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

capital dilution 93
demographic transition 97
mortality transition 97
fertility transition 97
life expectancy at birth 98
total fertility rate (TFR) 100
net rate of reproduction (NRR) 102

QUESTIONS FOR REVIEW

1. What two key mechanisms are at work in the Malthusian model? How do they lead to a steady-state level of population and income per capita?
2. How will changing the level of productivity in an economy affect income per capita in the Malthusian model?
3. How is population growth incorporated into the Solow model? Why does the model predict that countries with higher population growth rates will have lower steady-state income per capita?
4. What is a demographic transition?
5. How do fertility and mortality interact to determine the net rate of reproduction?
6. What are the possible channels through which economic growth leads to a reduction in fertility?
7. In *The Wealth of Nations* (1776), Adam Smith wrote, "The most decisive mark of the prosperity of any country is the increase in the number of its inhabitants." How would Smith's view have to be revised today? How would you explain the change to Smith?

PROBLEMS

1. Modern *Homo sapiens* emerged roughly 100,000 years ago. Assuming that originally there were just two *Homo sapiens* and that today there are 7 billion, what has the average growth rate of the population been?
2. For each of the following scenarios, use the graphical depiction of the Malthusian model to illustrate what happens to a country's population size and per-capita income in the short run and in the long run.
   a. Scientists discover a new strain of wheat that can produce twice as much grain per acre.
   b. A war kills half of the population.
   c. A volcanic eruption kills half the people and destroys half the land.
3. Consider the Malthusian model, as shown in Figure 4.3. Suppose that the economy is in steady state when suddenly there is change in cultural attitudes toward parenthood. For a given income, people now want to have more children than they formerly had. Draw a graph showing the growth rate of population over time.
4. How would you use a randomized controlled trial (see box in Chapter 2) to assess the importance of "quality-quantity tradeoffs" in determining how much parents invest in their children? Can you think of a "natural experiment" that allows for similar inference without so many ethical problems?
5. Suppose that there are two countries, X and Y, that differ in both their rates of investment and their population growth rates. In Country X, investment is 20% of GDP and the population grows at 0% per year. In Country Y, investment is 5% of GDP, and the population grows at 4% per year. The two countries have the same levels of productivity, A. In both countries, the rate of depreciation, δ, is 5%. Use the Solow model to calculate the ratio of their steady-state levels of income per capita, assuming that $\alpha = 1/3$.
6. Consider the Solow model with population growth, as presented in the text. Assume that population can grow at two different rates n_1 and n_2, where $n_1 > n_2$. The population growth rate depends on the level of output per capita (and therefore the level of capital per capita). Specifically, population grows at rate n_1 when $k < \bar{k}$ and slows down to rate n_2 when $k \geq \bar{k}$.

   Draw a diagram for this model. Assume that $(n_1 + \delta)\bar{k} > \gamma f(\bar{k})$ and that $(n_2 + \delta)\bar{k} < \gamma f(\bar{k})$. Explain what the diagram says about the steady state of the model.
7. Suppose that two countries, A and B, have the same rates of investment and depreciation, the same levels of productivity, and the same levels of output per worker. They differ, however, in their rates of population growth. The growth rate of population in Country A is greater than in Country B. According to the Solow model, which country should have a higher growth rate of output per worker? Explain your answer. (Hint: It may be helpful to look back at pp. 66–68)
8. Suppose that in a country one-third of all females born die in infancy, one-third die at age 30, and one-third live to age 60. Women bear one child at age 25, one child at age 28, one child at age 32, and one child at age 35. One-half of children are girls.
   a. Compute the TFR and the NRR.
   b. Suppose that mortality is reduced so that there is no infant mortality. Half of all women die at age 30 and half at age 60. Compute the NRR.
   c. Suppose now that age-specific fertility changes, so that women have (on average) one-half child at ages 25, 28, 32, and 35. Compute the TFR and the NRR.
9. Consider the following Malthusian model. Suppose that the relationship between income per capita (y) and the growth rate of the population ($\hat{L}$) is given by the equation:

$$\hat{L} = y - 100.$$

   Suppose that output is produced using labor and land, according to the equation

$$Y = L^{1/2}X^{1/2},$$

   where X is the quantity of land. Assume that $X = 1{,}000{,}000$.
   a. Draw a graph with y on the horizontal axis and $\hat{L}$ on the vertical axis, showing the relationship between income per capita and population growth.
   b. Derive the relationship between population, L, and income per capita, y. (Hint: Remember that $y = Y/L$.) Sketch this relationship on a graph with L on the vertical axis and y on the horizontal axis.
   c. Use the equations you have derived to compute the steady-state values of L and y.