

Chapter 10

Modern Economic Development

10.1 Introduction

In the previous chapter, we saw that despite the fact of technological progress throughout the ages, material living standards for the average person changed relatively little. It also appears to be true that differences in material living standards across countries (at any point in time) were relatively modest. For example, Bairoch (1993) and Pomeranz (1998) argue that living standards across countries in Europe, China, and the Indian subcontinent were roughly comparable in 1800. Parente and Prescott (1999) show that material living standards in 1820 across the ‘western’ world and ‘eastern’ world differed only by a factor of about 2. Overall, the Malthusian growth model appears to account reasonably well for the pattern of economic development for much of human history.

But things started to change sometime in the early part of the 19th century, around the time of the Industrial Revolution that was occurring (primarily in Great Britain, continental Europe, and later in the United States). There is no question that the pace of technological progress accelerated during this period. The list of technological innovations at this time are legendary and include: Watt’s steam engine, Poncelet’s waterwheel, Cort’s puddling and rolling process (for iron manufacture), Hargreave’s spinning jenny, Crompton’s mule, Whitney’s cotton gin, Wilkensen’s high-precision drills, Lebon’s gas light, Montgolfiers’ hydrogen balloon, and so on. The technological innovations in the British manufacturing sector increased output dramatically. For example, the price of cotton declined by 85% between 1780 and 1850. At the same time, per capita incomes in the industrialized countries began to rise measurably for the first time in history.

It is too easy (and probably wrong) to argue that the innovations associated with the Industrial Revolution was the ‘cause’ of the rise in per capita income in the western world. In particular, we have already seen in Chapter 9 that technological progress does not in itself guarantee rising living standards. Why, for example, did the rapid pace of technological development simply not dissipate itself entirely in the form of greater populations, consistent with historical patterns?¹ Clearly, something else other than just technological progress must be a part of any satisfactory explanation.

As per capita incomes began to grow rapidly in countries that became industrialized (i.e., primarily the western world), living standards in most other countries increased at a much more modest pace. For the first time in history, there emerged a large and growing disparity in the living standards of people across the world. For example, Parente and Prescott (1999) report that by 1950, the disparity in real per capita income across the ‘west’ and the ‘east’ grew to a factor of 7.5; i.e., see Table 10.1.

Year	West	East	West/East
1820	1,140	540	2.1
1870	1,880	560	3.3
1900	2,870	580	4.2
1913	3,590	740	4.8
1950	5,450	727	7.5
1973	10,930	1,670	6.5
1989	13,980	2,970	4.7
1992	13,790	3,240	4.3

The data in Table 10.1 presents us with a bit of a puzzle: why did growth in the east (as well as many other places on the planet) lag behind the west for so many decades? Obviously, most of these countries did not industrialize themselves as in the west, but the question is why not? It seems hard to believe that people living in the east were unaware of new technological developments or unaccustomed to technological progress. After all, as was pointed out in the previous chapter, most of the world’s technological leaders have historically been located in what we now call the east (the Moslem world, the Indian subcontinent, China). At the same time, it is interesting to note that the populations in the eastern world exploded over this time period (in accord with the Malthusian model).

Some social scientists (notably, those with a Marxian bent) have laid the blame squarely on the alleged exploitation undertaken by many colonial powers (e.g., Great Britain in Africa). But conquest and ‘exploitation’ have been with us throughout human history and has a fine tradition among many eastern

¹While populations did rise in the west, total income rose even faster.

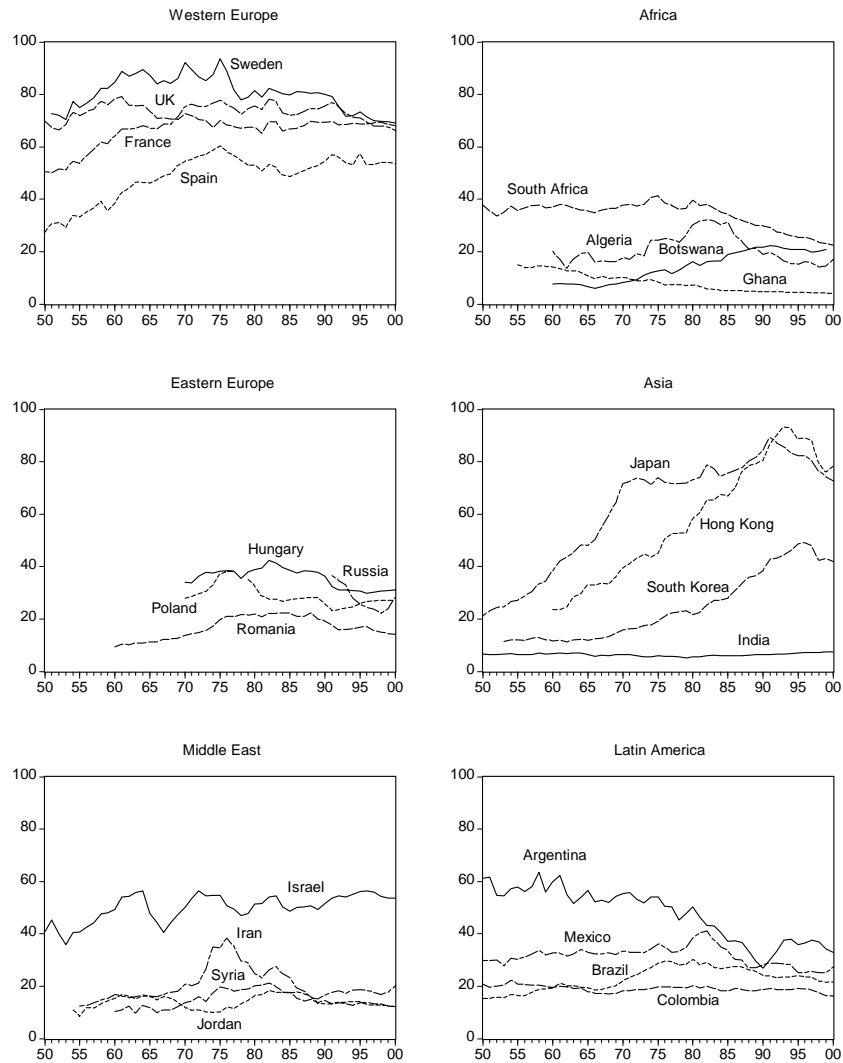
cultures too. So, perhaps one might ask why the east did not emerge as the world's colonial power?

In any case, it simply is not true that all eastern countries were under colonial domination. For example, Hong Kong remained a British colony up until 1997 while mainland China was never effectively controlled by Britain for any length of time. And yet, while Hong Kong and mainland China share many cultural similarities, per capita incomes in Hong Kong have been much higher than on the mainland over the period of British 'exploitation.' Similarly, Japan was never directly under foreign influence until the end of the second world war. Of course, this period of foreign influence in Japan happens to coincide with a period of remarkable growth for the Japanese economy.

Table 10.1 reveals another interesting fact. Contrary to what many people might believe, the disparity in per capita incomes across many regions of the world appear to be diminishing. A large part of this phenomenon is attributable to the very rapid growth experienced recently by economies like China, India and the so-called 'Asian tigers' (Japan, South Korea, Singapore, Taiwan). So again, the puzzle is why did (or have) only some countries managed to embark on a process of 'catch up' while others have been left behind? For example, the disparity in incomes across the United States and some countries in the sub-Saharan African continent are still different by a factor of 30!

The 'development puzzle' that concerns us can be looked at also in terms of countries within the so-called western world. It is not true, for example, that all western countries have developed at the same pace; see, for example, Figure 10.1. The same can be said of different regions within a country. For example, why are eastern Canadian provinces so much poorer than those in central and western Canada? Why is the south of Italy so much poorer than the north? Why is the northern Korean peninsula so much poorer than the South (although, these are presently separate countries)? In short, what accounts for the vast disparity in per capita incomes that have emerged since the Industrial Revolution?

FIGURE 10.1
Real per Capita GDP Relative to the United States
Selected Countries



10.2 The Solow Model

The persistent rise in living standards witnessed in many countries and the large disparity in per capita incomes across countries are facts that are difficult to account for with the Malthusian model. For this reason, economists turned to developing an alternative theory; one that would hopefully be more consistent with recent observation. The main model that emerged in the mid-20th century was the so-called Solow growth model, in honor of Robert Solow who formalized the basic idea in 1956 (Solow, 1956). Keep in mind that, like the Malthusian model, the Solow model does not actually explain why technological progress occurs; i.e., it treats the level (and growth rate) of technology as an exogenous variable. The name of the game here is see whether differences in per capita incomes can be explained by (exogenous) technological developments (among possibly other factors).

We remarked in Chapter 9 that China has much more cultivated land per capita as Great Britain. But what then accounts for the higher standard of living in Great Britain? One explanation is to be found in the fact that Great Britain has considerably more railroads, refineries, factories and machines per capita. In other words, Great Britain has more *physical capital* per capita (a higher capital-labor ratio) relative to China (and indeed, relative to Great Britain 100 years ago). Of course, this does not answer the question of *why* Britain has more physical capital than China. The model of endogenous fertility choices in Chapter 9 suggests that one reason might be that the institutional environment in China is (or was) such that the Chinese (like many lesser developed economies in history) are restricted from accumulating physical or financial assets, so that ‘retirement saving’ must be conducted through family size.²

In any case, the Solow model is firmly rooted in the model developed in Chapter 8, which assumes that individuals can save through the accumulation of physical and/or financial assets. Now, unlike land, which is largely in fixed supply (this is not exactly true, since new land can be cultivated), the supply of physical capital can grow with virtually no limit by producing new capital goods. Hence, the first modification introduced by the Solow model is the idea that output is produced with both labor and a time-varying stock of physical capital; i.e.,

$$Y_t = F(K_t, N_t), \quad (10.1)$$

and that the capital stock can grow with net additions of new capital. Let X_t denote gross additions to the capital stock (i.e., gross investment). Assuming that the capital stock depreciates at a constant rate $0 \leq \delta \leq 1$, the net addition to the capital stock is given by $X_t - \delta K_t$, so that the capital stock evolves according to:

$$K_{t+1} = K_t + X_t - \delta K_t. \quad (10.2)$$

²Of course, this does not explain why the institutional environments should differ the way that they do.

Of course, by allocating resources in an economy toward the construction of new capital goods (investment), an economy is necessarily diverting resources away from the production (and hence consumption) of consumer goods and services. In other words, individuals as a group must be *saving*. In the Malthus model, individuals were modeled as being either unwilling or unable to save. Perhaps this was a good description for economies prior to 1800, but is not a good description of aggregate behavior since then. Thus, the second modification introduced by the Solow model is the idea that a part of current GDP is saved; i.e.,

$$S_t = \sigma Y_t, \quad (10.3)$$

where $0 < \sigma < 1$ is the *saving rate*. In the Solow model, the saving rate is viewed as an exogenous parameter. However, as we learned in Chapter 6, the saving rate is likely determined by ‘deeper’ parameters describing preferences (e.g., time preference) and technology.

The final modification made by the Solow model is in how it describes population growth. Unlike the Malthus model, which assumed that mortality rates were a decreasing function of living standards, the Solow model simply assumes that the population growth rate is determined exogenously (i.e., is insensitive to living standards and determined largely by cultural factors). Consequently, the population grows according to:

$$N_{t+1} = (1 + n)N_t, \quad (10.4)$$

where n denotes the *net* population growth rate.

We are now in a position to examine the implications of the Solow model. We can start with the production function in (10.1), letting $F(K, N) = K^{1-\theta} N^\theta$ as we did earlier. As before, we can define per capita output $y_t \equiv Y_t/N_t$ so that:

$$y_t = \left(\frac{K_t}{N_t} \right)^{1-\theta} \equiv f(k_t),$$

where $k_t \equiv K_t/N_t$ is the capital-labor ratio. Thus, per capita output is an increasing and concave function of the capital-labor ratio (try drawing this).

By dividing the saving function (10.3) through by N_t , we can rewrite it in per capita terms:

$$\begin{aligned} s_t &= \sigma y_t; \\ &= \sigma f(k_t). \end{aligned} \quad (10.5)$$

Now, take equation (10.2) and rewrite it in the following way:

$$\frac{N_{t+1} K_{t+1}}{N_{t+1} N_t} = \frac{K_t}{N_t} + \frac{X_t}{N_t} - \frac{\delta K_t}{N_t}.$$

Using equation (10.4), we can then express this relation as:

$$(1 + n)k_{t+1} = (1 - \delta)k_t + x_t, \quad (10.6)$$

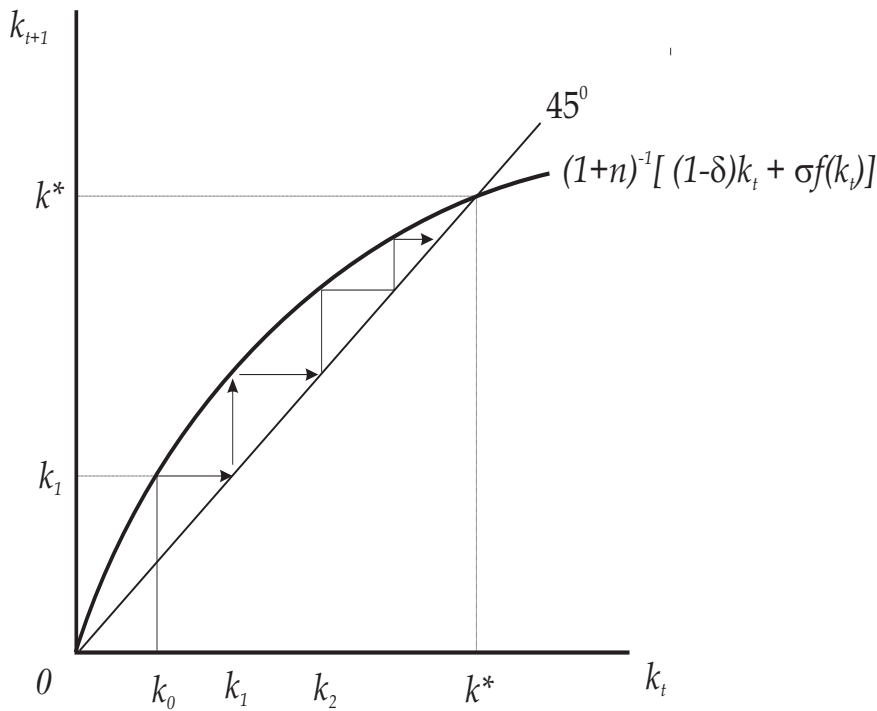
where $x_t \equiv X_t/N_t$.

In a closed economy, net saving must equal net investment; i.e., $s_t = x_t$. We can therefore combine equations (10.5) and (10.6) to derive:

$$(1+n)k_{t+1} = (1-\delta)k_t + \sigma f(k_t). \quad (10.7)$$

For any initial condition k_0 , equation (10.7) completely describes the dynamics of the Solow growth model. In particular, given some k_0 , we can use equation (10.7) to calculate $k_1 = (1+n)^{-1}[(1-\delta)k_0 + \sigma f(k_0)]$. Then, knowing k_1 , we can calculate $k_2 = (1+n)^{-1}[(1-\delta)k_1 + \sigma f(k_1)]$, and so on. Once we know how the capital-labor ratio evolves over time, it is a simple matter to calculate the time-path for other variables since they are all functions of the capital-labor ratio; e.g., $y_t = f(k_t)$. Equation (10.7) is depicted graphically in Figure 10.2.

FIGURE 10.2
Dynamics in the Solow Model



As in the Malthus model, we see from Figure 10.2 that the Solow model predicts that an economy will converge to a steady state; i.e., where $k_{t+1} =$

$k_t = k^*$. The steady state capital-labor ratio k^* implies a steady state per capita income level $y^* = f(k^*)$. If the initial capital stock is $k_0 < k^*$, then $k_t \nearrow k^*$ and $y_t \nearrow y^*$. Thus, in contrast to the Malthus model, the Solow model predicts that real per capita GDP will *grow* during the transition period toward steady state, even as the population continues to grow. In the steady state, however, growth in per capita income ceases. Total income, however, will continue to grow at the population growth rate; i.e., $Y_t^* = f(k^*)N_t$.

Unlike the Malthus model, the Solow model predicts that growth in per capita income will occur, at least in the ‘short run’ (possibly, several decades) as the economy makes a transition to a steady state. This growth comes about because individuals save output to a degree that more than compensates for the depreciated capital and expanding population. However, as the capital-labor ratio rises over time, diminishing returns begin to set in (i.e., output per capita does not increase linearly with the capital-labor ratio). Eventually, the returns to capital accumulation fall to the point where just enough investment occurs to keep the capital-labor ratio constant over time.

The transition dynamics predicted by the Solow model may go some way to partially explaining the rapid growth trajectories experienced over the last few decades in some economies, for example, the ‘Asian tigers’ of southeast Asia (see Figure 10.1). Taken at face value, the explanation is that the primary difference between the U.S. and these economies in 1950 was their respective ‘initial’ capital stocks. While there may certainly be an element of truth to this, the theory is unsatisfactory for a number of reasons. For example, based on the similarity in per capita incomes across countries in the world circa 1800, one might reasonably infer that ‘initial’ capital stocks were not very different in 1800. And yet, some economies industrialized, while others did not. Transition dynamics may explain a part of the growth trajectory for those countries who chose to industrialize at later dates, but it does not explain the long delay in industrialization.

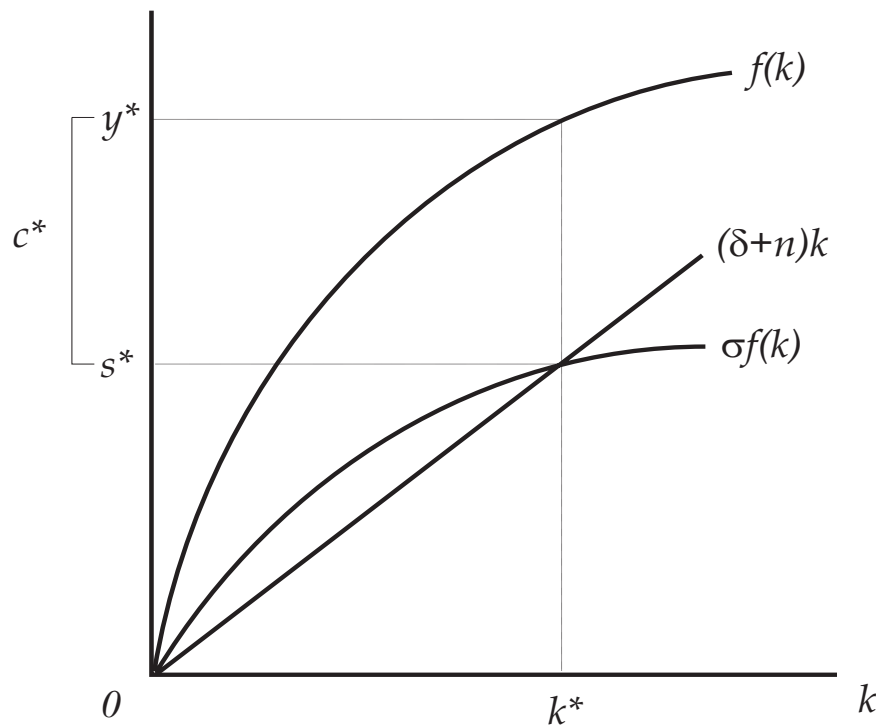
10.2.1 Steady State in the Solow Model

Because the level of income disparity has persisted for so long across many economies, it may make more sense to examine the steady state of the Solow model and see how the model interprets the source of ‘long-run’ differences in per capita income. By setting $k_{t+1} = k_t = k^*$, we see from equation (10.7) that the steady state capital-labor ratio satisfies:

$$\sigma f(k^*) = (n + \delta)k^*. \quad (10.8)$$

Equation (10.8) describes the determination of k^* as a function of σ , n , δ and f . Figure 10.3 depicts equation (10.8) diagrammatically.

FIGURE 10.3
Steady State in the Solow Model

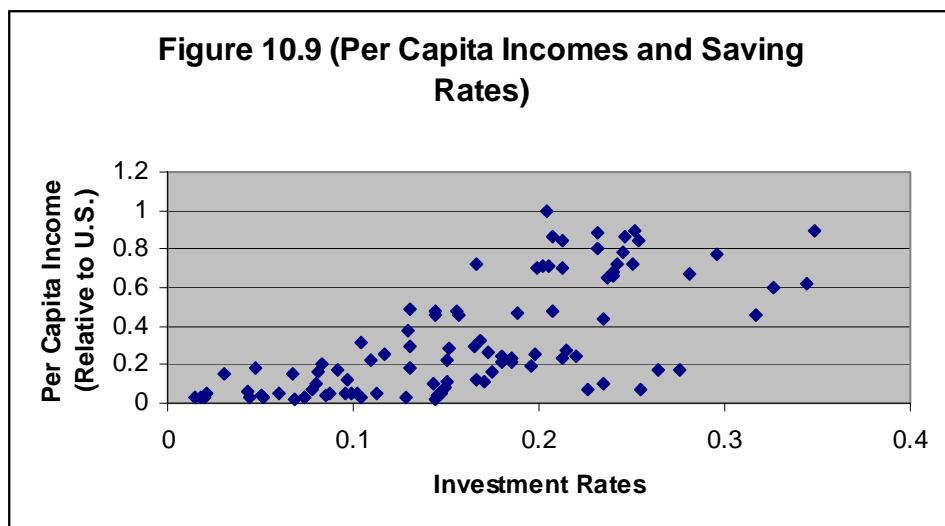


According to the Solow model, exogenous differences in saving rates (σ), population growth rates (n), or in technology (f) may account for differences in long-run living standards (y^*). Of course, the theory does not explain why there should be any differences in these parameters, but let's leave this issue aside for the moment.

10.2.2 Differences in Saving Rates

Using either Figure 10.2 or 10.3, we see that the Solow model predicts that countries with higher saving rates will have higher capital-labor ratios and hence, higher per capita income levels. The intuition for this is straightforward: higher rates of saving imply higher levels of wealth and therefore, higher levels of income.

Using a cross section of 109 countries, Figure 10.9 plots the per capita income of various countries (relative to the U.S.) across saving rates (using the investment rate as a proxy for the saving rate). As the figure reveals, there appears to be a positive correlation between per capita income and the saving rate; a prediction that is consistent with the Solow model.



- **Exercise 10.1.** Consider an economy that is initially in a steady state. Imagine now that there is an exogenous increase in the saving rate. Trace out the dynamics for income and consumption predicted by the Solow model. If the transition period to the new steady state was to take several decades, would all generations necessarily benefit from the higher long-run income levels?
- **Exercise 10.2.** According to the Solow model, can sustained economic growth result from ever rising saving rates? Explain.

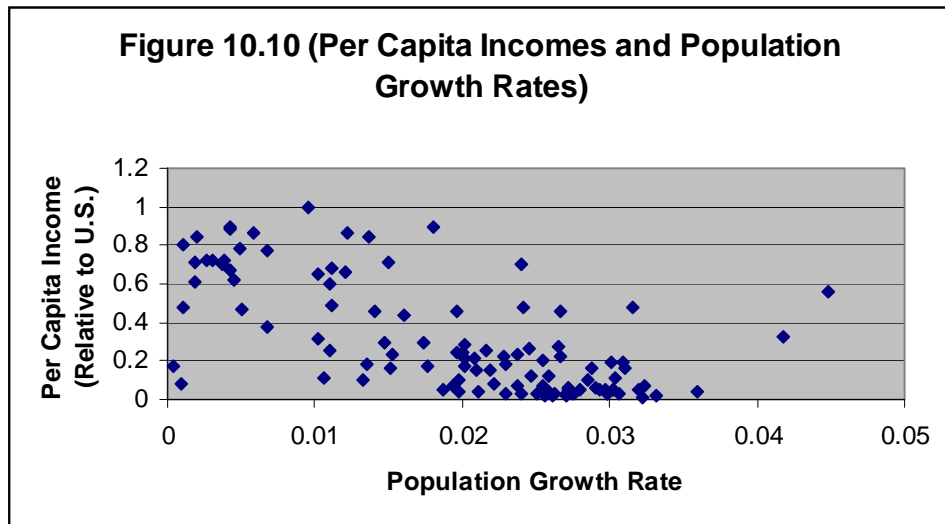
The deeper question here, of course, is why countries may differ in their rate of saving. One explanation may be that savings rates (or the discount factor in preferences) are ‘culturally’ determined. Explanations that are based on ‘cultural’ differences, however, suffer from a number of defects. For example, when individuals from many cultures arrive as immigrants to a new country, they often adopt economic behavior that is more in line with their new countrymen. As well, many culturally similar countries (like North and South Korea) likely

have very different saving rates (I have not checked this out). A more likely explanation lies in the structure of incentives across economies. Some of these incentives are determined politically, for example, the rate at which the return to saving and investment is taxed. But then, the question simply turns to what determines these differences in incentives.

10.2.3 Differences in Population Growth Rates

Again, using either Figure 10.2 or 10.3, we see that the Solow model predicts that countries with relatively high population growth rates should enjoy relatively high per capita incomes. This prediction is similar to the Malthusian prediction, but different in an important way. In particular, the Malthusian model predicts that countries with high population densities should have lower living standards, while the Solow model makes no such prediction. That is, in the Solow model, even high density populations can enjoy high income levels, as long as they have a sufficient amount of physical capital. A higher population *growth rate*, however, spreads any given level of capital investment more thinly across a growing population, which is what accounts for their lower capital-labor ratios.

Using a cross section of 109 countries, Figure 10.10 plots the per capita income of various countries (relative to the U.S.) across population growth rates. According to this figure, there appears to be a mildly negative correlation between per capita income and the population growth rate; a prediction that is also consistent with the Solow model.



Again, the deeper question here is why do different countries have different population growth rates? According to the Solow model, the population growth rate is exogenous. In reality, however, people make choices about how many children to have or where to move (i.e., population growth is endogenous). A satisfactory explanation that is based on differences in population growth rates should account for this endogeneity.

10.2.4 Differences in Technology

Parente and Prescott (1999) argue that exogenous differences in savings rates (and presumably population growth rates) can account for only a relatively small amount of the income disparity observed in the data. According to these authors, the proximate cause of income disparity is attributable to differences in total factor productivity (basically, the efficiency of physical capital and labor). In the context of the Solow model, we can capture differences in total factor productivity by assuming that different economies are endowed with different technologies f .

For example, consider two economies A and B that have technologies $f^A(k)$ and $f^B(k)$, where $f^A > f^B$ for all values of k . You can capture this difference by way of a diagram similar to Figure 10.3. Since the more productive economy can produce more output for any given amount of capital (per worker), national

savings and investment will be higher. This higher level of investment translates into a higher steady state capital labor ratio. Per capita output will be higher in economy A for two reasons: First, it will have more capital (relative to workers); and second, it is more productive for any given capital-labor ratio.

Differences in the production technology f across countries can be thought of as differences in the type of engineering knowledge and work practices implemented by individuals living in different economies. Differences in f might also arise because of differences in the skill level or education of workers across countries. But while these types of differences might plausibly lead to the observed discrepancy in material living standards around the world, the key question remains unanswered: Why don't lesser developed economies simply adopt the technologies and work practices that have been so successful in the so-called developed world? Likewise, this theory does not explain why countries that were largely very similar 200 years ago are so different today (in terms of living standards).

10.3 The Politics of Economic Development

Perhaps more headway can be made in understanding the process of economic development by recognizing the politics that are involved in implementing new technologies and work practices. By 'politics' I mean the conflict that appears to arise among 'different' groups of people and the various methods by which people in conflict with one another use to try to protect themselves and/or harm others for private gain.

One thing that we should keep in mind about technological improvement is that it rarely, if ever, benefits everyone in an economy in precisely the same way. Indeed, some technological improvements may actually end up hurting some segments of the economy, even if the economy as a whole benefits in some sense. Whether a particular technological improvement can be implemented or not likely depends to some extent on the relative political power of those special interests that stand to benefit or lose from the introduction of a new technology. If the political power of the potential losers is strong enough, they may be able to erect laws (or vote for political parties that act on their behalf) that prevent the adoption of a new technology.

10.3.1 A Specific Factors Model

Consider an economy populated by three types of individuals: capitalists, landowners, and laborers. All individuals have similar preferences defined over two consumer goods (c_1, c_2) . For simplicity, let the utility function be $u(c_1 + c_2) = c_1 + c_2$. With this assumption, the relative price of the two goods is fixed at unity (so that they are perfect substitutes).

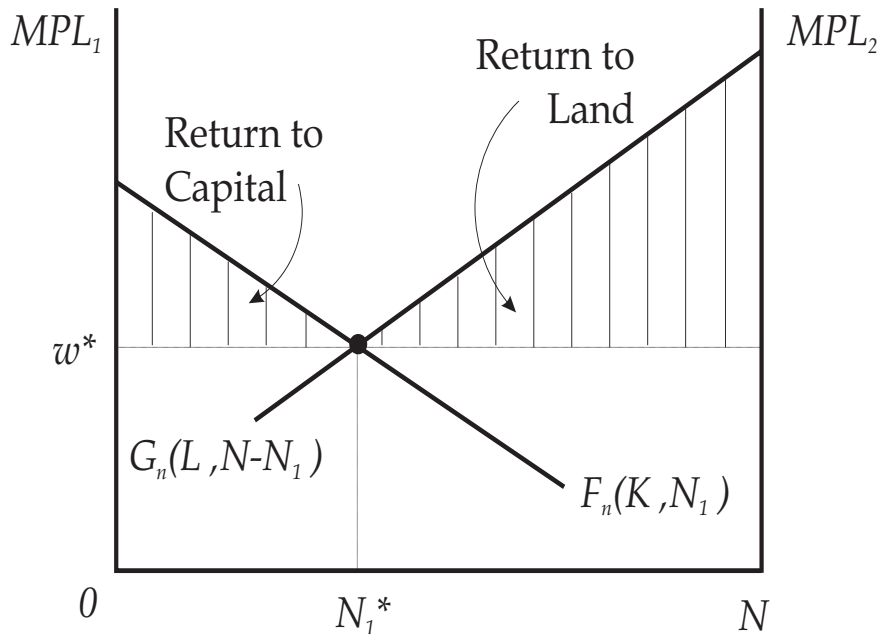
Capitalists are endowed with a fixed amount of physical capital K . Landowners are endowed with a fixed amount of land capital L . There are N laborers, each of whom are endowed with one unit of human capital. The two goods are produced according to the following technologies:

$$\begin{aligned} Y_1 &= F(K, N_1); \\ Y_2 &= G(L, N_2); \end{aligned}$$

where N_j represents the number of workers employed in sector j . Assume that F and G are regular neoclassical production functions. Notice that Y_1 is produced with capital and labor, while Y_2 is produced with land and labor. In this model, capital and land are factors of production that are specific to a particular sector. Labor is used in the production of both goods (so you can think of labor as a general factor of production). Assume that labor is freely mobile across sectors.

Let F_n and G_n denote the marginal product of labor associated with each production function. Since F and G are neoclassical production functions, F_n and G_n are positive and declining in the labor input (i.e., there are diminishing returns to labor, given a fixed capital stock). In a competitive economy, labor is paid its marginal product. If labor is mobile across sectors, then the sectoral composition of employment will adjust to the point $F_n(K, N_1^*) = G_n(L, N_2^*)$, with $N_1^* + N_2^* = N$. Figure 10.4 displays the general equilibrium of this economy.

FIGURE 10.4
General Equilibrium
Specific Factors Model

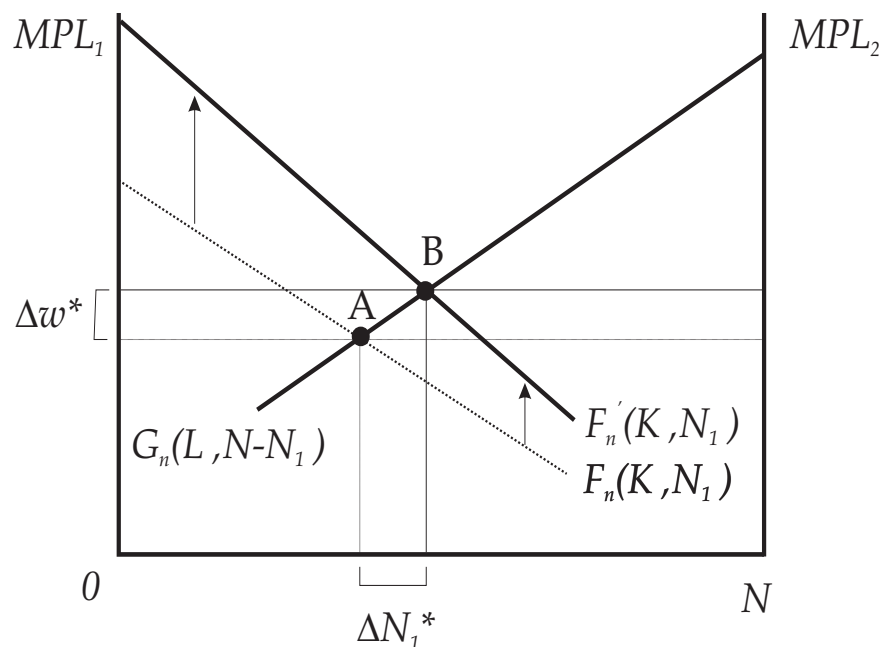


The triangular regions in Figure 10.4 represent the total returns to the specific factors. The rates of return accruing to each specific factor need not be equated, since these factors are, by assumption, immobile. The total return to labor is given by w^*N , with each worker earning the return w^* . In equilibrium, each worker is indifferent between which sector to work in, since each sector pays the same wage rate. To see why both sectors pay the same wage, suppose that they did not. For example, imagine that $w_1 > w_2$. Then workers in sector 2 would flock to sector 1, leading to an increase in N_1 (and a corresponding decline in N_2). But as N_1 expands, the marginal product of labor must fall in sector 1. Likewise, as N_2 contracts, the marginal product of labor in sector 2 must rise. In equilibrium, both sectors must pay the same wage.

Now, let us suppose that the capitalists of this economy realize that there is some better technology out there F' for producing the output Y_1 . The effect of implementing this new technology is similar to the effect of a positive productivity shock studied in earlier chapters. The new technology has the effect of increasing the marginal product of labor at any given employment level N_1 .

Imagine that the new technology shifts the MPL_1 up, making it steeper, as in Figure 10.5.

FIGURE 10.5
A Sector-Specific Technology Shock



Point A in Figure 10.5 depicts the initial equilibrium and point B depicts the new equilibrium. Notice that the new technology implemented in sector 1 has led to an increase in the wage in *both* sectors. The economic intuition for this is as follows. Since the new technology improves the marginal product of labor in sector 1, the demand for sector 1 workers increases. The increase in demand for labor puts upward pressure on the real wage, which attracts sector 2 workers to migrate to sector 1. Once again, in equilibrium, the wage must be equated across sectors so that any remaining workers are just indifferent between migrating or staying at home.

The new technology also increases the return to capital, since the new technology makes both capital and labor more productive. However, note that the increase in the economy-wide wage rate *reduces* the return to land. This is be-

cause the new technology does not increase the efficiency of production in sector 2. Yet, sector 2 landowners must pay their labor a higher wage, increasing their costs and hence lowering their profit.

The political economy implications of this simple model are rather straightforward. If landowners (in this example) wield enough political power, they may be able to ‘block’ the implementation of the superior technology. While per capita incomes will be lower as a result, *their* incomes will be spared the adverse consequences of a new technology that serves to reduce the value of their endowment (land, in this example).

- **Exercise 10.3.** Re-examine the specific factors model described above by assuming that the two fixed factors constitute ‘high-skill’ and ‘low-skill’ labor, with a freely mobile factor (capital) that is used in both sectors of the economy. Explain how a skill-biased technological advance may harm low-skill workers. Now imagine that low-skill workers are highly organized (represented by strong unions) and explain the pressure that politicians may face to ‘regulate’ the adoption of the new technology. What other ways may such workers be compensated?

10.3.2 Historical Evidence

It is important to realize that barriers emanating from special interests have always been present in all economies (from ancient to modern and rich to poor), so that any differences are really only a matter of degree. For example, as early as 1397, tailors in Cologne were forbidden to use machines that pressed pinheads. In 1561, the city council of Nuremberg, apparently influenced by the guild of red-metal turners, launched an attack on Hans Spaichl who had invented an improved slide rest lathe. The council first rewarded Spaichl for his invention, then began to harass him and made him promise not to sell his lathe outside his own craft, then offered to buy it from if he suppressed it, and finally threatened to imprison anyone who sold the lathe. The ribbon loom was invented in Danzig in 1579, but its inventor was reportedly secretly drowned by the orders of the city council. Twenty five years later, the ribbon loom was reinvented in the Netherlands (and so became known as the Dutch loom), although resistance there too was stiff. A century and a half later, John Kay, the inventor of the flying shuttle, was harassed by weavers. He eventually settled in France, where he refused to show his shuttle to weavers out of fear. In 1299, an edict was issued in Florence forbidding bankers to use Arabic numerals. In the fifteenth century, the scribes guild of Paris succeeded in delaying the introduction of the printing press in Paris by 20 years. In the sixteenth century, the great printers revolt in France was triggered by labor-saving innovations in the presses.

Another take on the special interest story pertains to case in which the government itself constitutes the special interest, as in the case of autocratic rulers. It seems as a general rule, the weaker the government, the less is resis-

tance to technology able to mobilize. With some notable exceptions, autocratic rulers have tended to be hostile or indifferent to technological change. Since innovators are typically nonconformists and since technological change typically leads to disruption, the autocrat's instinctive desire for stability and suspicion of nonconformism could plausibly have outweighed the perceived gains to technological innovation. Thus, in both the Ming dynasty in China (1368–1644) and the Tokugawa regime in Japan (1600–1867) set the tone for inward-looking, conservative societies. Only when strong governments realized that technological backwardness itself constituted a threat to the regime (e.g., post 1867 Japan and modern day China) did they intervene directly to encourage technological change.

During the start of the Industrial Revolution in Britain, the political system strongly favored the winners over the losers. Perhaps this was because the British ruling class had most of its assets in real estate and agriculture which, if anything, benefited from technological progress in other areas (e.g., by increasing land rents). However, even in Britain, technological advances were met by stiff opposition. For example, in 1768, 500 sawyers assaulted a mechanical saw mill in London. Severe riots occurred in Lancashire in 1779, and there many instances of factories being burned. Between 1811 and 1816, the Midlands and the industrial counties were the site of the 'Luddite' riots, in which much damage was inflicted on machines. In 1826, hand-loom weavers in a few Lancashire towns rioted for three days. Many more episodes like these have been recorded.

But by and large, these attempts to prevent technological change in Britain were unsuccessful and only served to delay the inevitable. An important reason for this is to be found in how the government responded to attempts to halt technological progress. In 1769, Parliament passed a harsh law in which the wilful destruction of machinery was made a felony punishable by death. In 1779, the Lancashire riots were suppressed by the army. At this time, a resolution passed by the Preston justices of peace read: "The sole cause of the great riots was the new machines employed in cotton manufacture; the country notwithstanding has greatly benefited by their erection and destroying them in this country would only be the means of transferring them to another...to the great detriment of the trade of Britain."

The political barriers to efficiency manifest themselves in many ways, from trade restrictions and labor laws to regulatory red tape. For example, a recent World Bank report (*Doing Business in 2004: Understanding Regulation*) documents the following. It takes two days to register a business in Australia, but 203 days in Haiti. You pay nothing to start a business in Denmark, while in Cambodia you pay five times the country's average income and in Sierra Leone, you pay more than 13 times. In more than three dozen countries, including Hong Kong, Singapore and Thailand, there is no minimum on the capital required by someone wanting to start a business. In Syria, the minimum is 56 times the average income; in Ethiopia and Yemen, it's 17 times and in Mali, six. You can enforce a simple commercial contract in seven days in Tunisia and 39 days in the

Netherlands, but in Guatemala it takes more than four years. The report makes it clear, however, that good regulation is not necessarily zero regulation. The report concludes that Hong Kong's economic success, Botswana's stellar growth performance and Hungary's smooth transition (from communism) have all been stimulated by a good regulatory environment. Presumably, a 'good' regulatory environment is one which allows individuals the freedom to contract while at the same time providing a legal environment that protects private property rights.

While there are certainly many examples of special interests working against the implementation of better technology, our political economy story is not without shortcomings. In particular, special interest groups are busy at work in *all* societies. The key question then is why different societies confer more or less power to various special interests. Perhaps some societies, such as the United States, have erected institutions that are largely successful at mitigating the political influence of special interests. These institutions may have been erected at a time when a large part of the population shared similar interests (e.g., during the American revolution).

But even if new technologies have sectoral consequences for the economy, it is still not immediately clear why special interests should pose a problem for the way an economy functions. For example, in the context of the model developed above, why do individuals not hold a diversified portfolio of assets that would to some extent protect them from the risks associated with sector-specific shocks? In this way, individuals who are diversified can share in the gains of technological progress. Alternatively (and perhaps equivalently), why do the winners not compensate (bribe) the losers associated with a technological improvement? These and many other questions remain topics of current research.

10.4 Endogenous Growth Theory

To this point, we have assumed that technological progress occurs exogenously. The models developed to this point have concentrated on economic behavior *given* the nature of the technological frontier and how it evolves over time. But now it is time to think about what determines this frontier and its development over time. The large literature that has emerged recently to deal with this question is called *endogenous growth theory* and was spawned largely through the work of Paul Romer (1986, 1994).

While the Solow model is useful for thinking about the determinants of the *level* of long-run living standards, it is not capable (or designed to) explain the determinants of long-run growth *rates* (although the model is capable of explaining the short-run dynamics toward a steady state). In the absence of technological progress, growth in per capita income must eventually approach zero. The reason for this is to be found in the fact (or assumption) that capital accumulation is subject to *diminishing returns*.

But now let us think of knowledge itself as constituting a type of capital good. Unlike physical capital goods (or any other physical input), there are no obvious limitations to the expansion of knowledge. Romer has argued that the key feature of knowledge capital is its *nonrivalrous* nature. A good is said to be *rivalrous* if its use by one person excludes its use by someone else. For example, if I use a lawnmower to cut my lawn, this precludes anyone else from using my lawnmower to cut their lawn at the same time. Knowledge, on the other hand, is a different matter. For example, if I use a theorem to prove a particular result, this does not preclude anyone else from using the same theorem at the same time for their own productive purposes. Because of the nonrival nature of technology, there are no obvious diminishing returns from knowledge acquisition.

10.4.1 A Simple Model

Let z_t denote the stock of ‘knowledge capital’ available at date t , for $t = 1, 2, \dots, \infty$. Output per capita is given by the production function $y_t = z_t f(k_t)$. For simplicity, let us assume a constant population and a constant stock of physical capital and normalize units such that $f(k) = 1$. In this case, we have $y_t = z_t$. What this says is that per capita output will grow *linearly* with the stock of knowledge. In other words, there are *constant returns to scale* in knowledge acquisition.

The economy is populated by a representative individual who has preferences defined over sequences of consumption (c_t) and leisure (l_t). Assume that these preferences can be represented with a utility function of the following form:

$$U(c_1, l_1, c_2, l_2, \dots) = u(c_1) + v(l_1) + \beta [u(c_2) + v(l_2)] + \dots$$

where $0 < \beta < 1$ is an exogenous time-preference parameter. For these preferences, the marginal rate of substitution between current leisure (l_t) and future consumption (c_{t+1}) is given by:

$$MRS(l_t, c_{t+1}) = \frac{v'(l_t)}{\beta u'(c_{t+1})}.$$

As well, the marginal rate of substitution between consumption at two different points in time is given by:

$$MRS(c_t, c_{t+1}) = \frac{1}{\beta} \frac{u'(c_t)}{u'(c_{t+1})}.$$

Individuals are endowed with two units of time per period. One unit of this time is used in production, which generates $y_t = z_t$ units of output. In a competitive labor market, z_t would also represent the equilibrium real wage. Output is nonstorable (the physical capital stock cannot be augmented), so that $c_t = y_t = z_t$. The remaining unit of time can be used in one of two activities:

leisure (l_t) or learning effort (e_t). Thus, individuals are faced with the time constraint:

$$e_t + l_t = 1. \quad (10.9)$$

Learning effort can be thought of the time spent in R&D activities. While diverting time away from leisure is costly, the benefit is that learning effort augments the future stock of knowledge capital. We can model this assumption in the following way:

$$z_{t+1} = (1 + e_t)z_t. \quad (10.10)$$

Observe that $e_t = 0$ implies that $z_{t+1} = z_t$ and that $e_t > 0$ implies $z_{t+1} > z_t$. In fact, e_t represents the rate of growth of knowledge (and hence the rate of growth of per capita GDP).

Since $c_t = z_t$, we can combine equations (10.10) and (10.9) to form a relationship that describes the trade off between current leisure and future consumption:

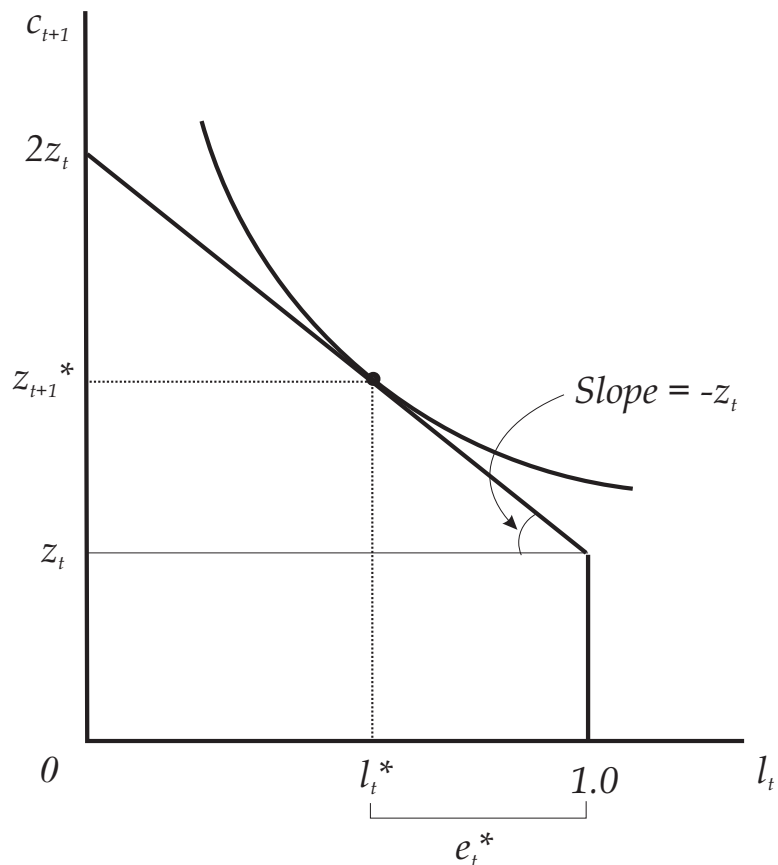
$$c_{t+1} = (2 - l_t)z_t. \quad (10.11)$$

This constraint tells us that if $l_t = 1$ (so that $e_t = 0$), then $c_{t+1} = z_t$ (consumption will remain the same). On the other hand, if $l_t = 0$ (so that $e_t = 1$), then $c_{t+1} = 2z_t$ (consumption will double from this period to the next). In general, individuals will choose some intermediate level of l_t (and hence e_t) such that the marginal cost and benefit of learning effort is just equated. In other words,

$$\frac{v'(l_t)}{\beta u'(c_{t+1})} = z_t. \quad (10.12)$$

Conditions (10.12) and (10.11) are depicted in Figure 10.6.

FIGURE 10.6
Equilibrium Growth Rate



We want to see whether this model economy is capable of generating long-run growth endogenously. To this end, let us restrict the utility function such that $u(c) = \ln(c)$. In this case, $u'(c) = 1/c$ and the marginal rate of substitution between l_t and c_{t+1} becomes $MRS = c_{t+1}v'(l_t)/\beta$. From condition (10.12), we see that:

$$\frac{c_{t+1}v'(l_t)}{\beta} = z_t.$$

Of course, since $c_t = y_t = z_t$, we can rewrite this expression as:

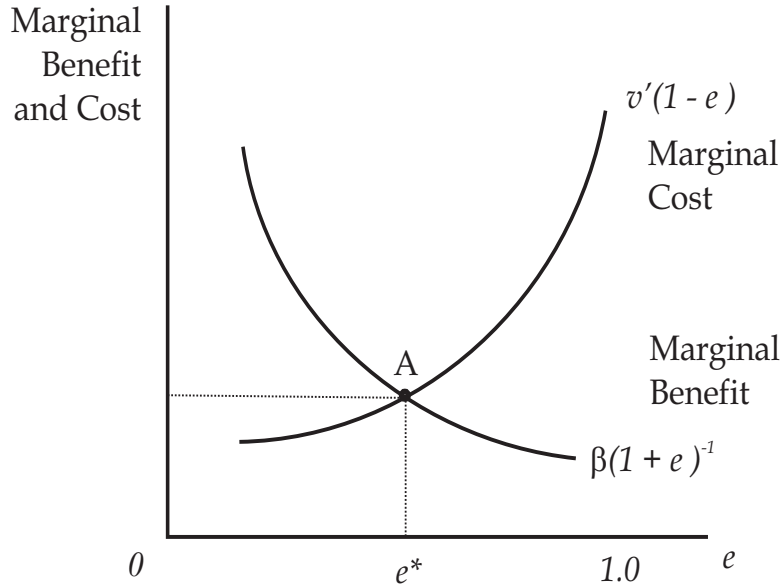
$$v'(l_t) = \beta \left(\frac{z_t}{z_{t+1}} \right).$$

Now, using the fact that $l_t = 1 - e_t$ and $z_{t+1} = (1 + e_t)z_t$, we can write:

$$v'(1 - e^*) = \beta \left(\frac{1}{1 + e^*} \right). \quad (10.13)$$

Equation (10.13) is one equation in the one unknown, e^* . Thus, this condition can be used to solve for the equilibrium growth rate e^* . The left hand side of equation (10.13) can be thought of as the marginal utility cost of learning effort. Since v is strictly increasing and concave in leisure, increasing e (reducing leisure) increases the marginal cost of learning effort. The right hand side of equation (10.13) can be thought of as the marginal utility benefit of learning effort. An increase in learning effort increases future consumption, but since u is concave, the marginal benefit of this extra consumption falls with the level of consumption. Figure 10.7 displays the solution in (10.13) with a diagram. The equilibrium steady state growth rate is determined by the condition that the marginal cost of learning effort is just equated with the marginal benefit; i.e., point A in Figure 10.7.

FIGURE 10.7
Steady State Growth Rate



Note that for the specification of preferences that we have assumed, the equilibrium growth rate does not depend on z_t .

- **Exercise 10.4.** Using a diagram similar to Figure 10.6, show how it is

possible for an increase in z_t not to affect the equilibrium growth rate. Provide some economic intuition.

With e^* determined in this manner, the equilibrium growth rate in per capita GDP is given by $(y_{t+1}/y_t) = (1 + e^*)$. Note that long-run growth is endogenous in this model because growth is not assumed (instead, we have derived this property from a deeper set of assumptions). In particular, note that zero growth is feasible (for example, by setting $e^* = 0$). In general, however, individuals will find it in their interest to choose some positive level of e^* .

Finally, note that we can derive an expression for the equilibrium real rate of interest in this economy. Since the marginal rate of substitution between time-dated consumption is given by $MRS = c_{t+1}/(\beta c_t)$, we can use what we learned in Chapter 6 by noting that the desired consumption profile must satisfy:

$$\frac{c_{t+1}}{\beta c_t} = R_t,$$

where R_t is the (gross) real rate of interest (which is earned on or paid for risk-free private debt). Because this is a closed endowment economy, we know that the interest rate must adjust to ensure that desired national savings is equal to zero. In other words, it must be the case that $c_t^* = z_t$ for every date t . Thus, it follows that:

$$R^* = \frac{1}{\beta}(1 + e^*). \quad (10.14)$$

10.4.2 Initial Conditions and Nonconvergence

Now, let us consider two economies that are identical to each other in every way except for an initial condition z_1 . For example, suppose that $z_1^A > z_1^B$, so that economy A is initially richer than economy B. Furthermore, assume that each economy remains closed to international trade and knowledge flows (so that economy B cannot simply adopt z_1^A). Then our model predicts that these two economies will grow at exactly the same rate (see Exercise 10.4). In other words, economy A will forever be richer than economy B; i.e., the levels of per capita GDP will never converge. Note that this result is very different than the prediction offered by the Solow model, which suggests a long-run convergence of growth rates (to zero).

Some economists have proposed this type of explanation for the apparent lack of convergence in per capita GDP across many countries. In Figure 10.1, for example, we see that many countries (in this sample) are growing roughly at the same rate as the world's technological leader (the United States).³

As with many models, there is probably an element of truth to this story. But the theory also has its challenges. For example, I noted in the introduction that

³Remember that since Figure 10.1 plots a country's per capita GDP relative to the U.S., a 'flat' profile indicates that the country is growing at the same rate as the U.S.

according to our best estimates, the 'initial conditions' around the world c. 1800 were not that different. On the other hand, even very small differences in initial conditions can manifest themselves as very large differences in levels over an extended period of time. But then again, what might explain the fact that some countries have managed to grow much faster than the U.S. for prolonged periods of time? Perhaps this phenomenon was due to an international flow of knowledge that allowed some countries to 'catch up' to U.S. living standards. A prime example of this may be post war Japan, which very quickly made widespread use of existing U.S. technology. Similarly, growth slowdowns may be explained by legal restrictions that prevent the importation of new technologies. At the end of the day, the million dollar question remains: Why do lesser developed countries not do more to encourage the importation of superior technologies? In other words, why don't countries simply imitate the world's technological leaders?

10.5 References

1. Bairoch, P. (1993). *Economics and World History: Myths and Paradoxes*, New York: Harvester-Wheatsheaf.
2. Parente, Stephen L. and Edward C. Prescott (1999). “Barriers to Riches,” *Third Walras-Pareto Lecture*, University of Lausanne.
3. Pomeranz, K. (1998). “East Asia, Europe, and the Industrial Revolution,” Unpublished Ph.D. Thesis, University of California (Irvine).
4. Romer, Paul M. (1986). “Increasing Returns and Long-Run Growth,” *Journal of Political Economy*, 94: 1002–1037.
5. Romer, Paul M. (1994). “The Origins of Endogenous Growth,” *Journal of Economic Perspectives*, 8: 3–22.
6. Solow, Robert M. (1956). “A Contribution to the Theory of Economic Growth,” *Quarterly Journal of Economics*, 70: 65–94.