ECONOMIC GROWTH
AND THE STATE OF HUMANITY

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"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."
—*Global 2000 Report to the President*

Introduction

With this Neo-Malthusian vision of the future, the *Global 2000 Report to the President* (Barney 1980) began a chilling description of the problems that lay ahead for the world unless radical changes were made. Fifteen years later, Julian Simon (1995) quoted these words in his introduction to the monumental collection of essays, *The State of Humanity*. The point of that book, which Simon also edited, was to determine whether trends in human well-being and environmental quality were in accord with a Neo-Malthusian world view.

The State of Humanity, in fifty-eight chapters by more than fifty scholars, documented the tremendous strides in human well-being over the centuries, as well as trends in natural resource use and environmental quality. Based on these discussions, Simon (1995, 1) wrote: "Our species is better off in just about every measurable material way."

Yet today anxiety about the future continues. Calls to restructure our economy to avoid the pending insurmountable problems are typical. "The challenge facing the entire world is to design an economy that can satisfy the basic needs of people everywhere without self-destructing," said Lester Brown (1998, 4), president of World Watch Institute in 1998.

This paper is a conscious effort to emulate, build upon, and update the work of Julian Simon and to provide empirical data to help evaluate the heated rhetoric of Lester Brown and other Neo-Malthusian alarmists. While no one can confidently predict the future, it is possible to scrutinize the past and present to determine the current state of humanity and identify which factors have helped, and which hindered, progress.

Thus, the goal of this much smaller paper is to collect in a convenient and portable volume the historical trends for indicators that are widely used to illustrate human welfare. These trends are presented not only across time, but, where data are available, across countries with different levels of economic development. In some cases, the data go back to when modern economic growth began—around 1800 (see Maddison 1999).

This paper will address whether and to what extent modern economic growth has improved humanity's lot, using the following indicators.

- *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, while 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 valu-

able indicator of human well-being. Longer life expectancy is also 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 spent by women in child-bearing.

- *Economic development*. Gross domestic product (GDP) per capita is a measure of people's income. Thus, it measures the wealth or level of economic development of a country. While wealth is not an end in itself, it indicates how well a nation can achieve the ends its people desire, from greater availability of food, safe water, and sanitation to higher levels of education and health care.

- *Education*. While education is an end in itself, it also adds to human capital and can accelerate the creation and diffusion of technology. Education (particularly of women) helps to spread knowledge about 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 the pursuit of happiness, which are among the inalienable rights of human beings.

- *A composite human development index*. Using an approach similar to that employed in the United Nations Development Program (UNDP), this index combines indicators for life expectancy, education, and per capita income.[1]

After examining trends in the above indicators, this paper will address whether differences in human well-being have widened between developed and developing countries and whether urban residents fare worse than rural residents. Finally, it will

discuss the factors that appear to be responsible for the remarkable cycle of progress that has accompanied modern economic growth.

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 latter part of the century in the developing countries (Ehrlich 1968; Paddock and Paddock 1967). But 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 1961–98, as indicated by Table 1. The increase for developing countries was even larger, 38 percent.

The Food and Agriculture Organization (1996a) 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. Adding to this threshold an allowance for moderate activity results in an estimate of the national average requirement from 2,000 to 2,310 Calories per person per day. (This assumes equal food provisions are likely to be equally available to the population.)

The improvements in India and China since the middle of the twentieth century are especially remarkable. 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 in 1950–51. Between 1969–71 and 1995–97 such increases in food sup-

plies reduced the number of chronically undernourished people in developing countries from 920 million to less than 800 million (or from 35 percent to 19 percent of their population) despite a 70 percent growth in population (FAO 1996b, 1999).

Figure 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).[2] 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 through time is consistent with the fact that increases in food production outpaced population growth, largely due to technological change (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), making more food available for people in the lower rungs of the economic ladder.

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 between 20 to 30 years (Preston 1995). By 1998 it had increased to 66.9 years worldwide (UNDP 2000), as Table 2 indicates. For the wealthiest group of nations, the Organization for Economic and Co-operative Development (OECD), life expectancy at birth was 76.4 years in 1998.

Life expectancy in the countries that are developed today fluctuated in the early nineteenth century, followed by small declines in the middle two quarters of the nineteenth century. Then, with a few notable exceptions and some minor fluctuations, it began a sustained improvement that continues to this day.

In England and Wales, life expectancy was 35.9 years in 1801.

After some ups and downs, it increased to 40.8 years in 1831 but then declined to 39.5 in 1851. After further fluctuations in the range of 40.2 to 41.2 years, it has been climbing since 1871 (Floud and Harris 1997, 116). The same broad pattern seems to fit the United States from the 1850s to the present, with steady improvements from 1880 on (Haines 1994). The nineteenth century fluctuations were probably due to a combination of factors. Urbanization, ignorance of germs, and poor sanitation helped spread infectious and parasitic diseases such as cholera, smallpox, malaria, tuberculosis, and typhoid.

Once solutions to these diseases were identified—in some cases before understanding their causes—nations cleaned up their water supplies and instituted basic public health measures, such as sanitation, pasteurization, and vaccination. Mortality rates dropped rapidly in the late nineteenth and early twentieth century.

Then, in the first half of the twentieth century, antibiotics, pesticides such as DDT, and an array of vaccines were added to the arsenal of weapons against disease. Once the traditional infectious and parasitic diseases were essentially conquered, the developed countries turned to dealing with so-called diseases of affluence: cancer, heart diseases and strokes (plus HIV/AIDS, a nontraditional infectious disease).

During the second half of the twentieth century, the diffusion of technology from the developed to developing countries, as well as greater wealth in the developing countries, increased access to safe water and sanitation services in developing countries. This is shown, for example, in Figure 2.[3] Such access, coupled with increases in per capita food supplies (see Table 1 and Figure 1), basic public health services, and the newer weapons such as antibiotics reduced mortality rates (see, for example, Table 3). As a result, life expectancies lengthened worldwide, not just in the richest nations.

Figure 3 shows that life expectancy increases as GDP per capita increases, using data for 1962, 1980, and 1997. Average global life expectancy increased from 55.0 to 66.7 years between 1962 and 1997 (World Bank 1999), as technology, including knowledge, was diffused around the world. 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 3 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),[5] life expectancy at birth was 52.5 years (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).

Not only are we living longer; we are also healthier (OECD 1998; Shalala 1998). The World Health Organization (2000) reports on disability-adjusted life expectancy, which is calculated by subtracting the years of ill-health (weighted according to severity) from the expected overall life expectancy to give the equivalent years of healthy life. According to the latest *World Health Report*, disability-adjusted life expectancies for 1997–99 for the U.S., China, and India, were 70.0, 62.3, and 53.2 years, respectively. This is substantially more than these countries' corresponding *total* life expectancies before industrialization (Table 2). Moreover, disability in the older populations of such developed nations as the United States, Canada, and France has been declining (U.S. Dept. of Health and Human Services 1997). In the United States, for instance, the disability rate dropped 1.3 percent per year between 1982 and 1994 for persons aged 65 and over.

To illustrate the changes in the populous and less affluent countries, Figure 4 shows trends in life expectancies from the years 1950–55 to 1997 for ten countries that together contained 54 percent of the world's population in 1997.[6] Life expectancy has been increasing for each of the ten except Russia, where it has declined since the late 1980s (Becker and Bloom 1998).

Russia's decline reflects economic deterioration. Between 1989 and 1997, GDP per capita (in real dollars) declined 41 percent. 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 countries and those of the former Soviet Union. Life expectancies are also declining in a number of Sub-Saharan countries, seemingly due to a vicious cycle involving HIV/AIDS and a drop in economic output (UNDP 2000).

INFANT MORTALITY

Before industrialization, one out of every five children died before reaching his or her first birthday. As indicated in Table 3, infant mortality, measured as the number of children dying before reaching one year, typically exceeded 200 per 1,000 live births (Hill 1995). The rate fell to 58 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). In the United States, as late as 1900, infant mortality was about 160; but in 1997 it was about 7 (Bureau of the Census 1975, 60; 1999).

In the developing countries, the declines started later but may be occurring more rapidly in some areas. For instance, between 1950–55 and 1998, India's infant mortality fell from 190 to 69, and China's from 195 to 38 (World Resources Institute 1998; UNDP 2000).

It is well known that infant mortality declines as a nation's income increases (see, e.g., Pritchett and Summers 1996; World Bank 1993). Figure 5 illustrates this relationship (using data for 1962, 1980, and 1997). It also shows the general worldwide decline in infant mortality over time. It dropped from a global average of 114 in 1962 to 56 in 1997 (World Bank 1999).[7]

The declines in infant mortality were accompanied by even more spectacular declines in maternal mortality. In the United States, for instance, while infant mortality rates declined from around 100 per 1,000 live births in 1915 to 7.2 in 1996, maternal mortality rates declined from 220 per 100,000 live births to 7.6 (Bureau of the Census 1975, 57; 1999).

ECONOMIC DEVELOPMENT

Long-term trends in economic growth, based on data from Maddison (1998, 1999), are shown in Table 4 for the United States, India, China, Japan, Europe, and the world. While these estimates are less than precise, they do indicate that for most of this millennium, GDP per capita worldwide was below $600, measured in 1990 international dollars.[8] Today, as Figure 6 shows, it is more than eight times that.

Acceleration of economic growth began around 1800 and has been dramatic in recent years. Basic necessities such as food are much more easily obtained 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, 48, and 36 percent for the U.S., 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 has declined from 50 percent to 20 percent of his or her disposable life hours. In other words, the average person has more disposable time for leisure, hobbies, and personal development.

Thus, trends in real wages measured in dollars per hour would show an even more dramatic improvement than the income growth shown in Figure 6. However, even these trends would substantially underestimate the true improvements in wages because methods to convert current dollars in one year to real dollars in another year are not robust when there has been a vast technological change between the two years. Goods and services available in the year 1950, for instance, were vastly different from those available in 1995. Personal computers, cell phones, VCRs, and instant access

to the Library of Congress's electronic catalogue, to mention a few, simply were not available in 1950. Today, for a few hundred dollars people can buy goods and services they could not buy for all the money in the world a generation or two ago.

EDUCATION AND CHILD LABOR

Figure 7 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 5 shows long-term improvements in the levels of education for the United States, France, China, and India based on data from Maddison (1995, 1998).

Literacy has increased worldwide as well, rising for each of the ten countries shown in Figure 4 (World Bank 1999). Between 1970 and 1997, global illiteracy rates dropped from 45.8 percent to 25.6 percent. Complementing these increases are declines in the portion of the population aged 10 to 14 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

In 1900, no country had universal adult suffrage; today virtually all do. Multiparty electoral systems were introduced in 113 countries in the quarter century following 1974 (UNDP 2000).

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 98 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 8.

HUMAN DEVELOPMENT INDEX

While the above indicators make a strong case for a steady increase in many aspects of human well-being, it is possible to create a single indicator that incorporates a number of key measurements of well-being. The United Nations Development Program has popularized this approach with its Human Development Index. This index is based on life expectancy, education, and GDP per capita.[10]

According to the latest *Human Development Report* (UNDP 2000), the Human Development Index (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, the data show that:

- All but one of the 101 countries for which data are available showed improvement in the human development index between 1975 and 1998. The exception, Zambia, had increased its HDI between 1975 and 1985 (due to longer life expectancy and higher literacy rates despite a decline in GDP per capita). However, by 1998, continuing declines in GDP per capita and lower life expectancy due to HIV/AIDS more than erased those gains, and the presence of refugees may have contributed to these declines in Zambia.

- Ten countries in Sub-Saharan Africa and thirteen in Eastern Europe and the former Soviet Union had lower HDIs in 1998 than in 1985 or 1990. The ten Sub-Saharan countries were all affected by HIV/AIDS, and some also had declining GDP per capita. Of those, three were plagued by civil conflict or unrest (Democratic Republic of the Congo, South Africa, and Burundi); at least two more chose sides and expended scarce resources in those conflicts (Zimbabwe and Namibia); and at

least three (Zambia, Congo, and Kenya) were contending with refugee populations (*Daily Mail* and *Guardian* 1998; U.N. High Commission on Refugees 1998, 1999).

- Of the 166 countries for which the World Resources Institute (1998) has data, only thirteen had lower life expectancies between 1995–2000 than between 1970–75. These included seven Eastern European and former Soviet Union countries and six Sub-Saharan countries. GDP per capita has declined in eleven of these thirteen, at least since 1990.

In summary, 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 10 to 15 years, however, well-being has been reduced in some Sub-Saharan, Eastern European, and former Soviet Union nations.

One of the critical factors underlying these declines is insufficient wealth. HIV/AIDS is identified as the major cause of reductions in HDI in Sub-Saharan countries (UNDP 2000). When AIDS first appeared, it resulted in almost certain death. Developed countries, particularly the United States, launched a massive assault on the disease. U.S. deaths due to HIV/AIDS dropped from a high of 43,115 in 1995 to 13,210 in 1998 (Centers for Disease Control and Prevention 1998; Martin et al. 1999, 28). In 1996, it was the eighth leading cause of death; by 1998 it had dropped off the worst-fifteen list. But similar improvement is unlikely to occur soon in Sub-Saharan countries because they cannot afford the cost of treatment unless it is subsidized by the governments, charities, or industry from the richer nations.

For the United States, I have constructed a similar index. Instead of education per se, I use literacy data, which are more readily available. The minimum value for each of the three components corresponds roughly to what it was around 1820, approximately the start of industrialization. These are: 30 years for life expectancy, 73.7 percent for literacy, and $1,350 (in 1992$) for GDP per capita (Costa and Steckel 1997; Maddison 1999). For the maximum values, I assume 85 years, 100 percent, and $40,000, respec-

tively, similar to what UNDP (2000) assumes. My index assumes that literacy stays at 99 percent after 1970. This actually understates the level of improvement since it does not account for long-term increases in the educational level of the average American.

Based on these assumptions, Figure 9 shows trends in the composite HDI and its individual components for the United States from 1870–1997. Despite minor fluctuations in the components, there has been a general improvement in overall human well-being in the United States during the twentieth century. Each component improved throughout the century except for literacy, which reached saturation around 1970.

Have Gaps in Human Well-Being Widened?

While human well-being has improved continually over the past two centuries, it is often claimed that inequalities continue to widen between the developed and developing nations. A typical observation is the following from the United Nations Development Program's 1999 Human Development Report:

> 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. . . . (UNDP 1999, 11)

As Figure 6 showed, there are wide—and, in many cases, growing—disparities in income between the richer and 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 one

U.S. dollar per day) and at least 35 nations had lower per capita incomes in 1998 than in 1975 (measured in real dollars).

However, measurements that describe human well-being more directly than income do not show quite the same pattern. Yes, gaps in life expectancy and infant mortality between the more and less developed countries are substantial. However, these gaps have narrowed by 55 percent since World War II. The gap in life expectancy was 25.4 years in the 1950–1955 period but fell to 10.9 years in the 1995–2000 period, while the gap in infant mortality fell from 121 to 53 deaths per 1,000 live births.[11]

In addition, as shown in Table 1 and Figure 1, food supplies per capita have increased. Hunger is less prevalent than it was thirty years ago, and the number of people suffering from chronic undernourishment has declined in both absolute and relative terms (FAO 1996b, 1999). Thus, while income inequalities have widened, in the aspects of human well-being that are truly critical—life expectancy, infant mortality, hunger—the world is far more equal.

ARE RURAL RESIDENTS BETTER OFF?

Historically, as the currently developed countries embarked on modern economic growth, the welfare of urban dwellers generally lagged behind that of their rural compatriots (Easterlin 1996; Fogel 2000; Lerner and Anderson 1963). Fogel (2000, 149) notes that U.S. cities with populations above 50,000 had twice the death rates of rural areas in the 1830s. Evidently, overcrowding, lack of knowledge about hygiene, and the lack of safe water and sanitation made urban populations more susceptible to contagious diseases such as cholera, typhoid, and tuberculosis. The image of urban suffering compared to a healthier rural life is reinforced in the mind of anyone who visits the overcrowded and polluted urban areas of the developing world, which give the impression that life in developing countries is worsening as cities grow.

In fact, however, urban residents are better off in most developing countries. When measured by the United Nations' Human

Development Index and its related Human Poverty Index, there is more progress and less deprivation in urban areas (UNDP 2000, 152). For instance, in Swaziland, the rural HDI is 35 percent below the urban level, reflecting less access to safe water, sanitation, and public health services; lower rates of literacy; and higher rates of undernourishment. Figure 10 shows for 1990–96 the urban–rural divide for access to safe water and access to sanitation for some of today's more populous developing nations. In each case, rural residents have lower access.

The Cycle of Progress

We have seen that human welfare advanced more during the twentieth century than it did in all the rest of mankind's tenure on earth. I contend that this progress in human well-being was sustained, and perhaps even initiated, by a cycle composed of the mutually reinforcing, co-evolving 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 wastage. Use of this technology is closely linked to economic development because not everyone can afford it. One reason why poorer countries have lower cereal yields is that farmers cannot afford sufficient fertilizer and other yield-enhancing technologies (Goklany 1998, 2000). Thus we see in Figure 11 that yields increase over time and with wealth.[12]

Higher crop yields translate into more food. Even if food deficits exist, trade moves agricultural crops and products voluntarily from surplus to deficit areas, allowing developing countries like Afghanistan and Zimbabwe to reduce their food shortfalls. Thus, global trade in conjunction with improved technology increases food security (Goklany 1995, 1998). The infrastructure—ships, refrigerated trucks, roads, and rails—that trade depends on, as well as financial mechanisms that transfer money and hedge

risks, are products of technology, capital, and human resources.

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 (see, e.g., Figure 2)—has reduced mortality and increased life expectancy worldwide (Fogel 1995, 2000; World Health Organization 1999). Hence, as populations become more affluent, mortality decreases, as shown in Figure 5 for infant mortality, and life expectancy increases, as shown in Figure 3 (Goklany 1999b; see also, Pritchett and Summers 1996; World Bank 1993). Thus, a wealthier population is healthier.

A healthier population is also 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 were 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 3 hours of light work).

Citing a United Nations study, Easterlin (1996) notes that when malaria was eradicated in Mymensingh (now in Bangladesh), crop yields increased 15 percent because farmers could spend more time and effort on cultivation. In other areas elimination of seasonal malaria enabled farmers to plant a second crop. According to the World Bank (1993, 18), the near-eradication of malaria in Sri Lanka between 1947 and 1977 raised its national income by an estimated 9 percent. A joint study by the Harvard University Center for International Development and the London School of Hygiene and Tropical Medicine estimated that if malaria had been eradicated in 1965, Africa's GDP would have been 32 percent higher today (Malaria Foundation International 2000; see, also, *Guardian* 2000).

A healthier and longer-lived population is also 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 liter-

ally a lifetime to acquire skills and expertise necessary for careers 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). The World Bank (1993, 19) reported that an international program to curtail river blindness, the Onchocersiasis Control Program, a mixture of drug therapy and insecticide spraying, has protected 30 million people (including 9 million children) from the disease. It is also freeing up 25 million hectares (60 million acres) of land for cultivation and settlement. Similarly, improved food supplies and nutrition by themselves 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 farms to markets, and vice versa. 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.

As Figure 7 showed, the proportion of the eligible population enrolled in postsecondary schools increases with wealth. Anecdotal evidences reinforces the importance of wealth in developing human capital. Wealthy countries have the best education. An informal survey of fellow immigrants suggests that many of the most talented people from poorer countries end up in the universities and research establishments of the richer nations not only because they expect a higher quality of education but because they anticipate job opportunities that will better use their education and talents. In 1993, for instance, ten of the richest (and most well-educated) countries accounted for 84 percent of global research and development and controlled more than 80 percent of the patents acquired in the United States and in developing countries (UNDP 1999).

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 Iraq. Because of trade sanctions, it is unable to operate and maintain its water, sanitation, and electricity systems, resulting in significant public health problems (United Nations 2000).

Without the additional food supplies obtained through trade, prices would be higher and levels of hunger and malnutrition would increase in developing countries. These countries would have had to increase their cereal production by 10 percent to make up the shortfall from the absence of any international trade in cereals (Goklany 1998). The result would be higher food prices (which would price more poor people out of the market), greater cultivation of more marginal lands, or both.

In terms of income alone, trade raises incomes for both the

poor and the rich (Dollar and Kraay 2000; see also Frankel and Romer 1999). Dollar and Kraay (2000) 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 2000).

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 (Figure 11), food supplies per capita (Figure 1), safe water (Figure 2), life expectancy (Figure 3) and postsecondary education (Figure 7) when plotted against per capita income look similar, and all look like mirror images of Figure 5 for infant mortality rates.

Conclusion

Since 1800, global population has increased about sixfold (FAO 2000; McEvedy and Jones 1978, 342). Manufacturing industries have increased seventy-five times in value (Bairoch 1982)[13] and coal production has increased 500 times (Smil 1994). Overall, global economic product has multiplied more than fiftyfold (Maddison 1999).[14] Despite the environmental disruption which might have been caused by all this activity, the state of humanity has never been better. Specifically:

- In the last two centuries, the average person's life expectancy at birth has doubled, infant mortality is less than a third of what it used to be, and real income has grown sevenfold. Food is more affordable. A child is less likely to go to bed hungry and a woman is far less likely to die in child birth. Children are more likely to be in school than at work. People are more educated and freer to choose their rulers and ex-

press their views. They are more likely to live under the rule of law and are less fearful of being arbitrarily deprived of life or limb, freedom, property, wealth, and other basic human rights. Not only is work less physically demanding, but people work fewer hours and have more leisure time and money to devote to optional pursuits.

- Although gaps between richer and poorer nations may be expanding in terms of per capita income, gaps in the critical aspects of human well-being (particularly life expectancy, infant mortality, hunger and malnourishment, and literacy) have for the most part shrunk over the past half-century.

- Developing nations on the whole have benefited from knowledge and technology generated in developed countries. With respect to the most critical indicators of human well-being—life expectancy, infant mortality, and hunger—developing countries are better off than were developed countries at equivalent levels of income. These improvements have come from reducing death and disease due to inadequate food supplies and infectious and parasitic diseases such as cholera, malaria, typhoid, diarrhea, dysentery, and other water-related illnesses.

- The reductions in water-related diseases and diseases caused or aggravated by inadequate food and nutrition have not yet run their full course. Thus, improvements in infant mortality and life expectancy in developing countries may continue, shrinking the gap between developing and developed countries for these indicators. However, once the easy and relatively cheap improvements in health and life expectancy have been captured, the gap may widen again. Further improvements will come only through dealing with nontraditional diseases such as AIDs and the diseases of affluence. While the United States has reduced deaths from HIV/AIDS by almost 70 percent between 1995 and 1998, treatment is expensive and unaffordable to most in the developing world. This illustrates not only the need for improved technology but also the importance of eco-

nomic growth as well as trade in ideas and products.

- Economic growth, technological change, and trade become even more crucial for the continued improvement in the state of humanity when one considers that global population may grow anywhere between 20 and 80 percent during the next century, according to the United Nation's latest projections (United Nations Population Division 1999).

NOTES

1. UNDP (2000). The logarithm of per capita income is used to moderate the impact on the index from additional increases in income.

2. 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, i.e., the coefficients of the log (GDP per capita) term, are significant (i.e., $p < 0.001$). In Figure 1, for 1961, the number of observations (N) were 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, i.e., 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.

3. N was 64 for 1970 and 51 for 1995. Because a number of countries were already at 100 percent in 1995, a Tobit model was used for truncation at that level. The untruncated log-linear regressions had R^2 of 0.35 and 0.55 for 1970 and 1995, respectively. The

rise in the intercept was significant ($p < 0.001$), as were the slopes, i.e., coefficients for GDP per capita, for the individual years. Also, see note 2.

4. N and R^2 for 1962, 1980, and 1997 are 96 and 0.71, 121 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 2.

5. Dollars for United States, China, and India are all adjusted for purchasing power parity (Maddison 1995 and 1999).

6. Figure 4 uses data from the World Resources Institute (1998) for 1950–55 and 1955–60 (plotted as 1952.5, and 1957.5, respectively). For Russia, it plotted the World Resources Institute data for 1960–65, 1965–70, 1970–75 as 1962, 1967, and 1972 data. The multiple years reflect five-year averages, using real or expected values. The rest of the data are from World Bank (1999).

7. The curves in Figure 5 were fitted using a log-log relationship. N and R^2 for each of the years 1962, 1980, and 1997 were 96 and 0.71, 123 and 0.74, 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 2.

8. 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 paper) is the amount of the currency one can buy with one U.S. dollar on the open currency market.

9. N and R^2 for 1965, 1980, and 1996 were 82 and 0.54, 112 and 0.47, and 137 and 0.64, respectively. The increases in the intercepts, which are significant, are probably owing 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 edu-

cation. Globally, postsecondary enrollment increased from 6.8 percent in 1965 to 18.8 percent in 1996. Also, see note 2.

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

11. World Resources Institute (1998). The multiple years reflect five-year averages, using real or expected values.

12. For 1961, there were 96 observations (=N) and R^2 was 0.34; for 1980, N=120 and R^2 =0.35; and for 1997, N=138 and R^2 =0.49. The slopes for each curve were significant ($p < 0.001$), as were the changes in the intercepts (for cereal yields) from 1961–80, and from 1980–97. Also, see note 2.

13. Bairoch (1982) defines manufacturing industry as industry in general except mining, construction, electricity, gas, and water.

14. This is calculated from GDPs provided by Maddison (1999, 40) for 1820 and 1995, and annual growth rates from 1700–1820 and 1978–95.

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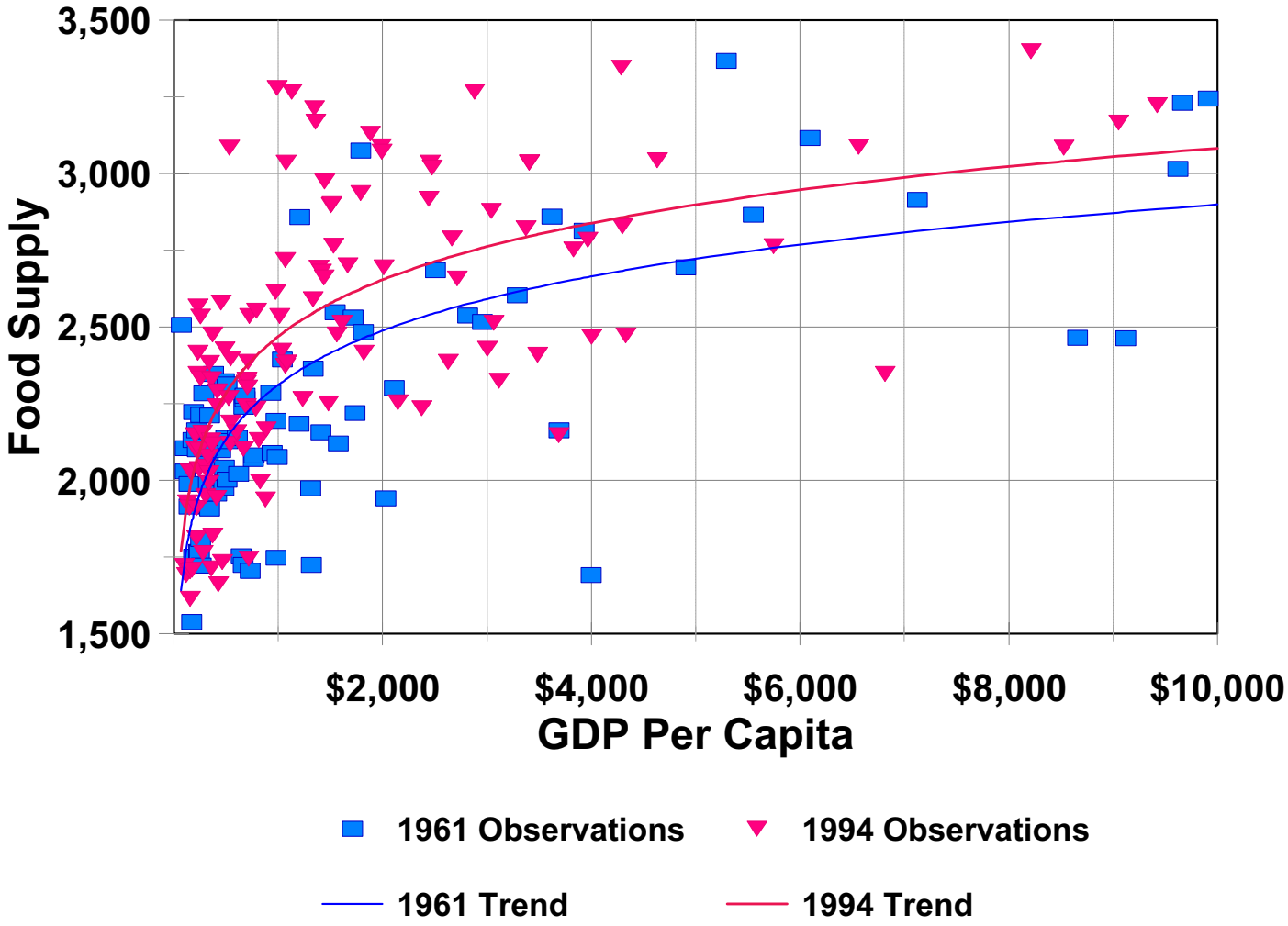
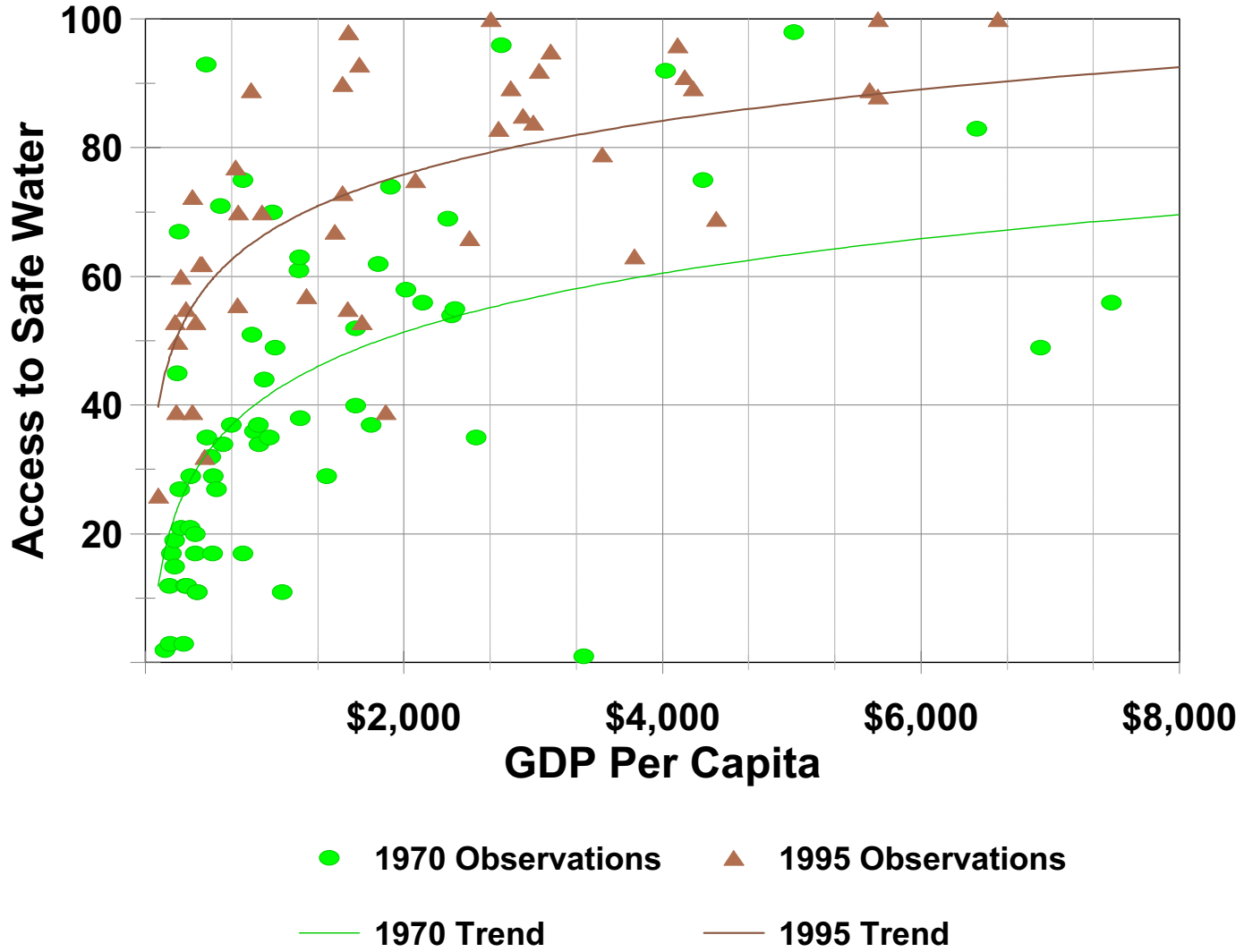
Figure 1
Food Supply and Income, 1961 to 1994



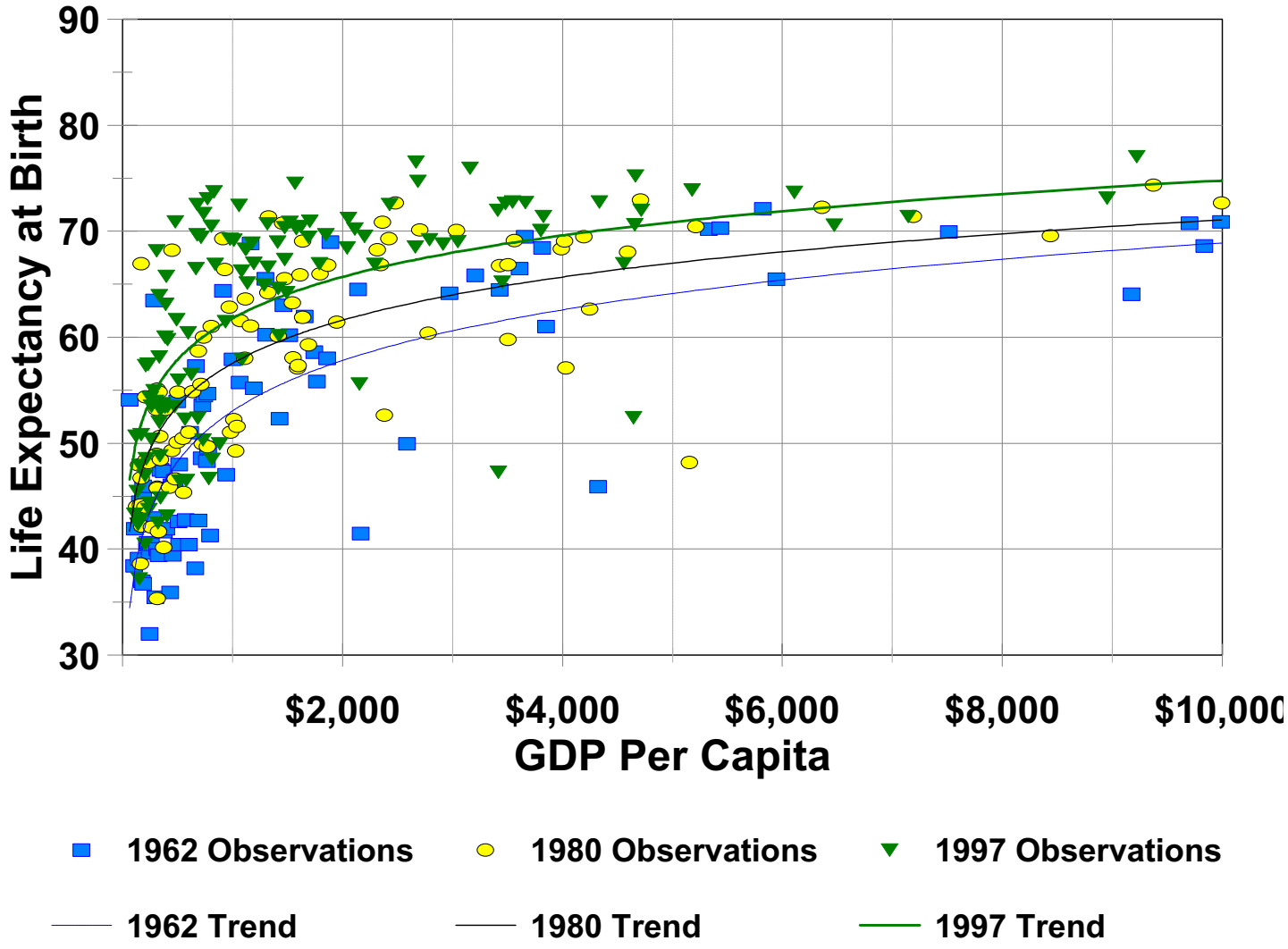
Note: Food supply data in kcalories per day, per capita; income is expressed as GDP per capita in 1995 dollars.
Sources: World Resources Institute (1998).

Figure 2
Access to Safe Water and Income, 1961–1994



Note: Data represent the percent of population with access to safe water; income is expressed as GDP per capita in 1995 dollars.
Sources: World Bank (1999).

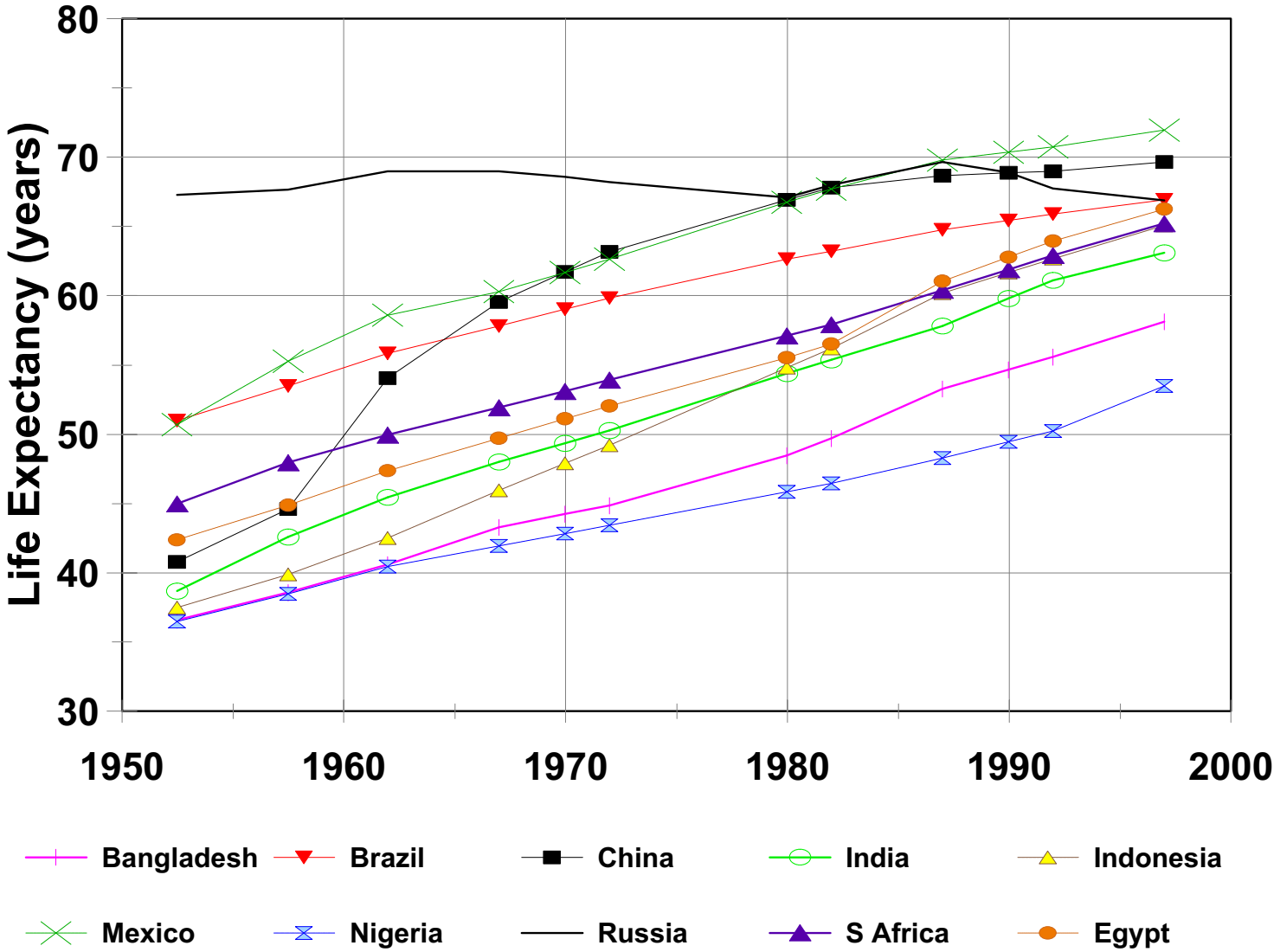
Figure 3
Income and Life Expectancy at Birth, 1962–1997



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

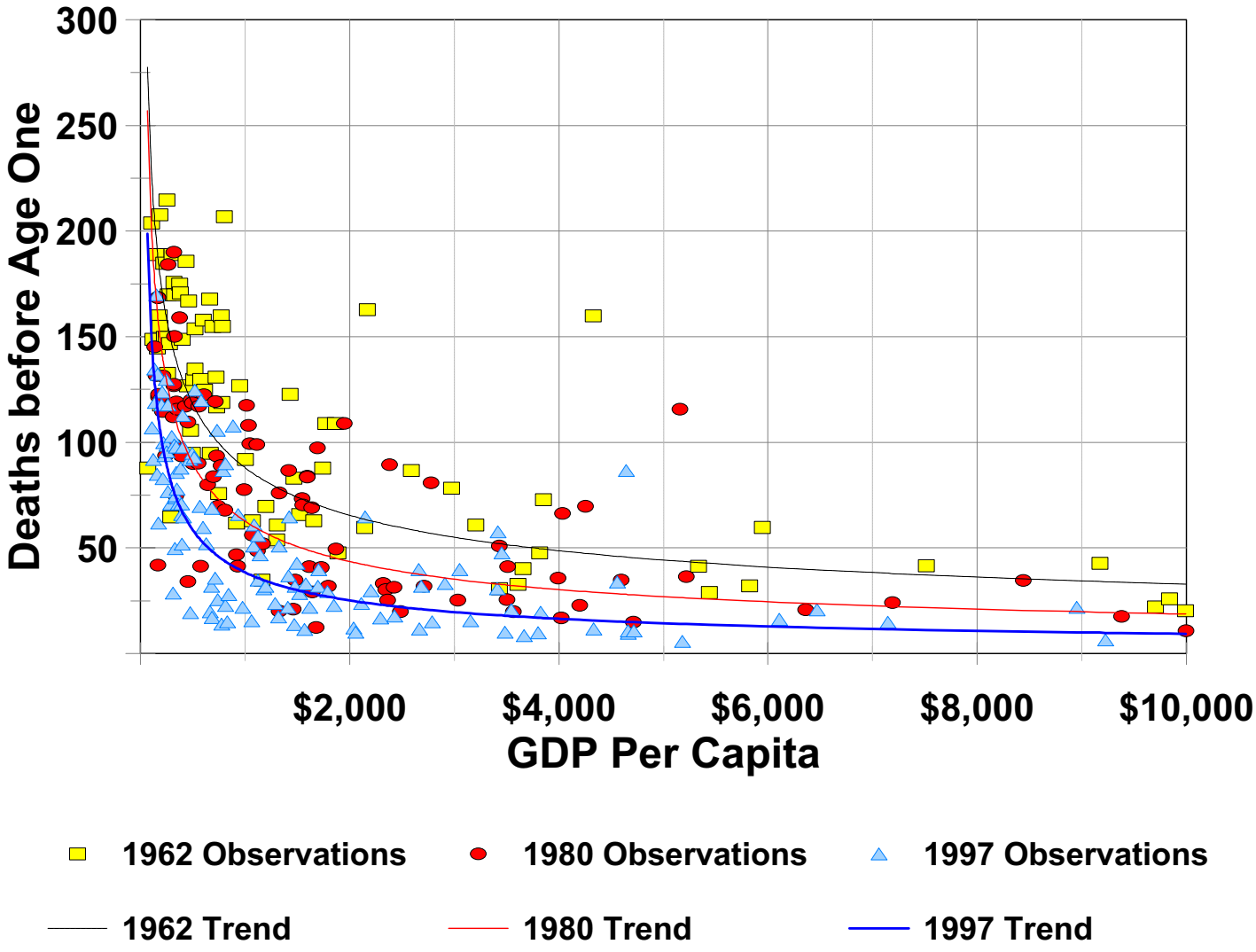
Sources: World Bank (1999).

Figure 4
Life Expectancy at Birth, 1950–55 to 1997



Sources: World Bank (1999); World Resources Institute (1998).

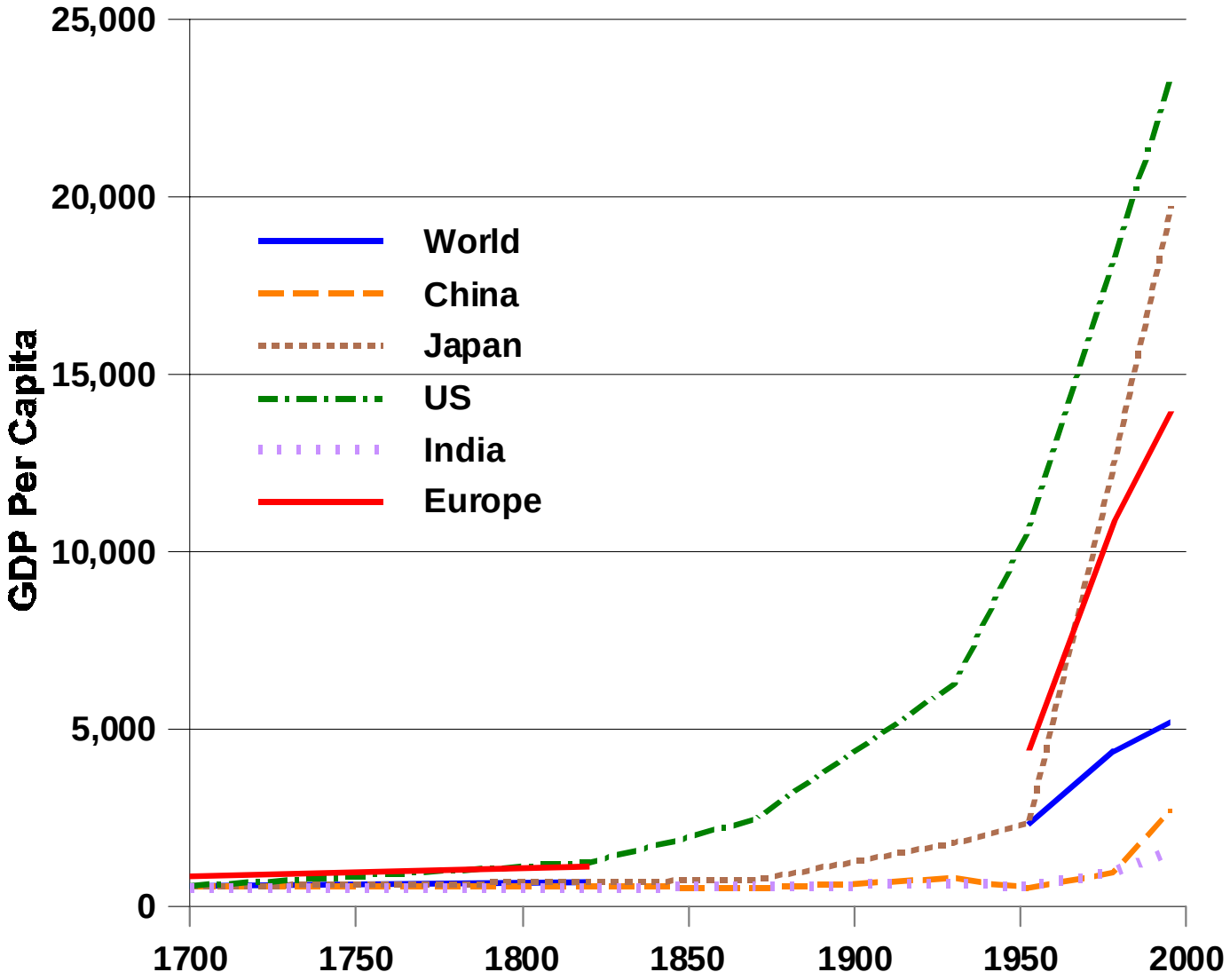
Figure 5
Infant Mortality and Income, 1962–1997



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 dollars.

Source: World Bank (1999).

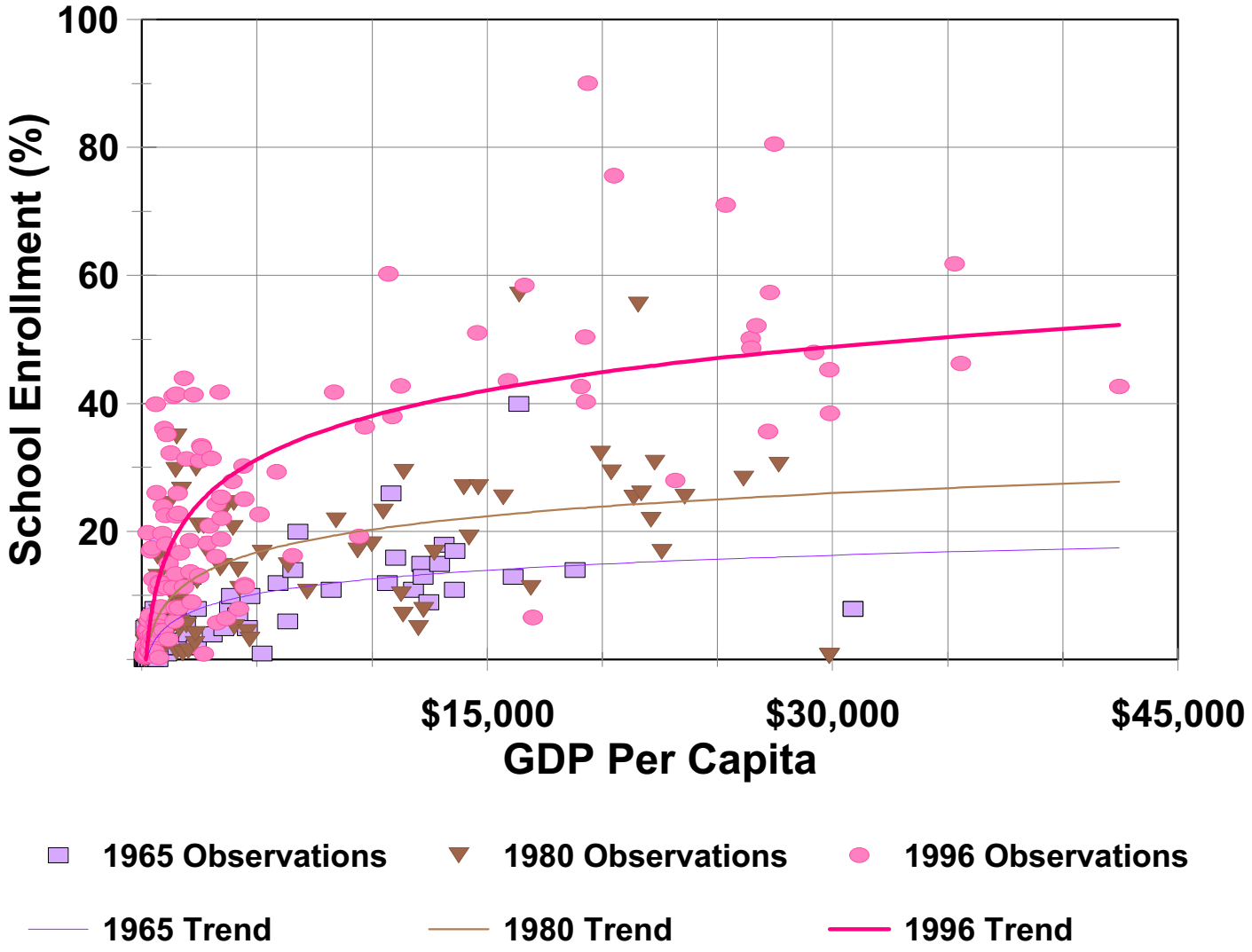
Figure 6
GDP Per Capita, 1700–1995



Note: GDP per capita in 1990 international dollars (see endnote 8).

Sources: Maddison (1998, 1999).

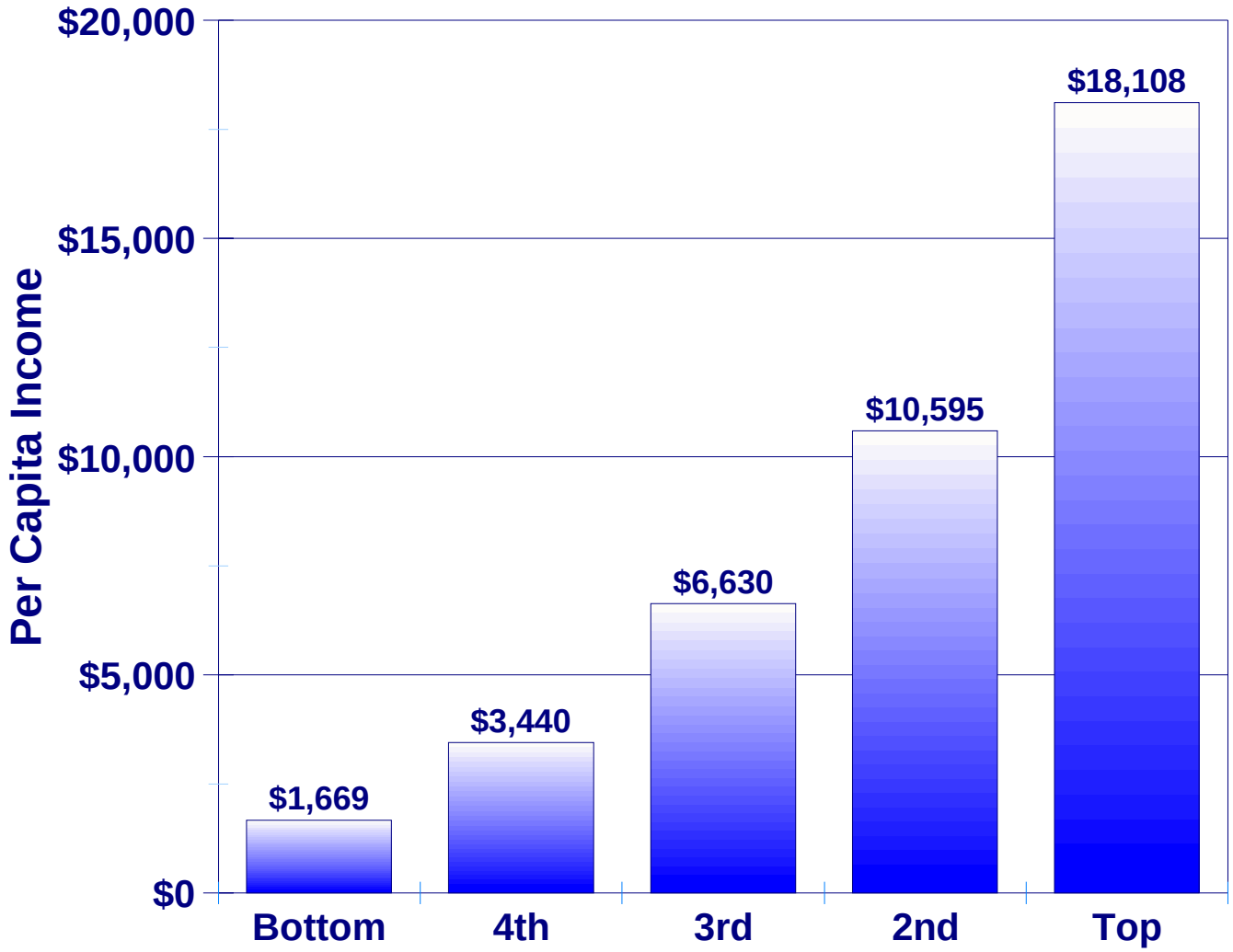
Figure 7
Postsecondary Education and Income, 1965–1996



Note: School enrollment is the percent of relevant population; GDP per capita is in 1995 dollars.

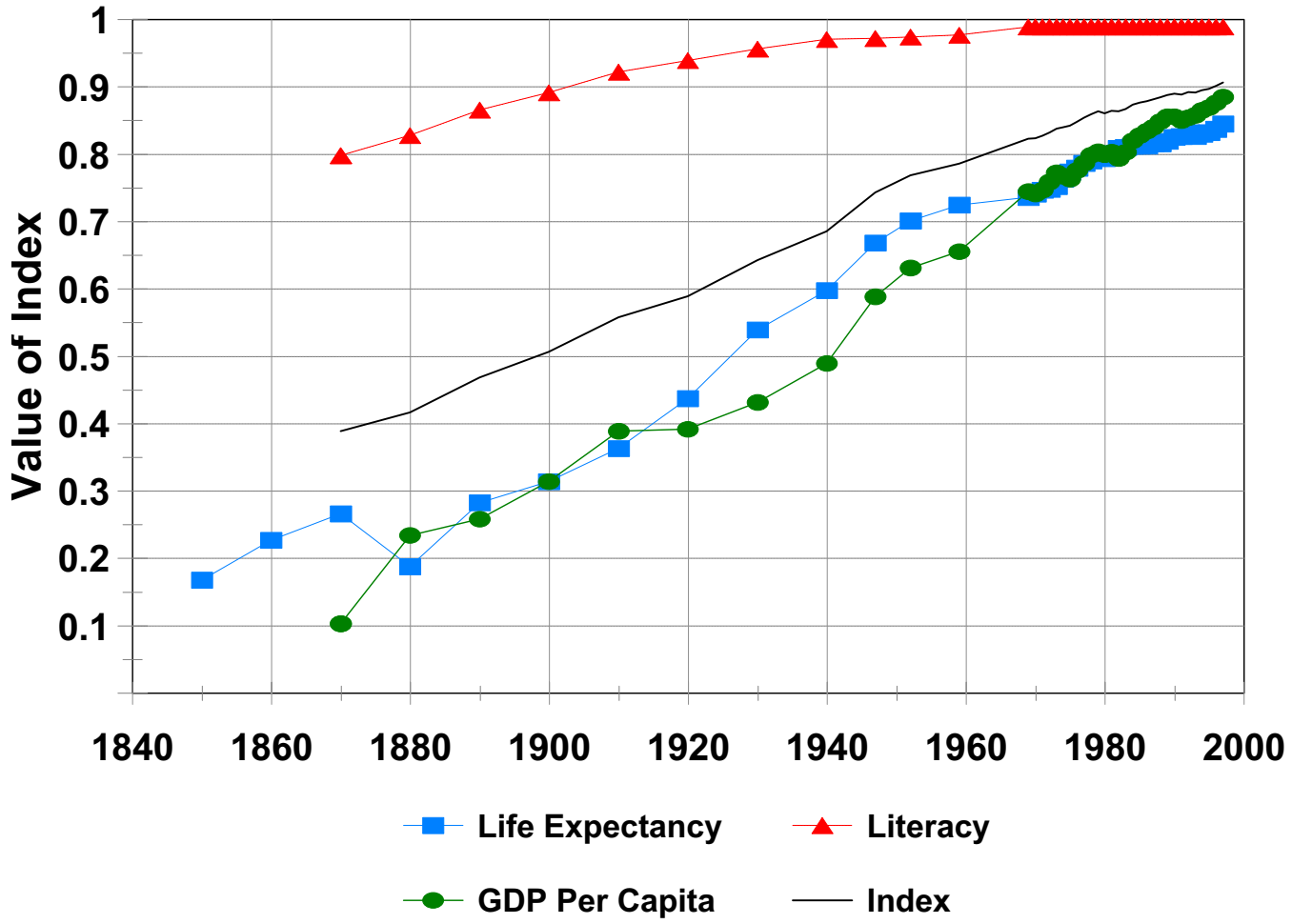
Source: World Bank (1999).

Figure 8
Economic Freedom Rankings by Quintiles
(for 116 countries)



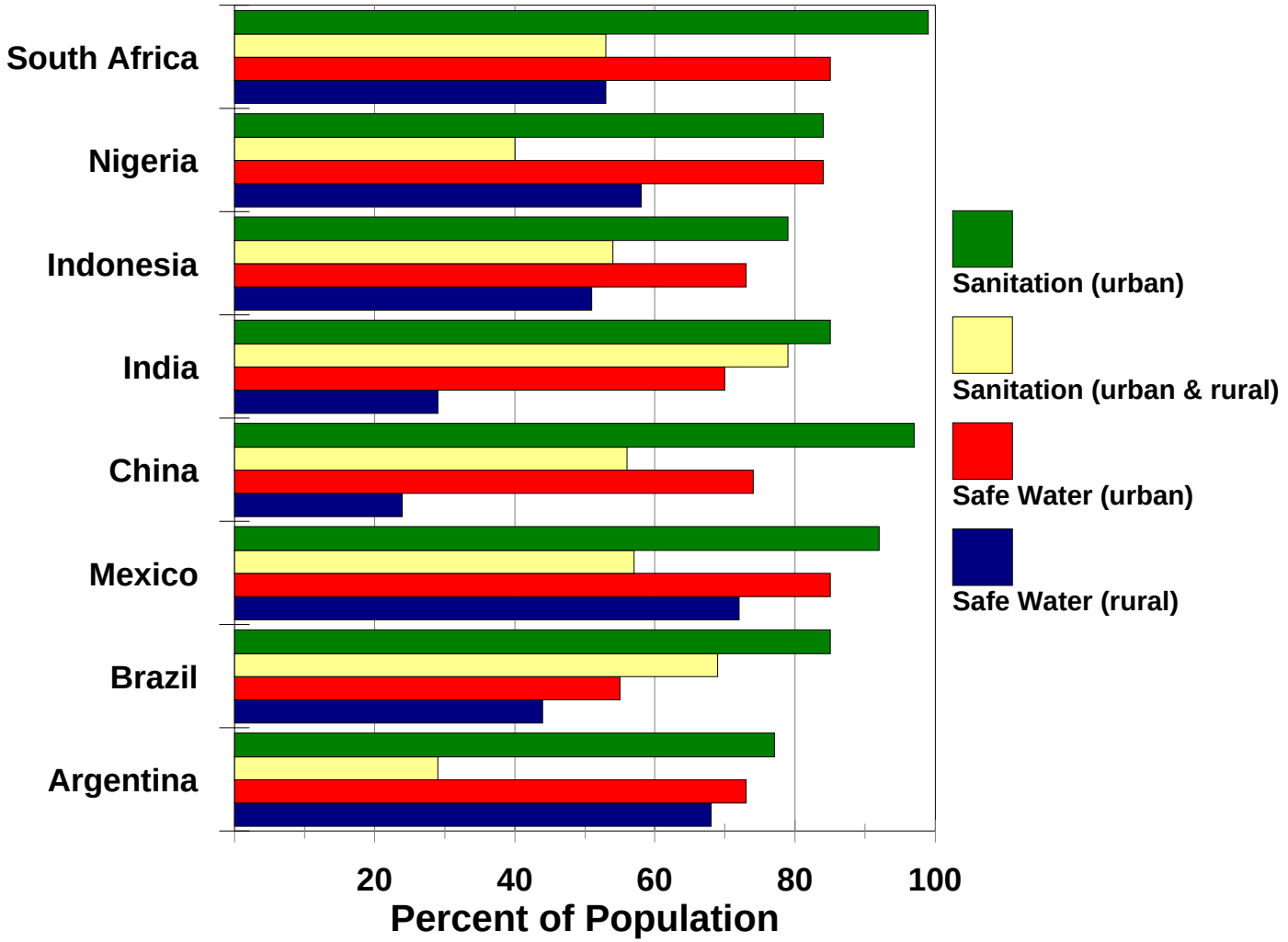
Sources: Gwartney, Lawson, and Samida (2000).

Figure 9
Human Development Index
United States, 1850–1997



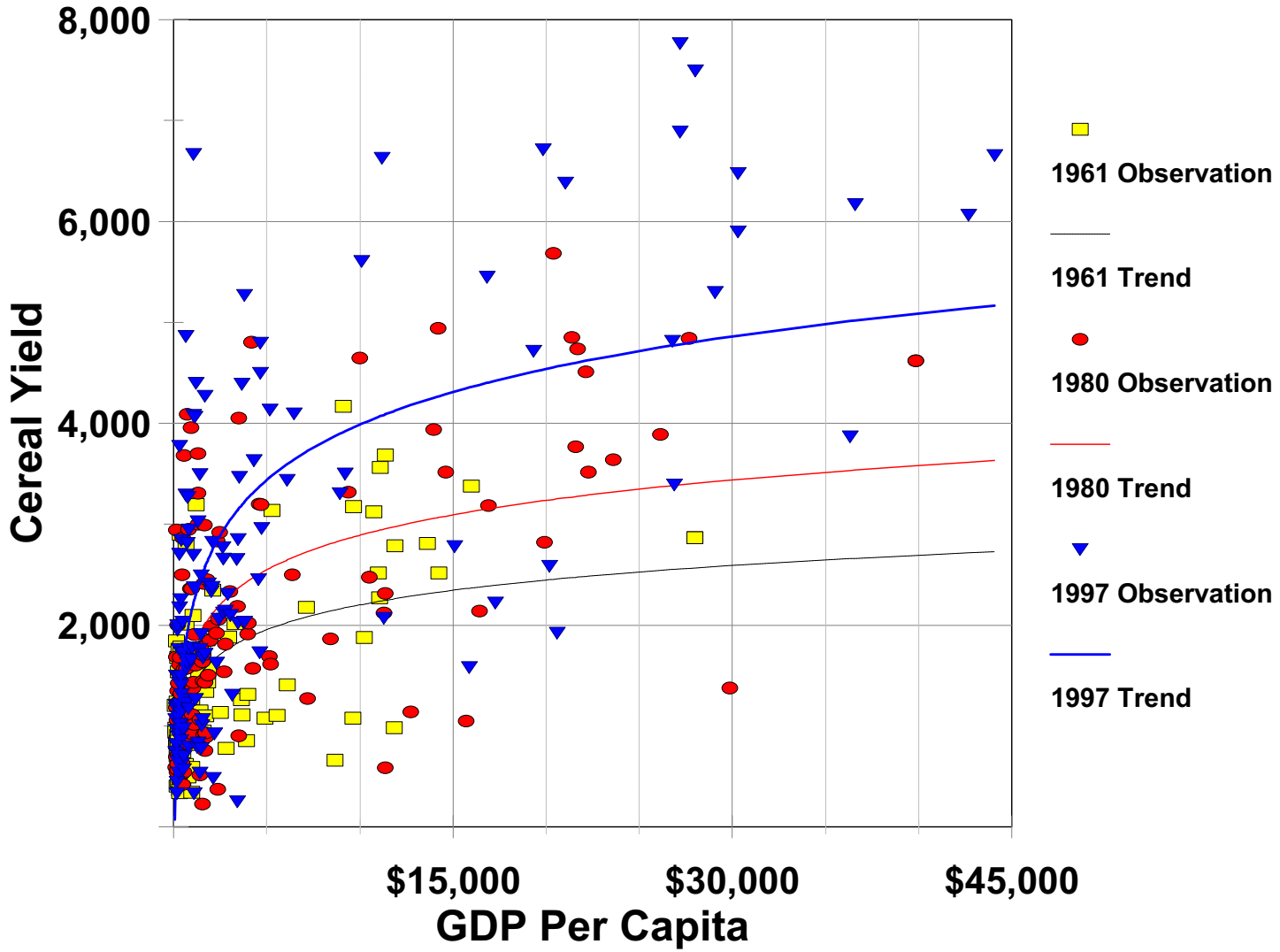
Sources: Life expectancy data: 1850–90, Haines (1994); 1900–1970, Bureau of the Census (1975); 1971–97, various *Statistical Abstracts* including Bureau of the Census (1999). GDP per capita data: 1900–1928, calculated from Bureau of the Census (1975); 1929–1997, Bureau of Economic Analysis (1998), per Goklany (1999c, 68–69). Literacy data: Bureau of the Census (1975); Costa and Steckel (1997).

Figure 10
Access to Sanitation and Safe Water, 1990–1996



Source: World Resources Institute (1998).

Figure 11
Cereal Yield and Income, 1961 to 1997



Note: Cereal yield data in kilograms per hectare; income is expressed as GDP per capita in 1995 dollars.

Source: World Bank (1999).

Table 1
Daily Food Supplies, c. 1790–1998

(kcalories 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 (1950–51)	2,073	1,942	2,143	2,466
China	2,115 (1947–48)	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

Notes: Pre- or early industrial phase data are for the year(s) shown in parenthesis; data for China are based on twenty-two 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).

Table 2
Life Expectancy at Birth, in Years

(Middle Ages to 1998)

Area	Middle Ages	Pre- or Early Industrial Phase	1950–55	1975–80	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 (1901–11)	38.7	52.9	62.9
China		25–35 (1929–31)	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 parenthesis; UK data, 1799–1803, are for England and Wales only.

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

Table 3
Infant Mortality
(Middle Ages to 1998)

Area	Middle Ages	Pre- or Early Industrial Phase	1950–55	1975–80	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

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

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

Table 4
Gross Domestic Product Per Capita
(A.D. 1 to 1995)

Area	A.D. 1	1000	1500	1700	1820	1952	1995
Europe	~$ 425	$ 400	~$ 640	$ 870	$ 1,129	$ 4,374	$ 13,951
USA	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

Notes: In 1990 international dollars (see endnote 8). Data for Europe A.D. 1 and 1500 based on Maddison (1999), using arithmetical average for "Western Europe" and the "Rest of Europe." Data for USA A.D. 1 to 1500 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).

Table 5
Education, Average Number of Years
(c. 1820 to 1992)

Area	1820	1870	1913	1950	1973	1992
France			6.99	9.58	11.69	15.96
USA	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

Sources: Maddison (1998, 1999).