lore of nation building, it is supposed that American experts applied sophisticated social engineering that forced these countries to become democracies against their will. It wasn't that way at all. These countries became democracies on their own, and the bumptious generals and paper-shuffling bureaucrats of the military occupation were generally more of a hindrance than a help.

The recent intervention in Iraq further illustrates how haphazard and unfocused nation building is in practice. While the military campaign was a success, the occupation and administration has been characterized by naïveté and improvisation. The U.S. had no policy to check looting after victory, nor the forces to do it, and the result was a ravaging of local infrastructure, the rapid formation of gangs of thugs and paramilitary fighters, and a loss of local support for the U.S. effort. The civilian administration was first put in the hands of retired Lt. Gen. Jay Garner, who was two weeks late getting to Baghdad, and who naively expected to find a functioning government in the country. After a month, the hapless Garner was fired, replaced by Paul Bremer as chief administrator. Two months after the invasion, Lt. Gen. William Wallace, the V Corps commander, described the nation-building "technique" U.S. officials were applying in Iraq: "We're making this up here as we go along."

Nation building by military force is not a coherent, defensible policy. It is based on no theory, it has no proven technique or methodology, and there are no experts who know how to do it. The record shows that it usually fails, and even when it appears to succeed, the positive result owes more to historical evolution and local political culture than anything nation builders might have done.

THE ENVIRONMENT AND CLIMATE CHANGE

The Tragedy of the Commons

GARRETT HARDIN

We can make little progress in working toward optimum population size until we explicitly exorcize the spirit of Adam Smith in the field of practical demography. In economic affairs, *The Wealth of Nations* (1776) popularized the "invisible hand," the idea that an individual who "intends only his own gain," is, as it were, "led by an invisible hand to promote . . . the public interest."[1] Adam Smith did not assert that this was invariably true, and perhaps neither did any of his followers. But he contributed to a dominant tendency of thought that has ever since interfered with positive action based on rational analysis, namely, the tendency to assume that decisions reached individually will, in fact, be the best decisions for an entire society. If this assumption is correct it justifies the continuance of our present policy of laissez-faire in reproduction. If it is correct we can assume that men will control their individual fecundity so as to produce the optimum population. If the assumption is not correct, we need to reexamine our individual freedoms to see which ones are defensible.

TRAGEDY OF FREEDOM IN A COMMONS

The rebuttal to the invisible hand in population control is to be found in a scenario first sketched in a little-known pamphlet in 1833 by a mathematical amateur named William Foster Lloyd (1794–1852).[2] We may well call it "the tragedy of the commons," using the word "tragedy" as the philosopher Whitehead used it: "The essence of dramatic tragedy is not unhappiness. It resides in the solemnity of the remorseless

working of things."[3] He then goes on to say, "This inevitableness of destiny can only be illustrated in terms of human life by incidents which in fact involve unhappiness. For it is only by them that the futility of escape can be made evident in the drama."

The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work reasonably satisfactorily for centuries because tribal wars, poaching, and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning, that is, the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the commons remorselessly generates tragedy.

As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility *to me* of adding one more animal to my herd?" This utility has one negative and one positive component.

The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1.

The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of −1.

Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another. . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all. . . .

In an approximate way, the logic of the commons has been understood for a long time, perhaps since the discovery of agriculture or the invention of private property in real estate. But it is understood mostly only in special cases which are not sufficiently generalized. Even at this late date, cattlemen leasing national land on the western ranges demonstrate no more than an ambivalent understanding, in constantly pressuring federal authorities to increase the head count to the point where overgrazing produces erosion and weed-dominance. Likewise, the oceans of the world continue to suffer from the survival of the philosophy of the commons. Maritime nations will respond automatically to the shibboleth of the "freedom of the seas." Professing to believe in the "inexhaustible resources of the oceans," they bring species after species of fish and whales closer to extinction. . . .

POLLUTION

In a reverse way, the tragedy of the commons reappears in problems of pollution. Here it is not a question of taking something out of the commons, but of putting

something in—sewage, or chemical, radioactive, and heat wastes into water; noxious and dangerous fumes into the air; and distracting and unpleasant advertising signs into the line of sight. The calculations of utility are much the same as before. The rational man finds that his share of the cost of the wastes he discharges into the commons is less than the cost of purifying his wastes before releasing them. Since this is true for everyone, we are locked into a system of "fouling our own nest," so long as we behave only as independent, rational, free-enterprisers.

The tragedy of the commons as a food basket is averted by private property, or something formally like it. But the air and waters surrounding us cannot readily be fenced, and so the tragedy of the commons as a cesspool must be prevented by different means, by coercive laws or taxing devices that make it cheaper for the polluter to treat his pollutant than to discharge them untreated. We have not progressed as far with the solution of this problem as we have with the first. Indeed, our particular concept of private property, which deters us from exhausting the positive resources of the earth, favors pollution. The owner of a factory on the bank of a stream—whose property extends to the middle of the stream—often has difficulty seeing why it is not his natural right to muddy the waters flowing past his door. The law, always behind the times, requires elaborate stitching and fitting to adapt to it this newly perceived aspect of the commons.

The pollution problem is a consequence of populations. It did not much matter how a lonely American frontiersman disposed of his waste. "Flowing water purifies itself every 10 miles," my grandfather used to say, and the myth was near enough to the truth when he was a boy, for there were not too many people. But as population became denser, the natural chemical and biological recycling processes became overloaded, calling for a redefinition of property rights.

HOW TO LEGISLATE TEMPERANCE?

Analysis of the pollution problem as a function of population density uncovers a not generally recognized principle of morality, namely: *The morality of an act is a function of the state of the system at the time it is performed.*[4] Using the commons as a cesspool does not harm the general public under frontier conditions, because there is no public; the same behavior in a metropolis is unbearable. A hundred and fifty years ago a plainsman could kill an American bison, cut out only the tongue for his dinner, and discard the rest of the animal. He was not in any important sense being wasteful. Today, with only a few thousand bison left, we would be appalled at such behavior. . . .

That morality is system-sensitive escaped the attention of most codifiers of ethics in the past. "Thou shalt not . . . "is the form of traditional ethical directives which make no allowance for particular circumstances. The laws of our society follow the pattern of ancient ethics, and therefore are poorly suited to governing a complex, crowded, changeable world. Our epicyclic solution is to augment statutory law with administrative law. Since it is practically impossible to spell out all the conditions under which it is safe to burn trash in the backyard or to run an automobile without smog-control, by law we delegate the details to bureaus. The result is

administrative law, which is rightly feared for an ancient reason—*Quis custodiet ipsos custodes?*—" Who shall watch the watchers themselves?" John Adams said that we must have "a government of laws and not men." Bureau administrators, trying to evaluate the morality of acts in the total system, are singularly liable to corruption, producing a government by men, not laws.

Prohibition is easy to legislate (though not necessarily to enforce); but how do we legislate temperance? Experience indicates that it can be accomplished best through the mediation of administrative law. We limit possibilities unnecessarily if we suppose that the sentiment of *Quis custodiet* denies us the use of administrative law. We should rather retain the phrase as a perpetual reminder of fearful dangers we cannot avoid. The great challenge facing us now is to invent the corrective feedbacks that are needed to keep custodians honest. We must find ways to legitimate the needed authority of both the custodians and the corrective feedbacks.

FREEDOM TO BREED IS INTOLERABLE

The tragedy of the commons is involved in population problems in another way. In a world governed solely by the principle of "dog eat dog"—if indeed there ever was such a world—how many children a family had would not be a matter of public concern. Parents who bred too exuberantly would leave fewer descendants, not more, because they would be unable to care adequately for their children. . . .

If each human family were dependent only on its own resources; *if* the children of improvident parents starved to death; *if*, thus, overbreeding brought its own "punishment" to the germ line—*then* there would be no public interest in controlling the breeding of families. But our society is deeply committed to the welfare state and hence is confronted with another aspect of the tragedy of the commons.

In a welfare state, how shall we deal with the family, the religion, the race, or the class (or indeed any distinguishable and cohesive group) that adopts overbreeding as a policy to secure its own aggrandizement? To couple the concept of freedom to breed with the belief that everyone born has an equal right to the commons is to lock the world into a tragic course of action. . . .

CONSCIENCE IS SELF-ELIMINATING

It is a mistake to think that we can control the breeding of mankind in the long run by an appeal to conscience. Charles Galton Darwin made this point when he spoke on the centennial of the publication of his grandfather's great book. The argument is straightforward and Darwinian.

People vary. Confronted with appeals to limit breeding, some people will undoubtedly respond to the plea more than others. Those who have more children will produce a larger fraction of the next generation than those with more susceptible consciences. The difference will be accentuated, generation by generation.

In C. G. Darwin's words: "It may well be that it would take hundreds of generations for the progenitive instinct to develop in this way, but if it should do so, nature would have taken her revenge, and the variety *Homo contracipiens* would become extinct and would be replaced by the variety *Homo progenitivus*."[5]

The argument assumes that conscience or the desire for children (no matter which) is hereditary—but hereditary only in the most general formal sense. The result will be the same whether the attitude is transmitted through germ cells, or exosomatically. . . . The argument has here been stated in the context of the population problem, but it applies equally well to any instance in which society appeals to an individual exploiting a commons to restrain himself for the general good—by means of his conscience. To make such an appeal is to set up a selective system that works toward the elimination of conscience from the race. . . .

MUTUAL COERCION MUTUALLY AGREED UPON

The social arrangements that produce responsibility are arrangements that create coercion, of some sort. Consider bank-robbing. The man who takes money from a bank acts as if the bank were a commons. How do we prevent such action? Certainly not by trying to control his behavior solely by a verbal appeal to his sense of responsibility. Rather than rely on propaganda we follow Frankel's lead and insist that a bank is not a commons; we seek the definite social arrangements that will keep it from becoming a commons. That we thereby infringe on the freedom of would-be robbers we neither deny nor regret.

The morality of bank-robbing is particularly easy to understand because we accept complete prohibition of this activity. We are willing to say "Thou shalt not rob banks," without providing for exceptions. But temperance also can be created by coercion. Taxing is a good coercive device. To keep downtown shoppers temperate in their use of parking space we introduce parking meters for short periods, and traffic fines for longer ones. We need not actually forbid a citizen to park as long as he wants to; we need merely make it increasingly expensive for him to do so. Not prohibition, but carefully biased options are what we offer him. A Madison Avenue man might call this persuasion; I prefer the greater candor of the word coercion. . . .

To many, the word coercion implies arbitrary decisions of distant and irresponsible bureaucrats; but this is not a necessary part of its meaning. The only kind of coercion I recommend is mutual coercion, mutually agreed upon by the majority of the people affected.

To say that we mutually agree to coercion is not to say that we are required to enjoy it, or even to pretend we enjoy it. Who enjoys taxes? We all grumble about them. But we accept compulsory taxes because we recognize that voluntary taxes would favor the conscienceless. We institute and (grumblingly) support taxes and other coercive devices to escape the horror of the commons. . . .

RECOGNITION OF NECESSITY

Perhaps the simplest summary of this analysis of man's population problems is this: The commons, if justifiable at all, is justifiable only under conditions of low

population density. As the human population has increased, the commons has had to be abandoned in one aspect after another.

First we abandoned the commons in food gathering, enclosing farm land and restricting pastures and hunting and fishing areas. These restrictions are still not complete throughout the world.

Somewhat later we saw that the commons as a place for waste disposal would also have to be abandoned. Restrictions on the disposal of domestic sewage are widely accepted in the Western world; we are still struggling to close the commons to pollution by automobiles, factories, insecticide sprayers, fertilizing operations, and atomic energy installations. . . .

Every new enclosure of the commons involves the infringement of somebody's personal liberty. Infringements made in the distant past are accepted because no contemporary complains of a loss. It is the newly proposed infringements that we vigorously oppose; cries of "rights" and "freedom" fill the air. But what does "freedom" mean? When men mutually agreed to pass laws against robbing, mankind became more free, not less so. Individuals locked into the logic of the commons are free only to bring on universal ruin; once they see the necessity of mutual coercion, they become free to pursue other goals. I believe it was Hegel who said, "Freedom is the recognition of necessity."

The most important aspect of necessity that we must now recognize is the necessity of abandoning the commons in breeding. No technical solution can rescue us from the misery of overpopulation. Freedom to breed will bring ruin to all. At the moment, to avoid hard decisions many of us are tempted to propagandize for conscience and responsible parenthood. The temptation must be resisted, because an appeal to independently acting consciences selects for the disappearance of all conscience in the long run, and an increase in anxiety in the short.

The only way we can preserve and nurture other and more precious freedoms is by relinquishing the freedom to breed, and that very soon. "Freedom is the recognition of necessity"—and it is the role of education to reveal to all the necessity of abandoning the freedom to breed. Only so can we put an end to this aspect of the tragedy of the commons.

NOTES

1. Adam Smith, *The Wealth of Nations* (New York: Modern Library, 1937), p. 423.
2. William Foster Lloyd, *Two Lectures on the Checks to Population* (Oxford: Oxford University Press, 1853), reprinted in part in *Population, Evolution, and Birth Control*, A. Harding, ed. (San Francisco: Freeman, 1964), p. 37.
3. A. N. Whitehead, *Science and the Modern World* (New York: Mentor, 1948), p. 17.
4. J. Fletcher, *Situation Ethics* (Philadelphia: Westminster, 1966).
5. S. Tax, ed., *Evolution after Darwin*, Vol. 2 (Chicago: University of Chicago Press, 1960), p. 469.

Environmental Changes as Causes of Acute Conflict

THOMAS HOMER-DIXON

. . . How might environmental change lead to acute conflict? Some experts propose that environmental change may shift the balance of power between states either regionally or globally, producing instabilities that could lead to war. Or, as global environmental damage increases the disparity between the North and the South, poor nations may militarily confront the rich for a greater share of the world's wealth. Warmer temperatures could lead to contention over new ice-free sea-lanes in the Arctic or more accessible resources in the Antarctic. Bulging populations and land stress may produce waves of environmental refugees that spill across borders with destabilizing effects on the recipient's domestic order and on international stability. Countries may fight over dwindling supplies of water and the effects of upstream pollution. In developing countries, a sharp drop in food crop production could lead to internal strife across urban-rural and nomadic-sedentary cleavages. If environmental degradation makes food supplies increasingly tight, exporters may be tempted to use food as a weapon. Environmental change could ultimately cause the gradual impoverishment of societies in both the North and South, which could aggravate class and ethnic cleavages, undermine liberal regimes, and spawn insurgencies. Finally, many scholars indicate that environmental degradation will "ratchet up" the level of stress within national and international society, thus increasing the likelihood of many different kinds of conflict and impeding the development of cooperative solutions. . . .

THE RANGE OF ENVIRONMENTAL PROBLEMS

Developing countries are likely to be affected sooner and more severely by environmental change than rich countries. By definition, they do not have the financial, material, or intellectual resources of the developed world; furthermore, their social and political institutions tend to be fragile and riven with discord. It is probable, therefore, that developing societies will be less able to apprehend or respond to environmental disruption.

From Thomas F. Homer-Dixon, "On the Threshold: Environmental Changes as Causes of Acute Conflict," *International Security*, Vol. 16, No. 2 (Fall 1991), pp. 76–116. © 1991 by the President and Fellows of Harvard College and the Massachusetts Institute of Technology. Reprinted by permission of The MIT Press. Portions of the text and some footnotes have been omitted.

Seven major environmental problems . . . might plausibly contribute to conflict within and among developing countries: greenhouse warming, stratospheric ozone depletion, acid deposition, deforestation, degradation of agricultural land, overuse and pollution of water supplies, and depletion of fish stocks. These problems can all be crudely characterized as large-scale human-induced problems, with long-term and often irreversible consequences, which is why they are often grouped together under the rubric "global change." However, they vary greatly in spatial scale: the first two involve genuinely global physical processes, while the last five involve regional physical processes, although they may appear in locales all over the planet. These seven problems also vary in time scale: for example, while a region can be deforested in only a few years, and severe ecological and social effects may be noticeable almost immediately, human-induced greenhouse warming will probably develop over many decades and may not have truly serious implications for humankind for half a century or more after the signal is first detected. In addition, some of these problems (for instance, deforestation and degradation of water supplies) are much more advanced than others (such as greenhouse warming and ozone depletion) and are already producing serious social disruption. This variance in tangible evidence for these problems contributes to great differences in our certainty about their ultimate severity. The uncertainties surrounding greenhouse warming, for example, are thus far greater than those concerning deforestation.

Many of these problems are causally interrelated. For instance, acid deposition damages agricultural land, fisheries, and forests. Greenhouse warming may contribute to deforestation by moving northward the optimal temperature and precipitation zones for many tree species, by increasing the severity of windstorms and wildfires, and by expanding the range of pests and diseases. The release of carbon from these dying forests would reinforce the greenhouse effect. The increased incidence of ultraviolet radiation due to the depletion of the ozone layer will probably damage trees and crops, and it may also damage the phytoplankton at the bottom of the ocean food chain.

Finally, when we consider the social effects of environmental change, especially of climate change, we should be especially aware of changes in the incidence of "extreme" environmental events. Social impacts result "not so much from slow fluctuations in the mean, but from the tails of the distribution, from extreme events." While a two-to-three degree celsius mean global warming might not seem too significant for agricultural production, it may produce a large increase in crop-devastating droughts, floods, heat waves, and storms.

FOUR PRINCIPAL SOCIAL EFFECTS

Environmental degradation may cause countless often subtle changes in developing societies. These range from increased communal cooking as fuel-wood becomes scarce around African villages, to worsened poverty of Filipino coastal fishermen whose once-abundant grounds have been destroyed by trawlers and industrial pollution. Which of the many types of social effects might be crucial links between environmental change and acute conflict? This is the first part of the "how" question. To address it, we must use both the best knowledge about the social effects of environmental change and the best knowledge about the nature and causes of social conflict.

In thus working from both ends towards the middle of the causal chain, I hypothesize that four principal social effects may, either singly or in combination, substantially increase the probability of acute conflict in developing countries: decreased agricultural production, economic decline, population displacement, and disruption of legitimized and authoritative institutions and social relations. These effects will often be causally interlinked, sometimes with reinforcing relationships. For example, the population displacement resulting from a decrease in agricultural production may further disrupt agricultural production. Or economic decline may lead to the flight of people with wealth and education, which in turn could eviscerate universities, courts, and institutions of economic management, all of which are crucial to a healthy economy.

Agricultural Production

Decreased agricultural production is often mentioned as potentially the most worrisome consequence of environmental change. . . .

Large tracts are being lost each year to urban encroachment, erosion, nutrient depletion, salinization, waterlogging, acidification, and compacting. The geographer Vaclav Smil, who is generally very conservative in his assessments of environmental damage, estimates that two to three million hectares of cropland are lost annually to erosion; perhaps twice as much land goes to urbanization, and at least one million hectares are abandoned because of excessive salinity. In addition, about one-fifth of the world's cropland is suffering from some degree of desertification. Taken together, he concludes, the planet will lose about 100 million hectares of arable land between 1985 and 2000. . . .[1]

Greenhouse warming and climate change [can affect] . . . agricultural production. Coastal cropland in countries such as Bangladesh and Egypt is extremely vulnerable to storm surges. Such events could become more common and devastating, because global warming will cause sea levels to rise and might intensify storms. The greenhouse effect will also change precipitation patterns and soil moisture; while this may benefit some agricultural regions, others will suffer. . . .

Economic Decline

If we are interested in environment-conflict linkages, perhaps the most important potential social effect of environmental degradation is the further impoverishment it may produce in developing societies. . . . A great diversity of factors might affect wealth production. For example, increased ultraviolet radiation caused by ozone depletion is likely to raise the rate of disease in humans and livestock which could have serious economic results. Logging for export markets may produce short-term economic gain for the country's elite, but increased runoff can damage roads, bridges, and other valuable infrastructure, while the extra siltation reduces the

transport and hydroelectric capacity of rivers. As forests are destroyed, wood becomes scarcer and more expensive, and it absorbs an increasing share of the household budget for the poor families that use it for fuel. . . .

Population Displacement

Some commentators have suggested that environmental degradation may produce vast numbers of "environmental refugees." Sea-level rise may drive people back from coastal and delta areas in Egypt; spreading desert may empty Sahelian countries as their populations move south; Filipino fishermen may leave their depleted fishing grounds for the cities. The term "environmental refugee" is somewhat misleading, however, because it implies that environmental disruption could be a clear, proximate cause of refugee flows. Usually, though, environmental disruption will be only one of many interacting physical and social variables, including agricultural and economic decline, that ultimately force people from their homelands. For example, over the last three decades, millions of people have migrated from Bangladesh to neighboring West Bengal and Assam in India. While detailed data are scarce (in part because the Bangladeshi government is reluctant to admit there is significant out-migration), many specialists believe this movement is a result, at least in part, of shortages of adequately fertile land due to a rapidly growing population. Flooding, caused by deforestation in watersheds upstream on the Ganges and Brahmaputra rivers, might also be driving people from the area. In the future, this migration could be aggravated by rising sea-levels coupled with extreme weather events (both perhaps resulting from climate change).

Disrupted Institutions and Social Relations

The fourth social effect especially relevant to the connection between environment change and acute conflict is the disruption of institutions and of legitimized, accepted, and authoritative social relations. In many developing societies, the three social effects described above are likely to tear this fabric of custom and habitual behavior. A drop in agricultural output may weaken rural communities by causing malnutrition and disease, and by encouraging people to leave; economic decline may corrode confidence in the national purpose, weaken the tax base, and undermine financial, legal, and political institutions; and mass migrations of people into a region may disrupt labor markets, shift class relations, and upset the traditional balance of economic and political authority between ethnic groups.

The Capacity of Developing Countries to Respond: First-Stage Interventions

Can developing countries respond to environmental problems effectively enough to avert these negative social effects? The aggregate data on world food production might give us reason for optimism. Between 1965 and 1986, many developing regions suffered serious environmental problems, including erosion, salinization, and loss of land to urbanization. Yet global cereal production increased at 3 percent a year, meat and milk output increased 2 percent annually, while the rate for oil

crops, vegetables, and pulses was 2.5 percent. At the regional level, increased food production kept ahead of population growth, except in Africa, and local shortfalls were alleviated by exports from developed countries with huge surpluses. We might therefore conclude that developing countries have sufficient capacity, with intermittent assistance from Northern grain exporters, to respond to environmental problems.

But aggregate figures hide significant disparities in food availability among and within developing countries. Moreover, these figures are becoming less promising than they once were: many developing countries have already reaped most of the green revolution's potential benefit, and the rate of increase in global cereal production has declined by over 40 percent since the 1960s. For three successive years—from 1987 through 1989—estimated global cereal consumption exceeded production. Bumper grain crops were again harvested in 1990, but carry-over stocks can be depleted rapidly, and we remain within one or two years of a global food crisis.

Over the long term, the capacity of developing countries to respond effectively to the consequences of environmental change on agriculture will depend on the complex interactions within each society of . . . the society's prevailing land-use practices, land distribution, and market mechanisms within the agricultural sector. Market factors are especially relevant today as numerous developing countries are relinquishing state control over the marketplace, reducing government spending, and removing impediments to foreign investment. Economists often contend that—in a market economy with an efficient price mechanism—environmentally induced scarcity will encourage conservation, technological innovation, and resource substitution. Julian Simon, in particular, displays an unwavering faith in the capacity of human ingenuity to overcome scarcity when spurred by self-interest.[2] Many economists point to the success of the green revolution, which was often driven by market forces; it involved both new technologies and the substitution of petroleum resources (in the form of fertilizer) for inadequate or degraded nutrients in the soil. This argument supports the policies for market liberalization and "structural adjustment" currently promoted by international financial and lending institutions, such as the International Monetary Fund and World Bank. Below, however, I suggest why these policies will not be an effective response to environmental scarcity in the future.

CORNUCOPIANS AND NEO-MALTHUSIANS

Experts in environmental studies now commonly use the labels "cornucopian" for optimists like Simon and "neo-Malthusian" for pessimists like Paul and Anne Ehrlich.[3] Cornucopians do not worry much about protecting the stock of any single resource, because of their faith that market-driven human ingenuity can always be tapped to allow the substitution of more abundant resources to produce the same end-use service. . . .

Historically, cornucopians have been right to criticize the idea that resource scarcity places fixed limits on human activity. Time and time again, human beings

have circumvented scarcities, and neo-Malthusians have often been justly accused of "crying wolf." But in assuming that this experience pertains to the future, cornucopians overlook seven factors.

First, whereas serious scarcities of critical resources in the past usually appeared singly, now we face multiple scarcities that exhibit powerful interactive, feedback, and threshold effects. An agricultural region may, for example, be simultaneously affected by degraded water and soil, greenhouse-induced precipitation changes, and increased ultraviolet radiation. This makes the future highly uncertain for policymakers and economic actors; tomorrow will be full of extreme events and surprises. Furthermore, as numerous resources become scarce simultaneously, it will be harder to identify substitution possibilities that produce the same end-use services at costs that prevailed when scarcity was less severe. Second, in the past the scarcity of a given resource usually increased slowly, allowing time for social, economic, and technological adjustment. But human populations are much larger and activities of individuals are, on a global average, much more resource-intensive than before. This means that debilitating scarcities often develop much more quickly: whole countries may be deforested in a few decades; most of a region's topsoil can disappear in a generation; and critical ozone depletion may occur in as little as twenty years. Third, today's consumption has far greater momentum than in the past, because of the size of the consuming population, the sheer quantity of material consumed by this population, and the density of its interwoven fabric of consumption activities. The countless individual and corporate economic actors making up human society are heavily committed to certain patterns of resource use; and the ability of our markets to adapt may be sharply constrained by these entrenched interests.

These first three factors may soon combine to produce a daunting syndrome of environmentally induced scarcity: humankind will face multiple resource shortages that are interacting and unpredictable, that grow to crisis proportions rapidly, and that will be hard to address because of powerful commitments to certain consumption patterns.

The fourth reason that cornucopian arguments may not apply in the future is that the free-market price mechanism is a bad gauge of scarcity, especially for resources held in common, such as a benign climate and productive seas. In the past, many such resources seemed endlessly abundant; now they are being degraded and depleted, and we are learning that their increased scarcity often has tremendous bearing on a society's well-being. Yet this scarcity is at best reflected only indirectly in market prices. In addition, people often cannot participate in market transactions in which they have an interest, either because they lack the resources or because they are distant from the transaction process in time or space; in these cases the true scarcity of the resource is not reflected by its price.

The fifth reason is an extension of a point made earlier: market-driven adaptation to resource scarcity is most likely to succeed in wealthy societies, where abundant reserves of capital, knowledge, and talent help economic actors invent new technologies, identify conservation possibilities, and make the transition to new production and consumption patterns. Yet many of the societies facing the most serious environmental problems in the coming decades will be poor; even if they

have efficient markets, lack of capital and know-how will hinder their response to these problems.

Sixth, cornucopians have an anachronistic faith in humankind's ability to unravel and manage the myriad processes of nature. There is no *a priori* reason to expect that human scientific and technical ingenuity can always surmount all types of scarcity. Human beings may not have the mental capacity to understand adequately the complexities of environmental-social systems. Or it may simply be impossible, given the physical, biological, and social laws governing these systems, to reduce all scarcity or repair all environmental damage. Moreover, the chaotic nature of these systems may keep us from fully anticipating the consequences of various adaptation and intervention strategies. Perhaps most important, scientific and technical knowledge must be built incrementally—layer upon layer—and its diffusion to the broader society often takes decades. Any technical solutions to environmental scarcity may arrive too late to prevent catastrophe.

Seventh and finally, future environmental problems, rather than inspiring the wave of ingenuity predicted by cornucopians, may instead reduce the supply of ingenuity available in a society. The success of market mechanisms depends on an intricate and stable system of institutions, social relations, and shared understandings. . . . Cornucopians often overlook the role of *social* ingenuity in producing the complex legal and economic climate in which *technical* ingenuity can flourish. Policymakers must be clever "social engineers" to design and implement effective market mechanisms. Unfortunately, however, the syndrome of multiple, interacting, unpredictable, and rapidly changing environmental problems will increase the complexity and pressure of the policymaking setting. It will also generate increased "social friction" as elites and interest groups struggle to protect their prerogatives. The ability of policymakers to be good social engineers is likely to go *down*, not up, as these stresses increase.

NOTES

1. Smil gives a startling account of the situation in China. From 1957 to 1977 the country lost 33.33 million hectares of farmland (30 percent of its 1957 total), while it added 21.2 million hectares of largely marginal land. He notes that "the net loss of 12 million hectares during a single generation when the country's population grew by about 300 million people means that per capita availability of arable land dropped by 40 percent and that China's farmland is now no more abundant than Bangladesh's—a mere one-tenth of a hectare per capita!" See Smil, *Energy, Food, Environment*, pp. 223 and 230.
2. Simon, *The Ultimate Resource*. Population growth, by Simon's analysis, is not necessarily a bad thing; in fact, it may be helpful because it increases the labor force and the pool of potential human ingenuity. See also Ester Boserup, *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure* (Chicago: Aldine, 1965).
3. Ehrlich, Ehrlich, and Holdren, *Ecoscience*; Ehrlich and Ehrlich, *The Population Explosion*.

Beyond Kyoto

JOHN BROWNE

THE CARBON CHALLENGE

In 1997, more than 180 countries gathered in Kyoto, Japan, in search of a coordinated international response to global warming. The provisional agreement they reached appeared to mark a significant step forward. But the Kyoto Protocol is coming unraveled. Despite nearly a decade of effort, it may not even enter into force as a binding instrument. Canada, Japan, and the European Union—the most enthusiastic advocates of the Kyoto process—are not on track to meet their commitments. And the United States has withdrawn from the agreement entirely. Those concerned with the sustainability of the earth's climate could be forgiven for feeling depressed.

Clear-eyed realism is essential. But dismay, however understandable, is a mistaken reaction. There is scope for a different and more positive view of the last seven years and of the future. First, it has become obvious that Kyoto was simply the starting point of a very long endeavor—comparable, perhaps, to the meetings in 1946 at which a group of 23 countries agreed to reduce tariffs. Those meetings set in motion a process that led to the establishment of the General Agreement on Tariffs and Trade in 1948, which, in turn, led to the creation of the World Trade Organization in the mid-1990s. Second, we have improved, if still imperfect, knowledge of the challenges and uncertainties that climate change presents, as well as a better understanding of the time scales involved. Third, many countries and companies have had experience reducing emissions and have proved that such reductions can be achieved without destroying competitiveness or jobs. Fourth, science and technology have advanced on multiple fronts. And finally, public awareness of the issue has grown—not just in the developed world but all around the globe.

Seven years after the Kyoto meeting, it is becoming clear that the reduction of greenhouse gas emissions is a soluble problem, and that the mechanisms for delivering the solutions are within reach. In that spirit of cautious optimism, it is time to move beyond the current Kyoto debate.

KNOWNS AND UNKNOWNS

Before considering new approaches, it is necessary to distill some basic facts from the voluminous, complex, and incomplete scientific work on global warming.

From John Browne, "Beyond Kyoto." Reprinted by permission of *Foreign Affairs*, Vol. 83, No. 4 (July/August 2004), pp. 20–32.

Global temperatures have risen by about 0.6 degrees Celsius since the nineteenth century. Other measures of climate bolster the theory that the world is getting warmer: satellite measurements suggest that spring arrives about a week earlier now than in the late 1970s, for example, and records show that migratory birds fly to higher latitudes earlier in the season and stay later. According to the UN's Intergovernmental Panel on Climate Change (IPCC)—by far the most authoritative body of scientists working on this issue—humans are probably not responsible for all the measured warming. But the trend is undoubtedly due in large part to substantial increases in carbon dioxide emissions from human activity. Since the middle of the nineteenth century, the average concentration of carbon dioxide—a so-called greenhouse gas—in the world's atmosphere has risen from some 280 parts per million (ppm) to around 370 ppm. Burning fossil fuels account for about three-quarters of human emissions, with deforestation and changes in land use (mainly in the tropics) accounting for the rest.

There are two main reasons why it has been hard for societies to tackle climate change. First, carbon dioxide has a very long life span: it exists for hundreds of years in the atmosphere, making this a multigenerational issue. Second, reducing carbon dioxide in the atmosphere can be done only on a truly global basis, since emissions mix throughout the atmosphere much quicker than individual processes can limit their impact.

Beyond these known facts, the picture becomes murkier. For instance, nobody knows how rapidly emissions of carbon dioxide and other greenhouse gases will rise in the future. That outcome depends on the pace of global economic growth and on the impact of technology on the ways society generates and deploys useful energy. Equally, it is impossible to determine precisely how the climate will respond as greenhouse gases accumulate to ever-higher concentrations in the atmosphere. The brightness and altitude of clouds, for example, determine whether warming is amplified or diminished, yet it is not known how exactly climate change will affect cloud patterns. Nor is it known how the world's carbon cycle will respond. A warmer climate might make the planet greener—which would mean more carbon dioxide would be sucked from the atmosphere. Alternatively, climate change might impose such severe stress on the biosphere that nature's processes for removing carbon dioxide from the atmosphere would become less efficient than normal.

The most recent IPCC assessment, published in 2001, concludes that if no precautionary action is taken, carbon dioxide concentrations will rise by 2050 to between 450 and 550 ppm and will continue to increase throughout the twenty-first century. The IPCC estimates that temperatures will rise by between 0.5 degrees Celsius and 2.5 degrees Celsius by 2050, with an increase of 1.4 degrees to 5.8 degrees possible by 2100.

One of the most likely effects of global warming is a rise in sea level, as glaciers melt and warmer water expands in the oceans. The best projections suggest seas of between 5 centimeters and 32 centimeters higher by 2050; the outer limit projected for 2100 approaches one meter. These numbers seem small, but coastlines are shallow slopes, not firm walls, so a rise in water levels of just tens of centimeters would erase kilometers of wetlands and beaches.

Industrialized countries will probably be able to handle rising water levels, at least in the next few decades. London and cities in the Netherlands, for example, already have defenses to hold back surging seas. And farmers in wealthy countries can respond to changes in climate by adjusting irrigation and varying the crops they plant, in many cases with government financial support. But the developing world, home to four-fifths of humanity, is likely to fare considerably worse on both fronts. Hundreds of thousands of people have already been displaced by periodic flooding in Bangladesh, and subsistence farmers—who are far less adaptive than their richer counterparts—are already struggling at the climatic margin.

The most dramatic scenarios, although unlikely, would have grave consequences for humanity and ecosystems. Rapid changes in climate could upset the circulation of the North Atlantic, for example—which, ironically, would cause much colder regional temperatures in northern Europe by weakening the heat-rich Gulf Stream. The Amazon rain forest could deplete dramatically due to drying in the atmosphere, in turn releasing huge volumes of carbon that is stored in trees. And an accelerated rise in sea level from melting ice in Antarctica could occur. These uncertain consequences do not lead to crisp timetables for policy. But they mean that precaution and improvements in measurement and learning will be crucial.

A sober strategy would ensure that any increase in the world's temperature is limited to between 2 or 3 degrees Celsius above the current level in the long run. Focused on that goal, a growing number of governments and experts have concluded that policy should aim to stabilize concentrations of carbon dioxide in the atmosphere in the range from 500 to 550 ppm over the next century, which is less than twice the pre-industrial level.

On the basis of known technology, the cost of meeting this goal would be high. But the track record of technological progress in other fields indicates an enormous potential for costs to fall as new ideas are developed and applied. In the energy industry, for example, the costs of deep-water oil and gas development have fallen by a factor of three over the last 15 years, dramatically extending the frontier of commercial activity. There is no reason to think that research and development in the area of benign energy systems would be less successful. Predicting where that success might come will not be easy—but that means progress must be made on multiple fronts.

Many people believe that the 500–550 ppm goal would help avoid the worst calamities. But we must recognize this assessment for what it is: a judgment informed by current knowledge, rather than a confirmed conclusion to the story. . . .

EFFICIENCY AND TRANSFORMATION

Both the exact level of the peak in global carbon dioxide emissions over time and the subsequent decline are unknown. We can safely assume, however, that emissions from developing countries will keep rising as economic activity and incomes grow. . . . This means that leadership must come from the industrialized world.

In the short term, the developed world can use energy much more efficiently and profitably. With a clear impetus for change, business could put new technologies and services to use: cautiously at first, but more aggressively as the best systems are identified and put into practice with the normal turnover of capital.

Business has already found that it is possible to reduce emissions from its operations. Counterintuitively, BP found that it was able to reach its initial target of reducing emissions by 10 percent below its 1990 levels without cost. Indeed, the company added around $650 million of shareholder value, because the bulk of the reductions came from the elimination of leaks and waste. Other firms—such as electricity generator Entergy, car manufacturer Toyota, and mining giant Rio Tinto—are having similar experiences. The overwhelming message from these experiments is that efficiency can both pay dividends and reduce emissions.

Yet reducing emissions by . . . 25 billion tons per year in 2050 will require more than just efficiency improvements. Given the world's rising demand for energy, we must also transform the energy system itself, making fuller use of low-carbon fuels as well as carbon-free energy systems. Paradigm shifts must occur across the economy: transportation accounts for 20 percent of total emissions, industry contributes another 20 percent, the domestic and commercial sectors emit around 25 percent, and power-generation accounts for another 35 percent. A wide-ranging set of policies is thus called for.

In power generation, options include switching from coal to less-carbon-intensive natural gas. For example, 400 new gas plants, each generating 1,000 megawatts, would reduce emissions by one billion tons per year. Such a reduction would be difficult within the parameters of today's electricity systems—400,000 megawatts is roughly equal to all of China's electric power capacity, or half the installed capacity in the United States. Zero-carbon fuels would also help reduce emissions. If 200,000 megawatts of coal-generated power were to be replaced with nuclear power, carbon dioxide emissions would be reduced by one billion tons per year. Progress on the nuclear front will demand investment in new technologies, as well as a viable plan for locating reactors that ensures that radioactive materials are kept out of the environment and beyond terrorists' reach.

Coal, too, could be made carbon-free, using advanced power plants that gasify the fuel and then generate power while stripping away the carbon for sequestration underground. Coal gasification could become a huge growth industry. China is among the top investors in this technology, not just because these plants are much cleaner, but also because they could be keystones in a program to synthesize clean liquid fuels for transportation needs.

More efficient buildings would also result in large energy savings, since over one-third of today's energy is used indoors. Given that electrification is a central feature of industrial and postindustrial societies, innovators must tap the potential for ultra-efficient electrical appliances. Investment in a digitally controlled power grid could aid this effort by allowing major appliances to "talk" directly with power generators so that the whole system operates closer to its optimum potential. Such a "smart grid" would reduce losses in electricity transmission while also allowing fuller use of waste heat from power generators in factories and homes.

There are efficiency savings to be made in transportation too. Given the massive advantages of gasoline over rival fuels—both in terms of its power density and its ease of storage—transport is unlikely to switch to new fuels in the near future. More

promising approaches will focus on making transportation more efficient, while meeting the ever-stricter limits on other emissions that cause air pollution. For example, running 600 million diesel or gasoline cars at 60 miles per gallon (mpg) instead of 30 mpg would result in a billion fewer tons of carbon dioxide per year. Advanced ultra-efficient diesel engines, meanwhile, are so clean that even the strictest regulatory body in the world—the California Air Resources Board—is taking a second look. Advanced techniques for gasoline injection also hold promise, as do hybrid electric-gasoline cars already on the road. Such vehicles have the potential to get more than twice the mileage per gallon of their conventional counterparts. Given the increasing consumer demand for speed and flexibility in air travel, policymakers should also focus on the opportunities for cutting emissions from aircraft.

All of these efforts will require major investments. Some will also require new infrastructures. But we must begin to build and test such systems. Only with evidence from actual experience can we decide how best to direct our efforts.

DOWN TO BUSINESS

The role of business is to transform possibilities into reality. And that means being practical, undertaking focused research, and testing the different possibilities in real commercial markets. The energy business is now global, which offers a tremendous advantage: international companies access knowledge around the world and apply it quickly throughout their operations.

But the business sector cannot succeed in isolation. Harnessing business potential requires fair and credible incentives to drive the process of innovation and change. In responding to global warming, that role must fall to the government. Neither prescriptive regulations nor fiscal interventions designed to collect revenue rather than to alter behavior provide the answer. Rather, governments must identify meaningful objectives and encourage the business sector to attain them by using its knowledge of technology, markets, and consumer preferences.

Recent experience suggests that emissions trading regimes—whereby government sets a binding cap on total emissions, dividing the total into "emission credits" that are given to those who emit carbon dioxide—are the best policy for encouraging business. Policymakers (notably in the United States) have demonstrated that it is possible to design such systems for other pollutants, such as sulphur dioxide, thereby harnessing the power of innovation and the flexibility of the market to protect the environment, while avoiding crippling costs. The same insights should apply to carbon dioxide. A well-designed trading regime would include a strictly enforced cap, which would make carbon dioxide emission credits scarcer (and thus more valuable) and would thereby increase the incentive for business to control emissions. Such a system would also allow firms and households the flexibility to apply resources where they have the greatest impact, which is essential, because the best measures for controlling carbon dioxide are hard to anticipate with precision and are widely dispersed across the economy. And a credible emission trading system would create incentives to invest in radical new technologies, the kind that will be crucial in building a carbon-free energy system in the future.

Emissions trading systems need not be identical in every country, nor be applied universally from day one. The political reality is that we are unlikely to see the sudden emergence of a single regime; in scope and ambition, that would be comparable to the emergence of a single global currency. Instead, progress is much more likely to come through the gradual process of knitting together diverse national and regional efforts on the basis of their track records of experience and achievement. The key task today is to find practices that will lead to a system that will enable today's diverse and fragmented reduction efforts to be valued on a common basis. The history of trade liberalization over the second half of the twentieth century shows that gradualism can yield impressive results.

At present, the nascent European emission trading system . . . is the most advanced example. Built on sound monitoring and verification policies, the system is the centerpiece of the European effort to implement the commitments adopted at Kyoto. . . . The potential for extending the scope of the trading base is indeed considerable, not least through the incorporation of effective incentives that will reward businesses whose investments reduce emissions outside Europe, such as in Russia and the emerging market economies of Asia—where large and relatively low-cost reductions of emissions are possible.

Markets are emerging in other regions as well. The Chicago Climate Exchange, opened in December 2003, involves 19 North American entities that have agreed to reduce their emissions by one percent per year over four years. Canada may yet create a market for carbon dioxide as it aims to meet the Kyoto targets. And U.S. states have become laboratories for innovation and change. For example, Massachusetts, New York, and New Hampshire are adopting rules that will spur the creation of market-based emission trading systems. Voluntary systems for measuring emissions—such as one being crafted in California—may also provide further foundations for emission trading. There is a strong argument for linking these efforts. U.S. policymakers should also consider establishing a transatlantic partnership to work toward a common market-based trading system.

Offering positive incentives is one key contribution that government can make to stimulate business. Another is organizing research. It is crucial to extend our understanding of the science of climate change: monitoring key variables with sufficient precision to understand both natural variability and the climate's response to human activity. A key target of such work must be to understand the precise connection between the concentration of carbon dioxide in the atmosphere and changes in climate. Such research must also advance our knowledge of available choices: with the clock ticking, we cannot wait for definite answers before we take action.

Government intervention must take other forms too. Transforming the energy system will require new technologies with risks that will be too high (and benefits too remote) for private firms to provide all the needed investment. This is one area in which the United States, with its outstanding technical capacity, should take a leadership role. Innovation will require an across-the-board infusion of resources for basic science and technology, as well as the development of a portfolio of key demonstration projects. The priorities for such work might include photovoltaic cells (which convert sunlight into electricity), fission reactor technology, energy from biomass, and the use of hydrogen.

Given the costs and risks involved in such investment, governments with common interests and common views of the future have every incentive to combine their efforts and resources. Fortunately, there are many precedents of international partnerships in innovation—from high-energy physics to astronomy and nuclear fusion. The global warming challenge is different, in that it involves not only basic science but also the application of novel techniques through products that must withstand the test of competition. But that is why the program of research and development work should involve collaboration not just between different countries but also between governments and business.

There are examples of such collaborative work already underway. In November 2003, a ministerial-level meeting held in Washington, D.C., began the process of building international partnerships for research on the potential of the hydrogen economy. The United States has already pledged $1.7 billion over the next five years for work in this area. A similar collaboration—the International Carbon Sequestration Leadership Forum—is built around the concept of capturing carbon and storing it geologically. Again, this scheme complements programs in the United States, such as FutureGen, a $1 billion public-private partnership to promote emissions-free coal-fired electricity and hydrogen production. These research efforts are a good start, but they must go hand-in-hand with the creation of credible caps on emissions and trading systems, which will create the incentives to transform the energy system.

DEVELOPING SOLUTIONS

It would be morally wrong and politically futile to expect countries struggling to achieve basic levels of development to abandon their aspirations to grow and to improve their people's living standards. But it would be equally wrong to ignore the fact that by 2025, energy-related carbon dioxide emissions from developing countries are likely to exceed those from the member states of the Organization of Economic Cooperation and Development. Instead of being daunted by the scale of this challenge, policymakers must recognize the scale of the opportunity: developing countries have the potential to leapfrog the developed world's process of industrialization, thereby providing an enormous opportunity to improve energy efficiency and reduce emissions.

So far, most international efforts to engage developing countries have focused on the Kyoto Protocol's Clean Development Mechanism (CDM)—a scheme that would encourage investment by awarding emission credits for the quantity of emission reductions flowing from a particular project. In principle, the CDM was a good idea. In practice, it has become tangled in red tape and has required governments and investors to do the impossible: estimate the level of emissions that would have occurred in the absence of a project and then to calculate the marginal effect of their actions. The only projects that can meet this test are small and discrete: a steel mill that uses sustainably grown wood instead of coal for coke, for example, or a tiny hydroelectric dam that averts the need to build a coal-fired power plant. Such efforts are important, but they are hardly the stuff of radical transformation.

There is no neat, off-the-shelf solution for engaging the developing world. But there are encouraging signs of the process of economic development acting as a force for modernization. In China and India, infrastructure necessary to substitute natural gas for coal is already being put in place. And in many of the oil-producing regions of the world, the spread of international technology is making it possible to capture and reinject the natural gas that is often associated with oil, rather than venting or flaring it into the atmosphere. Efforts to change the incentives that govern land use in the developing world are also encouraging. From the Congo Basin to the Amazon and the forests of Southeast Asia, practical partnerships of governments, nongovernmental organizations, and businesses are showing the way. Small amounts of money and skillfully designed incentives are stemming the tide of deforestation by creating a stake in protecting the forests.

These and other efforts reflect the determination of publics, governments, and business to transcend the harsh and unacceptable trade-off between the desire to improve living standards and allow people the freedom to use energy for heat, light, and mobility on the one hand, and the desire for a clean environment on the other.

UNFINISHED BUSINESS

The appropriate response to the faltering Kyoto Protocol is neither dismay nor fatalism. A complete international agreement on a subject of such complexity and uncertainty is still a long way off. But as those who championed the cause of liberal trade found after that first meeting in 1946, great causes acquire lives of their own. Consolidated political agreements often follow, rather than lead, the realities on the ground.

Taking small steps never feels entirely satisfactory. Nor does taking action without complete scientific knowledge. But certainty and perfection have never figured prominently in the story of human progress. Business, in particular, is accustomed to making decisions in conditions of considerable uncertainty, applying its experience and skills to areas of activity where much is unknown. That is why it will have a vital role in meeting the challenge of climate change—and why the contribution it is already making is so encouraging.