Chapter Focus Questions

- How fast is world population growing?
- What are the prospects for future population growth?
- What relationship exists between population and economic development?
- How does population growth affect the global environment?

10.1 THE DYNAMICS OF POPULATION GROWTH

Human population has grown slowly throughout most of our history. Only within the last two hundred years has more rapid global population growth become a reality. Figure 10.1 shows the history of global population increase during the nineteenth and twentieth centuries, with a baseline projection for the twenty-first century. As the diagram shows, in the past 100 years, population growth has accelerated at a pace unprecedented in global history.

In 1800, global population stood at about 1 billion after many centuries of slow growth. By 1950, the figure had reached 2.5 billion. A rapid post-World War II growth acceleration doubled population to 5 billion in less than 40 years (by the year 1987). By the year 2000, world population had passed six billion and by the end of 2011, it reached 7 billion. Current “median” projections show population eventually leveling off at around 10 billion by the year 2100.¹

Extraordinarily rapid population growth—about 2% per year—took place from 1960 to 1975. At first consideration, 2% may not sound so remarkable—but at this rate of growth, population doubles in about 35 years. After 1975, the growth rate slowed, but the much larger size of total population meant that the absolute number of people added each year continued to increase until the first decade of the twenty-first century (Figure 10.2).

During this period of extremely rapid growth, various authors sounded the alarm regarding the dangers of exponential growth. A population of 5 billion that continued to grow at 2% per year, for example, would reach 20 billion in 70 years and 40 billion in a little over a century. Finding food, water, and living space for such a vastly increased population would be impossible; the grim Malthusian controls of famine and disease would take over.²

² As noted in Chapter 2, Thomas Malthus predicted in the nineteenth century that population growth would outrun food supplies, leading to population control via famine and disease.
Authors such as Paul and Anne Ehrlich have repeatedly warned since the late 1960s that humanity was on a collision course with the natural world and that runaway population growth could overcome all the benefits of modern science and economic growth, leaving a devastated and miserable planet. This neo-Malthusian perspective has gained much attention, and provides the starting point for the modern debate on population growth.

Those who find the Ehrlichs' perspective overly negative often point out that population growth rates have been declining since the 1970's; as of 2011, overall global rate was down to 1.1% and continuing to fall. Does this mean that population will soon stabilize, and fears of rapid growth are mere alarmism? Unfortunately not.

First, the declining growth rate is occurring at a time when total population is much higher than ever before. According to United Nations figures, the global gross annual population increase as of 2011 was 77 million. This annual addition to the planet's human numbers is the equivalent of more than the entire population of Germany. Each year, we now add more people than we added annually during the 1960's, when the growth rate was at its highest (See Table 10.1 and Figures 10.2 and 10.3). The equivalent of a new New York City every 5 weeks, a new France every nine months, a new India in about 14 years—this is hardly cause for complacency.

With a population of 7 billion people at the end of 2011, United Nations "median" projections indicate that the 8th billion will be reached in 2025, the 9th billion in 2043, and the 10th billion sometime around the last two decades of the 21st century. The global demographic picture is far from stabilized, and this reality will continue to underlie environmental issues for many more decades.

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4 The Population Reference Bureau gives a higher estimate of 83 billion for net annual addition to population in 2011 (Population Reference Bureau, 2011).
Figure 10.1 Global Population Growth and Projections, 1750-2100


Figure 10.2 Net Annual Increase in Population By Decade 1750-2100

<table>
<thead>
<tr>
<th></th>
<th>1950s</th>
<th>1960s</th>
<th>1970s</th>
<th>1980s</th>
<th>1990s</th>
<th>2000s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Growth Rate</td>
<td>1.80%</td>
<td>2.00%</td>
<td>1.90%</td>
<td>1.80%</td>
<td>1.40%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Average Annual Increase (millions)</td>
<td>50.6</td>
<td>65.7</td>
<td>75.6</td>
<td>85.3</td>
<td>81.6</td>
<td>76.5</td>
</tr>
</tbody>
</table>

**Table 10.1 Global Population Growth Rates and Average Gross Annual Increase**

*Source: United Nations, 2010*

**Figure 10.3 World Population Growth Rate 1950-2010, with Projections to 2050**

*Source: United States International Census Bureau, http://www.census.gov/population/international/data/idb/informationGateway.php*
The second reason why population is a crucial concern has to do with the regional pattern of population growth. It is precisely in the poorest and most hard-pressed nations that continuing population growth will be most rapid. More than 90% of the projected growth will come in the currently developing nations of Asia, Africa, and Latin America (Table 10.2). Many of these nations, especially in Africa, have trouble providing adequate food supplies and basic goods to their present populations.

Developed nations currently create the greatest environmental impact through their high per capita demand on resources, as well as pollution generation. If the developing nations succeed in raising living standards for their expanding populations—as China and other East Asian nations have done—their per capita demands for food and resources, as well as their pollution generation, will also increase. The combined effects of population and economic growth will significantly increase environmental pressures.

<table>
<thead>
<tr>
<th>Regions</th>
<th>2010 Population (millions)</th>
<th>Low fertility</th>
<th>Medium fertility</th>
<th>High fertility</th>
</tr>
</thead>
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<tr>
<td>Africa</td>
<td>1,022</td>
<td>1,932</td>
<td>2,192</td>
<td>2,470</td>
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<tr>
<td>Asia</td>
<td>4,164</td>
<td>4,458</td>
<td>5,142</td>
<td>5,898</td>
</tr>
<tr>
<td>Latin America/Caribbean</td>
<td>590</td>
<td>646</td>
<td>751</td>
<td>869</td>
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<tr>
<td>Europe</td>
<td>738</td>
<td>632</td>
<td>719</td>
<td>814</td>
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<tr>
<td>Northern America</td>
<td>345</td>
<td>396</td>
<td>447</td>
<td>501</td>
</tr>
<tr>
<td>Oceania</td>
<td>37</td>
<td>49</td>
<td>55</td>
<td>62</td>
</tr>
<tr>
<td>More developed regions</td>
<td>1,236</td>
<td>1,158</td>
<td>1,312</td>
<td>1,478</td>
</tr>
<tr>
<td>Less developed regions</td>
<td>5,660</td>
<td>6,955</td>
<td>7,994</td>
<td>9,136</td>
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<tr>
<td>World</td>
<td>6,896</td>
<td>8,112</td>
<td>9,306</td>
<td>10,614</td>
</tr>
</tbody>
</table>

Table 10.2 Population Projects for Three Fertility Scenarios

The three fertility scenarios used by the UN population projections

Future population growth is highly dependent on the path that future fertility takes.

The United Nations uses three scenarios or “variants” for the future evolution of fertility:

- **Medium variant**: assumes that world average fertility will decline from 2.52 children per woman in 2005-2010 to 2.17 children per woman in 2045-2050.
- **High variant**: assumes that fertility levels will remain about half a child above the levels projected in the medium variant, i.e. will reach 2.64 children per woman in 2045-2050. In this scenario, world population would reach 10.6 billion by 2050 and 15.8 billion by 2100.
- **Low variant**: assumes that world average fertility will drop to a level of about half a child below the medium variant, i.e. to 1.71 children per woman in 2045-2050. In this scenario, world population peaks at mid-century at about 8.1 billion, then decreases to 6.2 billion by the end of the century.

10.2 PREDICTING FUTURE POPULATION GROWTH

How well can we predict future population growth? The projected population shown in Figure 10.1 is a baseline “median” prediction. Could the actual figures be much higher, or much lower? As Table 10.2 and Figure 10.4 show, assumptions about changes in fertility rates significantly influence projections. The three scenarios shown cover a range of possibilities for global population in the year 2050, ranging from 8.1 to 10.6 billion people. Within this range, the major factor lending credibility to projections of continued population growth is the phenomenon of population momentum.

To understand population momentum, let’s consider a hypothetical country, Equatoria, which has been experiencing rapid population growth for several generations. For simplicity, we’ll define a generation as equal to 25 years, and divide the population of Equatoria into three age categories: under 25, 25 to 50, and over 50 years old. Suppose the population growth rate averages 3% per annum (this is a high but not unprecedented rate in developing nations— the current population growth rates for Liberia, Niger, Gambia, and Mali, for example, are close to 3%). At this rate, each generation will be roughly twice as numerous as the preceding generation. This will give a population age profile which is shaped like a pyramid (Figure 10.5).

Now consider the future demographics of Equatoria. If this growth rate continues, the population will double every 25 years. If it was 7 million in 2000, as shown in our diagram, it will be 14 million by 2025, 28 million by 2050, and 56 million by 2075. No nation can long withstand the environmental and social pressures of such growth. But of course the growth rate may decline.

For this to happen, the average fertility rate must fall. The fertility rate is defined as the number of children born by the average woman during her lifetime. The fertility rate in Equatoria must be around 5 children per woman to account for such rapid rates of growth. Again, this is not unusual in the developing world. The average fertility rates in Sub-Saharan Africa in 2011 were often higher than 5 children per women: 5.7 in Nigeria, 6.4 in Mali and 7.0 in Niger. In other parts of the world, high levels of fertility can be found in countries such as Guatemala (3.6 children per women), Iraq (4.7) or Afghanistan (6.3). 6

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6 Population Reference Bureau, nb2011.
Stabilizing population requires achieving a replacement fertility level, which is just over 2 children per woman (the precise number depends on the rate of infant and child mortality). At replacement fertility level, each new generation will be exactly the size of the preceding one. Achieving such a lowered fertility rate usually takes many years in a country such as Equatoria. Suppose Equatoria reaches this goal. Does this mean that the population growth problem is over? Absolutely not!

Imagine a fantastically effective population policy that would lower fertility to replacement level immediately. Equatoria’s demographic future would then be as shown in the second and third parts of Figure 10.5. Each new generation would be exactly the size of the last. The current generation of under-25’s, however, is Equatoria’s largest ever. Even if they only replace themselves in numbers, the population will continue to grow for two more generations.
The next generation of children will be four times as large as the current over-50 generation, meaning that the birth rate will be several times as high as the death rate for another 25 years. For the 25 years after that, the birth rate will still be around double the death rate. The population growth rate, which is the difference between the birth and death rates, will continue to be positive. Only when the current generation of children reaches the end of their life span will their grandchildren no longer outnumber them. Thus Equatoria's population will continue to grow for 50 years before it stabilizes, reaching a total of 12 million, 71% more than its current level, before it stabilizes.

This is the meaning of population momentum. When a nation has a history of rapid population growth, continued growth for the next several generations is virtually guaranteed, short of some massive Malthusian catastrophe which dramatically raises death rates. A more realistic projection for Equatoria might be that fertility rates, rather than falling instantaneously as in our hypothetical case, would take about a generation to reach replacement level. In that case, population would continue to grow for 75 years, finally stabilizing at a level that would be more than double the 2000 level.

The case of Equatoria is not merely an abstract example. As Figure 10.6 shows, the simplified population pyramid we have described is very close to the reality for much of Africa. (Use Figure 10.5, frame 3, to visualize a future Africa where all population age groups or population cohorts are at least as large as the present cohorts of young children.)

Population momentum is also considerable throughout Asia and Latin America. Projections of population growth for these regions are therefore well founded. The inexorable logic of population momentum guarantees growing human numbers well into the twenty-first century. The stable age structure of Western Europe shown in the second frame of Figure 10.5 is the exception, not the rule. This is why even the lowest global population projections for 2050 are still about 8.1 billion.7

Population momentum makes substantial increase inevitable, but a huge difference remains between "low" and "high" forecasts for the years 2050 and beyond (see Table 10.2 and Figure 10.7). The critical variable in these differing projections is the rate of future fertility decline. If fertility falls rapidly throughout the developing world, the global population age pyramid could approach a more stable pattern within the next 35 years. (Compare the global low fertility scenario for 2030 in Figure 10.7 with the West European population age structure in Figure 10.6.) On the other hand, a slow decline would leave the world with both a higher population and considerable remaining momentum in 2030 (see Figure 10.7).

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7 United Nations Department of Economic and Social Affairs, Population Division, 2010.
Figure 10.6  Population Age Structures for Sub-Saharan Africa and Western Europe, 1990

Figure 10.7  Alternative Futures for World Population

Note: Male population on left, female on right.
Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2010 Revision,
http://esa.un.org/unpd/wpp/unpp/panel_indicators.htm
The Impact of AIDS

World population projections take into account the impact of diseases such as malaria, which kill millions annually. But the recent spread of HIV/AIDS has altered the picture of disease mortality. According to a 2010 United Nations report, more than 32 million people worldwide have lost their lives to the epidemic in the past three decades. This huge number makes HIV/AIDS one of the deadliest epidemics of all times, comparable to the Black Death in 14th century Europe that killed more than 20 million people.

Fortunately, prevention policies and medical discoveries have made dramatic progress since the HIV/AIDS virus was first identified 30 years ago. In 2009, there were 33.3 million people living with HIV/AIDS, among them 2.5 million children under 15. The number of people newly infected peaked in 1999 at 3.1 million per year, but as a result of better prevention, this figure has been slowly decreasing since then, reaching 2.6 million in 2009. Efficient treatments have been developed in the 1990s which slow down the effects of HIV among infected people and significantly improve their life expectancy. But these treatments were only accessible to 5 million people among the 33 million infected in 2009, the high costs of the needed medication putting them out of reach for many of the poor people infected in Africa. Of the 1.8 million people who died of AIDS in 2009, 72% (1.3 million) lived in Sub Saharan Africa.

International efforts by governments and private foundations have focused on making new medications more broadly available. The effects of antiretroviral therapy are especially evident in Sub-Saharan Africa, where an estimated 320,000 (or 20%) fewer people died of AIDS-related causes in 2009 than in 2004, when antiretroviral therapy began to be dramatically expanded. In 2009 alone, 1.2 million people received HIV antiretroviral therapy for the first time—an increase in the number of people receiving treatment of 30% in a single year. In Asia, an estimated 4.9 million people were living with HIV in 2009, about the same as five years earlier. Most national HIV epidemics appear to have stabilized.8

What is the effect of AIDS on world population growth? The epidemic affects population growth directly in terms of increased mortality related to AIDS and indirectly through the reduction in the number of births caused by the sickness or premature death of potential parents. In projections made in 2007 by the UN for the 62 countries most significantly affected by the epidemic, the population projection for 2015 is 2% smaller taking account of the impact of HIV/AIDS than it is in the absence of the disease. In Southern Africa, the most affected region, the reduction in the population projection for 2015 is 14%.9 But overall population in Southern Africa is still growing, with a projected increase of 9% by 2025 and 17% by 2050.10

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Thus AIDS, while creating a massive worldwide public threat and humanitarian disaster, will certainly not reverse population growth, not even in the hardest-hit countries in Southern Africa, where the increased death rates due to AIDS are still lower than birthrates driven by some of the highest fertility rates in the world. The AIDS epidemics will, however, add enormously to the public health burden on countries already struggling with the needs of a large population of children. Many of these children are or will become orphans, creating enormous stress on family, social and medical systems.\textsuperscript{11}

\textbf{BOX 10.1: RAPID POPULATION GROWTH STRESSES NIGERIA}

In a quarter-century, at the rate Nigeria is growing, 300 million people—a population about as big as that of the present-day United States—will live in a country roughly the size of Arizona, New Mexico and Nevada. Lifelong residents like Peju Taofika and her three granddaughters inhabit a room in a typical apartment block known as a “Face Me, Face You” because whole families squeeze into 7-by-11-foot rooms along a narrow corridor. Up to 50 people share a kitchen, toilet and sink—though the pipes in the neighborhood often no longer carry water.

Across sub-Saharan Africa, alarmed governments have begun to act, often reversing longstanding policies that encouraged or accepted large families. Nigeria made contraceptives free last year, and officials are promoting smaller families as a key to economic salvation, holding up the financial gains in nations like Thailand as inspiration. Nigeria, already the world’s sixth most populous nation with 167 million people, is a crucial test case, since its success or failure at bringing down birthrates will have outsize influence on the world’s population. If this large nation rich with oil cannot control its growth, what hope is there for the many smaller, poorer countries?

“Population is key,” said Peter Ogunjuyigbe, a demographer at Obafemi Awolowo University in the small central city of Ile-Ife. “If you don’t take care of population, schools can’t cope, hospitals can’t cope, there’s not enough housing—there’s nothing you can do to have economic development.”


\textsuperscript{11} In 2009, more than 16.6 million orphans worldwide had lost their parents to AIDS, 14.8 million of whom lived in Sub Saharan Africa.
10.3 THE THEORY OF DEMOGRAPHIC TRANSITION

From the 1960s to the 1990s, the international community has shown growing concern about rapid population growth, expressed at the third United Nations International Conference on Population and Development in Cairo in 1994, which grappled with the issue of an appropriate response to growing world population. This conference adopted the ambitious goal of stabilizing world population at about 7.27 billion by the year 2015—an increase of roughly 30% over 1994 levels.

This objective will obviously not be reached since, as of late 2011, the population has already reached 7 billion and will not stabilize any time soon. In the past two decades, the interest of the international community seems to have shifted away from its previous focus on population growth. There are several explanations for this, including 1) the strong resistance of developing nations of the global South to demographic goals imposed by developed countries 2) a political shift in the developed countries, in particular the United States, whose conservative politics and attitudes towards fertility and natality under the Bush Administration (2001-2008) undermined efforts to spreading and sustain worldwide strong policies of family planning (including broad access to contraception and abortion).

Current median projections by the United Nations indicate a world population of 8 billion by 2025, a net addition of 1 billion people over 2011 levels, with growth continuing after that towards a possible 9 billion in 2045 and 10 billion by 2100. Certainly the task of supplying the needs of an extra 2-3 billion people is a daunting one. The course of population growth and fertility levels over the next 20 years will profoundly affect all the issues of food production, resource use, and pollution generation which we consider in upcoming chapters. What then, can an environmental or ecological economics analysis tell us about population policy?

Much thinking about the relationship of population to economic growth rests on the experience of Western Europe. Western Europe’s situation is considered the final stage of demographic transition from high to low birth and death rates. Figure 10.8 shows the pattern of this demographic transition.

In the first stage, corresponding to pre-industrial Europe, both birth and death rates are high. Large families are common, but medical care is poor and many children die young. On average, a family only produces two surviving children. Thus the population remains about the same from generation to generation. These social conditions resemble in many ways the state of nature, where birds and animals typically produce numerous progeny to offset high rates of predation and disease. It is a harsh but ecologically stable regime.
The second stage sees the take-off of industrialization, as in nineteenth century Europe. Death rates fall rapidly as standards of living, public health, and medical care improve. Birthrates remain high, however, because families still view a large number of children as valuable, both to work on the farm or in the factory (child labor is still legal and common), and as a form of old-age insurance (no Social Security institutions exist). Since net population growth rate is equal to the birth rate minus the death rate (the distance between the two lines in Figure 10.8), the result is a rapidly growing population.

Population Growth Impact

Is growing population a good or bad thing for the country as a whole? If resources are abundant, the nation's leaders may welcome it. A large labor force promotes rapid economic growth, making it possible to take advantage of unexploited resources and new technology. However, this period of rapid population and economic growth probably contains some self-limiting factors.

One such factor is the improvement in social conditions which is likely to accompany economic growth. This development, by no means automatic, often requires hard-fought battles for social and economic reform. Eventually, however, the nation may achieve social changes characteristic of economically developed nations,
including child labor laws, unemployment compensation, social security systems, private pension plans, and greater educational opportunity.

In this changed atmosphere, people’s attitude towards family size changes. Smaller families are now seen as more desirable—a large family is an economic burden rather than a benefit, and greater opportunities arise, especially for women, as family size shrinks. Contraceptive techniques become more available. For all these reasons, fertility rates fall—often quite rapidly. The nation enters the third stage, of declining birthrates and declining net population growth rates.

Here we must remember that Figure 10.8 shows only the rate of population growth (the difference between birth and death rates in Figure 10.8). The total population, of course, is considerably larger at this stage, so that a lower rate of growth may still mean a higher net addition to population (gross annual population increase) each year. Population, as we have seen, could double or triple during this period of declining birth rates. But if birth rates continue to decline, eventually the country will reach the final stage of stabilized population with low birth rates and low death rates (stage 4).

As a retrospective view of European history, this process appears relatively benign. Despite the great hardships involved in the early stages, overall it appears that population growth, economic growth, and social progress went hand in hand, and that population growth was eventually self-limiting. The Malthusian vision failed to develop—on the contrary, larger populations typically led to better living conditions.

In both the European and U.S. cases, the third phase of the demographic transition, corresponding to the decrease of fertility rates (average numbers of children per women), was strongly correlated with an improvement in living conditions. Indeed, that strong relationship between better economic conditions and lower fertility is universally observed, both in long term trends and in comparative perspectives. Figure 10.9 shows this pattern for all the countries of the world, with fertility rate (Y axis) generally falling with increasing GDP per capita (X axis).
How well does the theory of demographic transition apply to present global population trends? Certainly the first two stages of the demographic transition theory apply well to the developing world’s experience in the second half of the twentieth century. Death rates have fallen much faster than birthrates; fertility and population growth rates rose to historic highs in the period 1950-1975. Since then, strong evidence indicates that most nations have entered the third phase, with overall growth rates falling. In many respects, however, currently developing nations’ experiences differ significantly from Europe’s:

- The total population numbers at issue are much larger, unprecedented in planetary history. Every decade, the developing nations add population equal to the entire population of Europe and Russia.

- In their expansion, Europe and the United States drew on the rest of the world for natural resources supplies. The currently developed nations have disproportionately exploited the global environment’s waste absorption capacities. There is significant uncertainty concerning the role of fertility decline.
Factors that contribute to fertility decline, such as female education, access to health care, and contraceptive availability, may be present in some nations but absent in others. Projections of population stabilization depend strongly on rapid fertility decline, which may or may not occur.

- The rapid economic growth that accompanied population growth in Europe has occurred in some parts of the developing world but not in others. Africa in particular has experienced high population growth together with stagnant or declining output and food production per capita. In places where economic growth has been strong, its benefits have not "filtered down" to the poor, resulting in increased inequality and a greater absolute number of extremely poor people. In the "dual economies" of many countries in Latin America and South Asia, modern urban development coexists with extreme rural poverty and huge slums surrounding major cities. Many people have not yet achieved the improved living standards that contribute to fertility decline.

These arguments suggest that “looking back” to the history of population and economic growth offers insufficient insight into the population-related issues of the next 40 or 50 years. Social, economic, and environmental factors intertwine with demographics. The impacts of population growth are not limited to the developing nations; the United States faces significant continuing population growth based on a combination of natural increase and immigration (see Box 10.2). We cannot simply wait for the second, global process of demographic transition to play itself out. Rather, we must apply the best analysis and policy response possible to an issue of fundamental importance to the economic and environmental parameters of the twenty-first century.
When we think of population problems, we tend to focus on rapid population growth rates in developing nations. But population is far from stable in the United States as well. Although Europe has completed the demographic transition to stable population levels, both natural increase and immigration keep the U.S. population growing. U.S. fertility rates are at replacement levels but population growth since 1950 has generated large cohorts of people still in their reproductive years, creating significant continuing population momentum.

The decade of the 1990s saw a larger increase in U.S. population than any other 10-year period in the nation’s history, surpassing even the baby boom decade of the 1950s. Population grew from 248.7 million to 281.4 million during the 1990s. In the decade between 2000 and 2010 the population grew another 30 million, to reach 311 million in 2011.

U.S. population is projected to continue growing for at least the next three decades. According to the United Nations, projected U.S. population for 2025 is 350 million, an increase of 68 million, or 24%, over 2000 levels. Projected population for 2050 is over 400 million. While there is some uncertainty about the longer-term figures, these numbers indicate the continuing power of population momentum combined with immigration.

Since U.S. residents have the highest resource consumption and waste generation rates on the planet, the environmental impacts of consumption by these additional people will be much greater than that of a comparable number in a low-income nation. Thus even though the projected U.S. population increase is only about 3% of likely global population growth, it has considerable significance for global environmental issues like greenhouse gas emissions.

An increased U.S. population will also put growing pressure on domestic land and resources. Urban and suburban sprawl, overdraft of water supplies, and air and automobile traffic congestion, will all become more difficult to manage. In considering these various environmental issues, we should not forget the underlying importance of population. Population policy is clearly as relevant for the United States as it is for developing nations.

10.4 POPULATION GROWTH AND ECONOMIC GROWTH

What does economic theory say about population? A typical economic model, the Cobb-Douglas production function, shows economic output as a function of labor input, capital input, and technological parameters:

\[ Q_t = A_t K_t^\alpha L_t^\beta \]

where \( Q \) is total output, \( K \) is the capital stock, \( L \) is the labor force, and \( \alpha \) and \( \beta \) are parameters related to the productivity of capital and of labor respectively; \( A \) reflects a given state of technology, and \( t \) indicates a particular time period. The values of \( \alpha \) and \( \beta \) are assumed to be fractions between zero and one; if \( \alpha + \beta = 1 \), the function shows constant returns to scale. This means that if labor and capital inputs were both doubled, output would also double.

Suppose that we increase only one factor, labor. Output will also increase, but by a smaller proportion than the increase in labor input.\(^{12}\) If labor is roughly proportional to total population, per capita output will decline. As more and more labor is added, the law of diminishing returns comes into play, giving smaller output boosts for each additional unit of labor input. Thus in a simple economic model, population increase alone would yield falling living standards. This is a result of capital shallowing, which means that each worker has less capital to work with and is thus less productive.

However, few economists would view this simple logic as an accurate representation of the effects of population growth. They would point to the capital stock variable \( K \), noting that if \( K \) grows at a rate at least equal to \( L \), output per capita will remain constant or rise. In addition, they would argue that we can safely bet that technological progress will increase the variable \( A \) over time, leading to greater output for each unit of labor or capital input. In this theoretical framework, provided capital formation and technological progress are adequate, population and labor force growth can be accompanied by a rising standard of living.

What about the issue of natural resource limitations? We can modify the Cobb-Douglas production function to take account of natural capital—natural resources such as arable land and water for agricultural products, and minerals and fossil fuels as key inputs for all of economic activities. If we denote natural capital by \( N \) and its productivity by the exponent \( \gamma \), we get a revised equation:

\[ Q_t = A_t K_t^\alpha L_t^\beta N \]

In this formulation, limitations on natural capital could cause diminishing returns even if labor and capital both increase. For example, if \( \alpha = \beta = \gamma = 1/3 \), a doubling of labor and human-made capital while natural resources remain constant would increase output by a factor of 1.59, leading to a fall in per-capita output. This decline could still be

\[^{12}\text{This is because the exponent } \alpha \text{ is less than one. If, for example, } \alpha = \beta = 1/2, \text{ then a doubling of labor alone would increase output by a factor of 1.414. A doubling of both labor and capital would increase output by a factor of 2.}\]
avoided by sufficiently rapid technological progress, but the natural resource limitation would be a steady drag on output expansion.

There is some evidence that population growth can actually spur technological progress in some cases. Ester Boserup has argued that increased population pressure forces the adoption of more efficient agricultural techniques.  

At least in the early stages of development, **economies of scale** may prevail; increasing population density may make it possible to develop more productive, larger-scale industry.

From the point of view of economic theory, then, population growth is inherently neither good nor bad. Its effects depend on the context in which it occurs. If economic institutions are strong, markets work well, and environmental **externalities** are not great, then population growth is not necessarily negative.

**Does population growth promote or retard economic development?**

Some analysts present a positive view of population growth both as a proof of successful advance in human technological skill and as a spur to further progress. One of the strongest proponents of this point of view, Julian Simon, suggested that we should welcome further population growth because human ingenuity will always overcome resource limitations and environmental problems. Most economists and ecologists, however, reject this unqualified optimism. While acknowledging the importance of technological progress, most analyses of the overall impact of population growth present the issue as significantly more complex.

Economic theory recognizes a number of ways in which population growth may negatively affect economic development. These include:

- **Increased dependency ratios.** We have seen that a growing population typically includes a high proportion of children. Families must spend more on supporting dependent children, and thus have less to save, lowering the national savings rate. Higher spending on health and education is required, reducing funds available for capital investment. These effects tend to slow capital accumulation and economic growth. As population eventually stabilizes, dependency ratios are raised by a high proportion of elderly people, creating a different set of economic problems (see Box 10-3).
- **Increased income inequality.** A rapidly growing population creates excess labor supplies, which draw down wage rates. High rates of unemployment and underemployment are likely, and a large class of extremely poor people receives no benefit from economic growth. This situation prevails in many Latin American countries as well as in India, where unemployed rural laborers migrate to large cities in search of jobs, creating vast slums surrounding city centers.

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13 Boserup 1981.
14 Simon, 1996.
• Natural resource limitations. As noted above, the inclusion of **fixed factors**, such as a limited supply of land or non-renewable natural resources, in the production function can lead to diminishing returns to labor and capital. In general, economists have tended to assume that technological progress can overcome these limitations,\textsuperscript{15} but as resource and environmental problems become more pervasive and complex, this assumption may not hold.

• In cases of **market failure**, like the open-access fishery discussed in Chapter 4, increased population accelerates excessive depletion of the resource. Where private or social property rights are poorly defined, as in the African Sahel or the Brazilian Amazon, population pressure contributes to rapid desertification and deforestation. Also, where externalities such as air and water pollution are uncontrolled, population growth will worsen existing pollution problems.

This more complex view of the relationship between population and economic development has been addressed by Nancy Birdsall, who has suggested that “the long debate over population growth and development is entering a new phase. The emphasis is now on the interaction of rapid population growth with market failures.”\textsuperscript{16} In a review of economic studies, she points out that policy also plays a crucial role:

Countries with higher rates of population growth have tended to see less economic growth. An analysis of the role of demography in the "Asian economic miracle" strongly suggests that changes in age structures resulting from declining fertility create a one-time "demographic gift" or window of opportunity, when the working age population has relatively few dependents, of either young or old age, to support. Countries which recognize and seize on this opportunity can, as the Asian tigers did, realize healthy bursts in economic output.

But such results are by no means assured: only for countries with otherwise sound economic policies will the window of opportunity yield such dramatic results. Finally, several of the studies demonstrate the likelihood of a causal relationship between high fertility and poverty. While the direction of causality is not always clear and very likely is reciprocal (poverty contributes to high fertility and high fertility reinforces poverty), the studies support the view that lower fertility at the country level helps create a path out of poverty for many families.\textsuperscript{17}

In view of these recent observations, the question arises: were the "positive" effects of population growth mainly characteristic of an earlier period in world history—what Herman Daly has referred to as the "empty world" stage in which resources and environmental absorptive capacities are abundant relative to the scale of the human economy?\textsuperscript{18} As global population rises towards eight billion or more, will the negative impacts become dominant? To answer these questions requires a consideration of a broader, more ecologically-oriented perspective on population growth.

\textsuperscript{15}See, for example, Solow 1986.
\textsuperscript{16}Birdsall, 1989.
\textsuperscript{17}Birdsall, Kelley and Sinding, 2001.
\textsuperscript{18}Daly 1996, Chapter 2.
Fertility, the most volatile variable in population projections, has declined worldwide, in many countries at a faster rate than expected. Does this mean that the “population problem” has gone into reverse? Some analysts think so. According to Phillip Longman “Some people think overpopulation is one of the worst dangers facing the globe. In fact, the opposite is true. As countries get richer, their populations age and their birthrates plummet. And this is not just a problem of rich countries: the developing world is getting older fast. Falling birthrates might seem beneficial, but the economic and social price is too steep to pay.”\(^{19}\)

Longman is really referring to two issues. One is in areas like Europe and Japan, where fertility rates have largely fallen below replacement levels. These countries face the prospect of a high dependency ratio of elderly people, with a diminished work force to support them. Another is in the developing world, where a small number of countries are now approaching, or have reached, replacement fertility levels. Slower population growth is likely to be beneficial in these developing nations, lowering the child dependency ratio, and providing a higher proportion of working-age people to contribute to national productivity.

Lower fertility in India, for example, has gone hand in hand with improvement of women’s status and economic well-being.\(^{20}\) Stabilizing populations also lessen pressure on scarce water supplies, arable land, and other resources. According to an expert panel on population issues, “fertility decline in high-fertility countries, by slowing population growth, makes many environmental problems easier to solve and development easier to achieve.”\(^{21}\)

A different story is unfolding in Japan, where the birthrate has been in sharp decline since the 1950s reached an all time low of 1.3 in 2010. If these trends continue, the population of Japan is projected to fall from 128 million to 95 million by 2050.\(^ {22}\) The elderly population has been growing steadily, so that by 2040 more than a third of the population will be older than 65 and “there will almost be one centenarian to welcome each Japanese newborn.”\(^{23}\) The problems of supporting an increasing number of elderly with a shrinking workforce also affect Europe, and within the next several decades will have a major impact in China and other developing nations.

The problems of population stabilization, however, will have to be faced if global population is not to grow indefinitely. As we have seen, even the lowest global projections show well over a billion additional population by 2025,and areas which still have high fertility, such as Africa, are likely to see population doubling before 2050. Rates of population growth are slower in Latin America and Asia, but increases of 150 million and 1 billion, respectively, are projected for these areas. Thus Longman’s prescription of trying to deal with the situation by policies to promote fertility seems unwise for the developing world, even if it might be relevant for Europe or Japan, where fertility has fallen well below replacement levels.

\(^{19}\) Longman, 2004.
\(^{21}\) International Institute for Applied Systems Analysis, 2011.
\(^{22}\) Population Reference Bureau, 2011.
\(^{23}\) Eberstadt, 2012.
10.5 ECOLOGICAL PERSPECTIVES ON POPULATION GROWTH

Whereas the standard economic perspective sees no inherent limitations on population or output growth, the ecological approach is based on the concept of **carrying capacity**, which implies some practical limits to the population that can occupy a certain region. This certainly applies to animal populations in nature.

If, for example, a herd of grazing animals exceeds the land's carrying capacity, food will run short, many individuals will starve, and the population will be reduced to more sustainable levels. Predator species are even more tightly constrained in numbers, based on the available prey populations. Since animals live by consuming either other animals or plants, all life on earth is dependent on the ability of green plants to capture solar energy. The available **solar flux**, or flow of sunlight to the earth's surface, is thus the ultimate determinant of carrying capacity.

Can human populations escape the logic of carrying capacity? Certainly we have been very successful at stretching its limits. The use of artificial fertilizers has greatly increased agricultural outputs. Fossil fuel and nuclear energy provide far more power for industrialization than any solar flux we currently capture, either directly through solar energy systems or indirectly through hydroelectric and wind power. Through these means, 7 billion people can live on a planet which a century ago supported only 1.5 billion.

However, this expansion of carrying capacity has a significant ecological cost. The extraction of large quantities of fossil fuels and mineral stocks causes environmental degradation both in production and through the waste products generated. Some of the wastes and pollutants are **cumulative**—their negative environmental effects build up over time.

A prime example is global climate change caused by burning fossil fuels. Soil erosion, depletion of aquifers, and buildup of long-lived toxic and nuclear wastes are also cumulative processes. While increasing Earth’s carrying capacity today, we build up problems for the future. Many of these issues already pose major problems—how much worse will they become if a significantly larger population is consuming at higher per capita levels than today? How can we accommodate an extra 2 billion or more people with their food demands, carbon emissions, and other ecological impacts?24

Ecologists identify three major areas in which current economic activities are systematically undermining the planet’s long-term carrying capacity. One is erosion and degradation of topsoil; topsoil losses worldwide are currently estimated at 24 billion tons annually, with nearly 11% of the world's vegetated land suffering moderate to extreme degradation. A second is overuse and pollution of fresh water supplies—a problem in virtually every country, reaching critical levels in China, India, and parts of the former Soviet Union. The third, and perhaps most serious, is the loss of biodiversity, with more

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24 See e.g. Ryerson 2010 on the relationship between population and other environmental issues.
species driven to extinction every year than at any time in the preceding 65 million years of planetary history.\footnote{\textcite{ehrlich2003, postel2003}}

Reviewing evidence gathered by dozens of scientists, Paul and Anne Ehrlich conclude “there is considerable evidence that the enormous expansion of the human enterprise has already caused \textit{Homo sapiens} to overshoot the long-term carrying capacity of Earth—the number of people that could be sustained for many generations without reducing the resources necessary to similarly maintain an equal population size in the future”\footnote{\textcite{ehrlich2004}}

\section*{The Impacts of Population, Affluence, and Technology}

We can conceptualize the interrelationship of population, economic growth, and environment in an equation linking all three, which has come to be known as IPAT. The equation states that:

\begin{equation}
I = P \times A \times T
\end{equation}

where:

- $I$ = Ecological Impact (e.g. pollution or natural resources depletion)
- $P$ = Population
- $A$ = Affluence measured as output/person
- $T$ = Technology variable measuring ecological impact per unit of output

This equation is an \textit{identity}, a mathematical statement which is true by definition. The right hand side of the equation can be mathematically stated as follows:

\begin{equation}
(P) \times (A) \times (I)
\end{equation}

"Population" and "Output" cancel out since they occur both in numerator and denominator, leaving only ecological impact—which is the same as the left hand variable. Thus we cannot argue with the equation itself. The only questions are what the levels of the variables will be, and what determines them. What do we know about these questions?

We have seen that global population is projected to increase by 2 billion, or about 30\%, over the next forty years, according to the United Nations medium-variant projection (see Table 10.2 and Figure 10.4). We also know that average per-capita consumption, the $A$ variable, is steadily increasing throughout the world. If per capita consumption grows at 2\% per year, which most development economists would view as a minimally satisfactory rate, it will increase by a factor of 2.7 in 50 years. The combined impacts of $A$ and $P$ will therefore multiply the right-hand side of the equation by a factor of 3.5.

What about the technology variable $T$? Improved technology could lower the ecological impact per unit of GDP—let us say by a factor of 2. This would still leave us...
with a significantly increased level of overall environmental impact (in terms of pollution and pressure on natural resources, land, water, forests, biodiversity, etc.) Given the current level of concern about environmental problems, this seems unacceptable. In order to project lower overall environmental impact, we will need technological improvements that would lower environmental impact by a factor of 4 or more.

Of course, a mathematical abstraction such as IPAT gives little insight into the specifics behind these very broad concepts. IPAT has been criticized because it assumes that the 3 factors \( P \), \( A \), and \( T \) are independent of one another when in fact there are related to each other—the true nature of that relationship being a subject of controversy, as we have seen earlier. In a review on the theoretical implications of the use of the IPAT equation, Marian Chertow stresses that

The chicken-and-egg nature of this debate—whether population or technology is a bigger contributor to environmental damage—is revealing. Does an increased population call for improved technology or does improved technology increase carrying capacity? (Boserup 1981; Kates 1997) Cross-country comparisons show that different types of ecological impacts present very different types of relation with the level of affluence (factor \( A \)) or economic prosperity as measured by GDP per capita. For instance, many types of air pollutants typically decrease with the level of GDP per capita, whereas CO2 emissions increase with the level of affluence (Shafik and Bandyopadhyay, 1992).\(^{27}\)

While the IPAT formulation has been mostly used by scientists (biologists, ecologists, engineers, etc.), it has faced strong criticism from social scientists and economists on the grounds that it covers up some basic issues concerning causes of population growth, consumption distribution, and the workings of markets. The field of industrial ecology has mostly focused its attention on the factor \( T \) in the IPAT equation, emphasizing the need for a major technological leap forward that would reduce \( T \) by a factor of 4 or even 10.\(^{28}\)

One obvious concern is highly unequal consumption per capita throughout the world. The one-quarter of the world’s population living in developed countries accounts for roughly three-quarters of global consumption. Poverty, lack of basic health services, and poor education in many developing nations contribute to high population growth rates. This suggests a crucial need to focus on issues of inequality, rather than only on total population or economic output.

Perhaps the economic and ecological perspectives can converge. Even if we cannot identify a fixed carrying capacity for the planet, it is clear that population growth at the levels we are now experiencing increases virtually all resource and environmental stresses (see Box 10.4). This means that it is vital to have progress on all fronts—reducing population growth, moderating the growth of consumption, improving social equity, and introducing environmentally friendly technologies.\(^{29}\)

\(^{27}\) Chertow, 2000.
Substantial research has focused on measuring humanity’s impact on the environment. Humans affect the environment in multi-dimensional ways, including disruption of natural cycles, depletion of the ozone layer, species extinction, and disposal of toxic pollutants. From a policy perspective, there may be advantages to converting all these effects to a single index. Further, this index should be measured in units that people can easily understand and interpret. Finally the necessary data for the measurement of this index should be available at all scales, from an individual to a country, and in all societies and countries of the world, to allow for comparisons.

One such index calculates environmental impacts using “ecological footprints.” Originally developed by Wackernagel and Rees (1996), the ecological footprint (EF) concept attempts to convert all human impacts into equivalent units of biologically productive land area. In other words, a person’s ecological footprint is the amount of land required to support his or her lifestyle.

Some effects convert easily to land-area footprints. For example, demand for meat converts to pasture area needed to raise livestock. Other impacts are more difficult to translate to land-area equivalents. For instance, carbon dioxide emissions from burning fossil fuels, are accounted for in the EF approach based on the area of vegetation that would be required to absorb the carbon emitted.

Calculation of a country’s ecological footprint requires data on more than 100 factors, including demand for food products, timber, energy, industrial machinery, office supplies, and vehicles. A demonstration of the detailed calculations involved in obtaining a country’s ecological footprint, using Italy as an example, is available on the Internet at http://www.footprintnetwork.org/. An individual ecological footprint calculation can be found at http://www.myfootprint.org/.

Comparing a region’s ecological footprint of a region to its available land helps determine whether the region creates a sustainable environmental impact. The table below presents the per capita ecological footprints and available productive land for major regions and the world. The per capita ecological footprints are much higher in developed countries as compared to developing countries.

Most countries, developed or developing, are currently running an ecological deficit. The global per capita impact of 2.69 hectares per person exceeds the available biologically productive land on Earth (2.0 ha/cap). Thus, the EF approach indicates that current global environmental impacts are not sustainable, implying a depletion of natural capital.

The concept and methodology of ecological footprints remains controversial. The March 2000 volume of the journal Ecological Economics presented a forum of twelve articles related to the ecological footprint concept. Some of the articles were particularly critical of the approach. For example, Ayres (2000) claims that the EF
concept “is too aggregated (and too limited in other respects) to be an adequate guide for policy purposes at the national level.” Other researchers, while recognizing that the EF approach requires further refinement, believe it is a valuable analytical tool with policy relevance. Herendeen (2000) notes that the “EF, as modified and improved, is an excellent tool to illustrate the larger picture, and the details.” At the least, the debate over the EF methodology has raised awareness of the need to go beyond the rhetoric of sustainability towards quantifiable results.

Sources:

<table>
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<th>Country/Region</th>
<th>Population [millions]</th>
<th>Ecological Footprint of Consumption [gha* per person]</th>
<th>Biocapacity [gha per person]</th>
<th>Ecological Deficit or Reserve [gha per person]</th>
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</table>

Gha = global hectare (a measure of area = 10,000 square meters or 2.47 acres). A global hectare represents one hectare of global average productivity.

Table 10.3: Per-Person Ecological Footprint of Consumption, 2005

Source: The Ecological Footprint Atlas 2008, Global Footprint Network, Research and Standards Department

<table>
<thead>
<tr>
<th>Country/Region</th>
<th>Population [millions]</th>
<th>Ecological Footprint of Consumption [gha*]</th>
<th>Biocapacity [gha]</th>
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Table 10.4: Total Ecological Footprint of Consumption, 2005

Source: The Ecological Footprint Atlas 2008, Global Footprint Network, Research and Standards Department
10.6 POPULATION POLICIES FOR THE TWENTY-FIRST CENTURY

In recent years, the discussion of population policy has shifted. Past debate was dominated by the conflict between “optimists”, who saw no problem in increasing population, and “pessimists” who predicted catastrophe. Now, elements of consensus are emerging. Most analysts accept that increasing population places extra stress on the environment and resources, and agree that slower population growth in the future is essential. How will we accomplish this?

Nations have sometimes attempted to control population growth by government compulsion. The most prominent example of this is China’s draconian “one-child family” policy. While effective in a strongly controlled economy and civil society such as communist China’s, such policies have been discredited in most other nations both on human rights grounds and because they fail to alter basic incentives regarding fertility. Rather than changing people’s desires to have children, they rely on penalties including forced abortions and sterilization of women.

Birthrates can fall rapidly, however, when people—especially women—reach higher levels of education and literacy, and enjoy better employment opportunities. Significant voluntary reduction of birthrates in many East Asian countries as well as in the state of Kerala in India has resulted from higher levels of basic education, health care, and job security.  

In analyzing which population policies are most effective, Nancy Birdsall focuses on the link between high fertility and poverty, and the resulting vicious circle of negative social and environmental outcomes. She identifies a significant range of policies that can help both to slow population growth and to improve economic efficiency and output. Prominent among these are the promotion of education and other social programs, improvement in the status of women, and improved nutrition and health care, including contraceptive availability.

All these policies tend to lower fertility rates, and are identified by Birdsall as “win-win” policies—policies which benefit both the economy and the environment through voluntary moderation of population growth. Sound macroeconomic policies, improved credit markets, and improved conditions for agriculture are also important in promoting broad-based growth and poverty reduction, which in turn is essential to population/environment balance.

Such policies are essential to avert serious environmental and social breakdowns in many developing nations. As people struggle to respond to higher demands on the land, slower population growth allows crucial breathing space—time to innovate and adapt. Higher population growth rates can push rural communities over the edge into neo-Malthusian collapse—not because of an absolute limit on carrying capacity, but

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30 The cases of China and Kerala are reviewed in Sen 2000, pp. 219-224. On India see also Pandya, 2008.
because the means and incentives to adopt new techniques were not forthcoming in time.

Urban areas, where population growth is most rapid, often experience major social and infrastructure problems. Urban populations in Asia and Africa are projected to double over the next 30 years. Inadequate housing and sanitation, congestion, air and water pollution, disruption of water cycles, deforestation, solid waste problems and soil contamination are typical of large cities in the developing world. Attempts to respond to massive social and environmental problems in cities are made more difficult by continuing rapid and unplanned growth. Moderation of overall population growth will have to be an essential component of efforts to achieve urban sustainability.

Population growth has been a major factor in shaping development patterns during the second half of the twentieth century, and will continue to play a central role during the first half of the twenty-first. The differing perspectives of economists, ecologists, demographers, and other social theorists all have something to contribute towards the goal of developing effective policies that can promote population stabilization and population/environment balance.

In later chapters, we will use this overview of population as our basis for examining specific stresses associated with growing population and higher consumption levels—in agriculture, energy use, demands on natural resources, and pollution generation. In Chapter 20 we will return to the issue of sustainable global futures for a growing human population.

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SUMMARY

Global population grew very rapidly during the second half of the twentieth century. Although population growth rates are now slowing, total annual additions to global population are still at an all-time high. With a global population of 7 billion in 2011, growth is projected to continue for at least the next four decades, reaching a level of 8 billion by 2025 and 9 billion by mid-century. Over 90% of the projected growth will be in the developing nations of Asia, Africa, and Latin America.

Population projections offer no certainty about actual future numbers, but the population momentum phenomenon guarantees significant further growth. Currently, average fertility rates (number of children per woman) are still high throughout the developing world. Although fertility rates are generally falling, it will be decades before population stabilizes.

In Europe, the demographic transition from rapid population growth to relatively stable population has been accomplished. In the United States, growth continues both due to population momentum and annual immigration. In the developing world, the demographic transition is far from finished, and significant uncertainty remains about future birth rates. Economic growth, social equity, access to contraception, and cultural factors all play a role.

The economic analysis of population growth emphasizes the potential of other factors such as technological progress to offset the effects of population growth. Under favorable conditions for economic and technological progress, population growth may be accompanied by rising living standards. However, rapid population growth accompanied by social inequity and significant environmental externalities may lead to a decline in living standards.

An ecological perspective recognizes more stringent limits to the population carrying capacity of regional and global ecosystems. Greater population increases the demand for materials, energy, and natural resources, which in turn increases pressures on the environment. Given the extent of existing environmental damage, especially where this damage is cumulative or irreversible, the challenge of providing for significantly larger populations poses severe challenges to the earth’s ecosystems.

Compulsory population control policies generally fail to alter basic incentives regarding fertility. More effective population policy measures include improved nutrition and health care, greater social equity, women’s education, and contraceptive availability.
KEY TERMS AND CONCEPTS

capital formation income inequality
capital shallowing law of diminishing returns
carrying capacity market failure
constant returns to scale natural capital
cumulative waste and pollutants natural resource limitations
demographic transition neo-Malthusianism
dependency ratios per capita output
economies of scale population age profile
exponential growth population momentum
externalities population growth rate
fertility rate population cohort
fixed factors replacement fertility level
gross annual population increase solar flux
growth rate technological progress
identity

DISCUSSION QUESTIONS

1. What criteria would you use to evaluate the argument between the neo-Malthusians who see population growth as the major problem facing humanity, and those who argue that population growth is a neutral, or even positive factor for economic development? How would you assess the relative urgency of population concerns in the United States (population growth rate 0.7% per annum), India (1.9% per annum) and Kenya (3.3% per annum)?

2. "Every extra mouth brings with it an extra pair of hands. Therefore we do not have to worry about growing population." Relate this statement to the more formal economic analysis of labor force and production. To what extent is the statement true? To what extent is it misleading?

3. The concept of carrying capacity is a useful one for the ecological analysis of animal and plant populations. Is it also useful for the analysis of human population growth? Why or why not?
REFERENCES


**WEBSITES**

1. [http://eee.prb.org/](http://eee.prb.org/) Homepage for the Population Reference Bureau, which provides data and policy analysis on U.S. and international population issues. Their World Data Sheet provides demographic data for every country in the world.


3. [http://www.populationconnection.org/](http://www.populationconnection.org/) Homepage for Population Connection, a nonprofit organization that “advocates progressive action to stabilize world population at a level that can be sustained by Earth’s resources.”