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Risk in Perspective

Global Climate Change: Are We Over-Driving Our Headlights?

"A sequential risk-management framework provides a rational approach to global climate change."

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The chance that human actions will alter global climate is one of the most serious environmental risks. The probability of significant change is difficult to assess, but most scientists who have studied the issue believe that continued emissions of carbon dioxide, methane, and other "greenhouse gases" to the atmosphere will increase the average air temperature at the Earth's surface and modify other aspects of climate. Changes in temperature, precipitation, and storm patterns are likely to differ between regions, seasons, and even between daytime and nighttime. The consequences for humans and wildlife are equally uncertain, although it is likely that some changes will be harmful and others beneficial. As both humans and ecosystems might, to some extent, adapt to otherwise harmful changes, the rate of change could be as important as its ultimate magnitude. In this issue of RISK IN PERSPECTIVE, I briefly describe the risk and suggest a way to frame the policy issue.

The Enhanced Greenhouse Effect

In addition to its primary constituents, nitrogen and oxygen, the atmosphere contains a number of gases that are present in only tiny proportions. Among these minor and trace gases, water vapor, carbon dioxide (CO_2), and ozone are important in shaping the Earth's climate. These gases allow the sun's visible, ultraviolet, and near-infrared radiant energy to penetrate to the Earth's surface, but trap the outgoing infrared radiation emitted by land and ocean, thus containing this energy within the Earth system. Without an atmosphere, the temperature at the Earth's surface would average 32° C lower than its current 15° C (59° F, about the annual average at Santa Barbara, CA and Charlotte, NC). At this temperature, water would freeze and life as we know it could not exist.

There is no doubt that CO_2, water vapor, and other trace gases keep the Earth's surface warmer than it would otherwise be. That is not at issue. The debate concerns the enhancement of this "greenhouse" effect by increasing atmospheric concentrations of greenhouse gases (GHGs) released through human activities. The major enhanced GHG is CO_2, which is released primarily through combustion of fossil fuels, with additional amounts from deforestation and cement production. Significant additional contributions to the greenhouse effect are due to methane, produced by sheep, cattle, and other ruminant (cud-chewing) animals, termites, rice paddies, landfills, leaking natural-gas pipelines, coal mining, and other sources; nitrous oxide (from agriculture and combustion); and various chlorofluorocarbons (CFCs) and related industrial compounds. Ironically, CFCs' direct greenhouse effect is roughly offset by their destruction of stratospheric ozone, itself a greenhouse gas, but the newly developed CFC substitutes also contribute to the greenhouse effect without providing this offsetting "benefit."

Although they have varied on geologic time scales, atmospheric concentrations of CO_2 and other GHGs have been fairly constant during the period when human civilization developed, until the nineteenth century when massive fossil-fuel combustion began with the Industrial Revolution. On current trends, concentrations of CO_2 and other anthropogenic GHGs will reach the greenhouse-equivalent of twice their pre-industrial level by the middle of the twenty-first century, and double again by 2100. The equilibrium effect of the first doubling is judged to be a 1.5 to 4.5° C increase in the annual average temperature at the Earth's surface. Interestingly, no explicit probability assignment is given to this range, which has persisted in numerous expert-panel reports since its introduction in a 1979 report of the U.S. National Academy of Sciences.

Climate Variation and Consequences

Despite the prominence given to estimates of global mean surface temperature, climate change is not anticipated to increase temperature uniformly, but rather to change climate in ways that vary both regionally and seasonally. Information on the potential changes comes from General Circulation Models (GCMs) and from records of past climate preserved in tree rings, sedimentary pollen, and air bubbles trapped deep in Antarctic and Greenland glaciers. Although these sources sometimes contradict one another, the general impression is one of warmer and wetter winters at high latitudes, with less change in summer and in the tropics. While this pattern of change appears relatively benign, drier and hotter summers in mid-continental agricultural areas—such as the U.S. grain belt—and unpredictable changes in the Asian monsoon are probable.

Sulfate emissions from fossil-fuel combustion may offset greenhouse warming over the industrialized regions, potentially altering global atmospheric circulation. Reductions in sulfate emissions may actually accelerate anthropogenic warming.

Global warming could also lead to a rise in sea level from expansion of warming seawater, with some contribution from melting glaciers. Current estimates are that sea level might rise about two-thirds of a meter over the next century. Earlier concerns about a 10 meter rise due to melting of Antarctic glaciers have subsided, and Antarctic glaciers may actually lock-up more of the Earth's water if warmer winters lead to heavier snowfall there.

From a policy perspective, arguably the key uncertainty is the seriousness of these changes, and the extent to which humans should divert resources from other goals to prevent or limit them. A number of studies have attempted to estimate the economic effects of changes in agricultural production, loss of land area to sea-level rise, and effects on health associated with worsened air pollution, possible spread of tropical-disease vectors, and heat stress. For industrial nations like the United States, where only a small share of economic activity is sensitive to climate, economic costs of a 3° C global warming have been estimated as something less than 1% of GDP, a big number but representing a minuscule reduction in the economic growth rate over several decades. Losses in developing countries, whose populations are closer to subsistence levels and are more heavily dependent on agriculture, fisheries, and other climate-sensitive sectors, are likely to be larger, relative to GDP, and displacement of "environmental refugees" from their homelands could contribute to civil strife.

Threats to wildlife may be more far-reaching than those to human society. Plant and animal species can migrate in response to changing conditions, but a variety of topographical obstacles, including roads and cities, pose formidable barriers. As illustrated by ongoing debates about protection of endangered species, the extent to which humans should compromise other objectives to preserve natural habitats and species is highly controversial. There is also the possibility that human society is far more dependent on natural environmental services than conventional estimates acknowledge.

The severity of climate change depends on whether it would be gradual, allowing valuable time to adapt agricultural, water-supply, and other infrastructure, or manifest as a series of abrupt shifts. One potential abrupt change might dramatically shift ocean circulation, shutting down the Gulf Stream and cooling western Europe. Recent findings from Greenland ice cores suggest that large and rapid climatic shifts have occurred before.

Abatement Options

While the risks of climate change are profoundly uncertain, so too are the costs of preventing or limiting it. Greenhouse-gas emissions result from a number of activities that are fundamental to modern society, especially reliance on fossil fuels. Although substitutes, in the form of nuclear, solar, and biomass energy sources and energy conservation exist, fossil fuels are currently much preferred for many applications, and weaning the world economy from them—at least in the near term—would be difficult and costly. Current estimates of the costs of simply preventing increases in GHG emissions as populations and economies grow are comparable to estimates of the costs of climate change—a few percent of GDP.

These estimates are highly uncertain. Future emissions depend on growth in populations and economic activity, the composition of economic activity (production of energy-intensive commodities like steel, aluminum, and transportation, for example), and changes in energy and other technologies that would occur due to innovation, depletion of low-cost oil reserves, environmental concerns, and other social forces.

Other, more speculative, measures for reducing the risk have been proposed. Many of these involve "geoengineering," or large scale modification of Earth systems. For example, proposals have been made to offset increasing CO_2 emissions by fertilizing the southern oceans with iron to stimulate the growth of phytoplankton, which absorb carbon through photosynthesis and store it in the deep ocean as they sink, or to offset the greenhouse effect by scattering aerosols in the upper atmosphere or placing giant mirrors in orbit.

Global Risk Management

From a risk-management perspective, three aspects of the greenhouse problem are fundamental: uncertainty, the prospect of learning, and the long time lags associated with the climate system.

There is tremendous uncertainty about all aspects of the problem—what future emissions of greenhouse gases will be in the absence of explicit climate policy, how those emissions would alter the climate, what effects an altered climate would have on human activities and ecosystems, what humans are willing (or should be willing) to trade for limiting climate change, and what it would cost, in foregone opportunities, to do so.

We can expect to reduce these uncertainties over time. Substantial research is ongoing in many countries. The U.S. Global Change Research Program, for example, has a FY95 budget of $1.8 billion. The Intergovernmental Panel on Climate Change (IPCC) coordinates the efforts of several hundred scientists worldwide and provides an effective institution for evaluating and summarizing new results and making them accessible to policy makers. Learning can be expected to progress through detailed observation of the climate system, theoretical, laboratory, and field study, and enhancement of computer-simulation models. Even if these forms of research are unsuccessful, ongoing monitoring programs will yield important information about whether or not the climate is changing over the next decades.

The climate system has tremendous inertia. This cuts two ways. Beneficially, changes in climate will lag increases in atmospheric GHG concentrations by years or decades, because the oceans have tremendous thermal capacity. This thermal inertia should act like a giant flywheel, cushioning against abrupt changes and creating the possibility that high near-term emissions can be offset by subsequent reductions before serious harm results.

But considering what is required to move people to action, inertia can be a hindrance. By slowing climate change, the oceanic heat sink may delay recognition that global warming is occurring until human actions commit the Earth to serious climate change, if they have not already. Carbon dioxide and other GHGs remain in the atmosphere a century or longer. Combined with the ocean's thermal inertia, this produces a "warming commitment"—the difference between the current climate and the climate that will exist when the ocean catches up to the current atmospheric composition.

Sequential Policymaking

The risk of climate change is like driving a car on a dark road: one must proceed slowly to avoid obstacles when they become illuminated by the headlights. Current policy should include a portfolio with the following elements:

- Restrict near-term GHG emissions, to limit the buildup of the warming commitment until the danger it poses is better understood;
- Encourage innovation to reduce the cost of limiting climate change (alternative energy sources, for example) or to make it easier to adapt to change (improved climate forecasting, more resilient agriculture and water supplies);
- Stimulate research to better understand the causes and consequences of climate change and encourage a global discussion of the issues and how best to manage them.

There is an important precedent for this stepwise management approach—the Montreal Protocol on stratospheric-ozone depletion. Signed in 1987, this landmark agreement committed most of the nations of the world to limit CFC emissions. Significantly, the Protocol committed signatories to periodic assessments of the unfolding science of ozone depletion, with the understanding that the initial CFC control provisions would be modified in light of new information. To date, three such assessments have been conducted and the scope and stringency of emission controls have been substantially strengthened. Managing the risks of climate change will be much harder, because the activities that produce it are even more pervasive in human society than the CFCs that deplete ozone, but a sequential risk-management framework provides a rational approach to the problem.

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Further Readings

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