# ISSUE 19

## Are Major Changes Needed to Avert a Global Environmental Crisis?

**YES: Chris Bright**, from "Anticipating Environmental 'Surprise'," in Lester R. Brown et al., *State of the World 2000: A Worldwatch Institute Report on Progress Toward a Sustainable Society* (W. W. Norton, 2000)

**NO: Julian L. Simon**, from "More People, Greater Wealth, More Resources, Healthier Environment," *Economic Affairs* (April 1994)

### ISSUE SUMMARY

**YES:** Chris Bright argues that human impacts on the environment are so extensive that we face an era of catastrophic surprises unless we learn to think of the world as a complex system and behave accordingly.

**NO:** The late professor of economics and business administration Julian L. Simon predicts that over the long term, the brainpower of more people coupled with the market forces of a free economy will lead to improved standards of living and a healthier environment.

In 1972 the results of a study by a Massachusetts Institute of Technology computer modeling team triggered an avalanche of controversy about the future course of worldwide economic growth. The results appeared in a book entitled *The Limits to Growth* (Universe Books, 1972). The book's authors—Donella Meadows, Dennis Meadows, Jorgen Randers, and William Behrens—predicted that exponential growth in population and capital, accompanied by increasing pollution, would culminate in sudden resource depletion and economic collapse before the middle of the next century. The sponsors of the study, a group of rich European and American industrialists called the Club of Rome, popularized its conclusions by distributing 12,000 copies of the book to prominent government, business, and labor leaders. In 1992 the Meadows team published *Beyond the Limits: Confronting Global Collapse, Envisioning a Sustainable Future* (Chelsea Green), a sequel to the earlier report that was based on much-improved computer models. This book presents an even more pessimistic picture of the future.



Critiques of the study emerged from all sectors of the political spectrum. Conservatives rejected the implication that international controls on industrial development were necessary to prevent disaster. Liberals asserted that no-growth policies would hurt the poor more than the affluent. Radicals contended that the results were only applicable to the type of profit-motivated growth that occurs under capitalism. Among the universal criticisms of the study were the simplicity of the computer models used and the questionable practice of making long-term extrapolations based on present trends.

Although the debate about the specific catastrophic predictions of Meadows et al. has died down, the questions raised during that controversy continue to receive attention. In 1980 a three-volume publication entitled *The Global 2000 Report to the President* was released by the U.S. government. This report, which has sold over 500,000 copies, is the result of a study of trends in population growth, natural resource development, and environmental quality through the end of the twentieth century. The projections of this study include increased environmental degradation, continued abuse of natural resources, and a widening of the gap between the rich and the poor. As we enter the new millennium, most environmental analysts would agree that these predictions were accurate.

The *Global 2000 Report* has contributed to the widely held view that present patterns and rates of worldwide industrial growth are likely to cause intolerable environmental stress. This issue, the potential for conflict between the need for development and the need for environmental protection, was the central focus of the 1992 UN Earth Summit in Rio de Janeiro, which, in turn, was organized in response to a recommendation of the World Commission on Environment and Development, established by the UN in 1983 to produce a "global agenda for change." The concept of sustainable development, which requires a fundamental change in the technologies used by the world's economies in order to meet their energy, transportation, agricultural, and industrial production needs, has received increasing attention in the aftermath of the Rio meeting. Recently, several prominent ecological economists have proposed that continued economic growth and sustainable development are incompatible in a world with finite resources. They suggest that true sustainability requires development without net growth. Niles Eldredge, in *Life in the Balance: Humanity and the Biodiversity Crisis* (Princeton University Press, 1998), warns that without dramatic changes in industrial and agricultural activities, population growth, and economics, environmental problems will threaten the future of humanity.

In the first selection, Chris Bright states that simple straight-line extrapolation of past trends is not to be trusted, for the world is a complexly interwoven structure, human activities can have unforeseen and severe effects, and such effects are already upon us. Change in human activity and attitude is essential. In the second selection, Julian L. Simon asserts that there is no evidence that environmental degradation, health problems, or world hunger are increasing. He predicts that the world can look forward to an improved standard of living and a cleaner environment unless governments restrict the free-market trends.

**Chris Bright** → **YES**

# Anticipating Environmental "Surprise"

If there is any comfort to be found in the prospect of environmental decline, it lies in the idea that the process is gradual and predictable. All sorts of soothing cliches follow from this notion: Even if we have not turned the trends around, our children will rise to the challenge. There's time. We're constantly learning; you can see plenty of progress already.

But this way of thinking is sleepwalking. To understand why, you have to look at decline close up. Here, for instance, is how it has happened in one small country, with big implications. Honduras, in the early 1970s, was caught up in a drive to build agricultural exports. Landowners in the south increased their production of cattle, sugarcane, and cotton. This more intensive farming reduced the soil's water absorbency, so more and more rain ran off the fields and less remained to evaporate back into the air. The drier air reduced cloud cover and rainfall. The region grew warmer—a lot warmer. The local weather station recorded an increase in the median annual temperature of 7.5 degrees Celsius between 1972 and 1990, by which time it had exceeded 30 degrees.

The hotter, drier landscape was poor habitat for the kind of mosquitoes that carry malaria, so the mosquitoes largely died off and malaria infection declined. But of course the land was also becoming less productive, so people began to leave. Many found work on big plantations that were being carved out of the rainforests to the north. The plantations were growing export crops too, primarily bananas, melons, and pineapples. But it is difficult to mass-produce big, succulent fruits in a rainforest—even a badly fragmented rainforest—because there are so many insects and fungi around to eat them. So the plantations came to rely heavily on pesticides. From 1989 to 1991, Honduran pesticide imports increased more than fivefold, to about 8,000 tons.

This steaming, ragged forest was perfect habitat for malaria mosquitoes. Around the plantations, the insecticide drizzle suppressed them for a time, but they eventually acquired resistance to a whole spectrum of chemicals, and that basically released them from human control. When their populations bounced back, they encountered a landscape stocked with their favorite prey: people. And since these people were from an area where malaria infection had become rare, their immunity to the disease was low. Malaria rapidly reasserted itself: from 1987 to 1993, the number of cases in Honduras jumped from 20,000 to 90,000.

From Chris Bright, "Anticipating Environmental 'Surprise'," in Lester R. Brown et al., *State of the World 2000: A Worldwatch Institute Report on Progress Toward a Sustainable Society* (W. W. Norton, 2000).  Notes omitted.





The situation was brought to light in 1993 by a group of researchers concerned about the public health implications of environmental decline. But their primary interest was not in what had already happened—it was in what might happen next. Some very nasty surprises might be tangled up somewhere in this web of pressures. They argued, for example, that deforestation and changing patterns of disease had made the country "especially vulnerable to climatic change and climate instability."

They were right. In October 1998, Hurricane Mitch slammed into the Gulf coast of Central America and stalled there for four days. Nightmarish mudslides obliterated entire villages; half the population of Honduras was displaced and the country lost 95 percent of its agricultural production. Mitch was the fourth strongest hurricane to enter the Caribbean this century, but much of the damage was caused by deforestation: had forests been gripping the soil on those hills, fewer villages would have been buried in mudslides. And in the chaos and filth of Mitch's wake there followed tens of thousands of additional cases of malaria, cholera, and dengue fever.

It is hard to shake the feeling that "normal change"—even change for the worse—should not happen this way. In the first place, too many trends in this scenario are spiking. Instead of gradual change, the picture is full of discontinuities—very rapid shifts that are much harder to anticipate. There is a rapid warming in the south, then an abrupt expansion in deforestation in the north, as plantations are developed. Then malaria infections jump. Then those mudslides, in addition to killing thousands of people, cause a huge increase in the rate of topsoil loss.

There also seem to be too many overlapping pressures—too many synergisms. The mudslides were not the work of Mitch alone; they were caused by Mitch plus the social conditions that encouraged the farming of upland forests. The malaria emerged not just from the mosquitoes, but from the movement of a low-immunity population into a mosquito-infested area, and from heavy pesticide use.

Such discontinuities and synergisms frequently catch us by surprise. They tend to subvert our sense of the world because we so often assume that a trend can be understood in isolation. It is tempting, for example, to believe that a smooth line on a graph can be used to see into the future: all you have to do is extend the line. But the future of a trend—any trend—depends on the behavior of the entire system in which it is embedded. When we isolate a phenomenon in order to study it, we may actually be preventing ourselves from knowing the most important things about it.

This fragmented form of inquiry is becoming increasingly dangerous—and not just because we might miss problems in small, poor countries like Honduras. After all, there is nothing special about the pressures in the Honduran predicament. Deforestation, climate change, chemical contamination—these and many other forms of environmental corrosion are at work on a global scale. Each has engendered its own minor research industry. But even as the publications pile up, we may actually be missing the biggest problem of all: what might the inevitable convergence of these forces do?

"When one problem combines with another problem, the outcome may be not a double problem, but a super-problem." That is the assessment of Norman Myers, an Oxford-based ecologist who is one of the most active pioneers in the field of environmental surprise. We have hardly begun to identify those potential super-problems, but in the planet's increasingly stressed natural systems, the possibility of rapid, unexpected change is pervasive and growing. . . .

## Tropical Rainforests: The Inferno Beneath the Canopy

Eight thousand years ago, before people began to clear land on a broad scale, more than 6 billion hectares, or around 40 percent of the planet's land surface, were covered with forest. Today, Earth's tattered cloak of natural forests (as opposed to tree plantations) amounts to 3.6 billion hectares at most. Every year, at least another 14 million hectares are lost—and maybe considerably more than that. This is an enormous evolutionary tragedy. Among the many thousands of species that are believed to go extinct every year, the overwhelming majority are forest creatures, primarily tropical insects, who have been denied their habitat. That, anyway, is the best estimate, but the forests are vanishing far more rapidly than they can be studied. We really don't even know what we are losing.

Currently, well over 90 percent of forest loss is occurring in the tropics—on a scale so vast that it might appear to have exceeded its capacity to surprise us. In 1997 and 1998, fires set to clear land in Amazonia claimed more than 5.2 million hectares of Brazilian forest, brush, and savanna—an area nearly 1.5 times the size of Taiwan. In Indonesia, some 2 million hectares of forest were torched during 1997 and 1998. All this is certainly news, but if you are interested in conservation, it is the kind of dreadful news you have come to expect.

And yet our expectations may not be an adequate guide to the sequel, assuming the destruction continues at its current pace. A substantial portion of the damage is "hidden"—it does not show up in the conventional analysis. But once you take the full extent of the damage into account, you can begin to make out some of the surprises it is likely to trigger.

Consider, for example, the destruction of Amazonia. Over half the world's remaining tropical rainforest lies within the Amazon basin, where more forest is being lost than anywhere else on Earth. Deforestation statistics for the area are intended primarily to track the conversion of forest into farms and ranches. Typically, the process begins with the construction of a road, which opens up a new tract of forest to settlement. In June 1997, for instance, some 6 million hectares of forest were officially released for settlement along a major new highway, BR-174, which runs from Manaus, in central Amazonia, over 1,000 kilometers north to Venezuela. Ranchers and subsistence farmers clearcut patches of forest along the road and burn the slash during the July-November dry season. (The farmers generally have few other options: Brazil has large numbers of poor, land-hungry people, and the plots they cut from the forest usually lose their fertility rapidly, so there is a constant demand for fresh soil.)

But the damage to the forest generally extends much farther than the areas that are "deforested" in this conventional sense, because of the way fire works in



Amazonia. In the past, major fires have not been a frequent enough occurrence to promote any kind of adaptive "fire proofing" in the region's dominant tree species. Some temperate-zone and northern trees, by contrast, are "fire-adapted" in one way or another—they may have especially thick bark, for example, or the ability to resprout after burning. The lack of such adaptations in Amazonian trees means that even a small fire can begin to unravel the forest.

During the burning season, the flames often escape the cuts and sneak into neighboring forest. Even in intact forest, there will be patches of forest floor that are dry enough at that time of year to allow a small "surface fire" to feed on the dead leaves. Surface fires do not climb trees and become crown fires. They just crackle along the forest floor, here and there, as little patches of flame, going out at night, when the temperature drops, and rekindling the next day. They will not kill the really big trees, and they do not cover every bit of ground in a burned patch. But they are fatal to most of the smaller trees they touch. Overall, an initial surface fire may kill perhaps 10 percent of the living forest biomass.

The damage may not look all that dramatic, but another tract of forest may already be doomed by an incipient positive feedback loop of fire and drying. After a surface fire, the amount of shade is reduced from about 90 percent to around 60 percent, and the dead and injured trees rain debris down on the floor. So a year or two later, the next fire in that spot finds more tinder, and a warmer, drier floor. Some 40 percent of forest biomass may die in the second fire. At this point, the forest's integrity is seriously damaged; grasses and vines invade and contribute to the accumulation of combustible material. The next dry season may eliminate the forest entirely. Once the original forest is gone, the scrubby second growth or pasture that replaces it will almost certainly burn too frequently to allow the forest to restore itself.

New roads admit not just settlers and ranchers but loggers as well. Commercial logging involves a form of damage that is in some ways similar to the surface fires. Unlike its temperate-zone counterparts, the Amazonian timber industry does not generally clearcut. Most of its operations are what foresters call "high grading"—the best specimens of the most desirable species are cut and hauled out. The result is not outright deforestation, but the forest loses its largest trees and suffers extensive collateral damage from the felling and hauling. An intricate network of logging roads undermines the canopy—a human termite's nest through the wood. An Amazonian timber operation typically kills 10–40 percent of the forest biomass, thereby reducing canopy coverage by up to 50 percent. The forest floor grows warmer and drier; the forest becomes increasingly flammable.

As the main mechanisms of deforestation, the logging and burning are hardly surprising per se, but a great deal of the resulting damage is still obscure. Deforestation estimates are derived primarily from satellite photos, and while the photos show a great deal of detail, the mapping process is generally designed to give a picture of gross canopy destruction. Damage that leaves most of the canopy intact, or that has been masked by second growth, it usually not factored in to the estimates.

In a recent survey, researchers cross-checked satellite maps with field observations and concluded that conventional deforestation estimates for Brazilian Amazonia were missing some 1–1.5 million hectares of severe forest damage done by logging every year. Surface fire damage is harder to quantify, but the same researchers did a fire survey and found that the amount of standing forest that had suffered a surface fire in 1994 and 1995 was 1.5 times the area fully deforested in those years. Overall, they suggested, the area of Amazonian forest attacked by surface fire every year may be roughly equivalent to the area deforested outright. And in some parts of the basin, the extent of this cryptic damage is so great that the conventional measurements may no longer be all that useful. In one region, around Paragominas in eastern Amazonia, the researchers found that although 62 percent of the land was classified as forested, only about one tenth of this consisted of undisturbed forest.

Apart from these direct losses, the logging and burning are likely to trigger various forms of second-order damage through fragmentation. Cutting the forest up into smaller and smaller pieces renders the surviving tracts increasingly vulnerable to "edge effects." Near the edge of a major clearing, competing vegetation often invades forest, choking out saplings. Higher winds dry out the soil and sometimes topple trees. In Amazonia, these effects may extend a kilometer from the edge itself.

As the Amazonian forest dwindles, a more surprising second-order effect may emerge as the hydrological cycle changes. Because trees exhale so much water vapor, a forest to some degree creates its own climate. Much of this water vapor condenses out below the canopy and drips back into the soil. Some of it rises higher before falling back in as rain—researchers estimate that most of the Amazon's rainfall comes from water vapor exhaled by the forest. Widespread deforestation will therefore tend to make the region substantially drier, and that will accelerate the feedback loop created by the fires.

Some degree of deforestation-induced drought already appears to have affected other parts of the humid tropics—parts of Central America, for instance, Côte d'Ivoire, and peninsular Malaysia, where the drying has been severe enough to force the abandonment of some 20,000 hectares of rice paddy. It may not be possible to define the point at which such a drought takes hold in Amazonia, but about 13 percent of the Brazilian Amazon has now been deforested outright. If you add to that the tracts of forest that have been seriously degraded—by logging, surface fires, and fragmentation—that fraction could rise to more than a third.

The fire feedback loop is also likely to gain momentum from forces outside the region. Over the past two decades, Amazonia has seen several unusually intense dry seasons, during which the burning was far worse than normal. These periods correspond with recent El Niño weather events (in 1982–83, 1992–93, and 1997–98). El Niño events appear to be growing longer, more intense, and more frequent. Many climatologists regard this trend as a likely effect of climate change—the change in the behavior of Earth's climate system caused by increasing atmospheric concentrations of carbon dioxide ($CO_2$) and other greenhouse gases. Climate change, in other words, may be accelerating the Amazonian fire cycle. By burning large amounts of coal and oil, the United States, China, and other major carbon-emitting countries may in effect be burning the Amazon.



Other kinds of surprises are lurking in tropical forests as well. As developing countries industrialize, some forest maladies better known in the industrial world are likely to appear in these countries too. Acid rain, for example, is already reported to be affecting the forests of southern China. In parts of South Asia, Indonesia, South America, and West Africa, this form of pollution is bound to increase as industrialization proceeds and cities enlarge. The soil in these areas tends to be fairly acidic already, which would make it incapable of buffering large doses of additional acid. At least in some of these places, acid-induced decline may therefore be much more abrupt than in the temperate zone....

## The Atmosphere: An Invisible Confluence of Poisons

The delicate membrane of gases that makes up our atmosphere is as thin, comparatively speaking, as the skin of an onion. The atmosphere's outer border is very diffuse—a faint scattering of gas molecules extends into space for hundreds of kilometers—but 90 percent of those molecules lie within 16 kilometers of sea level. Every ecosystem on Earth is linked to the chemistry of the membrane that separates us from outer space, and that chemistry is changing in many ways. Levels of some "trace gases," such as sulfur dioxide, nitrogen oxides, and carbon dioxide, are increasing. Many novel compounds have entered the brew as well—for instance, chlorofluorocarbons, the ozone-destroying chemicals used as refrigerants. From this immense potential for change, look at just three basic phenomena: acid raid, nitrogen pollution, and increasing levels of $CO_2$.

Fossil fuel combustion is the source of acid rain (which falls not just as rain but also as dry particles). Acid rain is composed in large measure of sulfuric acid, which derives from the sulfur dioxide released by coal-burning power plants and metal smelters. (Sulfer is a common contaminant of coal and metal ores.) Smoke stack "scrubbers" and a growing preference for low-sulfur coal and natural gas have helped reduce sulfur dioxide emissions in North America and Western Europe, although high sulfur emissions are still common elsewhere. The other primary constituent of acid rain is nitric acid, which is generated from the nitrogen oxides in fossil fuel emissions. Unfortunately, nitric acid is likely to be more difficult to control than sulfuric acid, since a substantial share of the nitrogen oxides comes from gasoline burned in the world's expanding fleets of cars.

Acid rain can travel downwind for hundreds of kilometers—then fall on forests and farmland, where the idea of air pollution may seem quite incongruous. The acid can damage plant tissues directly, but its worst effects come as a series of discontinuities that are much harder to see. As the acid drips into the soil, decade after decade, it tends to leach out the stock of calcium and magnesium, both essential plant nutrients. Depending upon how nutrient-rich a soil is to begin with, this process may or may not be an immediate concern, but if it persists, the nutrient decline will eventually cross a threshold of scarcity: it will begin to cripple plant growth.

A second discontinuity will occur once soil calcium has grown scarce. Without calcium to neutralize it, the incoming acid will just build up in the soil—soil acidification will increase abruptly, even if the amount of incoming acid remains constant. The growing acidity will work another change, by releasing aluminum from its mineral matrix. Aluminum is a common soil constituent; when bonded to other minerals, it is biologically inert, but free aluminum in acid conditions is toxic to both plants and animals. In plants, acidity plus aluminum damages the fine roots. That could affect water uptake, and thereby increase susceptibility to drought. Root damage will also cripple a plant's ability to absorb whatever nutrients remain in the soil.

Acid lowers the calcium level, which allows the acid to build up, which releases aluminum, which interferes with calcium uptake. There is a cascade of chemical effects here, reinforcing the nutrient starvation. Other kinds of second-order effects may emerge as well. In the United States, for example, recent research over a swath of the Midwest from southern Illinois to southern Ohio has uncovered a correlation between increasing acidity in forest soils and a decline of soil organisms—earthworms, beetles, and so on. As biological activity in these soils has dropped off, decay of woody debris appears to have slowed radically, so the calcium "locked up" in the dead wood is not being released back into the soil. The nutrient cycle has apparently been constricted to some degree.

Because they are chronic, these changes in soil chemistry also create many opportunities for synergisms. Aluminum, for example, is not the only metal that acid tends to "mobilize." Toxic heavy metals such as cadmium, lead, and mercury may also be present in the soil, or they may arrive in trace amounts, on the same winds that brought in the acid. (Like sulfur, heavy metals are common contaminants of coal and ores, although usually in much smaller amounts.) Increasing acidity will tend to make these metals more soluble and toxic as well.

Even though it involves discontinuities, acid-induced decline may still unfold for decades as a hidden process that largely escapes casual notice. Does a tract of forest have fewer large trees than it once did, or fewer species that need more alkaline soil? Even if it does, it may still be perfectly green. It may still show vigorous growth, but the growth may be concentrated in younger plants, and in acid-tolerant species. It may be on its way to becoming a kind of "acid thicket."

In the eastern United States, over a large portion of Appalachia, the death rate of oaks appears to have doubled and that of hickories to have nearly tripled from 1960 to 1990; a recent review found a strong correlation between these declines and exposure to acid rain and ozone pollution. In the mountains of New Hampshire, at the Hubbard Brook Experimental Forest, acid-induced leaching of minerals has been identified as the main reason vegetation there has shown virtually no net growth since the mid-1980s. Here and there throughout the U.S. Northeast, acidity may be a factor in the failure of the sugar maple, one of the region's dominant tree species, to generate new seedlings. Acid rain is a threat elsewhere in the country as well—in the southern Appalachians, for example, and in the mountains of Colorado.



The worst acid rain, however, is in Asia, particularly in China, which gets 73 percent of its energy from burning coal. The vast quantities of sulfur dioxide released in the process are reportedly now affecting some 270 million hectares of land—more than a quarter of the country's land mass. The acid is reaching Japan and the Koreas as well; Japan, for instance, currently receives more than a third of its sulfur deposition from China. In a recent study, scientists built a computer model of China's energy development and concluded that if the country does not curb its appetite for coal, then over the next two decades acid rain could overwhelm many of the region's soils.

The study is not wholly pessimistic: under its best case scenario, state-of-the-art pollution controls are installed at all of China's coal-burning power plants and factories, causing sulfur dioxide emissions to fall to 31 percent of their 1990 value by 2020. But under a more realistic scenario—with state-of-the-art pollution control installed only in new power plants and some fuel-switching to cleaner energy—sulfur dioxide emissions actually increase by 40 percent over the same time frame. China's coal use is therefore an invitation to widespread discontinuity—not just on an ecosystem level, but also, because of its potential for poisoning cropland, on a social level as well.

Acid rain overlaps with another, broader form of global change: the alteration of the planet's "nitrogen cycle." Nitrogen is an essential plant nutrient and the main constituent of the atmosphere: 78 percent of the air is nitrogen gas. But plants cannot metabolize this pure, elemental nitrogen directly. The nitrogen must be "fixed" into compounds with hydrogen or oxygen before it can become part of the biological cycle. In nature this process is accomplished by certain types of algae and bacteria, as well as by lightning strikes, which fuse atmospheric oxygen and nitrogen into nitrogen oxides.

Humans have radically amplified this process. Farmers boost the nitrogen level of their land through fertilizers and the planting of nitrogen-fixing crops (actually, symbiotic microbes do the fixing). The burning of forests and the draining of wetlands releases additional quantities of fixed nitrogen that had been stored in vegetation and organic debris. And fossil fuel combustion produces still more fixed nitrogen, in the form of nitrogen oxides. Natural processes probably incorporate around 140 million tons of nitrogen into the terrestrial nitrogen cycle every year. (The ocean cycle is largely a mystery.) Thus far, human activity has at least doubled that amount.

Fixed nitrogen is often a "limiting nutrient" in terrestrial ecosystems: it is in high demand and relatively short supply, so its availability determines the amount of plant growth. If you add more, you get more growth—at least in some species. That is why fertilizer is mostly nitrogen. But if you keep adding more, you run into trouble. The excess nitrogen becomes a kind of poison that may interact synergistically with acid rain and other pressures. (Of course, since nitrogen compounds often contribute to the acidity, the processes are not entirely distinct.)

In forests, for example, excess nitrogen tends to inhibit fine root growth, just as the acid-aluminum combination does. Acidity plus nitrogen pollution could therefore deal a double blow to trees' ability to withstand drought and to take in calcium and magnesium. Above ground, excess nitrogen may stimulate extra growth, but it is likely to be produced faster than the tree can absorb those mineral nutrients. The new growth will therefore tend to be weak—essentially, malnourished. This effect also can be exacerbated by acid rain, since acid leaches out those minerals in the first place.

The weakness of the new growth is not just physical—there can be chemical weaknesses too. Since nitrogen may also be a limiting nutrient for insects and other small organisms that feed on trees, nitrogen-rich foliage is likely to be very attractive to pests. And the low mineral concentrations within the tree's tissues can interfere with its ability to produce the chemicals that make up its "immune system"—compounds that, for example, inhibit infection or make foliage less palatable to insects. Other physiological effects are probably at work as well; excess nitrogen, for instance, appears to lower a tree's ability to cope with cold weather. Combinations of various effects like these may eventually produce substantial discontinuities. In one monitoring experiment in the U.S. Northeast, researchers found that by increasing the nitrogen in pine and spruce-fir stands, they induced declines in growth and increases in tree mortality over a period of just six years.

Nor is it just forests that are at risk from excess nitrogen. In prairies and heaths, too much nitrogen can favor the terrestrial equivalent of algae—whatever fast-growing, weedy species happen to be present—at the expense of slower-growing species that do not have the adaptations necessary to use the extra fertilizer. Several field experiments have shown that this process can have a dramatic homogenizing effect. In one such study, a highly diverse prairie in Minnesota dissolved into a luxuriant patch of fast-growing, aggressive grass. The main beneficiaries of this process are often likely to be non-native "exotic" species, since the ability to grow fast (and therefore to capitalize on any extra nitrogen) will tend to make a plant a good invader in the first place. In this way, nitrogen pollution could converge synergistically with bioinvasion, the spread of exotic species.

Now factor in climate change. Although the processes of climate change are too complex to permit accurate prediction of local effects, the higher latitudes are generally expected to warm much more than the tropics. In the north, the warming is likely to proceed faster than forests can respond by "migrating" further north (where the soil and water conditions permit such movement). Unless carbon emissions are reduced, the result is likely to be substantial forest decline. The immediate causes of decline will likely vary from place to place, but will often involve drying and changes in the freeze-thaw regime during winter and early spring. (Such changes can cause trees to start growing too early in the season.) Both types of change invite an overlap with acid rain and nitrogen pollution, which can make trees less drought- and frost-tolerant. The biggest potential for such an overlap may be in Siberia, where air pollution has degraded vast areas and destroyed some 1 million hectares of forest outright.

In northern forests, unusually warm years often provoke massive defoliation from insects. Recent warming in Alaska, for example, apparently underlies a spruce budworm attack that had chewed up some 20 million hectares of forest by the end of 1998. In parts of northern Europe, southeastern Canada, and the U.S. Northeast, any such climate-driven insect response could combine with the tendency of nitrogen pollution to promote insect damage.

The warming may trigger less direct stresses as well. In the north, climate change is likely to weaken the stratospheric ozone layer, thereby allowing more harmful ultraviolet radiation to reach Earth's surface. (Greenhouse gases are keeping more heat in the lower atmosphere, so the stratosphere is cooling, and air currents are likely to exacerbate that effect in the north. Stratospheric cooling affects the ozone layer because ozone-destroying substances are more effective at lower temperatures.) The extra ultraviolet radiation will damage the foliage of many trees—another overlap with air pollution stress. Chronic damage to foliage slows growth and tends to increase susceptibility to other pressures, such as drought and pests.

Drought stress, pollution, insect attack, ultraviolet light—the critical issue here is not whether any particular synergism will occur, it is the increase in the aggregate risk of a major surprise. As the pressures build, so does the chance of triggering some unanticipated "super-problem."

## An Agenda for the Unexpected

Human pressures on Earth's natural systems have reached a point at which they are more and more likely to engender problems that we are less and less likely to anticipate. Dealing with this predicament is obviously going to require more than simply reacting to problems as they appear. We need to forge a new ethic for managing our relationship with nature—one that emphasizes minimal interference in the lives of wild beings and in the broad natural processes that sustain all living things. Such an ethic might begin with three basic principles.

First, nature is a system of unfathomable complexity. Our predominant response to that complexity has been specialization, in both the sciences and public policy. Learning a lot about a little is a form of progress, but it comes at a cost. Expertise is seductive: it is easy for specialists to get into the habit of thinking that they understand all the consequences of a plan. But in a complex, highly stressed system, the biggest consequences may not emerge where the experts are in the habit of looking. This inherent unpredictability condemns us to some degree of error, so it is important to err on the side of minimal disruption whenever possible.

Second, nature gives away nothing for free. You cannot get an appreciable quantity of anything out of nature without sacrificing something in the process. Even sustainable resources management is a trade-off—it's simply one we regard as acceptable. In our dealings with nature, as with any other sort of transaction, we need to know the full cost of the goods before deciding whether they are worth the price, or whether there is a better way to pay for them.

Third, nature has no reset button. Environmental corrosion is not just killing off individual species—it is setting off system-level changes that are, for all practical purposes, irreversible. Even if, for example, all the world's coral reef species were miraculously to survive the impending bout of rapid climate change, that does not mean that our descendents will be able to reconstruct reef communities. The near impossibility of restoring complex systems to some previous state is another strong argument for minimal disruption.

These are basic features of the natural world: we will never understand it completely, it will not do our bidding for free, and we cannot put it back the way it was. . . .

Solutions are almost never permanent, so plan to keep on planning. In the 1950s, organochlorine pesticides were hailed as a permanent "fix" for insect pest problems; given the pervasive ecological damage that these chemicals are now known to cause, the idea of a permanent chemical solution to anything may seem rather naive today. But because our relationship with nature is in a constant state of flux, even realistic fixes will need regular revision. The Montreal Protocol is not a permanent patch for the ozone layer, in part because climate change will probably exacerbate ozone loss. The Green Revolution is not a permanent answer to world hunger, in part because conventional agriculture is overtaxing aquifers. The growing strain on Earth's natural systems will probably force an increase in the tempo of policy revision—so it makes sense to take full advantage of the powerful new information and communications technologies. Because of their ability to bring together enormous quantities of data from different areas and disciplines, such technologies could help counter the blinkering effects of specialization.

None of us may find the answer alone, but together we probably can. In social as well as natural systems, there is a potent class of properties that exists only on the system level—properties that cannot be directly attributed to any particular component. In a political system, for example, institutional pluralism can create a public space that no single institution could have created alone. One of the most important policy activities may therefore be to encourage innovation outside policy institutions. Policy may need to become increasingly a matter of creating not so much solutions per se as the conditions from which solutions can arise. In the face of the unexpected, our best hopes may lie in our collective imagination.

# NO

Julian L. Simon

## More People, Greater Wealth, More Resources, Healthier Environment

This is the economic history of humanity in a nutshell. From 2 million or 200,000 or 20,000 or 2,000 years ago until the 18th century there was slow growth in population, almost no increase in health or decrease in mortality, slow growth in the availability of natural resources (but not increased scarcity), increase in wealth for a few, and mixed effects on the environment. Since then there has been rapid growth in population due to spectacular decreases in the death rate, rapid growth in resources, widespread increases in wealth, and an unprecedently clean and beautiful living environment in many parts of the world along with a degraded environment in the poor and socialist parts of the world.

That is, more people and more wealth have correlated with more (rather than less) resources and a cleaner environment—just the opposite of what Malthusian theory leads one to believe. The task before us is to make sense of these mind-boggling happy trends.

The current gloom-and-doom about a 'crisis' of our environment is wrong on the scientific facts. Even the US Environmental Protection Agency acknowledges that US air and water have been getting cleaner rather than dirtier in the past few decades. Every agricultural economist knows that the world's population has been eating ever-better since the Second World War.

Every resource economist knows that all natural resources have been getting more available not more scarce, as shown by their falling prices over the decades and centuries. And every demographer knows that the death rate has been falling all over the world—life expectancy almost tripling in the rich countries in the past two centuries, and almost doubling in the poor countries in only the past four decades.

### Population Growth and Economic Development

The picture is now also clear that population growth does not hinder economic development. In the 1980s there was a complete reversal in the consensus of thinking of population economists about the effects of more people. In 1986, the National Research Council and the National Academy of Sciences completely overturned its 'official' view away from the earlier worried view expressed in 1971. It noted the absence of any statistical evidence of a negative connection between population increase and economic growth. And it said that 'The scarcity of exhaustible resources is at most a minor restraint on economic growth'. This U-turn by the scientific consensus of experts on the subject has gone unacknowledged by the press, the anti-natalist [anti-birth] environmental organisations, and the agencies that foster population control abroad.

## Long-Run Trends Positive

Here is my central assertion: Almost every economic and social change or trend points in a positive direction, as long as we view the matter over a reasonably long period of time.

For a proper understanding of the important aspects of an economy we should look at the long-run trends. But the short-run comparisons—between the sexes, age groups, races, political groups, which are usually purely relative —make more news. To repeat, just about every important long-run measure of human welfare shows improvement over the decades and centuries, in the United States as well as in the rest of the world. And there is no persuasive reason to believe that these trends will not continue indefinitely.

Would I bet on it? For sure. I'll bet a week's or month's pay—anything I win goes to pay for more research—that just about any trend pertaining to material human welfare will improve rather than get worse. You pick the comparison and the year.

Let me quickly review a few data on how human life has been doing, beginning with the all-important issue, life itself.

## The Conquest of Too-Early Death

The most important and amazing demographic fact—the greatest human achievement in history, in my view—is the decrease in the world's death rate. Figure 1 portrays the history of human life expectancy at birth. It took thousands of years to increase life expectancy at birth from just over 20 years to the high twenties in about 1750. Then life expectancy in the richest countries suddenly took off and tripled in about two centuries. In just the past two centuries, the length of life you could expect for your baby or yourself in the advanced countries jumped from less than 30 years to perhaps 75 years. What greater event has humanity witnessed than this conquest of premature death in the rich countries? It is this decrease in the death rate that is the cause of there being a larger world population nowadays than in former times.

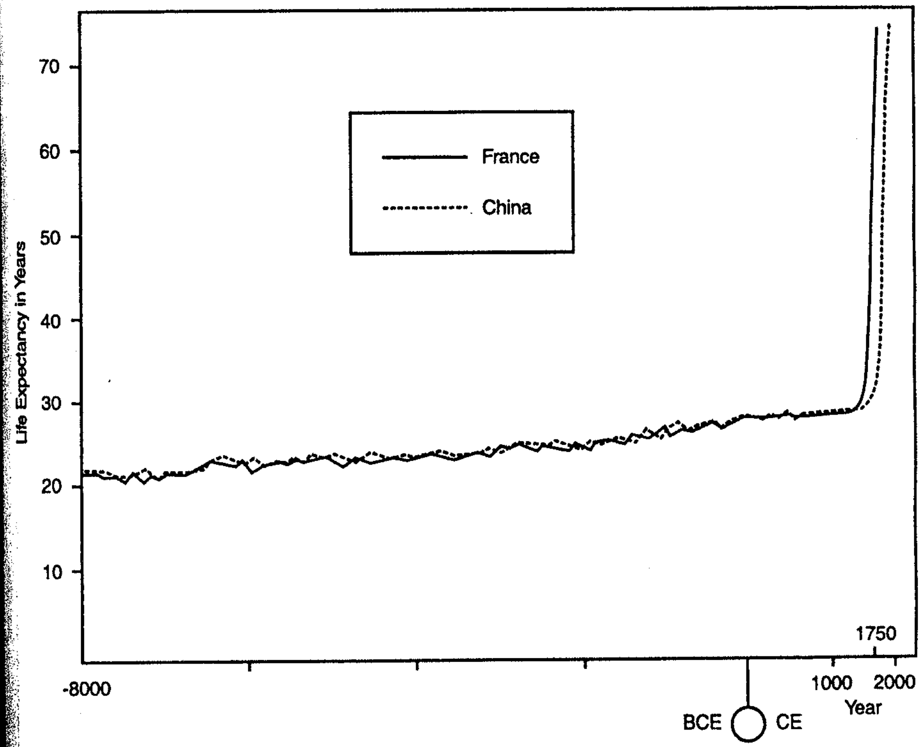
Then starting well after the Second World War, the length of life you could expect in the poor countries has leaped upwards by perhaps 15 or even 20 years since the 1950s, caused by advances in agriculture, sanitation, and medicine (Figure 2).

Let me put it differently. In the 19th century the planet Earth could sustain only 1 billion people. Ten thousand years ago, only 4 million could keep themselves alive. Now 5 billion people are on average living longer and more healthily than ever before. The increase in the world's population represents our victory over death.



*Figure 1*

**History of Human Life Expectancy at Birth (3000BCE–2000CE)**

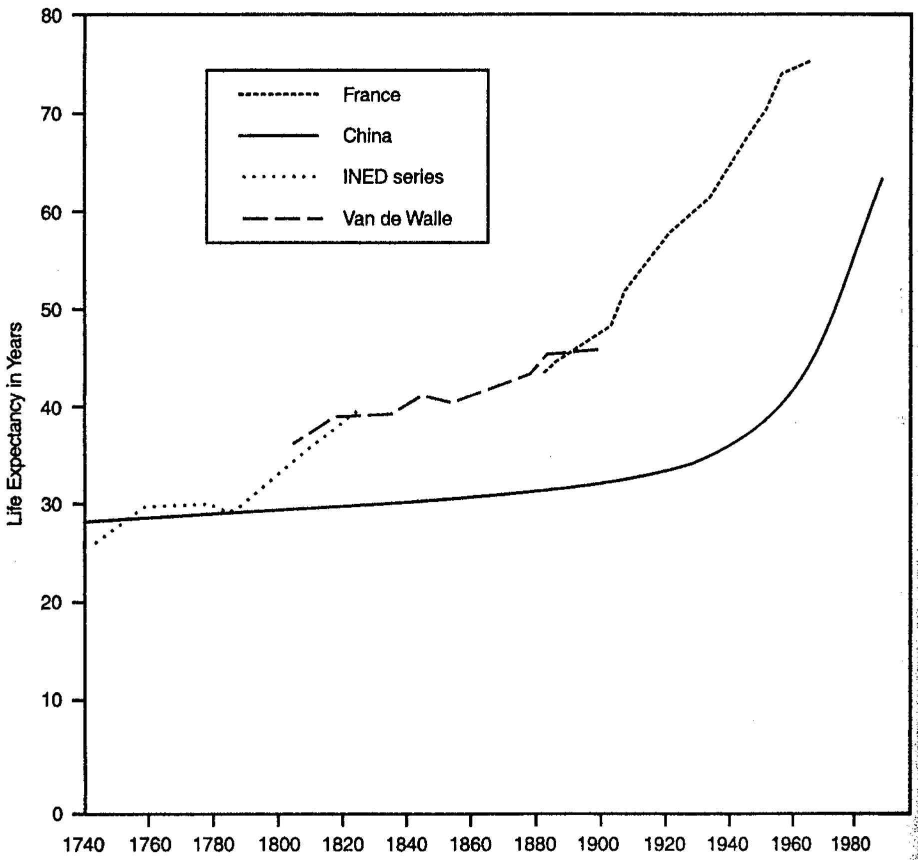



BCE: Before the Christian Era.

Here arises a crucial issue of interpretation: One would expect lovers of humanity to jump with joy at this triumph of human mind and organisation over the raw killing forces of nature. Instead, many lament that there are so many people alive to enjoy the gift of life. And it is this worry that leads them to approve the Indonesian, Chinese and other inhumane programmes of coercion and denial of personal liberty in one of the most precious choices a family can make—the number of children that it wishes to bear and raise.

*Figure 2*

Female Expectation of Life at Birth




*Source:* Official Statistics

## The Decreasing Scarcity of Natural Resources

Throughout history, the supply of natural resources has worried people. Yet the data clearly show that natural resource scarcity—as measured by the economically-meaningful indicator of cost or price—has been decreasing rather than increasing in the long run for all raw materials, with only temporary exceptions from time to time: that is, availability has been increasing. Consider copper, which is representative of all the metals. In Figure 3 we see the price



relative to wages since 1801. The cost of a ton is only about a tenth now of what it was two hundred years ago.

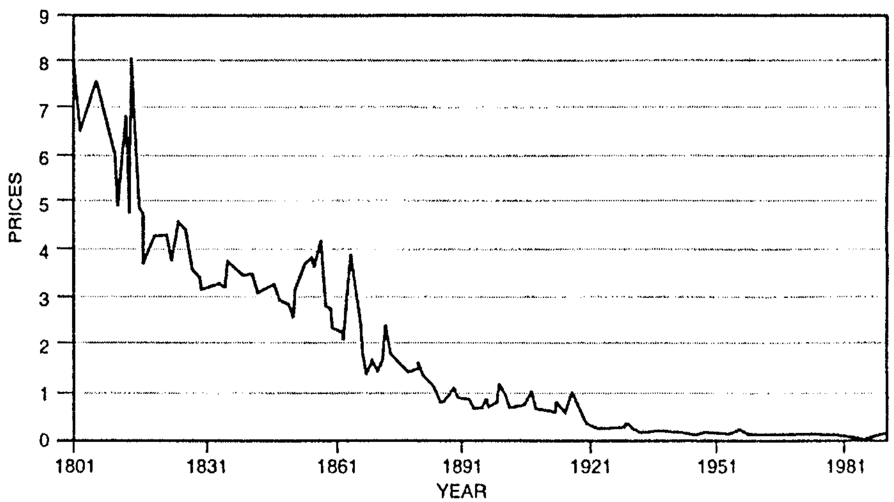
This trend of falling prices of copper has been going on for a very long time. In the 18th century BCE in Babylonia under Hammurabi—almost 4,000 years ago—the price of copper was about a thousand times its price in the USA now relative to wages. At the time of the Roman Empire the price was about a hundred times the present price.

In Figure 4 we see the price of copper relative to the consumer price index. Everything we buy—pens, shirts, tyres—has been getting cheaper over the years because we have learned how to make them more cheaply, especially during the past 200 years. Even so, the extraordinary fact is that natural resources have been getting cheaper even faster than consumer goods.

So, by any measure, natural resources have been getting more available rather than more scarce.

*Figure 3*

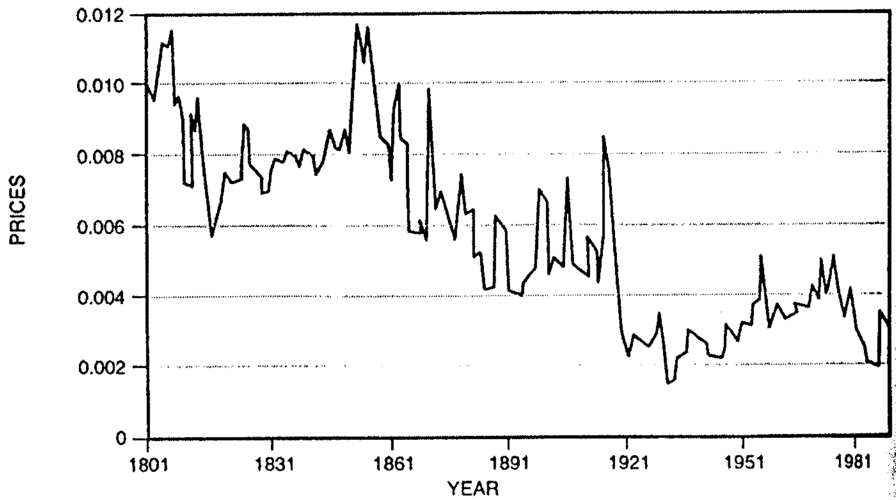
Copper Prices Indexed by Wages




In the case of oil, the shocking price rises during the 1970s and 1980s were not caused by growing scarcity in the world supply. And indeed, the price of petroleum in inflation-adjusted dollars has returned to levels about where they were before the politically-induced increases, and the price of gasoline is about at the historic low and still falling. Taking energy in general, there is no reason to believe that the supply of energy is finite, or that the price of energy will not continue its long-run decrease indefinitely....

*Figure 4*

Copper Prices Divided by CPI




## Food—'A Benign Trend'

Food is an especially important resource. The evidence is particularly strong for food that we are on a benign trend despite rising population. The long-run price of food relative to wages is now perhaps only a tenth as much as it was in 1800 in the USA. Even relative to consumer products, the price of grain is down because of increased productivity, as with all other primary products.

Famine deaths due to insufficient food supply have decreased even in absolute terms, let alone relative to population, in the past century, a matter which pertains particularly to the poor countries. Per-person food consumption is up over the last 30 years. And there are no data showing that the bottom of the income scale is faring worse, or even has failed to share in the general improvement, as the average has improved.

Africa's food production per person is down, but by 1994 almost no-one any longer claims that Africa's suffering results from a shortage of land or water or sun. The cause of hunger in Africa is a combination of civil wars and collectivisation of agriculture, which periodic droughts have made more murderous.

Consider agricultural land as an example of all natural resources. Although many people consider land to be a special kind of resource, it is subject to the same processes of human creation as other natural resources. The most important fact about agricultural land is that less and less of it is needed as the decades pass. This idea is utterly counter-intuitive. It seems entirely obvious that a growing world population would need larger amounts of farmland. But the title of a remarkably prescient article by Theodore Schultz in 1951 tells the story: 'The Declining Economic Importance of Land'.

The increase in actual and potential productivity per unit of land has grown much faster than population, and there is sound reason to expect this trend to continue. Therefore, there is less and less reason to worry about the supply of land. Though the stock of usable land seems fixed at any moment, it is constantly being increased—at a rapid rate in many cases—by the clearing of new land or reclamation of wasteland. Land also is constantly being enhanced by increasing the number of crops grown per year on each unit of land and by increasing the yield per crop with better farming methods and with chemical fertiliser. Last but not least, land is created anew where there was no land.

## The One Scarce Factor

There is only one important resource which has shown a trend of increasing scarcity rather than increasing abundance. That resource is the most important of all—human beings. Yes, there are more people on earth now than ever before. But if we measure the scarcity of people the same way that we measure the scarcity of other economic goods—by how much we must pay to obtain their services—we see that wages and salaries have been going up all over the world, in poor countries as well as rich. The amount that you must pay to obtain the services of a barber or cook—or economist—has risen in the United States over the decades. This increase in the price of people's services is a clear indication that people are becoming more scarce even though there are more of us.

Surveys show that the public believes that our air and water have been getting more polluted in recent years. The evidence with respect to air indicates that pollutants have been declining, especially the main pollutant, particulates. With respect to water, the proportion of monitoring sites in the USA with water of good drinkability has increased since the data began in 1961.

Every forecast of the doomsayers has turned out flat wrong. Metals, foods, and other natural resources have become more available rather than more scarce throughout the centuries. The famous Famine 1975 forecast by the Paddock brothers—that we would see millions of famine deaths in the US on television in the 1970s—was followed instead by gluts in agricultural markets. Paul Ehrlich's primal scream about 'What will we do when the [gasoline] pumps run dry?' was followed by gasoline cheaper than since the 1930s. The Great Lakes are not dead; instead they offer better sport fishing than ever. The main pollutants, especially the particulates which have killed people for years, have lessened in our cities. Socialist countries are a different and tragic environmental story, however!

. . . But nothing has reduced the doomsayers' credibility with the press or their command over the funding resources of the federal government. . . .

With respect to population growth: A dozen competent statistical studies, starting in 1967 with an analysis by Nobel prizewinner Simon Kuznets, agree that there is no negative statistical relationship between economic growth and population growth. There is strong reason to believe that more people have a positive effect in the long run.

Population growth does not lower the standard of living—all the evidence agrees. And the evidence supports the view that population growth raises it in the long run.

Incidentally, it was those statistical studies that converted me in about 1968 from working in favour of population control to the point of view that I hold today. I certainly did not come to my current view for any political or religious or ideological reason.

The basic method is to gather data on each country's rate of population growth and its rate of economic growth, and then to examine whether —looking at all the data in the sample together—countries with high population growth rates have economic growth rates lower than average, and countries with low population growth rates have economic growth rates higher than average. All the studies agree in concluding that this is not so; there is no correlation between economic growth and population growth in the intermediate run.

Of course one can adduce cases of countries that seemingly are exceptions to the pattern. It is the genius of statistical inference, however, to enable us to draw valid generalisations from samples that contain such wide variations in behaviour. The exceptions can be useful in alerting us to possible avenues for further analysis, but as long as they are only exceptions, they do not prove that the generalisation is not meaningful or useful.

## Population Density Favours Economic Growth

The research-wise person may wonder whether population density is a more meaningful variable than population growth. And, indeed, such studies have been done. And again, the statistical evidence directly contradicts the common-sense conventional wisdom. If you make a chart with population density on the horizontal axis and either the income level or the rate of change of income on the vertical axis, you will see that higher density is associated with better rather than poorer economic results. . . .

The most important benefit of population size and growth is the increase it brings to the stock of useful knowledge. Minds matter economically as much as, or more than, hands or mouths. Progress is limited largely by the availability of trained workers. The more people who enter our population by birth or immigration, the faster will be the rate of progress of our material and cultural civilisation.

Here we require a qualification that tends to be overlooked: I do not say that all is well everywhere, and I do not predict that all will be rosy in the future.



Children are hungry and sick; people live out lives of physical or intellectual poverty, and lack of opportunity; war or some new pollution may finish us off. What I am saying is that for most relevant economic matters I have checked, the aggregate trends are improving rather than deteriorating.

Also, I do not say that a better future happens automatically or without effort. It will happen because women and men will struggle with problems with muscle and mind, and will probably overcome, as people have overcome in the past—*if the social and economic system gives them the opportunity to do so.*

## The Explanation of These Amazing Trends

Now we need some theory to explain how it can be that economic welfare grows along with population, rather than humanity being reduced to misery and poverty as population grows.

The Malthusian theory of increasing scarcity, based on supposedly fixed resources (the theory that the doomsayers rely upon), runs exactly contrary to the data over the long sweep of history. It makes sense therefore to prefer another theory.

The theory that fits the facts very well is this: More people, and increased income, cause problems in the short run. Short-run scarcity raises prices. This presents opportunity, and prompts the search for solutions. In a free society, solutions are eventually found. And in the long run the new developments leave us better off than if the problems had not arisen.

To put it differently, in the short run more consumers mean less of the fixed available stock of goods to be divided among more people. And more workers labouring with the same fixed current stock of capital means that there will be less output per worker. The latter effect, known as 'the law of diminishing returns', is the essence of Malthus's theory as he first set it out.

But if the resources with which people work are not fixed over the period being analysed, the Malthusian logic of diminishing returns does not apply. And the plain fact is that, given some time to adjust to shortages, the resource base does not remain fixed. People create more resources of all kinds.

When we take a long-run view, the picture is different, and considerably more complex, than the simple short-run view of more people implying lower average income. In the very long run, more people almost surely imply more available resources and a higher income for everyone.

I suggest you test this idea against your own knowledge: Do you think that our standard of living would be as high as it is now if the population had never grown from about 4 million human beings perhaps 10,000 years ago? I do not think we would now have electric light or gas heat or cars or penicillin or travel to the moon or our present life expectancy of over 70 years at birth in rich countries, in comparison to the life expectancy of 20 to 25 years at birth in earlier eras, if population had not grown to its present numbers. . . .

## The Role of Economic Freedom

Here we must address another crucial element in the economics of resources and population—the extent to which the political-social-economic system provides personal freedom from government coercion. Skilled people require an appropriate social and economic framework that provides incentives for working hard and taking risks, enabling their talents to flower and come to fruition. The key elements of such a framework are economic liberty, respect for property, and fair and sensible rules of the market that are enforced equally for all.

The world's problem is not too many people, but lack of political and economic freedom. Powerful evidence comes from an extraordinary natural experiment that occurred starting in the 1940s with three pairs of countries that have the same culture and history, and had much the same standard of living when they split apart after the Second World War—East and West Germany, North and South Korea, Taiwan and China. In each case the centrally planned communist country began with less population 'pressure', as measured by density per square kilometre, than did the market-directed economy. And the communist and non-communist countries also started with much the same birth rates.

The market-directed economies have performed much better economically than the centrally-planned economies. The economic-political system clearly was the dominant force in the results of the three comparisons. This powerful explanation of economic development cuts the ground from under population growth as a likely explanation of the speed of nations' economic development.

## The Astounding Shift in the Scholarly Consensus

So far I have been discussing the factual evidence. But in 1994 there is an important new element not present 20 years ago. The scientific community of scholars who study population economics now agrees with almost all of what is written above. The statements made above do not represent a single lone voice, but rather the current scientific consensus.

The conclusions offered earlier about agriculture and resources and demographic trends have always represented the consensus of economists in those fields. And the consensus of population economists also is now not far from what is written here.

In 1986, the US National Research Council and the US National Academy of Sciences published a book on population growth and economic development prepared by a prestigious scholarly group. This 'official' report reversed almost completely the frightening conclusions of the 1971 NAS report. 'Population growth [is] at most a minor factor. . . .' As cited earlier in this paper, it found benefits of additional people as well as costs.

A host of review articles by distinguished economic demographers in the past decade has confirmed that this 'revisionist' view is indeed consistent with the scientific evidence, though not all the writers would go as far as I do in pointing out the positive long-run effects of population growth. The consensus



is more towards a 'neutral' judgement. But this is a huge change from the earlier judgement that population growth is economically detrimental.

By 1994, anyone who confidently asserts that population growth damages the economy must turn a blind eye to the scientific evidence.

## Summary and Conclusion

In the short run, all resources are limited. An example of such a finite resource is the amount of space allotted to me. The longer run, however, is a different story. The standard of living has risen along with the size of the world's population since the beginning of recorded time. There is no convincing economic reason why these trends towards a better life should not continue indefinitely.

The key theoretical idea is this: The growth of population and of income create actual and expected shortages, and hence lead to price rises. A price increase represents an opportunity that attracts profit-minded entrepreneurs to seek new ways to satisfy the shortages. Some fail, at cost to themselves. A few succeed, and the final result is that we end up better off than if the original shortage problems had never arisen. That is, we need our problems though this does not imply that we should purposely create additional problems for ourselves.

I hope that you will now agree that the long-run outlook is for a more abundant material life rather than for increased scarcity, in the United States and in the world as a whole. Of course, such progress does not come automatically. And my message certainly is not one of complacency. In this I agree with the doomsayers—that our world needs the best efforts of all humanity to improve our lot. I part company with them in that they expect us to come to a bad end despite the efforts we make, whereas I expect a continuation of humanity's history of successful efforts. And I believe that their message is self-fulfilling, because if you expect your efforts to fail because of inexorable natural limits, then you are likely to feel resigned; and therefore literally to resign. But if you recognise the possibility—in fact the probability—of success, you can tap large reservoirs of energy and enthusiasm.

Adding more people causes problems, but people are also the means to solve these problems. The main fuel to speed the world's progress is our stock of knowledge, and the brakes are (a) our lack of imagination, and (b) unsound social regulation of these activities.

The ultimate resource is people—especially skilled, spirited, and hopeful young people endowed with liberty—who will exert their wills and imaginations for their own benefit, and so inevitably benefit not only themselves but the rest of us as well.

# POSTSCRIPT

## Are Major Changes Needed to Avert a Global Environmental Crisis?

It is tempting to accept Simon's rosy predictions for the future and his faith in the ability of human beings to solve whatever problems they confront. However, he undermines his argument by falsely suggesting that environmental degradation is a problem only in poor and socialist parts of the world. He states that the Environmental Protection Agency (EPA) acknowledges that air and water in America have generally been getting cleaner. In actuality, however, while citing some significant local improvements, the EPA and most other analysts report continued deterioration of air and water quality in many parts of the United States as well as in the rest of the highly populated regions of the world.

Simon's view that increasing world population is positive rather than problematic is fully explicated in his book *The Ultimate Resource* (Princeton University Press, 1981). In the March/April 1997 issue of *The Futurist*, the topic "The Global Environment: Megaproblem or Not?" is debated by Simon and three other participants. A very pointed rebuttal to Simon and his perspective is Robert Cohen's guest opinion "Cornucopians, Global Resources and Technological Fixes," in the September 6, 1998, issue of the *Boulder Daily Camera* of Boulder, Colorado.

People who are concerned about a future environmental crisis usually promote the need for "sustainable development." This concept was popularized by the World Commission on Environment and Development in a much-publicized report entitled *Our Common Future* in 1987. Commission chairperson Gro Harlem Brundtland, then the prime minister of Norway, has actively publicized its findings and recommendations. Her keynote address at the 1989 Forum on Global Change, "Global Change and Our Common Future," was published in *Environment* (June 1989). For a detailed discussion of sustainable development from the perspective of Herman Daly and other environmental economists who believe that it requires development without growth, see the four weekly issues of *Rachel's Environment and Health Weekly* beginning November 12, 1998.

The limits on economic development and population growth based on the Earth's "carrying capacity" appear to be rejected by Simon. For more insight into this controversial concept, see the Worldwatch Institute's *State of the World* series of annual books (published by W. W. Norton). The need for a restructured, sustainable economy is a recurring theme. The 2000 volume's opening chapter, Lester R. Brown's "Challenges of the New Century," states, "If



we cannot stabilize climate and we cannot stabilize population, there is not an ecosystem on Earth that we can save.... There is no middle path. The challenge is either to build an economy that is sustainable or to stay with our unsustainable economy until it declines. It is not a goal that can be compromised. One way or another, the choice will be made by our generation, but it will affect life on Earth for all generations to come."