generally a good idea to encourage trade and a stable economic environment. In the following sections we briefly discuss these policy options.

4.5.1 Education and Research

It is well established that education is a key factor for economic growth. Although education is frequently a private investment, it is difficult to borrow money to pay for it. Unlike many investments, human capital does not involve collateral, an asset which can be pledged in case repayment of the loan does not occur. While firms can raise money from banks, stock markets, or their owners to buy equipment, many people cannot pay for their own education, especially in poor countries. The usual response is that governments provide public education, along with scholarships for poorer students. Yet if the returns from education are better salaries, should the state provide public money for private benefit? The answer may still be yes, if human capital creates a Marshallian externality. Being the only one in a country who knows how to read and write is less useful, both privately and collectively, if most others cannot read and write. As noted in Box 4.3, human capital may not face diminishing marginal productivity at the collective level.

Human capital is a linchpin for any theory of growth which is based on inventions and innovation. It raises current productivity and helps speed the **diffusion** of innovations. Figure 4.10 shows that countries that began the growth journey in 1960 with more average schooling generally grew at a faster pace over the next four to five decades, but the correlation is not perfect. One interpretation is the message of conditional convergence in Section 4.2 of this chapter: a low stock of human capital hampers growth, *ceteris paribus*, for reasons expressed by equation (4.2) and Figure 4.2.

As an example, compare the Republic of Korea and Honduras. In 1960, the GDPs per capita of the two countries were roughly equal. By 2005, Korea's GDP per capita exceeded that of Honduras *by a factor of 667%*. The most striking difference between the two countries appears to be education. In 1960, the average Korean had almost twice as much completed years of schooling than the average Honduran.

Naturally, causality could and probably does also run the other way as well. Poor countries simply cannot afford accumulating much human capital, given the costs of education systems. We need not choose between these two interpretations, because *both* can be correct at the same time. Taken together, they suggest the existence of poverty traps: poor countries cannot invest enough in human capital, which in turn hinders growth. For the same reasons, individuals too can be trapped in poverty, even in developed countries. This represents a key justification for means-tested scholarships for bright students.

Externalities can also justify state subsidies for research laboratories. Indeed, a great deal of research—especially basic research—must be funded by government or non-profit institutions. But then, the problem encountered with public infrastructure also arises with knowledge: it is difficult if not impossible to determine the proper level of public financing of research. To make things even more complicated, research is inherently uncertain and often entails very long gestation periods, it is a risky undertaking. This all makes it very possible that not enough is spent on an activity that is obviously not politically attractive and yet, over the long haul, may be an essential source of increases in standards of living.

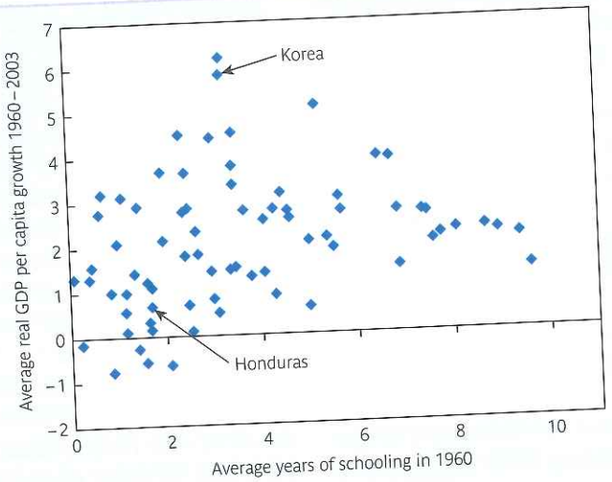

Fig. 4.10 Human Capital and Economic Growth, 1960–2003
The initial endowment of human capital—expressed crudely as average years of schooling in 1960—is strongly positively correlated with real growth over the following 4–5 decades. The cases of Honduras and Korea are striking examples of the correlation between education and growth.

4.5.2 Intellectual Property, Patents, and Competition Policy

Because knowledge is unlikely to face diminishing returns, it is a potential source of endless growth. To encourage the private production of knowledge, governments should protect its excludability for some period. Policies have been designed over the centuries to do precisely this. One is the **patent**. A patent confers the exclusive legal right on its owner to exploit an invention commercially, usually for a limited period of time. While not generally granted to ideas per se, patent protection is reserved for inventions that are sufficiently novel and wide-reaching. Similarly, **copyrights** safeguard artistic expression from plagiarism or outright duplication, and **trademarks** recognize exclusive use of a name or symbol to distinguish a firm's product in the market place. Like patents, copyrights and trademarks establish **intellectual property rights** on certain forms of knowledge.

With the possibility of obtaining intellectual property rights, investing in innovation—R&D, artistic expression, and brand development—can pay off. For some period, the holder of the patent can charge prices which are at least high enough to cover the costs of the research and development of the product. But there is a side-effect: patents confer monopoly power on their owners and thus allow them to charge much more than development costs. In one sense, monopoly is bad, since it allows the seller to set monopoly prices. Because demand is discouraged, patents limit the full exploitation of useful knowledge. At the same time, patents offer powerful incentives to researchers. Without them, knowledge creation and its contribution to economic growth would probably proceed at a much slower pace. As Box 4.5 shows, the border between fair remuneration and exploitation of monopoly power is arbitrary and subject to considerable legal wrangling.

Even if patent protection confers monopoly power on their inventors, it may be a necessary evil for promoting the production of knowledge and thus for economic growth. If the widely shared benefits of knowledge production are not reflected in their compensation, researchers will not deliver as much innovation as is socially desirable, if only because too few bright students will choose this career. Viewed this way, it is perhaps less objectionable that successful innovators derive extra profits from their temporary monopoly power. Naturally, after an invention is patented, the owner of the patent will charge a high price, possibly even higher than normal costs would warrant. Given that the invention has become public knowledge, governments have a strong *ex post* incentive to abrogate the original patent agreement. This would clearly make everyone better off in the short run, but would probably bring research and development to a standstill, since the promise of a patent would no longer be credible. For this reason, governments generally avoid breaking their promises.

Box 4.5 Protecting and Punishing Monopolists

To some people, Bill Gates is a bad, mean monopolist. Monopoly rights belonging to the Microsoft Corporation have made him into one of the richest men in the world, since virtually every computer in the world is equipped with its software products. Perhaps this is why many cheered when the US Department of Justice and the European Commission initiated lawsuits against Microsoft. The lawsuits, however, were not about monopoly power derived from legal patents and copyrights. They were aimed at Microsoft's alleged stifling or even elimination of new competitor products and services. While Microsoft has made it possible for hundreds of millions of people to use computers for work and pleasure, history and innovations must continue. New innovators will continue to improve computers' software, and should be encouraged to do so.

Microsoft's encounter with justice is reminiscent of an equally famous trial pitting the US Justice Department against International Business Machines (IBM) in the late 1970s. At the time, IBM dominated the computer hardware industry: PCs didn't exist, and there was hardly a competitor which could produce powerful mainframe computers the way IBM did. The charge was very similar. IBM was accused of using its dominant position to eliminate new competitors. In the end, IBM argued that it retained its lead only thanks to its ability to innovate, and was hard-pressed to do so because of pressure from the competition. IBM won twice. The case against it was dismissed and its argument was soon proved correct as it lost ground to competition, especially with respect to small portable computers and networking machines. In relative terms, IBM is now a shadow of its former self. Microsoft was punished severely by the European Commission for not revealing details about its operating system software to firms which use it. Whether it will soon become a minor player remains to be seen.

An altogether different story involves the pharmaceutical industry. Most wonder drugs are indeed patented, and their inventors reap massive profits. What makes the case different is that drugs are paid for by health insurance, private or public. Insurance agencies agree with the pharmaceutical industry on 'fair' prices, which exceed the marginal cost of producing the drugs by a factor commonly believed to be ten or more. Pharmaceutical firms claim that this is the only way for them to recoup the huge costs of R&D. Critics call the industry's profits excessive, but find it difficult to find solid evidence to back their claim. They correctly note that a significant part of humanity cannot afford these drugs and die or are permanently incapacitated as a result, a fact most recently underlined by the global AIDS epidemic. Even more troubling is the absence of priority in the pharmaceutical research community to develop drugs which could eliminate tropical diseases, such as malaria, which kill or cripple hundreds of thousands. These diseases are ignored because they affect primarily poor people in poor countries with no ability to pay for the R&D costs.

4.5.3 Openness to Trade and Competition

International trade is an engine of growth. First, openness to trade and the resulting competition from foreign firms serves to spread knowledge and technology across national boundaries. Competition encourages domestic firms to adopt leading-edge production techniques and become more efficient. Multinational corporations, which operate in several countries at once, serve as an important channel in the diffusion of innovations. This view is based on the phenomenon of **learning by doing**, whereby people and firms improve their knowledge on the job. When a multinational establishes a production unit in a developing country, it usually brings with it a technology invented in its home country. Individuals who work in such firms acquire the technology and can subsequently create their own firms based on the new technology, or migrate to other firms which can then tool up. This possibility should

be kept in mind when considering controversies that surround multinational corporations. From a *social* perspective, they contribute to convergence by accelerating the diffusion of innovations and thus the transfer of knowledge.

Growth and openness to international commerce are known to be positively related. Countries which have large trade exposure—measured as the ratio of exports plus imports to GDP—tend to grow faster. The experience of more open Western European countries, and especially the Asian Tigers of the last two decades, suggest that open economies grow faster, all things considered. This faster growth can be attributed to a number of possible effects. First, closed economic systems impede the transfer of knowledge, effectively excluding some individuals from what should be a non-excludable good. Openness allows for ideas to flow more easily across national boundaries. Second, openness means increased competition from abroad. Domestic producers cannot rely on protection to shield their market positions from the threat of imports. They must constantly remain at the 'cutting edge' of new areas of innovation and development. To use the terminology of Section 4.4.3, this requires either innovation or imitation; either will have positive effects on productivity and growth.

4.5.4 Politics: Democracy, Equality, and Stability

We saw in Section 4.3 that credible property rights and peace are important elements of social infrastructure and are essential for economic development. Beyond property rights, the legitimate scope of government and its behaviour should be directed towards establishing stability and continuity, rather than interrupting it. The system of government can therefore do much for economic growth in a passive way: it can work towards the establishment of stable conditions that improve the business climate. Since it is most likely to represent the wishes of its citizens, democracy should be the ideal means of translating the common will into policy. Democracy should be conducive to a better growth performance, for all the reasons reviewed so far: property rights, economic and political stability, health, and institutions which have broad public acceptance.

Democracies are not perfect institutions, and the relationship between democracy and economic growth is a controversial one. Democratically elected governments may change frequently—with shifting coalitions of smaller parties, for example—and this may lead to constantly changing tax and expenditure policy. This type of uncertainty, especially if it applies to the taxation of physical or human capital, may deter longer-term projects from being undertaken. The rule of majority does not necessarily protect minorities from violations of property and human rights. Such actions may include legal pressure on 'the rich', ranging from nationalizations to heavy taxation, both of which discourage investment. At the same time, well-organized lobbies in many democracies enable wealthy minorities to exert disproportionate influence on decision-making.

Democracies often find it difficult to organize the sacrifices necessary for sustained economic growth. Some salient examples are: (1) increasing the savings rate to accumulate capital for future generations; (2) the restructuring of economic activity, which implies the painful decline of some sectors (agriculture, mining, or heavy industries, for example); (3) reform of the social safety net and labour market regulations, and (4) migration towards cities, which is accompanied by some degree of social and family dislocation. In facing up to such painful changes, democracies can encounter political difficulties. Some have concluded that only dictatorships are capable of suppressing opposition to changing conditions long enough for economic growth to take hold. In their view, democracy is a luxury that only rich societies can afford.

It is for this reason that the best-functioning democracies operate within a widely accepted constitutional framework which is designed to be difficult for simple majorities to change. In such a setting, democracies offer many economic advantages. Only democracies have the legitimacy to guarantee the property rights needed for investment in human and physical capital (see Section 4.3). Inequality, which is an unavoidable by-product of market economies, is better tolerated when the political regime receives legitimacy from a majority of citizens. Such legitimacy is probably necessary to carry out the deep reforms that accompany sustained growth. Dictatorships can impose changes, which may be desirable from an economic viewpoint, but soon become as unacceptable as the dictatorship itself, and may be swept away in painful revolutions. Finally, democracies rarely go to war with each other.

Summary

1 The Solow model predicts that countries with identical production functions, savings rates, depreciation rates, and population growth will achieve the same level of production and income per capita, and they will grow at the same rate in the steady state. According to the convergence hypothesis, poorer countries should grow faster than wealthier ones.

2 Empirically, the convergence hypothesis fails in its unconditional form. While rich countries and wealthy regions of the world seem to converge in both level and growth rate of GDP per capita, a large part of the world does not. Many poorer countries appear to be locked in a poverty trap of economic stagnation.

3 The most compelling explanation of the lack of convergence in the data is that production functions are different across countries. Yet these differences are unlikely to be due to different technologies in the narrow sense, since blueprints, information, and techniques are readily transferred across national boundaries. International differences in production functions are mostly due to missing inputs which enhance the productivity of capital and labour.

4 The conditional convergence hypothesis states that nations converge to levels implied by these missing inputs. When they are accounted for, nations do seem to converge to their individual steady states. An important conclusion is that nations can improve their economic condition by increasing their endowments of these missing, complementary inputs: human capital, public infrastructure, and social infrastructure.

5 Human capital is a central missing input in the production function. It ranges from education and training to the health of individuals. Countries with better educated, trained, and healthier workers are more productive, all else constant.

6 Public infrastructure, defined as those public goods which are accessible to all and often provided by the government, include roads and bridges, highways, airports, railways, and hospitals. Public infrastructure is also an important determinant of the position of the production function, all other things being equal.

7 One of the most important missing factors for explaining the poor performance of many nations empirically is social infrastructure. Social infrastructure refers to those 'soft' factors which facilitate economic relations and thereby make all factors of production more effective. These factors include property rights and human rights, but extend to the rule of law and the sustainable absence of armed conflict.

8 Even if missing factors can explain a great deal of growth internationally, explaining the overall evolution of transferable technology in the leading nations remains a central goal of economics. This opens up the possibility of endogenous growth.

9 Endogenous growth is possible when the marginal product of capital or other accumulated factors is bounded from below by a value which exceeds the slope of the capital deepening line. An increase in the savings rate can then lead to permanently higher growth.

10 One of the most promising explanations of endogenous growth lies in seeing research and development as the outcome of economic decisions. This requires understanding the nature of