Chapter 2

Economic Growth, Technological Change, and Human Well-Being

Indur M. Goklany

> IF PRESENT TRENDS continue, the world in 2000 will be more crowded, more polluted, less stable ecologically, and more vulnerable to disruption than the world we live in now. Serious stresses involving population, resources, and environment are clearly visible ahead. Despite greater material output, the world's people will be poorer in many ways than they are today.
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> *The Global 2000 Report to the President of the U.S.: Entering the 21st Century* (Barney 1980)

This neo-Malthusian vision of the future stands in sharp contrast to the conclusions in *The State of Humanity* edited by Julian Simon (1995). That monumental collection of fifty-eight chapters by more than fifty scholars documents the tremendous strides that have been made in human well-being over the centuries, as well as trends in natural

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resource use and environmental quality. Based on these discussions, Simon wrote: "Our species is better off in just about every measurable material way" (1).

Bjørn Lomborg, determined to prove Julian Simon wrong and to verify the doomsday-visions of the kind that permeated *The Global 2000 Report*, enlisted ten of his "sharpest students" to comb through the empirical data (Lomborg 2001, xix) on long-term temporal trends in human and environmental well-being. Much to his surprise, they found that although the population continues to grow, albeit at a decelerating pace, the state of humanity has never been better, that the average person on the globe has never been less hungry, better educated, richer, healthier, and longer-lived than today.[1] No less important, not only is human well-being advancing but, in many cases, so seems to be the state of the environment, especially in the rich countries of the world.

Lomborg focused mainly on temporal trends in a variety of indicators rather than on how those indicators might vary with wealth or per-capita income across countries and regions. He also looked at temporal trends in infant mortality and life expectancy for various income groups (2001, 52, 55) and, as Yandle documents in Chapter 3 of this volume, these data suggest that richer groups are better off.

In this chapter, I examine trends in several of the most critical indicators of human well-being, paying special attention to how they vary across countries as a function of economic development and technological change. In that respect, the analysis presented here complements and extends Lomborg's analysis.

This chapter examines seven indicators of human well-being.

- *Available food supplies per capita*. Having sufficient food is the first step to a healthy society. It enables the average person to live a productive life, whereas hunger and undernourishment retard education and the development of human capital, slowing down technological change and economic growth.
- *Life expectancy*. To most people, this is the single most valuable

indicator of human well-being. Longer life expectancy is generally accompanied by an increase in disability-free years.

- *Infant mortality*. Throughout history, high levels of death in early childhood have produced enormous sorrow, reduced population growth, and lengthened the time women spend in childbearing.
- *Economic development*. Gross domestic product (GDP) per capita is a measure of people's income. Thus, it measures the wealth or the level of economic development of a country. Although wealth is not an end in itself, a nation's per-capita GDP indicates how well its people can achieve the ends they desire, from greater availability of food, safe water, and sanitation to higher levels of education and health care.
- *Education*. Education can be an end in itself, but it also adds to human capital and can accelerate the creation and diffusion of technology. Education (particularly of women) helps to spread knowledge of nutrition and public health practices.
- *Political rights and economic freedom*. The ability to conduct one's life creatively and productively usually depends on having political rights and economic freedom. They are critical to maintaining liberty and prosperity.
- *A composite human development index*. Using an approach similar to that employed in the United Nations Development Programme (UNDP), this index combines indicators for life expectancy, education, and per-capita income (UNDP 2000).[2]

As part of this examination, I will also address how factors contributing to or related to the improvements in these indicators vary with economic development, for example, access to safe water and sanitation, crop yields, and child labor. Have differences in human well-being widened between developed and developing countries? Do urban residents fare worse than rural residents? Finally, I discuss the factors that appear to be responsible for the remarkable cycle of progress that has

accompanied modern economic growth and the improvements in human well-being over the past two centuries.

Hunger and Undernourishment

Concerns about the world's ability to feed its burgeoning population have been around at least since Thomas Malthus's "Essay on the Principle of Population" two hundred years ago. Several neo-Malthusians of the twentieth century confidently predicted apocalyptic famines in the developing countries in the latter part of the century (Ehrlich 1968; Paddock and Paddock 1967). Even though the world's population is the largest it has ever been, the average person has never been better fed.

Since 1950, the global population has increased by 90 percent, increasing the demand for food, but at the same time the real price of food commodities has declined 75 percent (Mitchell and Ingco 1993; World Resources Institute 1998). Greater agricultural productivity and international trade have made this possible (Goklany 1998). As a result, average daily food supplies per person increased 24 percent globally from 1961 to 1998, as indicated by Table 2.1, and the increase for developing countries was even larger at 38 percent.

The Food and Agriculture Organization (FAO) estimates the minimum daily energy requirement for maintaining health and body weight and engaging in light physical activity to be between 1,720 and 1,960 calories (properly, kilocalories) per person per day (1996a). Adding an allowance for moderate activity to this threshold results in an estimate of the national average requirement of 2,000 to 2,310 calories per person per day. (This assumes equal food provisions are likely to be equally available to the population.)

Especially remarkable are the improvements in India and China since the middle of the twentieth century. By 1998, China's food supplies had gone up 82 percent from a barely subsistence level of 1,636 calories per person per day in 1961. India's food supplies went up 51 percent, from 1,635 calories per person per day compared with the

Table 2.1
Daily Food Supplies, c. 1790–1998
(kilocalories per capita per day)

Area	*Pre- or Early Industrial Phase*	*1961*	*1975*	*1985*	*1998*
France	1,753 (1790)	3,193	3,246	3,498	3,541
Developed Countries		2,948	3,144	3,284	3,246
India	1,635 (1950–1951)	2,073	1,942	2,143	2,466
China	2,115 (1947–1948)	1,636	2,084	2,616	2,972
Developing Countries		1,930	2,146	2,421	2,663
Sub-Saharan Africa		2,056	2,090	2,043	2,221
World		2,255	2,423	2,637	2,792

Note: Pre- or early industrial phase data are for the year(s) shown in parentheses; data for China are based on 22 provinces. Many developing countries, such as India and China, barely embarked on industrialization until after World War II.

Sources: Burnette and Mokyr (1995); FAO (2000); Fogel (1995); Goklany (1999a)

1950–1951 average. Increases in food supplies reduced the number of chronically undernourished people in developing countries from an average of 920 million in 1969–1971 to less than 800 million (on average) from 1995–1997 (or from 35 percent to 19 percent of their population) despite a 70 percent growth in population (FAO 1996b, 1999).

Figure 2.1, based on cross-country data for 1961 and 1994 from the World Resources Institute (1998), shows that available food supplies per capita per day increase with GDP per capita as well as with time. To better illustrate the change in food supplies for low-income people, the scale on the graph ends at a GDP per capita of $10,000 (in 1995 dollars).[3] The upward slope for each year probably reflects the fact that the wealthier the country, the greater its ability to afford more productive technologies to increase crop yields or purchase food in the global market. The upward shift of the available food supply curve between 1961 and 1994 resulted from technological improvement. This technological change allowed food production to outpace population

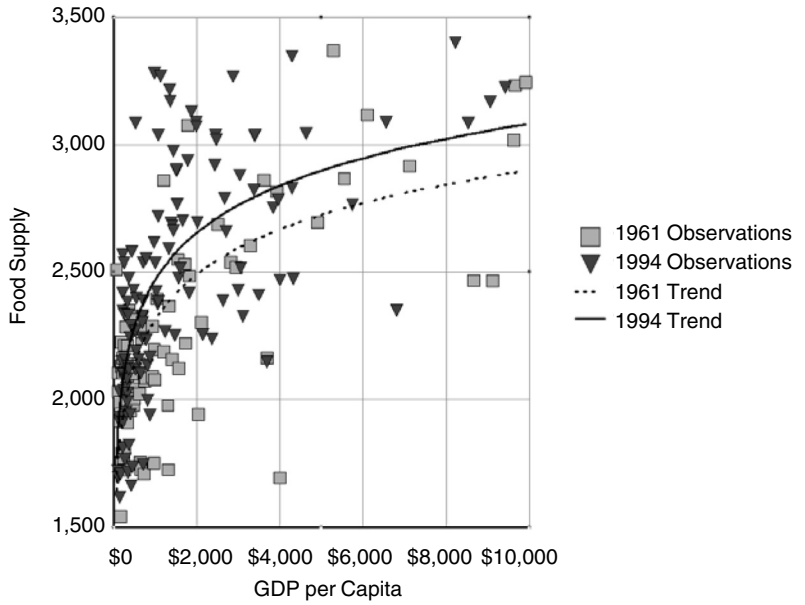

Figure 2.1 Food Supply and Income, 1961–1964

Note: Food supply data in kilocalories per day, per capita; income is expressed as GDP per capita in 1995 US$ at market exchange rates (MXR).

Source: World Resources Institute (1998)

growth (Goklany 1998). As a result, the real global price of food commodities declined 75 percent since 1950 (Mitchell and Ingco 1993; World Resources Institute 1998), and for any given level of income, more food was available in 1994 than in 1961.

Life Expectancy

Life expectancy at birth is probably the single most important indicator of human well-being. For much of human history, life expectancy was 20 to 30 years (Preston 1995). As Table 2.2 indicates, by 1998 it had increased to 66.9 years worldwide (UNDP 2000), and for developed countries, life expectancy at birth was 74.5 years in 1998.

Table 2.2
Life Expectancy at Birth, in Years, Middle Ages to 1998

Area	*Middle Ages*	*Pre- or Early Industrial Phase*	*1950–1955*	*1975–1980*	*1998*
France		−30 (1800)	66.5	73.7	78.2
United Kingdom	20–30	35.9 (1799–1803)	69.2	72.8	77.3
Developed Countries	20–30		66.5	72.2	74.5
India		24–25 (1901–1911)	38.7	52.9	62.9
China		25–35 (1929–1931)	40.8	65.3	70.1
Africa			37.8	47.9	53.8
Developing Countries			40.9	56.7	63.6
World	20–30		46.5	59.7	66.9

Note: Pre- or early industrial phase data are for the year(s) shown in parentheses; U.K. data for 1799–1803 are for England and Wales only; data for Africa and Developing Countries for 1998 are for 1995–2000 from the World Resource Institute (1998).

Sources: Lee and Feng (1999); Preston (1995); Wrigley and Schofield (1981, 529); World Resources Institute (1998); UNDP (2000)

Not only does life expectancy increase over time, it increases with per-capita income. Comparing data for 1962 and 1997, Figure 2.2 shows that a country with a GDP per capita of $300 per year would have increased its citizens' average life expectancy from 44.7 years in 1962 to 55.0 in 1997.[4]

Figure 2.2 also suggests that developing countries may have higher life expectancies than did the developed countries at equivalent levels of income. This, indeed, is the case for China and India, countries once synonymous with poverty and wretchedness. In 1913, when the United States had a GDP per capita of $5,305 (in 1990 dollars), life expectancy at birth was 52 years[5] (Bureau of the Census 1975). In 1995, when China and India had GDP per capita of a mere $2,653 and $1,568 respectively (also in 1990 dollars), they had life expectancies of approximately 69 and 62 years (World Bank 1999).

By and large, life expectancies continue to climb worldwide. However, life expectancies have dropped since the late 1980s and early

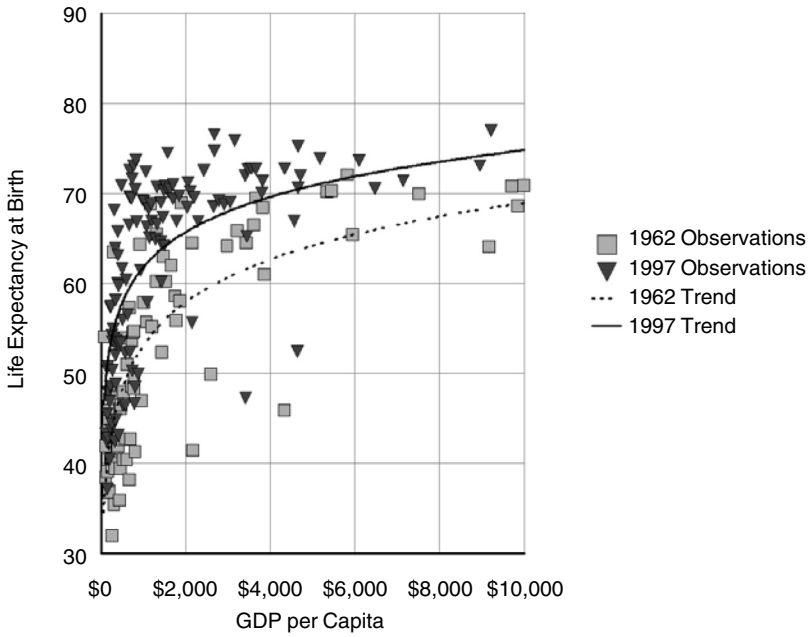

Figure 2.2 Income and Life Expectancy at Birth, 1962–1997

Note: Data represent the life expectancy at birth in years; income is expressed as GDP per capita in 1995 US$ at MXR.

Source: World Bank (1999)

1990s in many countries where economies have deteriorated. Russia's life expectancy, for example, declined 3.9 years between 1989 and 2000 (World Bank 2002). Over this period, its GDP per capita (in real dollars) declined 35 percent (World Bank 2002). Yields of cereal, which represent 50 percent of all crops, fell (Goklany 1998), and food supplies per capita, nutritional levels, and public health services all declined. Alcoholism increased, as did accidental deaths, homicides, hypertension, and suicides (Becker and Bloom 1998). Life expectancies have similarly declined in other Eastern European and former Soviet Union countries (EEFSU). Life expectancies also are declining in a number of sub-Saharan countries, seemingly due to a vicious cycle involving

Table 2.3
Infant Mortality, Middle Ages to 1998

Area	*Middle Ages*	*Pre- or Early Industrial Phase*	*1950–1955*	*1975–1980*	*1998*
Sweden		240 (1800)	22	8	4
France		182 (1830)	45	11	5
Developed Countries	>200		58	18	9
China			195	52	38
India			190	129	69
Developing Countries			179	98	64
Africa			185	120	91
World	>200		156	87	58

Note: Data represent the number of deaths before age one per 1,000 live births. Pre- or early industrial phase data are for the years shown in parentheses.

Sources: Hill (1995); Mitchell (1992, 116-23); UNDP (2000); World Resources Institute (1998)

HIV/AIDS, malaria, and a drop in economic output (UNDP 2000, Goklany 2002a).

Infant Mortality

Before industrialization, at least one out of every five children died before reaching his or her first birthday (see Table 2.3), but the rate fell to 58 per 1,000 live births worldwide in 1998. This is the same level that more developed countries had reached in the 1950 to 1955 period (World Resources Institute 1998; UNDP 2000). As recently as 1900, infant mortality in the United States was about 160; in 1997, it was about seven (Bureau of the Census 1975, 60; 1999).

In developing countries, the declines started later, but may be occurring more rapidly in some areas. For instance, between the early 1950s and 1998, India's infant mortality fell from 190 to 69, and China's from 195 to 38 (World Resources Institute 1998; UNDP 2000).

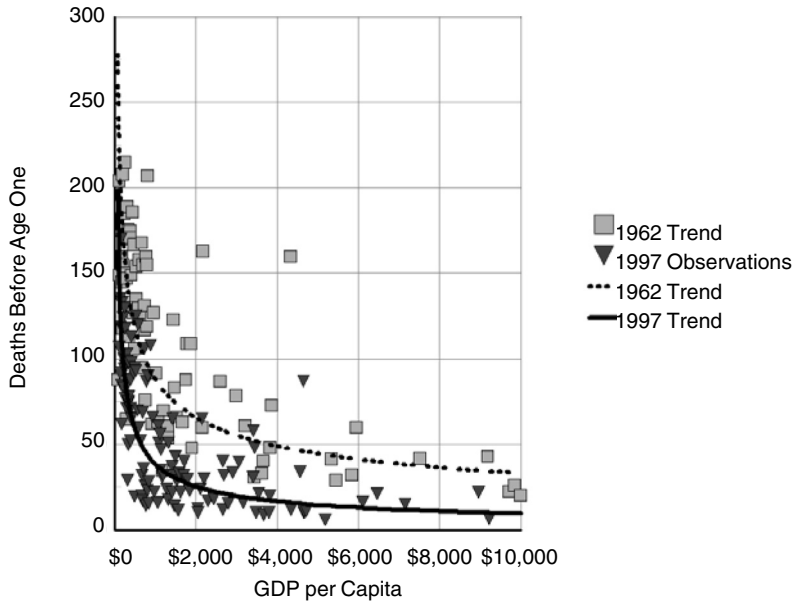

Figure 2.3 Infant Mortality and Income, 1962–1997

Note: Infant mortality is the number of deaths before age one per 1,000 live births; income is expressed as GDP per capita in 1995 US$ at MXR.

Source: World Bank (1999)

It is well known that infant mortality declines as a nation's income increases (see, for example, Pritchett and Summers 1996; World Bank 1993). Figure 2.3 illustrates this relationship (using data for 1962 and 1997). It also shows the general worldwide decline in infant mortality over time that is a consequence of technological change. It dropped from a global average of 114 in 1962 to 56 in 1997 (World Bank 1999).[6]

Economic Development

Long-term trends in economic growth, based on data from Maddison (1998, 1999), are shown in Table 2.4 for the United States, India, China, Africa, Europe, and the world. While these estimates are less

Table 2.4
Gross Domestic Product per Capita, A.D. 1–1995

Area	*1*	*1000*	*1500*	*1700*	*1820*	*1952*	*1995*
Europe	~$425	$400	~$640	$870	$1,129	$4,374	$13,951
United States	400	400	400	600	1,260	10,645	23,377
India				531	531	609	1,568
China	450	450	600	600	600	537	3,196
Africa	400	400	400	400	400		1,221
World	425	420	545	604	673	2,268	5,194

Note: In 1990 international dollars (see endnote 9). Data for Europe A.D. 1 and 1500 are based on Maddison (1999), using arithmetical average for "Western Europe" and the "Rest of Europe." Data for USA A.D. 1 to 1500 are based on Maddison's (1999) estimate for "North America." Data for Africa are assumed to be a straight line until 1820.

Sources: Maddison (1998, 1999)

than precise, they do indicate that for most of the last two millennia, GDP per capita worldwide was below $600, measured in 1990 international dollars.[7] Today it is more than eight times that.

In addition to incomes being higher, basic necessities such as food are cheaper than they were even a few decades ago. For instance, between the years 1897 to 1902 and 1992 to 1994, U.S. retail prices of flour, bacon, and potatoes relative to per-capita income dropped by 92 percent, 87 percent, and 80 percent, respectively (Goklany 1999c).

Not only is food cheaper and the average person's annual income higher, but workers spend fewer hours on the job. Between 1870 and 1992, average hours worked per person employed declined 46 percent, 48 percent, and 36 percent for the United States, France, and Japan, respectively. Ausubel and Grübler (1995) estimate that for the average British worker, total life hours worked declined from 124,000 in 1856 to 69,000 in 1981. Because the average Briton lives longer and works fewer hours each year, the life hours worked by the average British worker have declined from 50 percent to 20 percent of his or her "disposable" life hours.[8] In other words, the average person has more disposable time for leisure, hobbies, and personal development. Nota-

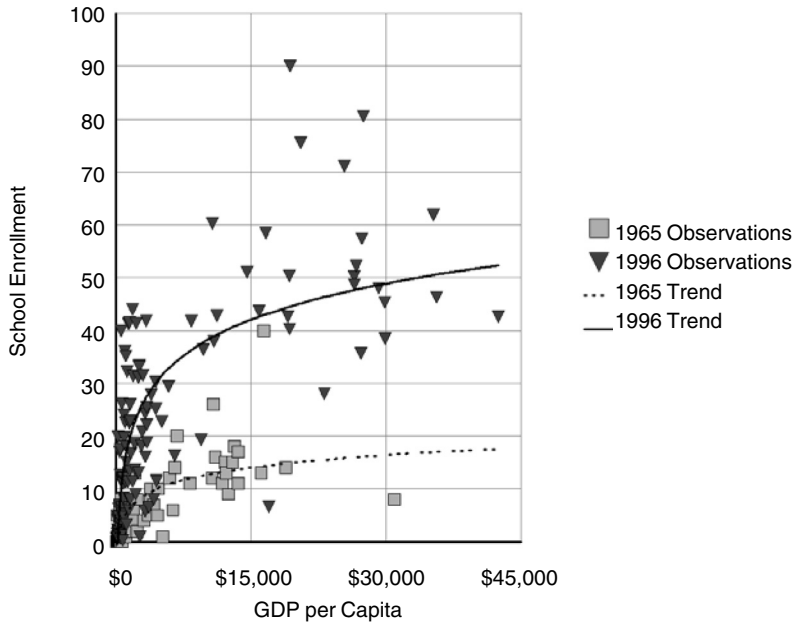

Figure 2.4 Postsecondary Education and Income, 1965–1996

Note: School enrollment expressed as the percent of relevant population; GDP per capita is in 1995 US$ at MXR.

Source: World Bank (1999)

bly, the above calculation did not account for the advent of cheap and better lighting which, if nothing else, has increased the menu of activities that individuals might choose to undertake in nondaylight hours.

Education

Figure 2.4 shows that the percent of the eligible population enrolled in postsecondary education increased with time and with affluence across a range of countries (World Bank 1999).[9] Table 2.5 shows long-term improvements in the levels of education for the United States, France, Japan, China, and India based on data from Maddison (1995, 1998).

Literacy has increased worldwide as well. Between 1970 and 1997,

Table 2.5
Education, Average Number of Years per Person, c. 1820–1992

Area	*1820*	*1870*	*1913*	*1950*	*1973*	*1992*
France			6.99	9.58	11.69	15.96
United States	1.75	3.92	7.86	11.27	14.58	18.04
Japan	1.50	1.50	5.36	9.11	12.09	14.87
India				1.35	2.60	5.55
China				1.60	4.09	8.93

Note: Data represent the average number of years per person aged 16-64.
Sources: Maddison (1995, 1998)

global illiteracy rates dropped from 45.8 percent to 25.6 percent. Complementing these increases are declines in the portion of the population aged ten to fourteen years who are working. Worldwide child labor measured this way has declined from 24.0 percent in 1960 to 12.6 percent in 1997 (World Bank 1999).

Political and Economic Freedom

Economic freedom is also ascendant around the world. Gwartney and his coworkers have constructed an index of economic freedom that takes into consideration personal choice, protection of private property, and freedom to use, exchange, or give property to another. According to this index, economic freedom increased in the 1990s in ninety-eight of the 116 countries for which they had data. Their analysis indicates that the more economically free a country's population, the higher its economic growth (Gwartney, Holcombe, and Lawson 1998; Gwartney, Lawson, and Samida 2000). See Figure 2.5.

Human Development Index

Each of the above indicators makes a strong case for a steady increase in many aspects of human well-being, but it is also possible to create a

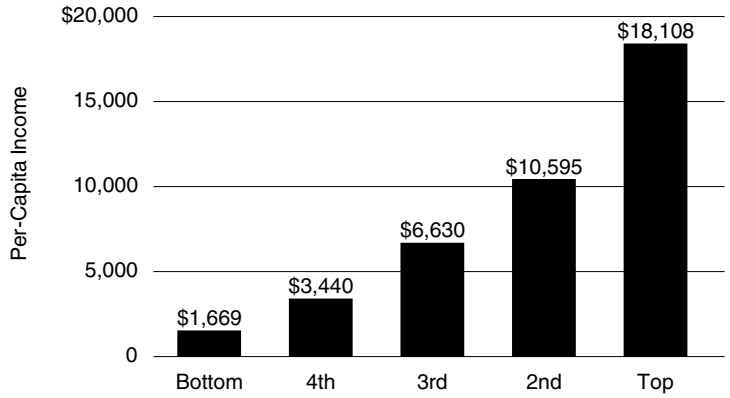

Figure 2.5 Economic Freedom Rankings by Quintiles for 116 Countries
Source: Gwartney, Lawson, and Samida (2000)

single index that incorporates a number of key measurements of well-being. The United Nations Development Program (UNDP) has popularized this approach with its Human Development Index (HDI). This index is based on life expectancy, education, and GDP per capita.[10]

According to the UNDP's *Human Development Report* (2001), the HDI has been going up for most countries. This index is somewhat arbitrary and probably understates improvements because it omits measurements of hunger and infant mortality. Nevertheless, as Figure 2.6 shows, since 1975—the first year for which that report provides data—the population-weighted HDI has improved for the so-called high, middle, and low development tiers of countries, as well as for sub-Saharan Africa (two-thirds of which are also included in the low development tier). The data indicate that human well-being has improved and continues to improve for the vast majority of the world's population. Over the past decade or so, however, well-being has been reduced in some sub-Saharan and EEFSU countries.

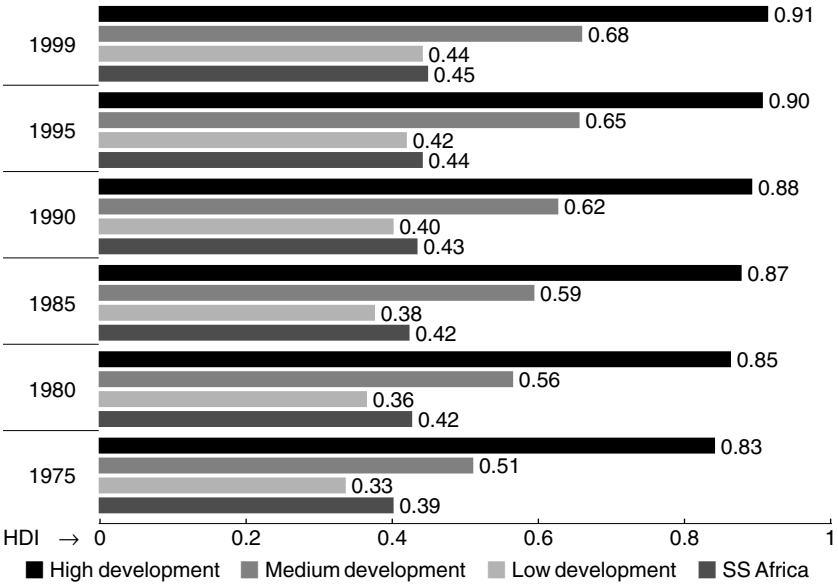

Figure 2.6 Human Development Index, 1975–1999
Note: The HDI scale tops out at 1 unit.
Sources: UNDP (2001), World Bank (2001)

Have Gaps in Human Well-Being Widened?

There can be no doubt that human well-being has improved continually over the past two centuries, but some people and organizations still claim that inequalities between the developed and developing nations continue to widen. Here is a typical observation, this one from the UNDP's *Human Development Report 1999*:

> Nearly 30 years ago the Pearson Commission began its report with the recognition that "the widening gap between the developed and developing countries has become the central problem of our times." But over the past three decades the income gap between the richest fifth and the poorest fifth has more than doubled. . . . Narrowing the gaps between rich and poor . . . should become explicit global goals. . . . (11)

Indeed, as Table 2.4 shows, there are wide—and, in many cases, growing—disparities in income between the richer and the poorer countries. The gaps in per-capita income between Western Europe and the United States and other regions have ballooned since 1700 (Maddison 1998, 1999), and many people remain terribly poor. According to the UNDP (2000), 1.2 billion people, mainly in the developing world, live in "absolute poverty" (defined as subsisting on less than US$1 per day), and at least thirty-five nations had lower per-capita incomes in 1998 than in 1975 (measured in real dollars). These claims have become a rallying cry for the forces that oppose globalization (see, for example, Goklany 2002a).

However, a number of recent studies have disputed the claim that income inequalities have been widening in recent decades. Dollar and Kraay, pro-globalization economists at the World Bank, have challenged such statements, countering that "the best evidence available shows the exact opposite to be true . . . [and that] . . . the current wave of globalization, which started around 1980, has actually promoted economic equality and reduced poverty" (2000b).

More recently, development economist Xavier Sala-i-Martin found that poverty rates declined substantially between the 1970s and 1998 (2002). Worldwide between 1976 and 1998, despite a population increase of 43 percent (FAO 2003), the number of people subsisting on an income of $1 a day declined from 16.1 percent to 6.7 percent of the population, or by 235 million, while those living on an income of $2 a day declined from 39.1 percent to 18.6 percent, or by 450 million (Sala-i-Martin 2002, 36). The bulk of the decline took place in Asia. Latin America reduced poverty overall, but most of the reduction occurred during the 1970s with little or no reduction after that. On the other hand, the number of people living in poverty in Africa increased by 175 million people (from 22 percent to 44 percent of the population) according to the one-dollar definition and by 227 million (from 53 to 64 percent) according to the two-dollar definition.

However, if consumption, rather than income, is used to determine

the $1- and $2-a-day poverty levels, then for any given year the portion of the population (as well as the numbers) living in poverty goes up. For instance, in 1998 the $1-a-day poverty rate based on income was 6.7 percent compared with 16.0 percent had it been based on consumption (Sala-i-Martin 2002, 36). The latter figure works out closer to the now-familiar 1.2 billion people estimated to live in absolute poverty (or on less than $1 a day). Notably, consumption-based global poverty levels also declined between 1976 and 1998—from 31.0 percent to 16.0 percent using the dollar-a-day definition and from 53.1 percent to 34.7 percent using the two-dollar definition (Sala-i-Martin 2002, 36).

Sala-i-Martin, using each of nine separate indices of income inequality, also showed substantial reductions in global income inequality during the 1980s and 1990s. Thus, it seems that claims of increasing poverty and rising income inequality in the recent past are not substantiated by data.

More important, what about gaps in other, more significant indicators of human well-being, such as hunger, infant mortality, life expectancy, education, and child labor? After all, as we have already seen, the importance of economic development stems from its ability to help improve these measures of welfare. The central issue is not whether income gaps are growing, but whether wealth and globalization advance well-being, and if inequalities in well-being have indeed expanded, whether that is because the rich have advanced at the expense of the poor.

Consider the trends in life expectancy, perhaps the single most important indicator of human well-being. Before industrialization, life expectancy at birth was about thirty years. But because the rich countries discovered, developed, and adopted modern public health and medical technologies first, large gaps in life expectancy had opened up between rich and poor countries by the mid-1900s. But these gaps have since shrunk because of the diffusion of those technologies owing to trade in and transfer of ideas, goods, and services from rich to poor. From 1960 to 1990, relative to high-income in the Organisation for

Economic Co-operation and Development countries (HiOECD), the gap for medium-income countries declined from 24.5 to 8.1 years; that for low-income countries declined from 25.7 to 18.8 years; and that for sub-Saharan Africa dropped from 29.4 to 26.4. Cross-country analysis for any specific year also indicates that, generally, richer is also longer-lived. It seems counterintuitive, however, that the lower the initial gap, the faster it closed (because the higher the life expectancy, the harder should it have been to raise further). But that is consistent with the fact that groups that lagged in globalization also lagged economically and in access to health technologies and should, therefore, have found it harder to close the life expectancy gap (Goklany 2002a).

Similar patterns were exhibited by trends related to other critical measures of well-being—such as freedom from hunger, infant mortality, and child labor between the 1960s and the late 1990s—and, between 1975 and 1999, for trends related to the UNDP's human development index. In each case, the indicators generally improved with wealth and the passage of time, and gaps in the indicators (relative to HiOECD) shrank the least for sub-Saharan Africa and the most for medium-income countries (Goklany 2002a).

From 1990 to 1999, however, life expectancy gaps widened. The gap between HiOECD and middle-income countries increased slightly, from 8.1 to 8.6 years, mainly because life expectancies in middle-income EEFSU nations declined along with their economies while the gap between HiOECD and sub-Saharan Africa increased from 26.4 to 31.2 years, largely due to HIV/AIDS, malaria, and tuberculosis and aggravated by additional economic disruption arising from civil and cross-border conflicts (Goklany 2002a, 11).

Increases in the life expectancy gap in the 1990s occurred because when faced with new diseases (for example, AIDS) or a resurgence of ancient ones (for example, malaria and tuberculosis), poor countries lacked the economic and human resources to develop effective treatments or to import and adapt treatments invented and developed in rich countries. In other words, although the technologies are out there

to cure many diseases, poor countries cannot afford them. This unfortunate state of affairs exists not only for expensive-to-treat diseases (for example, AIDS), but also for diseases that are relatively cheap to treat (for example, tuberculosis and malaria). Although neither globalization nor wealth are ends in themselves, globalization increases wealth, which in turn advances more direct measures of human well-being by providing the resources to improve these measures (see Chapter 4, by B. Delworth Gardner, in this book).

Regardless of whether globalization has increased income inequality, gaps between rich and poor in the more critical measures of human well-being have shrunk dramatically since the mid-1900s. Notably, where these gaps in well-being have shrunk the least or even expanded in recent years, it is because of too little, rather than too much, globalization.

Finally, the rich are not better off because they have taken something from the poor, rather the poor are better off because they have benefited from the technologies developed by the rich; their situation would have improved further had they been better able to capture the benefits of globalization. In fact, if the rich can be faulted at all, it is that by subsidizing favored economic sectors and maintaining import barriers, they have retarded globalization and made it harder for many developing countries to capture its benefits.

The Cycle of Progress

We have seen that human welfare advanced more during the twentieth century than it had in all the rest of mankind's tenure on Earth. This progress in human well-being was sustained, and perhaps even initiated, by a cycle composed of the mutually reinforcing, coevolving forces of economic growth, technological change, and free trade.

Technology increases food production through various mechanisms. It boosts yields through special seeds, mechanization, judicious application of inputs such as fertilizers and lime, and reductions of

losses to pests, spoilage, and waste. Use of this technology is closely linked to economic development because not everyone can afford it. One reason poorer countries have lower cereal yields is that farmers cannot afford sufficient fertilizer and other yield-enhancing technologies (Goklany 1998, 2000). Thus yields increase over time and with wealth (Goklany 2001a, 26).

More food also means more healthy people who are less likely to succumb to infectious and parasitic diseases. That—along with capital and human resources targeted on improvements in medicine and public health—has reduced mortality and increased life expectancy worldwide (Fogel 1995, 2000; World Health Organization 1999). Hence, as populations become more affluent, mortality decreases and life expectancy increases (Goklany 1999b; see also Pritchett and Summers 1996; World Bank 1993). Thus, a wealthier population is healthier.

A healthier population also is wealthier because it is more productive (Barro 1997; Bloom 1999; Fogel 1995; World Bank 1993; World Health Organization 1999). Fogel (1995, 65) estimates that the level of food supplies in eighteenth-century France was so low that the bottom 10 percent of the labor force could not generate the energy needed for regular work, and the next 10 percent had enough energy for about half an hour of heavy work (or less than three hours of light work).

A healthier and longer-lived population also is likely to invest more time and effort in developing its human capital, which contributes to the creation and diffusion of technology. It is not surprising that levels of education have gone up with life expectancy or that researchers today spend what at one period was literally a lifetime to acquire skills and expertise necessary for a career in research.

In addition, several measures undertaken to improve public health provided a bonus in economic productivity. Draining swamps not only reduced malaria but also added to the agricultural land base (Easterlin 1996). World Bank (1993, 19) reported that an international program to curtail river blindness, the Onchocersiasis Control Program, a mix-

ture of drug therapy and insecticide spraying, has protected thirty million people (including nine million children) from the disease, and it is freeing up 25 million hectares (60 million acres) of land for cultivation and settlement. The improved food supplies should result in better nutrition, which may aid learning. (This is one of the premises behind school meals programs [Watkins 1997].)

Improvements specific to health, food, and agriculture also benefit from a larger, more general cycle in which broad technological change, economic growth, and global trade reinforce each other. Other technologies—invented for other reasons—have led to medical advances and improved productivity or reduced the environmental impacts of the food and agricultural sector. For example, computers, lasers, and global positioning systems permit precision agriculture to optimize the timing and quantities of fertilizers, water, and pesticides, increasing productivity while reducing environmental impacts. Plastics—essential for food packaging and preservation—also increase productivity of the food and agricultural sector. Transportation of every kind increases the ability to move inputs and outputs from farm to market and from market to farm. Broad advances in physics and engineering have led to new or improved medical technologies, including electricity (without which virtually no present-day hospital or operating room could function), X-rays, nuclear magnetic resonance, lasers, and refrigeration.

These specific impacts do not exhaust the benefits of broad economic growth, technological change, and global trade. Technological change in general reinforces economic growth (Barro 1997; Goklany 1998), giving countries more resources to research and develop technological improvements (Goklany 1995) and to increase education.

Freer trade contributes directly to greater economic growth, helps disseminate new technologies, and creates competitive pressures to invent and innovate (Goklany 1995). As an example, trade accelerated the cleanup of automobile emissions in the United States because the threat of cleaner cars from imports advanced the introduction of catalytic converters in the 1970s (Barbour 1980; Seskin 1978).

By expanding competition, trade helps contain the costs of basic infrastructure, including water supply and sanitation systems. A vivid example of the importance of trade in improving human well-being comes from prewar Iraq. Because of trade sanctions, Iraq was unable to operate and maintain much of its water, sanitation, and electricity systems, resulting in significant public health problems (United Nations 2000).

In terms of income alone, trade raises incomes for both the poor and the rich (Dollar and Kraay 2000a; see also Frankel and Romer 1999). Dollar and Kraay (2000a) also find that economic growth favors rich and poor equally, confirming analyses by Ravallion and Chen (1997) and Easterly and Rebelo (1993). Similarly, increased protection of property rights and fiscal discipline (defined as low government consumption) raise overall incomes without increasing inequality (Dollar and Kraay 2000a).

Thus, each link in the cycle—higher yields, increased food supplies, lower mortalities, and higher life expectancies—is strengthened by the general forces of economic growth, technological change, and trade. Qualitatively at least, this explains why all the figures for cereal yields, food supplies per capita, safe water, life expectancy, and postsecondary education, when plotted against per-capita income (as seen in figures here and in Goklany 2001a), show improvement, with rising per-capita incomes.

Conclusion

The foregoing brief investigation into the course of human well-being since the start of industrialization reinforces Lomborg's (2001) conclusion that the state of humanity has never been better (87, 328). For every indicator of human well-being examined in this chapter, cross-country analysis shows that well-being advances with the level of economic development. These improvements are generally greatest at the lowest levels of economic development. This gives further credence to

Lomborg's contention that economic development is a key factor in advancing well-being (324, 327).

This chapter also extends Lomborg's analysis by showing explicitly that technological change is critical to such advances. Thus, Lomborg is justified in his skepticism of a precautionary principle that would—under the cover of the old aphorism "better safe than sorry"—limit new technologies if, despite clear and certain social, economic, or health-related benefits, they also might result in uncertain environmental costs (348–50; Goklany 2001b, 2002b). Calling such an approach a "precautionary principle" would be a misnomer; it would prolong existing risks to human well-being and, thereby, retard further progress. Perhaps the most vivid examples of the perverse outcomes of such misuse of the principle are Zambia's rejection of genetically modified maize to feed its starving population, and the discontinuation of spraying DDT indoors in areas where that effectively reduces malaria (Goklany 2001b). In order to ensure that the precautionary principle does indeed reduce overall risk, decisions regarding new technologies must weigh the social, public health, and environmental benefits against the costs associated with adopting (or rejecting) those technologies (Goklany 2002b).

The importance of both technological change and economic development is reinforced by trends in gaps in well-being in the past half-century. During the first two decades of that period, gaps in some well-being indicators between rich and poor countries shrank, although inequalities in income, that is, economic development, increased. The shrinkage was because of technological change brought about by the diffusion of technologies from the rich to the poor via trade in and transfer of goods, ideas, knowledge, and services, that is, through globalization. More recently, however, gaps in life expectancy between the rich countries and sub-Saharan Africa and EEFSU nations have begun to expand. This is largely because of economic difficulties in these areas, which rendered them unable to marshal the resources needed to acquire and implement the technologies for dealing with new diseases (for example, AIDS) or the resurgence of old diseases (for example, tuber-

culosis and malaria). Thus, despite the vociferous complaints one hears about globalization, insufficient globalization creates a larger problem.

Notably, improvements in well-being have not yet run their full course. Substantial additional improvements in infant mortality and life expectancy are possible in developing countries if they become wealthier and if existing-but-underused safe-water, sanitation, and agricultural technologies are more widely spread (Lomborg 2001, 334–35). However, once the easy and relatively cheap improvements in health and life expectancy have been captured, solutions to remaining problems (such as AIDS and the diseases of affluence), being expensive, might be increasingly unaffordable, whether one lives in a developed or developing country. Further improvements in human well-being will depend largely on the development of human and capital resources and encouraging the development and deployment of new risk-reduction technologies. Thus, it is critical to focus on strengthening the domestic and international institutions that will boost technological change and economic development, which include free markets, freer trade, individual property rights, the rule of law, and transparent government and bureaucracies.

Notes

1. For hunger, see Lomborg (2001) at 60–62; education, 80–82; wealth, 70–71; health as measured by infant mortality, 53–55; life expectancy, 50–53.
2. The logarithm of per-capita income is used to moderate the impact on the index from additional increases in income.
3. This is the first of several curves plotting various indicators against GDP per capita (in 1995 U.S. dollars at market exchange rates, MXR). To better illustrate the dependence of indicators at low- to mid-levels of economic development, the scales for this and similar figures are cut off at mid-levels of GDP per capita. Unless noted otherwise, the smoothed curves in all these figures were generated using log-linear relationships, and the slopes, that is, the coefficients of the log (GDP per capita) term, are significant ($p < 0.001$). In Figure 2.1, for 1961, the number of observations (N) was

92, and $R^2 = 0.61$. For 1994, $N = 150$ and $R^2 = 0.63$. Also, unless otherwise noted, the shifts in the indicator as we go from one year to the other, that is, the *y*-intercepts, are also significant ($p < 0.001$). This shift informs us about the effect of technology over time in the level of the indicator. According to the regression analyses, if per-capita income had been frozen at $300 (in 1995 U.S. dollars, MXR), available food supplies would have increased from 2,004 calories per capita per day in 1961 to 2,148 calories per capita per day in 1994.

4. *N* and R^2 for 1962 and 1997 are 96 and 0.71 and 148 and 0.65, respectively. If per capita income had been frozen at $300 (in 1995 U.S. dollars), life expectancy would have increased from 44.7 years in 1962 to 55.0 in 1997. Also see note 1.
5. Dollars for United States, China, and India are all adjusted for purchasing power parity (Maddison 1995 and 1999).
6. The curves in Figure 2.3 were fitted using a log-log relationship. *N* and R^2 for 1962 and 1997 were 96 and 0.71 and 147 and 0.79, respectively. The significant lowering of the curve over time is consistent with the creation and diffusion of new and existing-but-underused technologies. If GDP per capita had been frozen at $300 (in 1995 U.S. dollars), infant mortality rate would have declined from 147 per 1,000 live births in 1962 to 82 in 1997. Also see note 1.
7. International dollars are obtained using a special conversion factor, purchasing power parity, designed to reflect more accurately the purchasing powers of different currencies. Conversion is based on the number of units of a country's currency required to buy the same amounts of goods and services in the domestic market as $1 would buy in the United States. In contrast, the market exchange rate (MXR) of a currency in U.S. dollars (used elsewhere in this chapter) is the amount of the currency one can buy with one U.S. dollar on the open currency market.
8. Ausubel and Grubler define "disposable" life hours as the average hours in a lifetime minus: (a) the hours equivalent to ten years to account for childhood and basic elementary education, and (b) the hours needed to take care of basic physiological needs such as eating, sleeping, and basic hygiene.
9. *N* and R^2 for 1965 and 1996 were 82 and 0.54 and 137 and 0.64, respectively. The increases in the intercepts, which are significant, are probably due to increasing knowledge about the benefits of education and the willingness and ability of families and societies to incur the costs of longer

periods of education. Globally, postsecondary enrollment increased from 6.8 percent in 1965 to 18.8 percent in 1996. Also see note 1.

10. As noted previously, the index uses the logarithm of GDP per capita.

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