

Population problems: Recent developments and their impact

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The twenty-first century will differ from the twentieth century in population, economics, the environment and culture. In this article, Joel E. Cohen, Professor of Populations and Head of the Laboratory of Populations at Rockefeller University and Columbia University, examines 10 differences between the last century and the next, and the degree to which global population problems will interact with the economy, the environment and culture. Cohen argues that there is almost nothing inevitable about any human trends for the twenty-first century. Each trend is a result of many choices, both individual and collective, that will have to be made by our generation and our children's generation.

Demographic facts and projections

For most of the twentieth century, and for most of the last five centuries, the rate of growth of the human population was increasing. In the twentieth century, the population growth rate per year roughly tripled from 0.6 percent in 1900 to 1.8 percent in 1950. The all-time peak rate of global population growth, more than 2.0 percent, was reached around 1965. Since 1965, the population growth rate has dropped by one-third to perhaps 1.3 percent per year. The annual absolute increase in population grew from perhaps 10 million people in 1900 to 47 million people in 1950 to its all-time peak around 1990: approximately 90 million additional people per year. Since then, the absolute annual increase has fallen to 78 million additional people per year (150 additional people per minute). The population growth rate is dropping so rapidly that some demographers think there is a better-than-even chance that the world's population will never double to 12 billion people from today's 6 billion people.

The following are 10 important probable differences between the twentieth and twenty-first century.

1. Population growth

The past century saw mainly accelerating population growth. The next century, however, is very likely to see population growth slow down, perhaps even stop. If population growth slows, then the twentieth century was and will be the only century in the history of humanity to see a doubling of Earth's population within a single lifetime.

2. Population Size

The next century will have more people in it: world population grew from fewer than 1.7 billion in 1900 to 2.5 billion in 1950 and more than 6 billion by 2000. That is a 3.8-fold increase in one century. The twenty-first century is unlikely to see any decline in the absolute numbers of people for several decades at least, barring disasters. As a result of high fertility in the last few decades of the twentieth century, more young men and women than ever before are now entering the age of childbearing. By 2050, their descendants are likely to increase the world population by perhaps 2 billion to 4 billion people. The minimum expected increase is equal to the entire population of the world in 1927. Unless future population grows much less than anticipated in any official demographic projection, the twenty-first century will have more people in it than the twentieth.

3. Urbanization

The twentieth century was and will be the last century in human history in which most people live in rural areas. The twentieth century saw the fraction of world population living in cities rise from roughly 13 percent in 1900 to roughly 47 percent by the year 2000. That is a 3.6-fold increase. The absolute number of city dwellers increased by nearly 14-fold, from 0.2 billion people to 2.9 billion during the past century.

In Europe, the rush of people from the countryside to cities dates back to the eleventh century. Urbanization has occurred worldwide for at least two centuries. At the beginning of the twentieth century, no cities had 10 million people or more. One city did in 1950—New York. In 2000, there are 20 cities of 10 million people or more, and these megacities are home to more than 10 percent of urban people.

In the twenty-first century, humanity will be predominantly urban. Almost all population growth in the next half-century is projected to be located in cities, while the rural population of the world will remain nearly constant at around 3 billion people.¹

4. Aging of population

The twentieth century was and will be the last century in human history to see younger people outnumber older people: the twenty-first century will be a world of predominantly older people.

In the twentieth century, the fraction of the world's population who were children aged 0–4 years gradually declined to reach 10 percent by the year 2000. Meanwhile, the fraction of the world's population who were aged 60 years or more gradually increased to 10 percent by the year 2000. This convergence in the fractions of young children and older adults resulted from improved survival and reduced fertility. Improved survival raised the world's life expectancy from perhaps 30 years at the beginning of the twentieth century to about 66 years at its end (76 years in more developed regions, 64 years in less developed regions). Reduced fertility

rates added smaller cohorts to the younger age groups.

The twenty-first century is unlikely to see a reversal in the aging of world population. In 1998, the United Nations prepared high, medium, and low projections of future population to the year 2050.² All three projections start from a total fertility rate of 2.9 children per woman (worldwide) in 1990–1995. By 2040–2050, in the high projection the total fertility rate falls to 2.5 children per woman; in the medium projection to 2.03 children per woman; and in the low projection to 1.6 children per woman. According to the medium projection, by 2050 there will be 3.3 people aged 60 years or older for every child aged 0–4 years, up from a ratio of one-to-one now. In the high and low projections, this ratio of people aged 60 years or older to children aged 0–4 years ranges from 2.2 to 5.7. The lower future fertility falls, the more elderly people there will be for each young child. Grandparents will become a rare minority among the elderly.

Comparative trends

Demographically, the twenty-first century will have a global population that is growing more slowly, is larger, is more urban, and is older than the population of the twentieth century. Most (but not all) of these trends are expected for both the regions called “less developed” by the United Nations Population Division (Africa, Latin America, the Caribbean, Melanesia, Micronesia, Polynesia, and Asia except Japan) and the so-called more developed regions (North America, Japan, Europe, Australia and New Zealand). There are striking quantitative differences, however, as can be seen in Table 1.

The population of the more developed regions is projected to be declining slowly by 2050. The population of the less developed regions is projected to be growing more rapidly in 2050 than the population of the more developed regions is growing today. While the population size of the more developed regions is expected to decline slightly over the next half-century, the population size of the less developed regions is expected to increase by 59 percent. In the more developed regions, 5 people in 6 are projected to live in urban areas by 2030. The less developed regions are projected to be more urbanized by 2030 (4 people in 7) than the more developed regions were in 1950, though still substantially less urbanized than the more developed regions are expected to be by then.

The changes in age structure will be large. In the more developed regions, the ratio of adults aged 60 years or older to children aged 0–4 years rose from 1.2 in 1950 to 3.5 in 2000, and is projected to rise to 6.5 by 2050. The fraction of the population aged 60 years or older rose from 1 in 9 in 1950 to roughly 1 in 5 by 2000 and is projected to rise to 1 in 3 by 2050. In the less developed regions, by contrast, children aged 0–4 outnumbered adults aged 60 years or older by a ratio of 2.4 in 1950 and of 1.4 in 2000. By 2050, three times as many adults 60 years or older as children 0–4 years are projected for the less developed regions. The fraction of the population aged 60 years or older in the less developed countries is projected to be higher by 2050 than it is in the more developed regions today.

Table 1. Demographic features of the more developed regions and the less developed regions, 1950–2050, according to the United Nations' Medium projection (1998)

Indicator	More developed regions			Less developed regions		
	1950	2000	2050	1950	2000	2050
Population growth rate (percent per year)	1.2	0.3	-0.3	2.0	1.6	+0.5
Lifetime children per woman (total fertility rate)	2.8	1.6	1.8	6.2	3.0	2.1
Population size (billions)	0.81	1.19	1.16	1.71	4.87	7.75
Percent urban	54.9	76.1	*83.7	17.8	40.5	*57.3
Percent aged 0–4 years	10.0	5.5	5.0	15.1	11.1	6.8
Percent aged 60+ years	11.7	19.5	32.5	6.4	7.7	20.6
Ratio 60+ years/0–4 years	1.2	3.5	6.5	0.4	0.7	3.0
Median age (years)	28.6	37.5	45.6	21.3	24.4	36.7
Net migration (years)	NA	+2.0	+1.3	NA	-2.0	-1.3
Population density (per square kilometer)	15	22	22	21	59	94

* Projected for year 2030, not for 2050.

NA, not available.

Sources: All lines except "Percent urban" are from United Nations, *1999 World Population Prospects: The 1998 Revision, Vol. 1: Comprehensive Tables*, (UN: New York, 1999), pp. 10–13; "Percent urban" is from United Nations, *1997 World Urbanization Prospects: the 1996 Revision. Estimates and Projections of Urban and Rural Populations and of Urban Agglomerations*, (UN: New York, 1997), pp. 90–91.

Over the next half-century, the population of the less developed regions is projected to age to a greater extent than the population of the more developed regions. Between 2000 and 2050, the ratio of age groups 60+/0–4 years will rise by a factor of 1.83 in the more developed regions, and by a factor of 4.4 in the less developed regions. The median age is projected to increase in the coming half-century by 8.1 years in the more developed regions and by 12.3 years in the less developed regions. By both of these measures, the population of the less developed regions is projected to age more than the population of the more developed regions. Nevertheless, by 2050 the more developed regions will still have a higher fraction of elderly people and a higher median age than the less developed regions.

The aging of the population has an influence on family structure (the rising rate of divorce, extramarital childbearing and the decrease in the average number of children born) as well as posing new challenges in the care and support of the elderly (as a result of reduced household size). These challenges are important now in the more developed regions and can be expected to become more important soon

in the less developed regions. The average number of persons per household in Sweden, Denmark, South Korea, Canada, Japan, Hong Kong, and the United States fell sharply in the twentieth century while the percentage of single-person households in the US, Japan, France, Sweden and Finland rose.³ In the age-group 55–64 years, the number of divorced males surpassed the number of widowed males in the US between 1970 and 1980, and is projected to be 3.7 times as large by the year 2000. The number of divorced women aged 55–64 in the US is expected to surpass the number of widowed women by 2000.⁴ Being divorced in old age is associated with a higher poverty rate, greater dissatisfaction with one's financial situation, excess mortality, reduced contacts with the younger generation and reduced satisfaction with life.⁵ In developing countries, the high proportion of women among the elderly and their low earnings could entail substantial poverty among the elderly unless other support is forthcoming. The confluence of demographic and behavioral changes poses serious challenges to well being in the coming century.

Projections of migration are even more uncertain than projections of birth rates and death rates. Future migratory flows depend in part on national policies governing immigration and emigration, on future economic differentials between countries and regions, on future environmental changes (for example, in sea level and climate), and on future political upheavals and cultural changes. Migration from the less to the more developed regions is projected to decline from its present level of about 2 million people per year to about 1.3 million per year by 2025, and then remain constant at that level.⁶ This scenario is probably not more plausible than a variety of alternatives. The suggestion that substantial flows of people from the less to the more developed regions will continue seems plausible.

Such migratory flows do not counterbalance the higher population growth rates of the less developed regions or compensate for the anticipated deficit of births relative to deaths in the more developed regions. The population density of the less developed regions in 1950 (21 people per square kilometer) was about equal to that of the more developed regions in 2000 (22 people per square kilometer). By 2050, the projected population density of 94 people per square kilometer in the less developed regions would be more than four times the projected population density of 22 people per square kilometer in the more developed regions. It is not obvious that the projected 4-fold difference in population densities is compatible with the projected low level of migration from less to more developed regions.

Demographic changes will interact with changes in the technologies of the next century: information technology and biotechnology.

5. Information Technology

At the beginning of the twentieth century, automated information processing was largely limited to the use of punched cards to control looms. By the middle of the twentieth century, a few general-purpose digital computers had been developed to wage war. By the end of the twentieth century, personal computers were abundant in homes and landfills. Microprocessors are quietly tending to domestic, commercial,

industrial and military appliances. To understand what to expect in the twenty-first century, we should consider the history of plastics in the twentieth. Until Baekeland patented Bakelite in 1909, plastic was expensive and rare. In 1997, the world used 130 billion kilograms of plastics, nearly 22 kilograms for every man, woman and child in the world. At the end of the twentieth century, plastic bags are a ubiquitous, disposable and often annoying commodity. Before the end of the next century, microprocessors are likely to be as ubiquitous and disposable as plastic bags today. They will improve security, transport, sanitation and energy efficiency in cities. They will continuously monitor the health and safety of people and the status of local and global environments. The next century will be saturated by information technology, with all its potential for control and liberation.

6. Biotechnology

The twenty-first century will also be a century of biotechnology. In 1900, scientists rediscovered the 1865 experiments of Gregor Mendel and established the chromosomal basis of genetics. By 1944, DNA was known to be the genetic material. In 1995, the first completed genome of a non-viral self-replicating organism, *Haemophilus influenzae*, was published. About 20 to 30 genomes were completed by 1999.

The twenty-first century will soon see a nearly complete description of the three billion nucleotides of human genomes. The description will include many of the variations that make each human genetically unique except for identical siblings. The first complete description of the genome of a plant is also expected soon. Biotechnology will become cheap and universal. It will permeate medicine, public health, manufacturing, computing, agriculture, food processing, forestry, fisheries, mining, theology, ethics, law and military strategy. The book of life will lie open before us. It will be up to us to understand it, and to use it wisely.

7. Economic inequality

While the twentieth century experienced increasing economic inequality, the twenty-first century could experience decreasing economic inequality. During the twentieth century, the average gross domestic product per person more than quadrupled, from less than \$1300 to \$5200 per person per year. The aggregate size of the world economy grew 16-fold. The improvement in average incomes was shared very unequally among the world's peoples. Between 1870 and 1985, the ratio of average incomes per person in the richest countries to incomes in the poorest countries increased 6-fold. When the 1997 gross national product per person was adjusted for purchasing power parity, the poorest 2 billion people on the planet had incomes of \$1400 per year, less than one-sixteenth of the average incomes of the richest billion. By and large, the economies that were least integrated into the world economy fell furthest behind. Despite unprecedented economic growth for a minority, most of the world's people in the twentieth century have lived in poverty.

In the twenty-first century, if the globalization of the economy continues; if the rich countries see their self-interest in making the poor countries richer; if the spread of effective democratic governments continues; and if the political and religious cultures of rich and poor countries permit an integrated global economy to make constructive use of information technology and biotechnology, the less developed countries could become richer in an absolute sense, and could perhaps even partially catch up with the rich countries. The next century has the potential to end the moral disgrace of billions of people living in poverty.

So far I have proposed four demographic differences between the twentieth century and the twenty-first: slower population growth, more people, more urban people and older people. I have proposed three economic differences: more information technology; more biotechnology; and greater and more equitable wealth. These demographic and economic changes will interact with major cultural changes in the status of women and education.

8. Status of women

Women will be more nearly equal in the twenty-first century. Women won the right to vote in the US only in 1920. In 1946, the United Nations Commission on the Status of Women was formed to monitor and enhance the situation of women. The Commission initiated a series of conventions, which culminated by 1979 in a Convention on the Elimination of All Forms of Discrimination Against Women. These international conventions reflect aspirations more than achievements. By 1991, fewer than 5 percent of the world's heads of state, major corporations and international organizations were women.

More was changing for the majority of average women than for the elites. Women's participation in the economically active population (people engaged in the cash economy, working for pay or looking for paying work) nearly doubled in less than a generation, from 37 women per 100 men in 1970 to 62 women per 100 men in 1990. The increase in the economic activity of women was dramatic in the developing regions of Asia, the Pacific, Latin America, the Caribbean, and Africa. Fertility fell sharply in these regions during the same years. In the twenty-first century, if education is extended to all children, the status of women will continue to improve. The spread of information-based economies will enhance the employability of women as sheer muscular power and aggressiveness become less important than in the past.

Information technology will make it possible to ensure that more people are more educated in the next century. In the twentieth century, primary education spread across the world. A standard indicator of educational activity is the primary gross enrollment ratio (PGER). A gross enrollment ratio is calculated by dividing the number of children enrolled in school by the school-age population. Because children who are overage or underage may also enroll in school, the PGER over-represents the proportions of children of school age who are actually enrolled in school. The PGER may exceed 100 percent.

In northwestern Europe, North America and the Anglo Pacific, the PGER rose in the twentieth century from 72 percent to 103 percent. Latin America, the Caribbean, East Asia and Southeast Asia saw much larger increases, from as low as 4 percent in Southeast Asia to more than 100 percent in all these regions. Sub-Saharan Africa lagged behind other regions: its PGER progressed from 16 percent to 85 percent. Late in the twentieth century, about three-fourths of children eligible to attend primary schools in developing countries did so. The 130 million children who were out of school were disproportionately girls, and were mainly illiterate.

9. Quality of education

By the end of the twenty-first century all children will complete primary and secondary schooling of vastly better quality than now. Attaining that goal will require research to improve the quality of education. Today randomized clinical trials are universal and obligatory in the evaluation of proposed medical interventions. In the next century, properly designed experiments to determine what works (such as smaller classes or longer school days or better-trained teachers or different curricula) could become equally universal and obligatory in education. The improvement of education is too important to leave to preconceived notions. The spread of universal basic and secondary education could result from, and contribute to, slower population growth, new information technology, improved nutrition from biotechnology, diminished economic inequality between and within the regions, and the improved status of women.

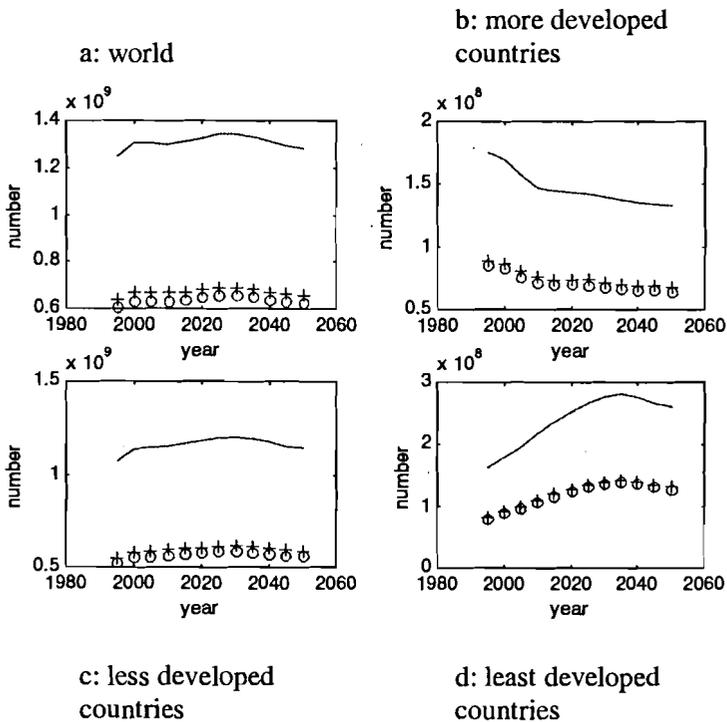
Gradually, the right to a good education for children from the age of 6 to 16 could become the norm. Translating this norm into reality would require educating many children. As of 1995, about 1.25 billion children in the world were aged 6 to 16 years old, inclusive.⁷ Of this “school-age population,” about 175 million lived in the more developed countries. About 1.07 billion lived in the less developed regions. Of those school-age children in the less developed countries, about 164 million lived in the 48 least developed countries, as defined in 1998 by the UN General Assembly (33 countries in Africa, 9 in Asia, 1 in Latin America and the Caribbean, and 5 in Oceania).

The size of the school-age population is not projected to change greatly in the next half-century (Figure 1). It may rise as high as 1.34 billion in the 2030s and then decline slightly. This relatively stable total disguises major shifts between regions. The school-age population in the more developed countries is expected to drop sharply until 2010, and more gradually after 2010 (Figure 1, graph b). Between 1995 and 2050, it is expected to drop by 24 percent. The school-age population in the least developed countries is expected to increase by 71 percent between 1995 and 2030 (Figure 1, graph d). For the less developed countries as a whole (including the least developed), the changes in the school-age population resemble the gradual changes in the school-age population for the whole world (Figure 1, graph c)

These projections of school-age population may have strategic military significance as well as educational importance. The ratio of the number of school-

aged boys in the least developed countries to the number of school-aged boys in the more developed countries is forecast to rise from 1.05 in 2000 to 2.02 in 2040. These ratios are a very good approximation to the ratios of military-aged young men (aged 16 to 26) 10 years later. If the medium projection of the UN is realized,⁸ the more developed regions and the least developed regions will move from parity in the soldier age group in 2010 to a two-to-one numerical predominance of the least developed regions by 2050.

Figure 1. Medium projection of numbers of school-aged children (6–16 years old) worldwide (a), in more developed countries (b), in less developed countries (c), and in least developed countries (d). Solid curve, both sexes; +, males; o, females. Original figure based on United Nations Population Division (1998).



10. Environmental impact of humans

In the twenty-first century, the human enterprise will no longer be small compared to the size of the Earth. Although individual human well-being is appropriately measured per person, human impact on global environmental systems is appropriately measured on an aggregate basis because the atmosphere, oceans and continents are all fixed in size.

In the twentieth century, human interventions in biotic and geological processes grew enormously, as can be seen by the global cycles of carbon, water and nitrogen. Human-induced emissions of carbon to the atmosphere grew from 0.5 billion in 1900 to 7.3 billion tons of carbon per year in 2000. The carbon dioxide concentration in the atmosphere rose in this century by about 20 percent. Atmospheric carbon dioxide concentrations are now higher than they have been in the last 150,000 years, a period that includes the emergence of “modern” humans. This level is well above any levels experienced since the end of the last ice age and the multiple independent inventions of agriculture.

World water withdrawals grew 8-fold from 500 cubic kilometers per year around 1900 to roughly 4000 cubic kilometers per year currently. Humans now withdraw annually roughly a quarter to half of all available renewable freshwater.

Human emissions of nitrogen in nitrogen oxides (NO_x) from the combustion of fossil fuels grew from 1.25 million to 25 million tons per year between 1900 and 2000. The mass fraction of nitrates in ice grew from 45 parts per billion at the beginning of the century to 120 parts per billion at the end. Current human activities emit 40 percent of the nitrous oxide (N_2O), 70 percent of the ammonia (NH_3) and at least 80 percent of the nitric oxide (NO) emitted to the atmosphere from all sources.

It may be that the atmospheric changes in the twentieth century, many of them associated with human activity, are affecting ocean circulation.⁹ If that is so, the changes in ocean circulation could have pronounced climatic effects that could last for centuries or millennia.

Humans are changing the biological world as well as the physical and chemical planet. In the course of their demographic and economic expansion, humans have altered the habitats and populations of many non-human species, raising widespread concerns about extinctions of species. It has been estimated that 98 percent of the animal extinctions in the past 400 years result from human economic activities, principally habitat alteration, hunting and the introduction of exotic species.

Human interventions in global physical, chemical and biological processes have grown faster than human understanding of the likely consequences of these interventions. The future of many planetary systems depends, at least in part, on what we humans decide to do or not to do, and on how well we understand the consequences of our decisions.

Conclusion

In human terms, almost nothing is inevitable about the twenty-first century. People may choose to have more or fewer children than anticipated, to pursue or to abandon biotechnology, to educate all children or not. A healthy aging population offers unprecedented opportunity for longer use of acquired skills and experience, but threatens to bring unprecedented numbers of abandoned elderly unless social institutions anticipate the consequences of smaller and differently constructed families. Urbanization offers unprecedented opportunities for educational and

cultural enrichment. Urbanization also threatens unprecedented hazards from infectious diseases unless clean water is supplied and wastes are removed. Global influence on the environment could convert the Earth into a more beautiful global garden, with wild places and cultivated places, but also threatens abrupt transitions in oceanic circulation and climate over intervals as short as a few decades.

Which way the twenty-first century will go is not determined by the situation today. The path will be substantially influenced by human choices that have yet to be made. I believe that we should devote more attention to thinking about how we want to live in the twenty-first century.

Choices for the future

The future will be strongly influenced by human choices. Here are four choices about population, economics, environment and culture that can make the next century a better century.

First, we can help make every human conception a wanted conception, every birth a wanted birth. We can help the 56 percent of the world's people who live in countries with continuing high fertility to achieve family sizes at or below replacement levels of fertility. We can achieve this by education and by providing health services, including reproductive health and family planning services, to every man, woman and adolescent. Research shows that healthy, educated parents generally choose to have fewer, healthier, better-educated children. If the freedom of individuals and couples to control their own fertility entails a declining and aging population, societies should increase their care for, and competition to attract, those who are born.

Second, we can organize our economic production efficiently. Until now, economic production has been a linear process: we extract some resource from nature, industry transforms it, consumers use it, and we throw away what is left. At the beginning of the twenty-first century, the global economy is so big that this mental picture is obsolete. There is no longer any "away" to throw things away to. Industrial ecology presents a new organization of economic production. The by-products of one economic activity become the inputs and resources of another. Instead of linear, independent production processes, the economy becomes a network of industries and consumptive activities feeding other productive activities, just as a food web in ecology links all species in a network of feeding and recycling.

Third, we can create a more conscious, forward-looking relationship with our physical, chemical and biological environments. An Earth wired with sensors will make it possible to monitor the impact and consequences of our own activities. Existing worldwide networks of weather stations, tide gauges and seismic sensors are early steps toward instrumenting the Earth. To understand the Earth's history and future and our place in it, we need to install more instruments in the atmosphere, continents and oceans at all depths and elevations. In biology, we do not understand the functions provided by most species and ecosystems on Earth, and we cannot replace the genetic information produced by the last 4 billion years of evolution.

We can stop throwing out living parts of the Earth before we read the instruction manual.

Fourth, no one can anticipate the challenges humans will face one-quarter, one-half or one century from now, but we can ensure that future generations are healthy, educated and supplied with the social and material means to respond to whatever challenges come their way. Universal education for 11 or 12 years would improve individual lives and provide society with a reserve of competence to face surprising challenges. It would have favorable effects on fertility, economic productivity and enterprise, environmental understanding and preservation, and human capacities to innovate and to adapt. There are 1.25 billion children in the world today between 6 and 16 years of age. Using information technology, we could probably educate all of them better than we do now at a global average cost of \$500 per child per year. That would cost less than 2 percent of the gross world product of about \$32 trillion. As much as any other single line of action, universal basic and secondary education would enhance human chances of a sustainable future. How can we afford not to educate all the children?

Notes

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