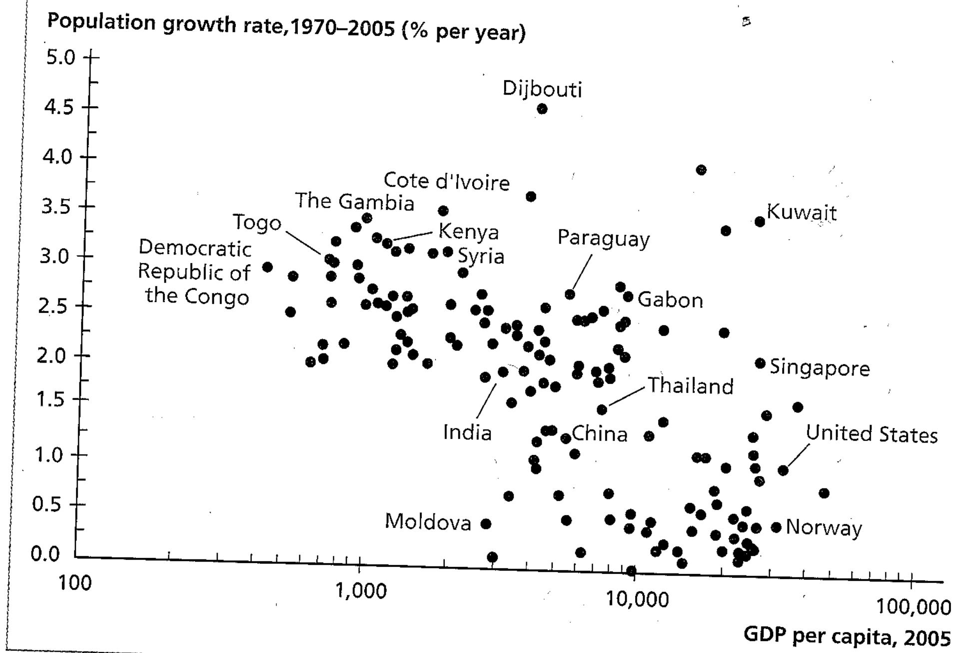
Of course, over time, the speed with which a population grows is what determines how many people there are. But the words *over time* make a big difference. Countries can have slow population growth and a large population relative to their resources. Or they can have rapid population growth but a population that is small relative to their resources. Japan and Kenya present examples of these two cases. Between 1970 and 2005, Japan's population grew at a rate of only 0.6% per year, but population density in 2005 was 340 people per square mile (131 people per square kilometer), among the highest in the world. In Kenya population growth over the same period was 3.2% per year, but in 2005, population density was only 61 people per square mile (24 people per square kilometer).

As Figure 4.1 shows, there is a strong negative correlation between income per capita and the growth rate of population. But while this negative correlation is easy to see in the data, fully understanding it is difficult. Recalling the discussion of causation in Chapter 2, the data in Figure 4.1 may be evidence that rapid population growth causes a country to be poor, or that something about being poor leads to rapid population growth, or that causality runs in both directions. It is even possible

FIGURE 4.1

Relationship Between Income per Capita and Population Growth



Source: Heston et.al. (2006), World Bank (2007a).

that population growth and income per capita are not directly related at all; some other factor may affect both income per capita and population growth.

In the first section of this chapter, we look at the historical relationship between population and economic growth. We see how economic forces kept population growth in close check for most of human history but that the relationship between population and the economy has changed radically in the last two centuries. In the second section we consider how population growth can be incorporated into the Solow model discussed in Chapter 3. We also conduct a quantitative exercise to ask how large the income differences caused by population growth should be. We next examine the two determinants of population growth: mortality and fertility. In the final section we look more closely at economic explanations of why fertility falls as countries get richer.

4.1 | Population and Output Over the Long Run

The last 200 years have been an extraordinary time in human history. As we saw in Chapter 1, only in the last two centuries have living standards anywhere in the world begun to show significant improvement. And as we will see in this chapter, a similar change occurred in the nature of population growth.

Most of this book is concerned with the current period of rapid change. For a complete understanding, however, it is helpful to get a running start by looking at how population and output interacted for most of human history.

Population Over the Long Run

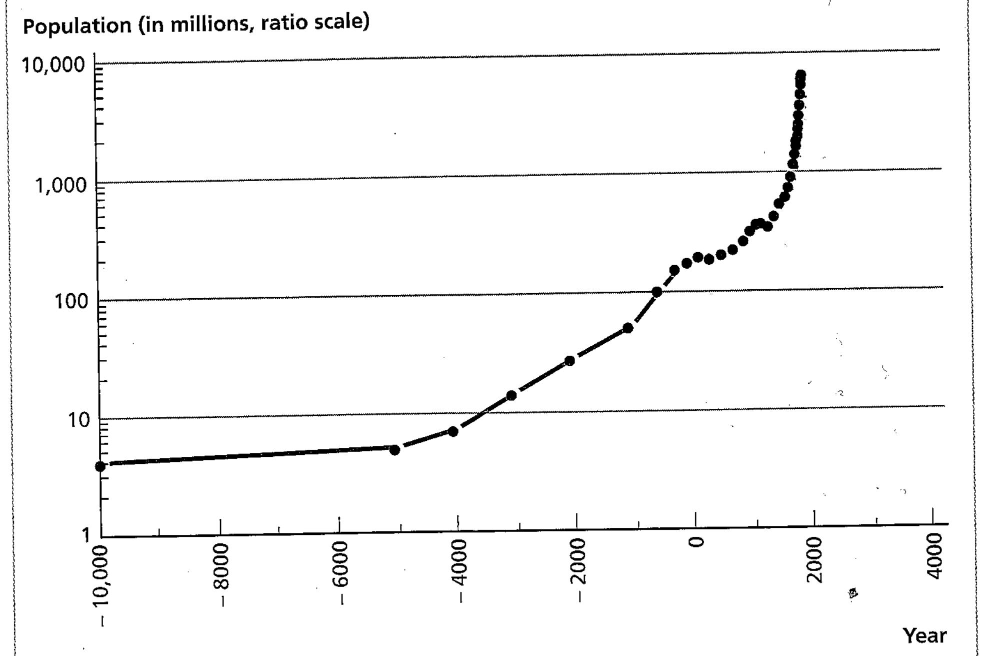
Figure 4.2 shows the size of the human population going back to 10,000 B.C. For most of history, the world's population was sparse in comparison with today's 6.4 billion. As late as A.D. 1000, for example, fewer humans walked the earth than now live in the United States.

Another striking aspect of the figure is how slowly the population grew for most of human history. Between 10,000 B.C. and the beginning of the first century A.D., the average growth rate of the world's population was only 0.04% per year—in other words, population increased by 1% every 25 years. In the next 1,800 years, population grew at an average rate of 0.09% per year—high in comparison with what had come before, but minuscule in today's terms. As the figure shows, only in the last 200 years has the growth rate of population taken off: World population growth averaged 0.6% in the 19th century, 0.9% in the first half of the 20th century, and 1.8% over the second half of the 20th century.

Thus, persistent population growth at a rate beyond a glacial crawl is a relatively new phenomenon. Exploring why population growth has behaved this way over the

FIGURE 4.2

World Population, 10,000 B.C. to A.D. 2005



Source: Kremer (1993).

long run will give us insight into what determines population growth and why it differs among countries today.

The Malthusian Model

The explanation for the historical constancy of population was most famously elucidated by Thomas Malthus (1766–1834), an English parson whose *Essay on the Principle of Population* was published in 1798. Malthus began with the observation that, given the right circumstances, humans can breed at a prodigious rate (see box "The Power of Population"). The force that limited human population in the face of this potential fertility was simply the limited quantity of available resources—in particular, land. The smaller the population relative to the available land, the better off people would be. The better off people were, the faster population would grow. As the population grew, however, the amount of land available for each person would fall, and people would become poorer. This poverty would in turn limit population growth. Eventually society would reach a level of income commensurate with constant population.

THE POWER OF POPULATION

The group that demographers use as the best example of humans' ability to breed quickly is the Hutterites, a communally oriented Christian sect that migrated from Russia to the Dakotas and Canada in the 1870s. The Hutterite lifestyle was almost perfectly designed for maximum fertility. Women married young, and for religious reasons, couples never practiced birth control. The sect's early weaning of babies eliminated the effect of breast-feeding in reducing fertility. Further, unlike high-fertility populations in the developing world today, the Hutterites were well nourished and healthy. Their mortality rates were no different from those of the American population as a whole.

The results of this high-fertility lifestyle were dramatic. The median Hutterite woman bore 10.4 children by the age of 45. One colony grew from 215 people in 1880 to 5,450 in 1960, without any outsiders moving in. The average growth rate over this period was 4.1%, roughly a doubling every 17 years. Although some countries in the developing world currently have population growth rates this high, none have kept up such growth for nearly as long.

Another example of the ability of human populations to expand in the presence of adequate resources—and of the power of compound growth—is the French Canadians, who arrived in Quebec in the 17th century. The 3,380 pioneers who migrated from France before 1680 grew, with very little additional immigration, to a population of 2.5 million by 1950. Of the population in 1950, 68% of the gene pool was attributable to the initial settlers.*

*Larsen and Vaupel (1993), Livi-Bacci (1997).

Described this way, Malthus's model sounds purely biological. But Malthus observed that there is a crucial difference between humans and other forms of life:

> Among plants and animals the view of the subject is simple. They are all impelled by a powerful instinct to the increase of their species; and this instinct is interrupted by no reasoning, or doubts about providing for their offspring. Where ever therefore there is liberty, the power of increase is exerted; and the superabundant effects are repressed afterwards by want of room and nourishment, which is common to animals and plants; and among animals, by becoming prey of others.[1]

In the case of humans, however, there is a second consideration:

> Impelled to the increase of his species by an equally powerful instinct, reason interrupts his career, and asks him whether he may or not bring beings into the world, for whom he cannot provide the means of subsistence. . . . Will he not lower his rank in life? Will he not subject himself to greater difficulties than he at present feels? Will he not be obliged to labour harder? And if he has a large family, will his utmost exertions enable him to support them? May he not see his offspring in rags and misery, and clamoring for bread that he cannot give them?[2]

[1]Malthus (1798), Ch. 2.
[2]Malthus (1798), Ch. 2.

Thus, Malthus argued, while animals and plants were limited in their multiplication only by limitations on resources, humans were subject to a second sort of limitation: the deliberate reduction of fertility in order to prevent poverty. Malthus called the first of these mechanisms the "positive check" and the second, the one unique to humans, the "preventive check." Because humans could apply a preventive check, they were not fated to live in the same dire circumstances as animals. But when this check failed, the positive check was waiting in the wings.

Figure 4.3 is a graphical representation of the Malthusian model. Panel (a) of the figure shows the relationship between income per capita on the horizontal axis and the size of the population on the vertical axis. The effect of population size on the standard of living is represented by the downward-sloping line. Panel (b) graphs income per capita on the horizontal axis and population growth on the vertical axis. The upward-sloping line in panel (b) shows that higher income will raise the growth rate of population.

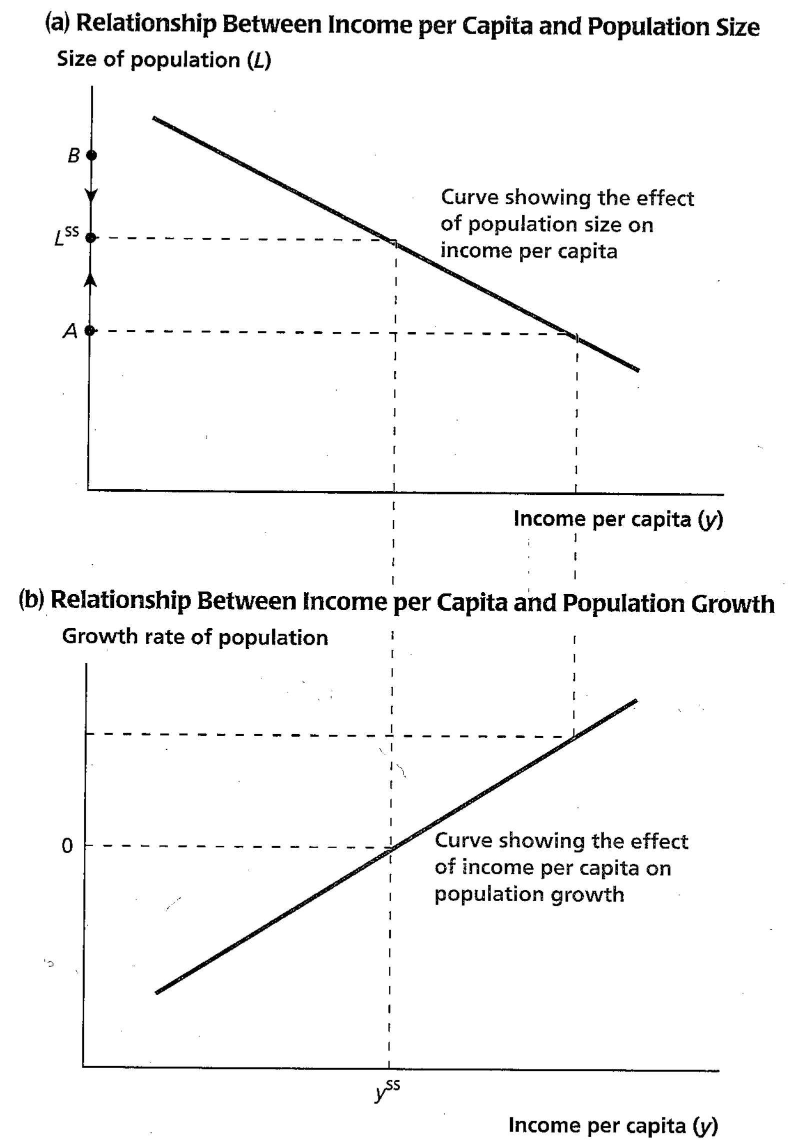
To use this diagram, consider starting with a given level of population, such as that represented by point *A* in panel (a). The panel shows how this population will translate into a level of income per capita. Reading down to panel (b), we can then see how this level of income per capita translates into a growth rate of population—and thus how the level of population will change over time. For example, the size of population represented by point *A* implies a high level of income per capita and positive population growth. If population starts out at point *A*, it will grow over time (that is, move up along the vertical axis in panel (a)). Similarly, if population starts out at the level designated by point *B*, income per capita will be low, and popultation growth will be negative—that is, population will get smaller over time. These movements in population are symbolized by the arrows along the vertical axis in panel (a).

As the figure shows, there is a steady-state level of income per capita, y^{ss}, that is consistent with zero population growth. There is a corresponding steady-state population size, L^{ss}. If the population is smaller than L^{ss}, income per capita will be above y^{ss}, so the population will be growing. Conversely, if the population is above L^{ss}, then the population will be shrinking. Thus, the steady state is stable: No matter what a country's initial level of population, it will end up at the steady state.

We can use this diagram to analyze how changes in the environment or in behavior will influence income and population in the Malthusian model. Consider first how improvements in the productive environment will affect the standard of living. Suppose there is some advance in productivity—for example, the introduction of irrigation or the arrival of a new crop—that raises the quantity of food that can be grown on a given amount of land. Or suppose that new land (without people) is discovered. Such a change is represented by a shift outward in the relationship between population size and income per capita, as shown in panel (a) of Figure 4.4. At any given level of population, income per capita will be higher.

FIGURE 4.3

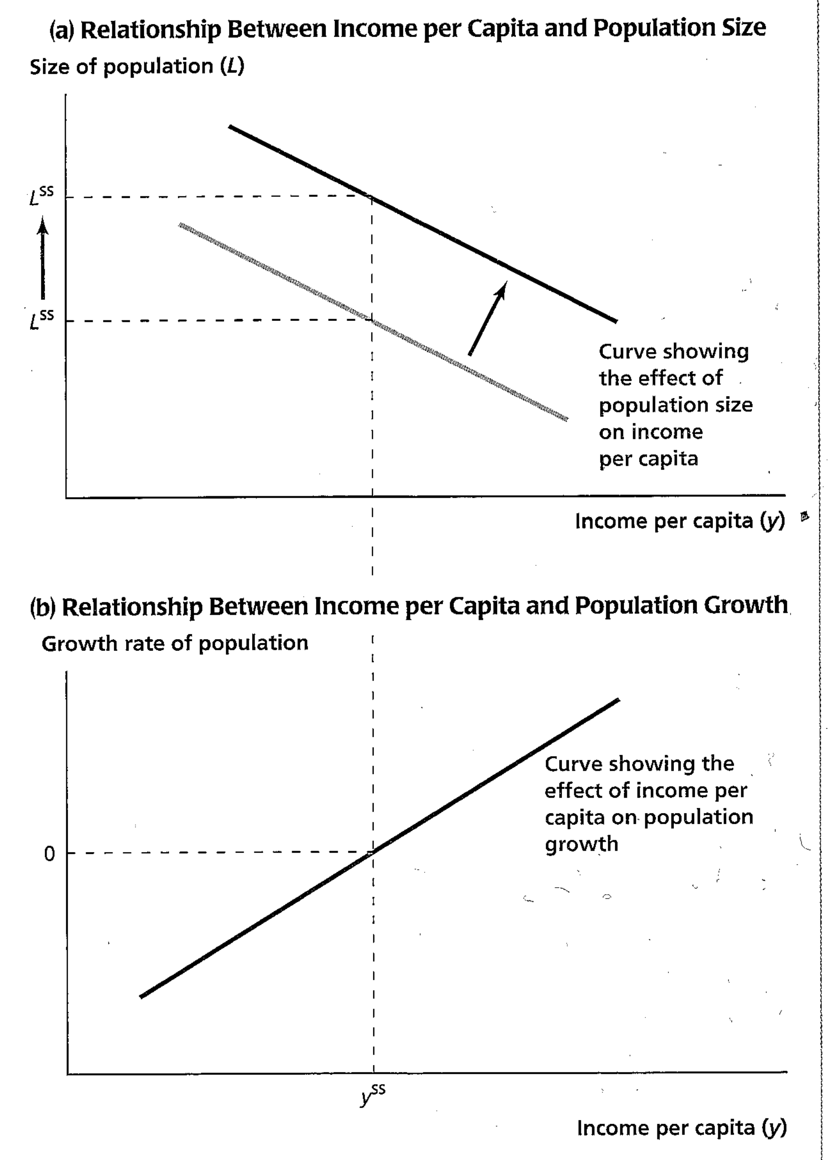
The Malthusian Model



The relationship between population growth and the level of income per capita, shown in panel (b), would not change.

The immediate effect of this improvement in the productive environment will be to raise living standards, just as we would expect. But over time, people who are better off will produce more children, and the larger number of people will dilute the

FIGURE 4.4
Effect of Productivity Improvement in the Malthusian Model



benefits of the new technology or land. Population will continue to grow until the standard of living has returned to its old level, that is, the level commensurate with zero population growth. In the new steady state of the economy, there will be a larger population, but the level of income per capita will not have changed. Better technology or more land, then, will *not* lead to healthier, happier people, just to more of them.

This implication of the Malthusian model—that countries with higher productivity will not have higher living standards but only more people—accords well with the data available from economic history. The slow pace of population growth over most of human history, shown in Figure 4.2, seems to match an equally slow rate of technological progress, both of which took place against a backdrop of roughly constant standards of living. When we compare different countries at the same point in time, the prediction of the model also seems to hold true. In A.D. 1000, China was the most technologically advanced country in the world, but because of its high population density, the Chinese people lived just as close to the margin of subsistence as technologically backward Europe. Another good example of this mechanism at work occurred when the potato, a plant native to the Americas, was introduced into Ireland. A field of potatoes could feed two or three times as many people as a similar field of grain, so the potato resulted in a significant rise in Ireland's agricultural productivity. In the century after 1750, as the potato became the primary Irish staple, the population of the island tripled. Just as Malthus would have predicted, this rise in population resulted in little improvement in the standard of living.

If the Malthusian model predicts that improvements in productivity will not make people better off, then what will? Malthus's answer was that "moral restraint" in preventing births is the only way in which a society can raise its standard of living. Such a change is represented in panel (b) of Figure 4.5 by a downward shift in the curve relating population growth to income per capita. At any given level of income, population growth will be lower. In this scenario, the curve relating income to population size is unchanged. As the figure shows, a country that adopted a policy of moral restraint would have a lower steady-state population but a higher steady-state level of income per capita. Malthus explains it this way:

> In an endeavor to raise the proportion of the quantity of provisions to the number of consumers in any country, our attention would naturally be first directed to the increasing of the absolute quantity of provisions; but finding that, as fast as we did this, the number of consumers more than kept pace with it, and that with all our exertions we were still as far as ever behind, we should be convinced that our efforts directed only in this way would never succeed. . . . Finding, therefore, that from the laws of nature we could not proportion food to the population, our next attempt should naturally be to proportion the population to the food.[3]

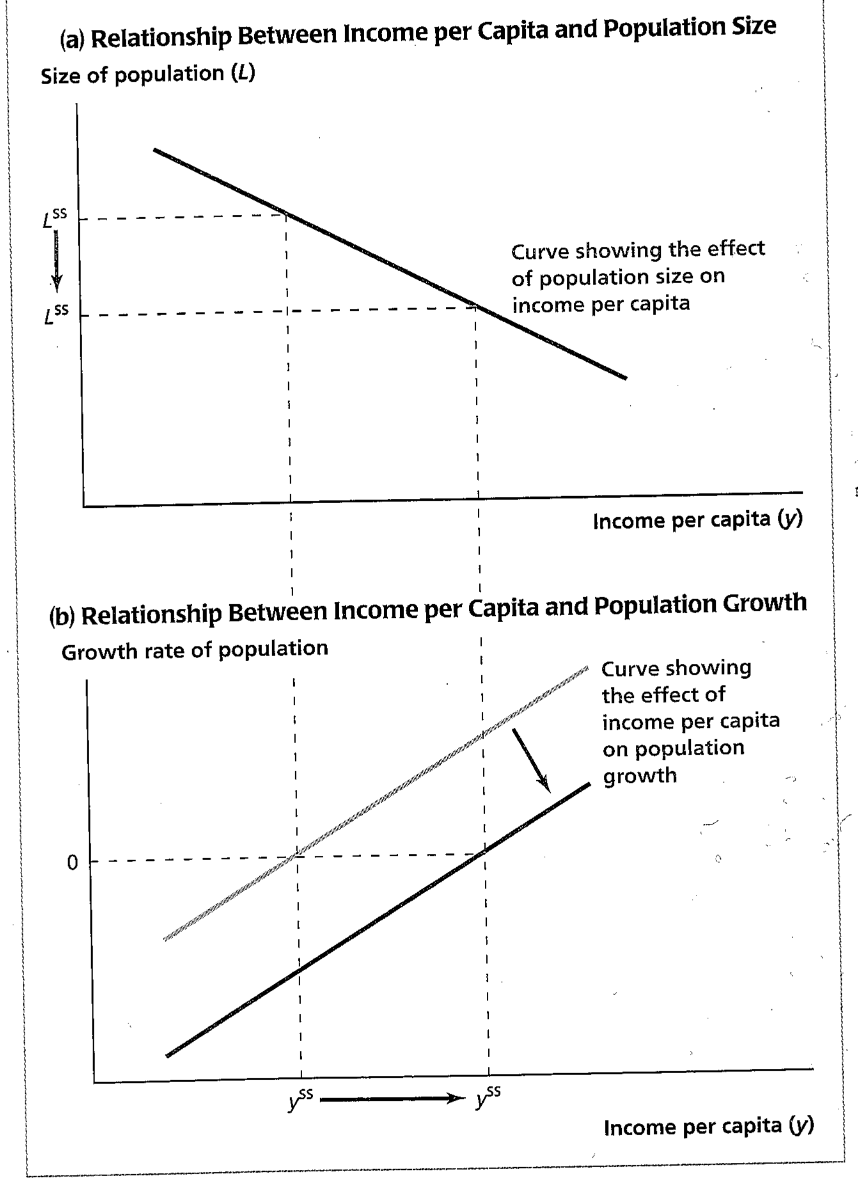
The Breakdown of the Malthusian Model

The Malthusian model clearly does not apply to the world today. Evidence that the model has broken down comes from living standards. The Malthusian

[3]Malthus (1826), Book 4, Ch. 3.

FIGURE 4.5

Effect of "Moral Restraint" in the Malthusian Model



model predicts that standards of living will remain constant over time, even in the face of technological progress. This was roughly true for most of human history, but over the last two centuries, living standards in much of the world have risen dramatically. We can also see the breakdown of the Malthusian model in the relationship between income per capita and population growth.

One of the key pieces of the Malthusian model is that higher income raises the growth rate of population. But Figure 4.1, contrary to what Malthus would have predicted, shows that the relationship between these two measures is negative: The richest countries in the world have the *lowest* rates of population growth.

Ironically, it was at roughly the time when Malthus wrote—the beginning of the 19th century—that the Malthusian model began to collapse. The changes affected the two key aspects of the Malthusian model: first, that the fixed supply of land means higher population will lead to declines in the standard of living, and second, that population will grow whenever income per capita is high enough. Over the last two centuries, both of these mechanisms have greatly weakened.

First consider the effect of population size on income per capita. The simple fact is that although population has grown enormously over the last two centuries, this increase has not prevented income per capita from rising as well. Growth in income has been possible because technological progress has been rapid enough to compensate for falling levels of natural resources per capita. We will consider the details of this process later in the book.

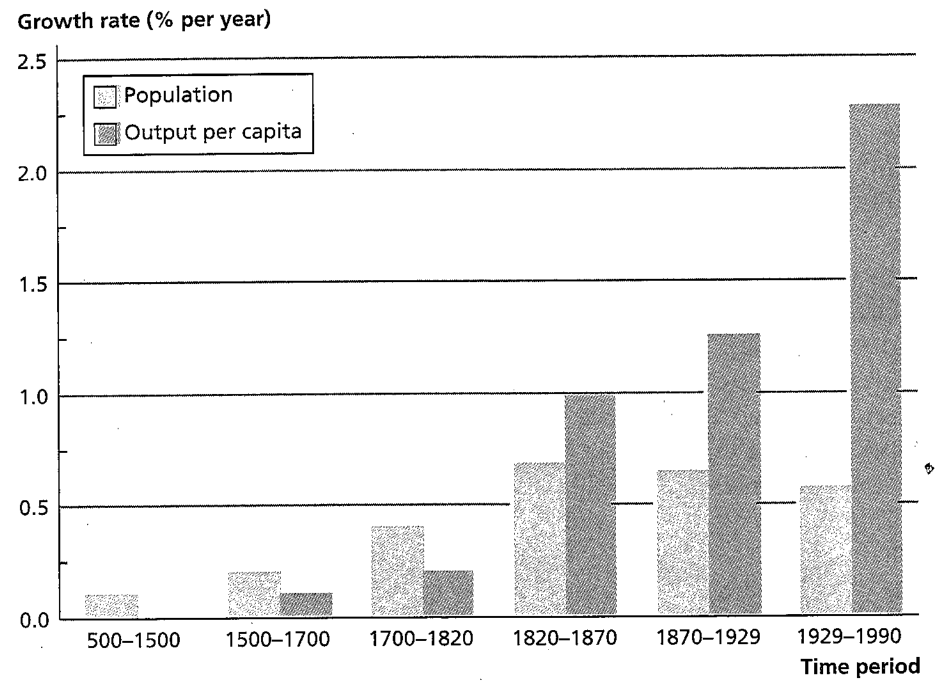
This chapter focuses on the weakening of the other part of the Malthusian mechanism: the dependence of population growth on the level of income per capita. Why haven't improvements in the standard of living led to large increases in population growth, as Malthus would have expected?

Figure 4.6 shows the growth rates of output per capita and population in Western Europe, which is where the Malthusian model first broke down. As the figure indicates, the link between income and population growth was not severed all at once. Rather, as Europe got richer, its population grew at an unprecedented pace. Population had grown at an average rate of only 0.2% per year for the 200 years before 1700. Between 1700 and 1820, it grew at 0.4% per year, and between 1820 and 1870, at 0.7% per year. Still, economic growth outstripped population growth, and income per capita continued to rise. Then, in the late 19th century came a puzzling phenomenon: As the growth of income accelerated, population growth began to fall. And when we look forward from the present over the next several decades, the departure from the Malthusian model is even more dramatic, because for many countries in Western Europe, population growth is projected to be negative! Clearly the Malthusian relationship between income and population growth is no longer operative.

This same pattern—economic growth initially leading to a period of rising population growth but later to a decline—has been repeated in many other parts of the world. Understanding this phenomenon is the subject of the second half of this chapter. But first we look at another channel by which population affects the level of income per capita: the effect of population growth on the quantity of capital per worker.

FIGURE 4.6

Breakdown of the Malthusian Model in Western Europe



Source: Galor and Weil (2000).

4.2 | Population Growth in the Solow Model

In the Malthusian model, the size of the population feeds back to affect the level of income per capita. This Malthusian mechanism kept the size of population and the level of income per capita relatively constant for most of human history. But as we just noted, in the last two centuries, the Malthusian mechanism has broken down as population growth and income per capita have risen to levels never before seen in history.

Does the fact that the Malthusian model no longer works mean that population has no effect on income per capita? The answer to this question is no, for two reasons. First, the Malthusian mechanism by which higher population will mean a shortage of resources such as land is still an important factor determining countries' income, even though it does not play the dominant role that it did historically. Second, there is a completely different channel, beyond the one that Malthus examined, by which population affects income per capita. This second

channel runs via the effect of population on capital, the factor of production that we studied in Chapter 3. Further, where the Malthusian model focused on the *size* of the population, this second channel operates through the *growth rate* of the population. This second channel by which population growth affects income per capita is best understood by extending the Solow model, presented in Chapter 3.

Population Growth and Capital Dilution

To see how the growth rate of population interacts with the quantity of capital to affect income per capita, consider what happens in a country where population is growing rapidly. If the quantity of capital in the country did not change, then population growth would result in less capital being available for each worker.[4] This negative effect of population growth on capital per worker is called **capital dilution.** The decline in the amount of capital per worker, for the reasons discussed in Chapter 3, would lead to a decline in the amount of output produced per worker. Alternatively, a country where population is growing rapidly could maintain a constant level of capital per worker, but only by investing a large fraction of its output in building new capital.

An in-depth look at the effect of capital dilution requires a model of how capital affects output. Luckily, we already have one: the Solow model. In the version of the Solow model presented in Chapter 3, there are two sources of change in capital per worker: investment (the building of new capital) and depreciation (the wearing out of old capital). The equation that describes the change in the quantity of capital per worker over time (Equation 3.1) is

$$\Delta k = \gamma f(k) - \delta k.$$

where γ is the fraction of output invested, δ is the rate of depreciation, $f(k)$ is the production function, and Δk is the change in the level of capital per worker.

We now want to incorporate capital dilution into this equation. As a concrete example, let's consider an economy in which the number of workers is rising at a rate of 1% per year and in which there is no depreciation of capital. If we wanted to keep the level of capital per worker constant in the face of this labor force growth, the quantity of investment would have to be large enough to supply each new worker with as much capital as each existing worker has to work with, so investment would have to equal 1% of the capital stock. Alternatively, if there were no investment in the face of this growth of the labor force, then the quantity of capital per worker would decline at a rate of

[4]We are assuming for now that the growth rate of the population is the same as the growth rate of the labor force. Chapter 5 explores what happens when this is not the case.

1% per year. Generalizing from this example and defining n as the growth rate of the labor force, we can write an equation for the change in the amount of capital per worker:[5]

$$\Delta k = \gamma f(k) - \delta k - nk = \gamma f(k) - (n + \delta)k.$$

Notice that dilution due to the arrival of new workers operates in exactly the same manner as depreciation.

Once we modify the equation for capital accumulation to take into account the effect of capital dilution, the rest of the Solow model is straightforward. The condition for a steady state is that the change in the capital stock, Δk, is equal to zero. This implies that

$$\gamma f(k) = (n + \delta)k.$$

We can show the determination of the steady state in a figure exactly like Figure 3.4, except that instead of a line with slope δ, there will be a line with slope $(n + \delta)$, as shown in Figure 4.7. Raising the rate of population growth rotates the curve representing $(n + \delta)k$ counterclockwise and leads to a lower steady-state level of output. Thus, the Solow model, modified to include population growth, provides a potential explanation for why countries with high population growth rates are poorer than countries with low population growth rates. Specifically, higher population growth dilutes the per-worker capital stock more quickly and so lowers the steady-state level of output per worker.

A Quantitative Analysis

As we did in Chapter 3, we can go further, asking *how large* the Solow model predicts the effect of population growth on steady-state income will be. As in the last chapter, we assume that the production function takes the Cobb-Douglas form, which in per-worker terms is

$$f(k) = Ak^{\alpha},$$

where the parameter A measures productivity. The condition for the steady state is thus

$$\gamma A k^{\alpha} = (n + \delta)k.$$

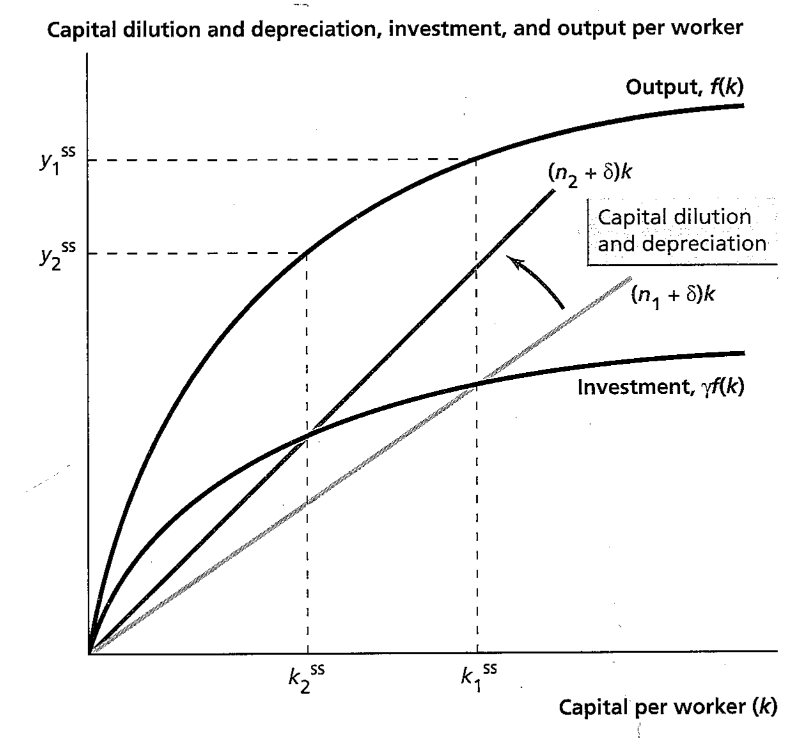
[5]Mathematical Note: We can derive the equivalent of this equation in continuous time by using calculus:

$$\dot{k} = \frac{dk}{dt} = \frac{d\left(\frac{K}{L}\right)}{dt} = \frac{L\frac{dK}{dt} - K\frac{dL}{dt}}{L^2} = \frac{\dot{K}}{L} - k\frac{\dot{L}}{L} = \frac{\gamma Y - \delta K}{L} - k\frac{\dot{L}}{L} = \gamma y - \delta k - nk.$$

Note that the definition of the labor force growth rate, n, is $n = \dot{L}/L$.

FIGURE 4.7

The Solow Model Incorporating Population Growth



The figure shows how raising the population growth rate from n_1 to n_2 affects the steady-state level of capital per worker (k) and the steady-state level of output per worker (y).

This equation can be solved to give the steady-state level of capital per worker, k^{ss}:

$$k^{ss} = \left(\frac{\gamma A}{n + \delta}\right)^{1/(1-\alpha)}.$$

Finally, substituting k^{ss} into the production function gives the steady-state level of output per worker, y^{ss}:

$$y^{ss} = A(k^{ss})^{\alpha} = A^{1/(1-\alpha)}\left(\frac{\gamma}{n + \delta}\right)^{\alpha/(1-\alpha)}.$$

To calculate the effect of population growth on the steady-state level of output per worker, suppose that we are comparing two countries that are the same in every dimension except their population growth rates. Thus, they have the same values for A (which measures productivity), γ (which measures the fraction of output that is invested), and δ (which measures depreciation). We call the countries i and j, and let n_i and n_j denote their growth rates of population (we continue to assume that population and labor force grow at the same rate). The equations for the steady-state levels of output per worker in the two countries are:

$$y_i^{ss} = A^{1/(1-\alpha)}\left(\frac{\gamma}{n_i + \delta}\right)^{\alpha/(1-\alpha)},$$

$$y_j^{ss} = A^{1/(1-\alpha)}\left(\frac{\gamma}{n_j + \delta}\right)^{\alpha/(1-\alpha)}.$$

To get an expression for the ratio of steady-state income in Country i to steady-state income in Country j, we divide the first of these expressions by the second:

$$\frac{y_i^{ss}}{y_j^{ss}} = \left(\frac{n_j + \delta}{n_i + \delta}\right)^{\alpha/(1-\alpha)}.$$

To implement this calculation, we need values for the rate of depreciation, δ, population growth in each country, n_i and n_j, and the exponent on capital in the production function, α. For the rate of depreciation, we will use the value 5%. For the rates of population growth, we pick values that span the rates that we observe in the data: $n_i = 0\%$ and $n_j = 4\%$. For the value of α, we use 1/3, for the reasons discussed in Chapter 3. The ratio of income per capita in the steady state is given by substituting these numbers into the previous equation:

$$\frac{y_i^{ss}}{y_j^{ss}} = \left(\frac{0.04 + 0.05}{0.00 + 0.05}\right)^{1/2} \approx 1.34.$$

Thus, our calculation says that the country with zero population growth (Country i) would have income per worker 34% higher than the country with 4% population growth (Country j).

This is a very small difference in comparison to the large differences in income per capita that are associated with differences in population growth according to Figure 4.1. Notice, however, that this calculation is very sensitive to the value of α. Suppose (for reasons that will be made clear in Chapter 6) that we use a value of $\alpha = 2/3$. In this case, the ratio of steady-state income in the two countries will be 3.24—that is, Country i will be more than three times as well off as Country j.

This difference in income per capita—a factor of 3.24—is still not as large as the differences between the high- and low-population-growth countries in Figure 4.1. Nonetheless, the differences explained by population growth are potentially significant. Further, we would not expect this factor alone to explain all of the differences in income that we observe. We already saw in Chapter 3 that differences in investment rates between countries can partially explain differences in income, and we will see in later chapters that there are other factors as well.

In sum, the Solow model, extended to incorporate population growth, explains how higher population growth can lower income per capita through the channel of capital dilution. As such, this extended Solow model can partly account for the negative correlation between income per capita and population growth shown in Figure 4.1. But just as the simple Solow model of Chapter 3, which focused on the effects of investment, left open the question of why countries differ in the fraction of their output that they invest, this extended Solow model leaves unanswered the question of why countries differ in their population growth rates. This is the issue to which we now turn.

4.3 | Explaining Population Growth

The Malthusian and Solow models both address the issue of how population affects the level of income per capita. The Malthusian model has an additional component that is lacking in the Solow model, however: The Malthusian model also explains how the size of the population is determined. Using the terminology introduced in Chapter 3, we say that the Malthusian model treats population as an endogenous variable—something determined within the model. By contrast, the Solow model treats population growth as exogenous (determined outside the model).

As we have seen, the Malthusian model provided a good explanation for both income and population until the last two centuries, but since that time, the Malthusian model of population has broken down. We also saw, in our quantitative analysis of the Solow model, that differences among countries in the growth rate of population can explain some (but not all) of the differences in income among countries. In the rest of this chapter, we explore the origin of these differences in population growth rates.

A useful framework for organizing our thinking about population growth is the idea of **demographic transition**—the process by which a country's demographic (population) characteristics are transformed as it develops. In this section we will see that the changes in population growth result from the interaction of changing patterns of death and birth—that is, a **mortality transition** and a **fertility transition.** The process of demographic transition is largely complete in the richest countries in the world but is still ongoing in much of the developing world. The incompleteness of the demographic transition—specifically, the fact that mortality rates have fallen faster than fertility rates—is the primary explanation for high population growth in much of the developing world.

Mortality Transition

The decline in the prevalence of death over the last two centuries has been one of the most remarkable transformations in human history. Living in a society where most children can expect to live long, healthy lives makes it difficult for us to understand the precariousness with which life was viewed for most of human history, and by most of the world as recently as half a century ago.

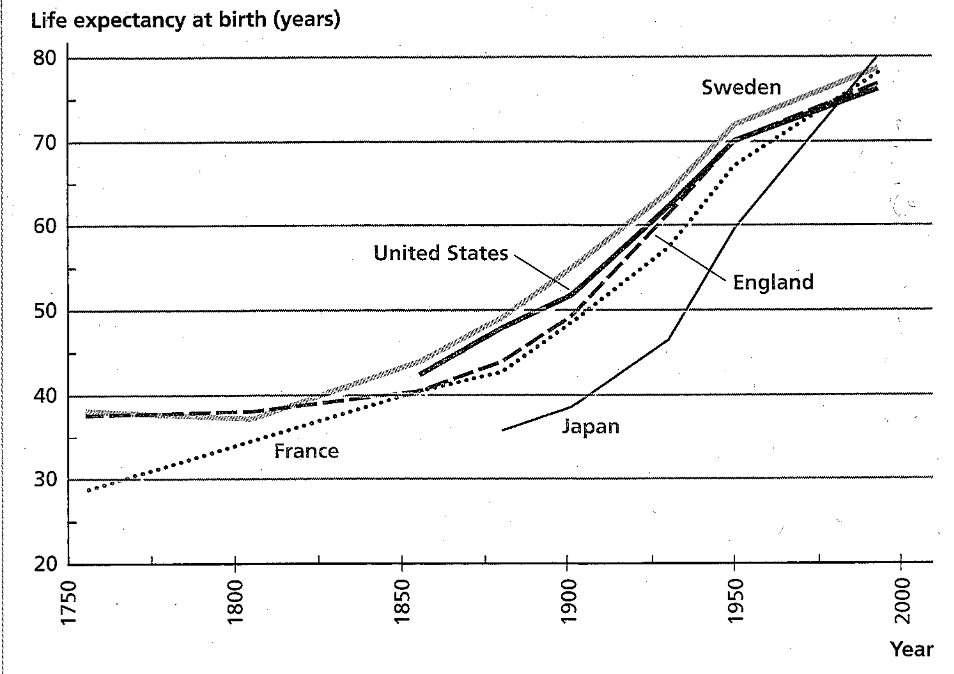
Demographers measure mortality by calculating **life expectancy at birth,** which is the average number of years that a newborn baby can be expected to live. For example, in a country where all newborns lived to age 40 and then died, life expectancy at birth would be 40 years. Similarly, in a country where half of all newborns died immediately and the other half died at age 80, life expectancy at birth also would be 40. The appendix to this chapter contains a more extensive discussion of how life expectancy and other demographic measures are defined and measured.

Figure 4.8 illustrates how life expectancy has evolved in a number of developed countries. The data go back to the middle of the 18th century and show a two-century-long period of improvement in mortality. As with income per capita, the available historical evidence indicates that there was little or no improvement in life expectancy before the 18th century, even in the most advanced countries.

For the set of developing countries in Figure 4.9, the data also indicate an improvement in life expectancy. In comparing Figures 4.8 and 4.9, note that the mortality transition in the developing world has been much more rapid than in the developed world. To give an example, in India life expectancy at birth increased

FIGURE 4.8

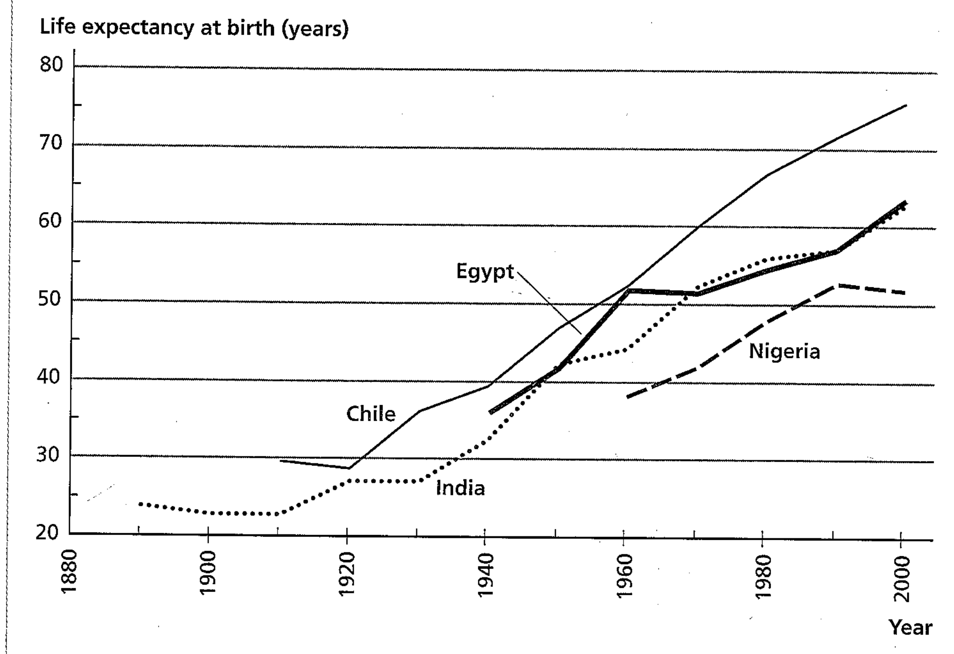
Life Expectancy in Developed Countries



Source: Livi-Bacci (1997).

FIGURE 4.9

Life Expectancy in Developing Countries



Source: Kalemli-Ozcan (2002).

from 26.9 years in 1930 to 55.6 years in 1980. In France a roughly comparable change took more than three times as long: Life expectancy at birth was 27.9 years in 1755 and reached 56.7 years only in 1930.

In addition to its speed, the crucial characteristic of the mortality transition in the developing world is its occurrence at a level of income per capita far below income in the rich countries when they went through a similar transition. For example, India achieved a life expectancy of 55.6 years in 1980 with income per capita of $1,239 (in 2000 dollars). By contrast, France achieved a life expectancy of 56.7 years in 1930 with income per capita of $4,998 (also in 2000 dollars).

Explaining the Mortality Transition. Reduced mortality has resulted from three forces. First, there have been improvements in the standard of living, most notably in the quantity and quality of food consumed. Preindustrial populations were often so chronically malnourished that people died from diseases that would not be serious problems among a better-fed population. As people became richer, they were less hungry and thus more resistant to disease. In addition to better food, other advances in living standards, such as improvements in housing and more frequent washing of clothes, reduced the toll taken by disease. A second factor in lowering mortality has been improvements in public health measures such as the securing of clean water and food and the draining of mosquito-infested swamps. A third force in lowering mortality has been the role of medical treatments in curing diseases.

In the countries that experienced economic development first, these three improvements in mortality took place more or less one at a time—first better nutrition and living standards, then improved public health measures, and then medical advances. The economic historian Robert Fogel concluded that improvements in nutritional status appear to explain about 90% of the decline in mortality rates in England and France between 1775 and 1875, but much less of the decline in mortality that took place thereafter.[6] The second half of the 19th century saw the creation of modern sewage and water supply systems in the cities of the most advanced countries, sharply reducing mortality from diseases such as cholera and typhoid fever. Only in the 20th century did medical treatment significantly contribute to improvements in life expectancy.

The explanation for the rapid declines in mortality in the developing world is exactly that many of the advances that accumulated slowly in the rich countries arrived in the developing world almost all at once. Governments and nongovernmental organizations rapidly imported public health techniques and modern medicine in the years before and after World War II. This difference in the sources of mortality improvement also explains why developing countries achieved improvements in longevity at much lower levels of income per capita than the income levels that prevailed when mortality fell in the developed world.

Fertility Transition

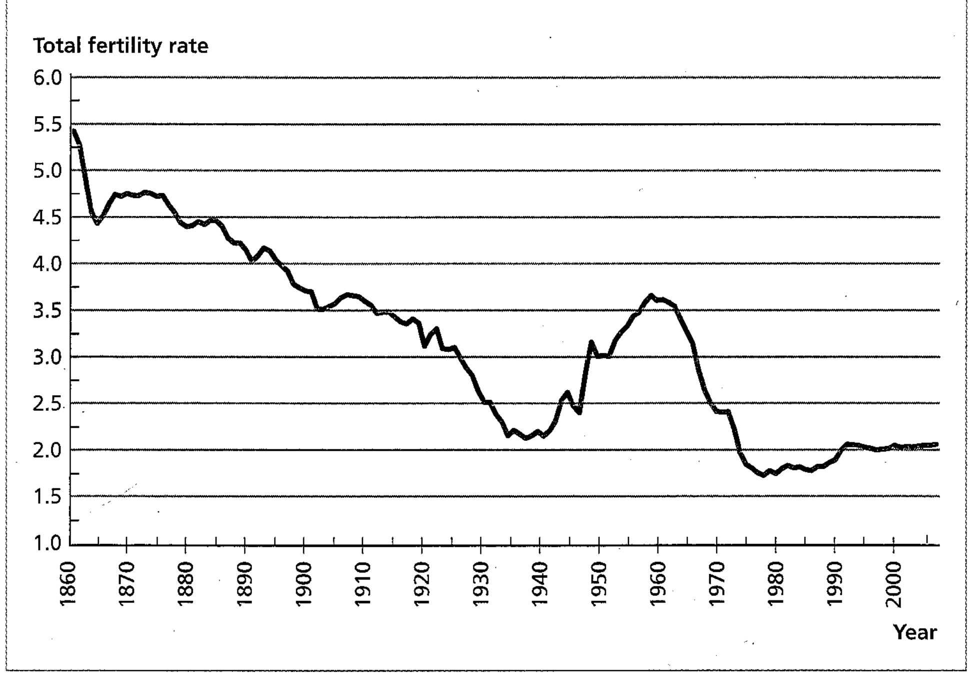
Demographers measure fertility by constructing an indicator called the **total fertility rate** (TFR), the number of children that a woman would have if she lived through all of her childbearing years and experienced the current age-specific fertility rates at each age. For example, if women aged 20–39 gave birth to an average of 0.2 children per year, and women outside this age group did not have any children, then the total fertility rate would equal 4 (that is, 20 years multiplied by 0.2 children per year). See this chapter's appendix for a longer discussion of how TFR is defined.

For an example of the fertility transition in the developed world, consider Figure 4.10, which shows the total fertility rate in the United States since 1860. Fertility has fallen dramatically over the last 140 years, from more than five children per woman to roughly two. But unlike the case of mortality, the change in fertility has not been a very smooth trend. Rather, there is a visible, temporary interruption in the downward trend of fertility: the baby boom of 1946 to 1964.

[6]Fogel (1997).

FIGURE 4.10

Total Fertility Rate in the United States, 1860–2005



Source: Coale and Zelnik (1963), Wade (1989).

This same pattern—particularly low fertility during the Great Depression and World War II, followed by a postwar burst of fertility—occurred throughout the developed world.

As in the case of mortality, the change in fertility in the developing world has been compressed into much less time than the fertility transition in the most developed countries. (For data on fertility change, see Table 5.1 in the next chapter.) For example, the movement from a TFR of 5 to a TFR of 3 took 63 years in the United States (from 1862 to 1925); in Indonesia the same change in the TFR occurred over only 15 years, between 1975 and 1990.

The Interaction of Fertility and Mortality

In Figure 4.10, we can see that the total fertility rate in the United States used to be roughly as high as that in many developing countries today (see Figure 5.4 in the next chapter). The same was true in Europe; for example, in the 18th century, England, France, and Spain all had TFRs greater than 5. How is it that population growth rates in Europe and the United States never approached the levels seen in the developing world today? We find the answer by recalling that the TFR expresses the number of children that a woman would have *if* she lived through all of her childbearing years. In historical populations, only a fraction of women were so lucky. Many never made it to maturity, and many more died during their fertile years, often in childbirth. Thus, to understand population growth, we have to look at the interaction of fertility and mortality.

A measure that combines the effects of fertility and mortality in determining population growth is the net rate of reproduction. The **net rate of reproduction** (NRR) is defined as the number of *daughters* that each girl who is born can be expected to give birth to, assuming that she goes through her life with the mortality and fertility of the current population (once again, see the appendix for a more formal definition). For example, suppose that half of all girls die in infancy and the other half live through their childbearing years, that women who live through their childbearing years give birth to an average of 4 children, and that half of all births are girls. The NRR will be 1, because 1/2 probability of having any children × 4 children × 1/2 children being girls = 1 expected number of daughters. Another way to think about the NRR is to consider it the factor by which the number of girls in each generation will increase. An NRR of 1 is consistent with population being constant—that is, zero population growth. An NRR of 2 means that the number of girls, and thus the population as a whole, will double every generation.

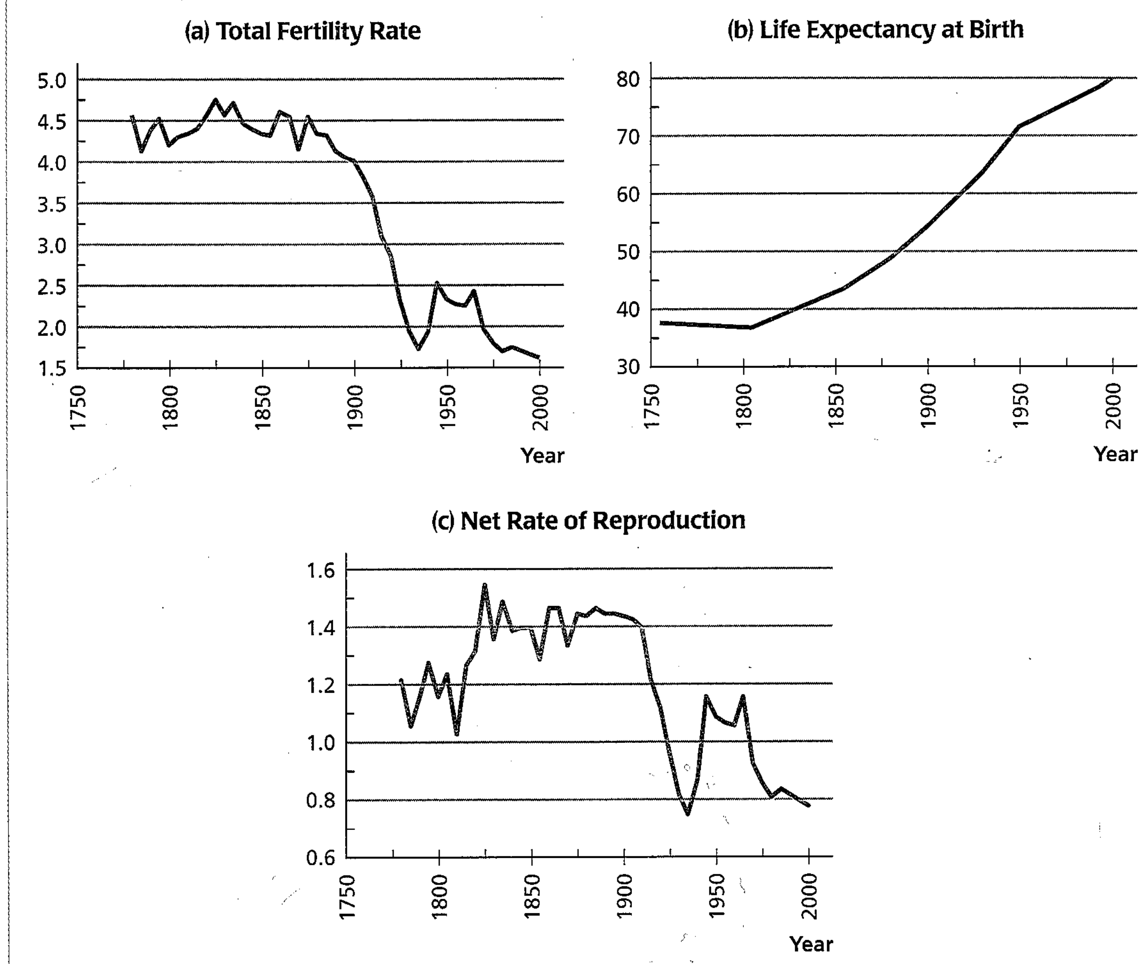
The NRR provides a way to see the important role that a decline in mortality can play in population growth. As an example, suppose that we are examining a country where, as was typical in many preindustrial societies, half of girls never lived to reach their reproductive years. Now imagine that mortality was somehow reduced so that all women survived their reproductive years. The NRR would double! If this population was exactly reproducing itself before the reduction in mortality (NRR of 1), then after the change, it would double every generation, without any change in fertility.

As a real-world example, Figure 4.11 shows the interaction of mortality and fertility changes in determining the net rate of reproduction in Sweden, whose experience is fairly typical. Panel (a) shows the total fertility rate; panel (b), life expectancy at birth; and panel (c), the net rate of reproduction. As the figure illustrates, the NRR rose well above 1 in response to the initial decline in mortality. There followed a long period (roughly a century) during which the NRR remained higher than 1 while both fertility and mortality fell. Finally, by the middle of the 20th century, improvements in mortality had lost their power to affect the NRR (because almost all girls were surviving through their fertile years), and further reductions in fertility translated into a reduction in the NRR.

In these data we can also see how different levels of fertility and mortality can combine to produce the same level of the NRR. The NRR was almost exactly the same in three different years: in 1780 (when it was 1.21), 1915 (when it was 1.21), and 1965 (when it was 1.15). But the underlying levels of fertility and mortality were very different. In 1780 the TFR was 4.54, and life expectancy was 36.9. In 1915

FIGURE 4.11

Fertility, Mortality, and the Net Rate of Reproduction in Sweden



Sources: Keyfitz and Flieger (1968, 1990), Livi-Bacci (1997).

the TFR was 3.08, and life expectancy was 58.6. And in 1965 the TFR was 2.41, and life expectancy was 73.7.

Thus, we can see the increase in the NRR above 1 for a sustained period of time as a result of the mismatch in timing between the mortality and fertility reductions. This century-long process led to a large multiplication of the population in Sweden, as indeed it did throughout Europe.

What about the developing world? Here there are two salient facts. First, while both fertility and mortality in the developing world have declined quickly relative to rates in the currently rich countries, the decline in mortality has been the faster of the two. As a result, the gap between fertility and mortality that has opened up in the developing world has been larger than any experienced in the rich countries. The net rate of reproduction (and thus the growth rate of population) has been correspondingly larger. Second, in many developing countries, the fertility transition is far from complete.

As examples, consider the experience of India and Nigeria, two of the most populous countries in the world today. In India, as shown in Table 4.1, the dramatic decline in the TFR over 40 years was sufficient to hold constant and then slightly reduce the NRR in the face of rising life expectancy. In Nigeria, according to the data in Table 4.2, the TFR was roughly constant. At the same time, life expectancy rose, causing a stunning increase in the NRR. Note that for both countries, the data start in the middle of the demographic transition. Even in 1955, the NRR in both countries was at the level found in Europe at the peak of population growth in the late 19th century.

TABLE 4.1

Demographic Data for India

Period	Total Fertility Rate	Life Expectancy at Birth	Net Rate of Reproduction
1955–1960	5.92	42.6	1.75
1965–1970	5.69	48.0	1.87
1975–1980	4.83	52.9	1.73
1985–1990	4.15	57.4	1.61
1995–2000	3.45	62.1	1.43

Source: United Nations Population Division (2002).

TABLE 4.2

Demographic Data for Nigeria

Period	Total Fertility Rate	Life Expectancy at Birth	Net Rate of Reproduction
1955–1960	6.90	38.2	1.97
1965–1970	6.90	42.0	2.12
1975–1980	6.90	46.1	2.28
1985–1990	6.70	50.2	2.38
1995–2000	5.92	52.5	2.20

Source: United Nations Population Division (2002).

4.4 | Explaining the Fertility Transition

Explaining the mortality transition is relatively easy for economists. As people grew richer, they consumed more of the things, like food and housing, that enabled them to live longer. And because most people want to live a long, healthy life, societies adopted new techniques for reducing disease when those techniques became available. Explaining the fertility transition, by contrast, is very hard. Like good health and long life, children are generally considered desirable. Why, then, as a country gets richer, do its citizens choose to have *fewer* children?

Economic theory has a lot to say about how many children people will want and how the optimal number will change over the course of economic development. But children are not like most other goods that economics considers, in that people may not always have the number of children they want. Thus, in considering fertility transition, we must also look at people's ability to control the number of their offspring.

Reduced Fertility: The Means

Malthus took it as fundamental that unless "passion between the sexes" could be suppressed, the human race was doomed to breed itself into poverty. Since well before Malthus's time, however, people have been attempting to avoid producing children without forgoing their passions. The oldest written reference to birth control, the Kahun Medical Papyrus (c. 1850 B.C.), gives recipes for three vaginal suppositories, including one based on crocodile feces and fermented dough. The Bible mentions (and condemns) the use of withdrawal to avoid conception. And ancient Greek medical texts discuss contraceptive potions, barriers, and suppositories, as well as the rhythm method and techniques for abortion.

A number of cultures have also practiced infanticide to control family size. The Greeks "exposed" (that is, left outdoors to die) children who were the products of rape or adulterous unions, and they may also have used the technique to limit the number of children. One ancient Greek writer commented, "Even a poor man will bring up a son, but even a rich man will expose a daughter."[7] The abandonment of children continued in Europe into the 19th century and was perhaps encouraged by the Catholic Church's policy of taking in foundlings—almost all of whom then succumbed to illness while under the Church's care.[8]

In Northern Europe before the Industrial Revolution, a pattern of relatively late marriage (the only birth-control method that Malthus approved of) served to reduce fertility. The median age at first marriage in 17th-century Britain was 28 for men and 27 for women. And in many cultures, a long period of breast-feeding has suppressed fertility. For example, in Indonesia in 1999, the median duration of

[7] McLaren (1990), Riddle (1992).
[8] Kertzer (1993).

breast-feeding was 24 months; one estimate is that if the duration of breast-feeding were to fall by half, the total fertility rate would rise by 37%.[9]

Over the last two centuries, the technology of fertility control has improved markedly. Condoms, which had existed for thousands of years, were improved in quality and fell in price after the invention of vulcanized rubber in 1844. The cervical cap was invented in 1838, the diaphragm in 1882, and the intrauterine device (IUD) in 1909. The contraceptive pill, now the most widely used form of contraception in the United States, became available in the 1960s.

Accompanying these technological changes, there has been a dramatic shift in the attitudes of society, and particularly government, toward fertility control. When U.S. birth-control pioneer Margaret Sanger (1879–1966) opened the first family-planning clinic in the United States in 1916, she was promptly arrested on obscenity charges. Theodore Roosevelt said, "The woman who flinches from childbirth stands on par with the soldier who drops his rifle and runs in battle." Only in 1965, with the Supreme Court's decision in *Griswold v. Connecticut*, were anti-contraception laws in the United States ruled unconstitutional. Many European countries maintained policies that were actively hostile toward birth control through much of the 20th century.

In the developing world, the post–World War II period has seen greatly increased concern about the consequences of rapid population growth, as well as the growth of policies designed to encourage fertility restriction. By 1990, 85% of the people in the developing world lived in countries where the government considered the rate of fertility too high.[10]

Does the increased availability of contraceptives explain the fertility transition? In Europe, the answer is certainly no, because the major decline in fertility took place before modern contraception became widely available. For example, in 1910, in the midst of a major drop in British fertility, only 16% of couples are estimated to have been using mechanical means of contraception such as condoms and diaphragms.[11]

In the developing world, the post–World War II decline in fertility did coincide with an increased use of birth control. Between the early 1960s and 1998, the rate of contraceptive prevalence—that is, the fraction of married couples aged 15–49 who are practicing some form of contraception—in the developing world rose from 9% to 55%.[12] But this fact does not prove that the increased availability of contraceptives caused fertility decline. Fertility could have fallen even if contraception had not been available, as in Europe. Studies of the effects of family-planning programs, which made contraception available, found that such programs explain between 10% and 40% of the decline in fertility in the developing world.[13] The rest of the decline is explained by changes in *desired* fertility—that is, in the number of children that families want to have. (See the box, "Family-Planning Programs and Their Effects.")

[9]Berg and Brems (1989), Population Reference Bureau (1999).
[10]Bongaarts (1994).
[11]McClaren (1990).
[12]Sadik (1991), United Nations (1998).
[13]Keyfitz (1989).

FAMILY-PLANNING PROGRAMS AND THEIR EFFECTS

The most effective example of a fertility reduction program, although at the cost of significant restrictions on human rights, is China's "one-child" policy, initiated in 1979. Under the policy, couples who agreed to have only one child received higher wages, as well as preferential treatment in housing, and those who had too many children were sometimes assessed a "social obligation fee" to offset the burden they imposed on society. The duty of couples to enforce family planning was even incorporated into the Chinese constitution. The policy had a dramatic effect: The TFR fell from 5.99 in 1965–1970 to 1.76 in 1995. By 2000, when the policy was relaxed, it is estimated to have resulted in the birth of 70 million only-children.

In India, the government used similarly drastic measures for a short time during the 1970s. Forcible sterilizations were carried out on people, who were sometimes literally snatched off the street and who afterward received a transistor radio as a "reward" for their participation. In 1976 alone, more than 8 million people were sterilized. Extremely unpopular, the program was quickly halted.

In contrast to these heavy-handed approaches, most family-planning programs in the developing world have relied on education and persuasion. In Mexico the government has incessantly broadcast the jingle "Small Families Live Better" on television since 1974. In India a campaign to encourage families to have two children used the slogan "We Two and Our Two" and was later replaced by a campaign for one-child families, using the catchphrase "We Are One and Our One."

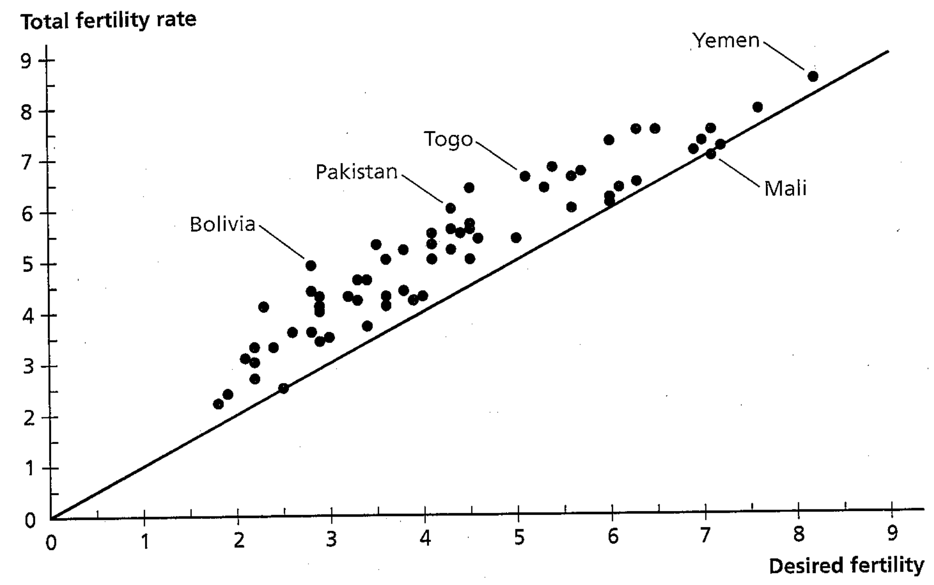
Indonesia in the 1970s and 1980s undertook a particularly broad program, with 40,000 village centers distributing free contraceptives and educational materials. The government promoted birth control relentlessly: The back of the five-rupiah coin displayed a two-child family with the message "Family Planning: The Way to Prosperity," and the national family-planning jingle played whenever a train passed a railway crossing. At five o'clock every afternoon, sirens went off around the country to remind women to take their birth-control pills. The number of couples practicing birth control rose from 400,000 in 1972 to 18.6 million in 1989, and over the same period, the TFR fell from 5.6 to 3.4 children per woman.*

Not all developing countries have encouraged fertility reduction, however, and some have even worked against it. In Ethiopia, for example, successive governments have opposed family planning, initially for religious reasons and later because such programs risked being perceived as an attempt to limit the growth of one ethnic group at the expense of another. Between 1975 and 1995, the country's total fertility rate rose from 5.2 to 7.4.†

How effective are government programs in reducing fertility? Researchers do not agree on the answer. Some estimate that government programs have only a trivial effect, but others say that such programs explain as much as 40% of the reduction in fertility that took place between the 1960s and the 1990s. Believers in the efficacy of government programs claim that a strong family-planning program will reduce the total fertility rate by roughly one child per woman.

*Keyfitz (1989).
†Berhanu and Hogan (1997).

FIGURE 4.12
Desired Fertility versus Total Fertility Rate in Developing Countries



Source: Pritchett (1994).

Figure 4.12 shows the relationship between actual fertility and desired fertility for a cross-section of developing countries, using data from the 1970s and 1980s. Desired fertility is measured based on surveys in each country asking women their ideal family size. If desired fertility were always equal to actual fertility, then all of the data points would lie along the 45-degree line shown in the figure. In fact, almost all of the data points lie above the 45-degree line, indicating that actual fertility is higher than desired fertility.

What is striking about the figure is that, for almost all of the countries, the two measures are fairly close. In a few countries, actual fertility is significantly higher than desired fertility—for example, in Bolivia (where the gap is 2 children), Pakistan (1.7 children), and Togo (1.5 children). But on average the difference is only 0.86 children per woman, and for the countries with the highest fertility, the gap is even smaller.[14]

Further evidence that differences in fertility among countries are not primarily due to the availability of contraception comes from surveys that ask women directly about their desires. A woman is defined as having an "unmet need" for contraception if she is biologically capable of becoming pregnant, wants no more children within the next two years, and is using neither traditional nor modern contraception. Women who are currently pregnant or have just given birth are considered to have an unmet need for contraception if they report that their pregnancy was unintended. By this definition, only 17 percent of women in developing countries who were married or in a consensual union reported an unmet need in 2002. Thus providing contraception to all women who wanted it in developing countries would reduce fertility by 17% at most.

[14]Pritchett (1994).

The data on unmet need, along with Figure 4.12, suggest that the biggest contributor to differences in fertility is not women's ability to achieve their desired fertility, but rather desired fertility itself. Thus, if we want to understand why fertility falls as countries grow, we should focus on why desired fertility falls. In other words, we should look at how economic growth changes the environment that families face in such a way that they want fewer children.

Reduced Fertility: The Motives

The idea that economic growth is the best way to reduce fertility was famously summarized at a United Nations conference in 1975 in the phrase "development is the best contraceptive." What is it about development that leads to lower fertility? In this section we discuss four possible channels.

The Effect of Mortality Reduction. Section 4.3 showed that the growth rate of population is determined by the interaction of fertility and mortality. We also learned that economic growth is generally accompanied by declines in both fertility and mortality. One reasonable hypothesis is that the decline in mortality is in fact *causing* the decline in fertility.

The starting point for understanding this effect is the observation that families care not about the number of children who are born but about the number who survive to adulthood—and often particularly about whether they produce a surviving son. As mortality falls, it becomes possible for families to produce the same number of surviving adults with lower fertility.

As was the case in Sweden (as shown in Figure 4.11), the typical pattern is for declines in mortality to precede declines in fertility, leading to a long period of time in which the net rate of reproduction is above 1. One explanation for this pattern is that it takes parents some time to recognize that mortality has fallen and consequently to adjust their fertility.

It is also possible for a decline in mortality to produce a more than offsetting decline in fertility—that is, for mortality decline to lower the net rate of reproduction. The reason is that when mortality is high, parents have even more children than is necessary, on average, to produce the number of survivors they want. The extra children are a form of insurance against the riskiness of survival. A drop in mortality rates eliminates the need for this extra fertility.

An example can make this point more concretely. Suppose that all couples would like to have one surviving son. Suppose further that the probability of a child's surviving into adulthood is only 50%. A couple that had two sons would, on average, see one survive into adulthood. But in such a case, there would still be a significant chance (one in four) that neither son would make it to adulthood. Couples might well view this risk as unacceptable and so continue having children until they had three sons. In that case, the chance that none would survive to adulthood would fall to one in eight. If all couples had three sons—and thus six children on average—the average number of surviving children would be three, and the net rate of reproduction would be 1.5.

Now consider what happens in this case when mortality falls to the point where all children will survive until adulthood. Couples will continue having children until they have one son (on average, two children). Because both children will survive to adulthood, the net rate of reproduction will be 1. A decline in mortality therefore will have produced a more than compensating decline in fertility.

Income and Substitution Effects. Before probing further into why fertility falls as income rises, we should consider the opposite question: Why doesn't fertility *rise* as income rises? The logic for such an effect seems simple: People value children just as they value other "goods" on which they spend resources. As people become wealthier, they consume more of most other goods (so-called *normal goods*). The same should be true with respect to their desire for children.

The fault with this logic is that it ignores a second effect of income growth, which is that it raises the *price* of children. One of the things that children demand most is their parents' time, and when a country's income rises, the opportunity cost of that time—in other words, the wage that a parent could earn if he or she were not taking care of children—also rises. Thus, economic growth has two effects on the demand for children that should be familiar from microeconomics:

- An *income effect*—When you are richer you can afford more of everything.
- A *substitution effect*—When your wage is higher, children are relatively more expensive.

Whether the income or substitution effect dominates—that is, whether economic growth raises or lowers desired fertility—depends on the exact nature of households' preferences for children versus the other things that they could buy with their money.

The substitution effect results from the fact that as wages rise, the cost of spending time on raising children rises as well. Thus, an increase in wages raises household income and the price of children at the same rate. Furthermore, there is a phenomenon that amplifies this substitution effect over the course of economic development: Not only do wages rise in general, but the *relative* wages of women, who tend to do most child-rearing, rise as well. For example, in the United States between 1890 and 1988, full-time earnings of women rose from 46% of men's earnings to 67% of men's earnings. This rise in women's relative wages causes the price of children—that is, the opportunity cost of women's time—to rise even faster than household income. This effect provides a further reason why fertility will fall with economic growth.[15]

The effect of women's relative wages on fertility has been reinforced by—and has in turn reinforced—the education of women. In a society where women will spend most of their adulthood tending to children, there is less economic motivation to provide girls with an education. As women spend more of their time working (and can earn fair wages for that work), the incentive to provide girls with education rises. Women who were educated as girls will in turn earn higher wages and thus face a higher opportunity cost of bearing children. Educated women are also more likely to know how to control fertility and to see a benefit in such control. Fertility surveys conducted in Latin America in the 1970s found that women with seven or more years of education had a total fertility rate of 3.2, while women with one to three years of schooling had a total fertility rate of 6.2.[16]

Resource Flows Between Parents and Children. As a country develops, the economic benefits of children tend to fall while the cost of raising children rises. In developing countries, children can be productive at a young age, for example by doing simple tasks around the farm. A study of a village in Bangladesh in the 1970s concluded that a boy could begin paying his own way—that is, producing enough to compensate his family for the costs of feeding and sheltering him—by age 12. A historical example from Europe makes a similar point. In the 19th century, the French government paid families to take in abandoned children, with the scale of payments falling as children got older. Until 1852, the government took no responsibility for children over 12, on the assumption that such children could pay their own way.[17] In developed countries, by contrast, the period of time during which children do not work is much longer. Moreover, costs for education can continue well into the third decade of the child's life.

In developing countries, children also often provide for their parents in old age. Typically, no other sources of old-age support are available, so producing children (especially sons) becomes an economic necessity. In developed countries, by contrast, financial markets are sufficiently well developed that people can save for their old age. Further, although the young generation provides support for the elderly through government programs like Social Security in the United States, this

[15] Galor and Weil (1996).
[16] Shultz (1997), Table 3.
[17] Cain (1977), Fuchs (1984).

support is not provided by one's own children. Thus, the incentive for an individual family to produce children is reduced.

This change in the relative costs and benefits of children is clearly part of the explanation for the decline in desired fertility as a country develops. But it is not a complete explanation, for two reasons. First, it is clear that parents don't value children solely in economic terms. If they did, people in developed countries today would never have any children. Second, the costs of children have to be explained themselves. Parents today spend much more on their children than past generations, but to a large extent this spending is voluntary—that is, the spending is well beyond what ensures their children's survival. Thus, we really must consider why parents spend more today, a question to which we now turn.

Quality-Quantity Trade-offs. Parents hope that the resources they devote to rearing and educating their children will have payoffs in terms of better health, higher earnings later in life, and the general well-being of their children. We can think of these expenditures, beyond the minimum necessary for survival, as investments in the *quality* of the child. Parents may value child quality for a number of reasons. In cases where they are relying on their children for support in old age, children who are healthier or better educated, and thus likelier to earn high wages, will be better providers. In cases where children do not support their parents in old age, parents may be made happier by their children's happiness, so they still have an incentive to spend money on child quality.

Using this perspective, we can think of the decline in fertility that takes place over the course of economic development as a change in the mix of quality and quantity that parents are purchasing. The question is, What is it about economic growth that makes parents alter the mix of quality and quantity they choose?

We have already seen one important way in which economic growth changes the choice between quality and quantity: Growth is associated with a decline in mortality. In an environment where many children will die before adulthood, parents will be reluctant to spend too much on the care or education of a single child. Instead, they will have many children and spread out their risk, much as investors diversify their portfolios by buying a number of different assets. In an environment where survival to adulthood is almost assured, parents will be secure in concentrating their resources on only a few children.

A second channel by which economic growth induces parents to invest more in the quality of their children is by increasing the benefits that this quality produces. Specifically, growth is associated with an increase in the value of education, giving parents an increased incentive to educate their children. As we will see in Chapter 6, parents' choice to invest more in each of their children has important implications. Children who receive more education and better health care will be more productive workers as adults, and this increase in the quality of workers is an important contributor to economic growth.

4.5 | Conclusion

In this chapter we have examined both how population affects economic growth and how population growth is itself determined. The Malthusian and Solow models provide two ways of analyzing how population affects growth. These models differ from each other in three respects. First, where the Malthusian model focuses on the interaction of population with a natural resource such as land, the Solow model focuses on how population interacts with capital. Second, where the Malthusian model concentrates on the effect of the *size* of the population on the income level, the Solow model concentrates on the effect of population *growth* on the income level. Third, in the Malthusian model, income and population are endogenously determined, while in the Solow model, the growth rate of population is taken as exogenous.

The Malthusian and Solow models are linked to other aspects of our study of economic growth. The Solow model presented in this chapter is an extension of the simpler version of the same model presented in Chapter 3. And in upcoming chapters we examine other aspects of the Solow model and further consider its ability to fit the data on cross-country differences in income. As to the Malthusian model's focus on the interaction between population and natural resources, Chapters 15 and 16 return to the more general question of how natural resources affect economic growth.

With the Malthusian and Solow models as our motivation, we investigated the determinants of population growth. The most important point to take from this analysis is the extent to which population is in rapid flux. The process of demographic transition—the reduction in both mortality and fertility that accompanies economic growth—which took roughly a century in the developed countries, is now occurring at greatly accelerated speed in the developing world.

Because the demographic transition in the developing world is incomplete, we do not know how it will end. Most important, it is difficult to forecast with any confidence whether population growth in the developing world will stabilize near zero. We return to this issue in the next chapter, where we also take up the question of whether population growth in the developed countries could potentially fall well below zero.

KEY TERMS