5. The Economic Costs (Benefits?) of a Warmer World

Casual analysis of the economic effects of climate change demonstrates that most modern industries are relatively immune to weather. Climate affects principally agriculture, forestry, and fishing, which together constitute less than 2 percent of U.S. gross domestic product (GDP). Manufacturing, most service industries, and nearly all extractive industries remain unaffected by climate shifts. Factories can be built in northern Sweden or Canada or in Texas, Central America, or Mexico. Higher temperatures will leave mining largely untouched; oil drilling in the northern seas and mining in the mountains might even benefit. Banking, insurance, medical services, retailing, education, and a variety of other services can prosper as well in warm climates (with air conditioning) as in cold (with central heating). A warmer climate will lower transportation costs: less snow and ice to torment truckers and automobile drivers; fewer winter storms to disrupt air travel—bad weather in the summer has fewer disruptive effects and passes quickly; a lower incidence of storms and less fog will make shipping less risky. Fuel consumption for heating will decline, while that for air conditioning will increase.

Inhabitants of the advanced industrial countries would scarcely notice a rise in worldwide temperatures. As modern societies have developed a larger industrial base and become more service oriented, they have grown less dependent on farming, thus boosting their immunity to variations in weather. A few services, such as tourism, may be susceptible to temperature or precipitation alterations: a warmer climate would be likely to shift the nature and location of pleasure trips. Ski resorts, for example, might face less reliably cold weather and shorter seasons. Warmer conditions might also mean that fewer northerners would feel the need to vacation in Florida or the Caribbean. On the other hand, new tourist opportunities might

develop in Alaska, northern Canada, and other locales at higher latitudes or upper elevations.

In many parts of the world, warmer weather should mean longer growing seasons. Should the world warm, the hotter climate would enhance evaporation from the seas, leading most probably to more precipitation worldwide. Moreover, the enrichment of the atmosphere with CO_2 would fertilize plants and make for more vigorous growth. Agricultural economists studying the relationship of temperatures and CO_2 to crop yields have found not only that a warmer climate would push up yields in Canada, Australia, Japan, northern Russia, Finland, and Iceland but also that the added boost from enriched CO_2 fertilization would enhance output by 17 percent (Wittwer 1995, 1997).

Several scientists have recently reported that the increased concentration of CO_2 has produced an increase from 1981 to 1991 in plant growth in the northern high latitudes (Myneni et al. 1997). More vigorous plant development, while possibly choking out a few species, provides a more plentiful habitat for animals.

Rising sea levels would, of course, impose costs on low-lying regions, including a number of islands and delta areas. For the United States—assuming a three-foot rise in sea level, at the high end of predictions for the year 2100—economists have estimated the costs of building dikes and levees and the loss of land at $7 billion to $10.6 billion annually, or less than 0.2 percent of GDP (Cline 1992, 109). For some small island nations, of course, the problems could be much more severe and their hardships should be addressed.

Past Studies

Few studies have evaluated the costs and the benefits from warming on human activity. Most have found only small costs to the advanced nations; even the rest of the world would suffer little. At least one major research effort, the U.S. Department of Transportation (DOT) study, has concluded that a warmer world would confer benefits on Americans.

Department of Transportation Study

The last two chapters discussed the 1974 U.S. Department of Transportation's findings on how climate affected health care expenditures and preferences of workers for various cities. The third gathering,

held in February 1974, examined the implications of climate change for the economy. The DOT study brought together scholars from around the world (Broderick and Hard 1974). They included researchers from the following institutions: American Geophysical Union, Boston College, Boston University, Brookhaven National Laboratory, Colorado State University, Cornell University, Florida State University, Harvard University; Illinois Institute of Technology Research Institute, Institute for Defense Analysis, Lawrence Livermore Laboratory, Los Alamos Scientific Laboratories, Massachusetts Institute of Technology, Mitre Corporation, National Academy of Sciences, National Resource Council of Canada, New York University, North Dakota State University, Ohio State University, Pennsylvania State University, Princeton University, RAND Corporation, Rice University; Sandia Laboratories, Scripps Institute of Oceanography, Stanford Research Institute, Stanford University, Temple University, University of Colorado, University of California at Los Angeles, University of California at Riverside and at Berkeley, University of Florida, University of Kentucky, University of Illinois, University of Maryland, University of Michigan, University of Missouri, University of Pittsburgh, University of Rhode Island; University of Texas at Dallas, University of Washington, University of Wyoming, Utah State University, Wayne State University, Yale University; and in addition several Canadian, French, Russian, Polish, Japanese, and other foreign universities and research institutes. Clearly a comprehensive body of researchers contributed to the project.

Table 5-1 summarizes the findings of the DOT research. The numbers have been brought up to 1990 levels to reflect inflation over the period. As may be seen, cooler weather would be costly for the United States, while a warmer climate would produce small but positive benefits.

The Environmental Protection Agency Study

In September of 1986, after Senate hearings on the problems of global climate change, the Senate Committee on Environment and Public Works wrote the Environmental Protection Agency (EPA) requesting two studies, the first to examine the ''health and environmental effects of climate change. This study should include, but not be limited to, the potential impacts on agriculture, forests, wetlands, human health, rivers, lakes, and estuaries as well as other ecosystems

Table 5-1
ECONOMIC COSTS OF COOLING AND WARMING: DOT STUDY BY RALPH D'ARGE
(billions of 1990 dollars)

Impact	**−2°F**	**+0.9°F**
Corn production	+	−
Cotton production	−9.0	+
Wheat production	−8.7	
Rice production	−3.0	
Forest production	−2.1	
Douglas fir production	−1.5	
Marine resources	−4.5	
Water resources	+	−
Health impacts	−12.4	
Wages	−19.1	8.0
Residential, commercial, and industrial fossil fuel demand	−0.9	0.5
Residential and commercial electricity demand	3.9	−1.8
Housing and clothing expenses	−2.6	1.3
Public expenditures	−0.1	0.1
Corn Belt investment costs	−0.3	
Total	−$51.5	$8.0

SOURCE: D'Arge 1974, 568, table 1.
NOTE: Gains and losses of less than a billion are simply indicated by + and −.

and societal impacts'' (letter to Lee Thomas 1986). The second study was to examine policy options that could stabilize current levels of greenhouse gas emissions.

The resulting study of the effects of climate change is a curious work. There is no reference to the earlier work done by the Department of Transportation, although it had been published only 12 years earlier. Unlike the DOT Climatic Impact Assessment report, which, as the previous section indicated, was conducted by serious scholars from around the world, the EPA report was crafted almost entirely by EPA staffers or their consultants.

The few outside experts called on by the EPA came from only a handful of organizations, most of them not in the top rank of research institutions. Even though the agency drew on scholars from Oregon

State University, University of California at Santa Barbara and at Davis, San Francisco State University, and the University of Delaware, no participant was connected with such major research centers as Stanford, Harvard, MIT, University of California at Berkeley, University of Michigan, National Academy of Sciences, Yale, or Princeton. The EPA study included no economists and produced few figures on the costs of warming.

Interestingly the authors of the EPA study assert that ''the cities with the highest average number of summer deaths are in the Midwest or Northeast, and those with the lowest number are in the South'' (Smith and Tirpak 1989, 224-5). This adds to the evidence in Chapter 3 that people adapt to warm weather but not to cold. Although the authors do say warming would reduce mortality slightly, overall the EPA's chapter on health appears to have chosen selectively those medical problems aggravated by high temperatures and generally ignored the effect of warmer winters.

Even though the discussion in the chapters suggests dire consequences, the EPA report to Congress fails to give any estimates of the costs of global warming. The chapters dealing with the effects cover Forests, Agriculture, Sea Level Rise, Biological Diversity, Water Resources, Electricity Demand, Air Quality, Human Health, Urban Infrastructure and regional studies of California, the Great Lakes, Southeast, and the Great Plains. The Report's findings on forests are typical:

> Global warming could significantly affect the forests of the United States. Changes could be apparent in 30 to 80 years, depending upon the region, the quality of the site, and the rate of climate change. There may be northward shifts in species ranges, dieback along the southern reaches of species ranges, and changes in forest productivity (Smith and Tirpak 1989, 71).

The other chapters have summary conclusions similar to those on forests. All predictions are hedged with ''could,'' ''may,'' and offsets, such as CO_2 fertilization acknowledged but played down. The major exception is for Sea Level Rise, which projects, for a one-meter rise (about three feet) of the oceans, a capital cost of $73 billion to $111 billion to prevent erosion and inundation through bulkheads, levees, and pumping sand (Smith and Tirpak 1989, 123). For the more likely one-foot increase, the total capital cost would be between $24 billion

Table 5-2
WILLIAM NORDHAUS'S ESTIMATES OF THE IMPACT OF DOUBLING OF CO_2 FOR VARIOUS SECTORS

Sectors	Billions of 1990 Dollars
Severely impacted sectors:	
Farms (warming and CO_2 fertilization)	−15.2 to +13.9
Forestry, fisheries, other	small + or −
Moderately impacted sectors:	
Construction	+
Water transport	?
Electricity demand	−2.4
Nonelectric heating	+1.7
Water and sanitary	− ?
Sea level rise damage:	
Loss of land	−2.2
Protection of sheltered areas	−1.3
Protection of open coasts	−4.1
Hotels, lodging, recreation	?
Total	−$8.9 billion

SOURCE: William Nordhaus 1991, 932, table 6.

and $37 billion. Spread over 50 years and at a 3 percent real interest rate, the annual cost would be slightly more than $1 billion per year.

Nordhaus Study

A few economists have made separate studies of the effect of climate change on the United States. William Nordhaus, professor of economics at Yale University, for example, has done some of the best work on this issue (Nordhaus 1991, 920-37). After a careful analysis of the effects of global warming on the United States, he found that the total loss for the United States from a doubling of CO_2 would be roughly 0.26 percent of national income (Nordhaus 1991, 932, table 6). In the 1990 economy, that would be about $14.4 billion. Table 5-2 gives Nordhaus's estimate with the dollars changed to 1990 levels, using the GNP deflator. The total in the table is smaller than the $14.4 billion because the individual items are not adjusted for the growth in the economy from 1981 to 1990.

Nordhaus claims that the figures underestimate the cost of warming because they fail to reflect nonmarketed goods and services, such as human health, biological diversity, amenity values of life and leisure, and environmental quality. As earlier chapters have indicated, health and amenity values would be benefited by warming, not harmed; and the dollar loss from reduced biodiversity would be very small.

Air pollution, particularly smog, might increase as a result of more hot weather; but the cost to the public, while unmeasurable, is probably small. Los Angeles, with the worst smog in the nation, still attracts millions of people. Although Nordhaus acknowledges that the National Research Council in 1978 found substantial amenity benefits from global warming (Nordhaus 1991, 932; NRC 1978), he arbitrarily quadruples his estimate of the costs of warming to 1 percent of world income to reflect the unmeasured sectors, even though he admits that one study found large *benefits* from warming for one of those areas. Nordhaus then writes, ''My hunch is that the overall impact upon human activity is unlikely to be larger than 2 percent of total output.'' How he got from one-quarter of 1 percent of GDP to 2 percent, he fails to explain; it seems to be nothing more than an exercise at arriving at a more politically expedient figure. Inexplicably, given his modest cost estimates, Nordhaus sponsored and signed the ''Economists' Statement on Climate Change,'' which urged the government to take action to slow the emission of greenhouse gas emissions. There was also an ''Economists' Statement on Climate Change'' sent to President Clinton in 1997.

Cline Study

William Cline of the Institute for International Economics has produced one of the most extensive treatments of the subject (Cline 1992). Even though he is a strong advocate of taking action now to slow greenhouse gas emissions, after examining a number of sectors he concludes that the results of warming would be small. To achieve a benefit/cost ratio greater than 1, that is, a measure where the benefits from abating CO_2 exceed the costs, he inflates the benefits from avoiding climate change to take into account unaccounted costs. Cline first estimates the benefit/cost ratio at 3:4, that is, for every $3 of benefits, there would be $4 of costs, and writes, ''The benefits of damage avoidance do not quite cover costs'' (Cline 1992,

8). He then goes on to apply arbitrary weights to boost the benefits, managing in this way to boost the benefit/cost ratio above 1. He has abatement costs peaking at 3.5 percent of GNP in 2040 and 2.5 percent for the rest of the century. To really justify and reinforce his advocacy of abatement, however, he extends his forecasts out 300 years to 2300, a time period of which we can have no knowledge (Cline 1992, 4).

To vindicate further his call for emission reductions, Cline tends to use higher than the usual estimate of 4.5°F warming in his text but then labels his table specifying the cost of warming as attributable to a rise of 4.5°F. He often resorts to the 300-year predictions of 18°F warming to achieve meaningful losses.

As stated, any forecast based on 300 years must be considered speculation. We can have no idea what the world will look like then and there is no way for us to know. Three hundred years ago, the chief means of transportation was by foot or, for the more affluent, by a horse-drawn carriage; wood was the main fuel; energy was produced with human effort or through animals; life expectancies were about 40 years; electricity was unknown; real democracy was unimagined. With change occurring ever more rapidly, what will the world look like 300 years hence?

Cline's discussion of farming stresses drought but never once mentions the forecasts that world rainfall would increase. In his section on the construction sector, however, he quotes predictions by the General Circulation Models of 8 to 15 percent increase in rainfall. According to his book, it would rain on residential and commercial building, thus limiting any benefits; but it would not rain on farms, thus leading to more devastating droughts! He says that there would be an increase in precipitation in winter in mid-latitudes and a year-round rainfall boost in the high latitudes and in the tropics (Cline 1992, 122). At an American Economic Association session in January 1995, dealing with a forthcoming IPCC report, he asserted that drought would make water pollution more of a problem. In fact, since rainfall would rise, the reverse is true.

In leisure activities, he stresses skiing losses without mentioning that most outdoor activities, such as camping, golf, tennis, canoeing, hiking, and bicycling, would benefit from warming. Those activities absorb the time of more people than does skiing, which is one of the least popular outdoor recreational activities. Most people in the

mid-latitude countries take their holidays in the summer; if they take them in the winter, it is to go South in search of warmth and sunshine. Nevertheless, Cline emphasizes skiing and its loss, ignoring that skiing can move north and that, with added precipitation, skiing might improve—the major difficulty most resorts experience today is lack of snowfall, not temperatures that are too warm. Although I am a fervent skier, the data show that most consumers are not and that they prefer warm weather recreation. At worst, it would seem that climate warming would produce a transfer of benefits from skiing to other forms of recreational activities.

Cline also stresses the areas that would receive less rainfall as opposed to those that would receive more. He expatiates on the Sacramento basin—a semiarid region and far from typical—and emphasizes that there would be less summer runoff as a result of less snowfall in the mountains. He fails to take into account the increase in winter runoff, which is just as good for filling reservoirs.

In discussing possible damage to water supplies, Cline asserts that ''summertime precipitation would be unlikely to rise in mid-latitudes'' (Cline 1992, 126). Four pages earlier he had written that there would be an *increase* in winter precipitation in mid-latitudes. He argues that there would be less cloud cover, yet acknowledges that the models predict greater total rainfall. If there is more rainfall, there must be more clouds. Actually the computer models are unable to predict where and how much rainfall will result from climate change. Any speculation about too little or too much rainfall in the winter or the summer or over the mountains or in California's Central Valley is just that, speculation.

Table 5-3 shows his estimates for the cost of global warming plus my own. I have reworked his figures and added other data to present another view and, in my opinion, a more accurate portrayal of the costs and benefits of climate change. The following sections describe the process used to arrive at the estimates. Two sectors of the economy that Cline ignored have been added; they are enclosed in brackets. The table values the human lives saved, as reported in Chapter 3 above, at $1 million each. Where the gain or loss is smaller than half a million, + and − are indicated in the table. The calculations also use the most conservative valuation of people's preferences for a warm climate. Under that conservative scenario, Americans would gain from a warmer climate about $100 billion dollars per year!

Table 5-3
ANNUAL BENEFITS (+) OR DAMAGES (−) FROM GLOBAL WARMING FOR THE UNITED STATES
(billions of 1990 dollars)

Activity	Cline	Moore
Agriculture	−17.5	+
Forest loss	−3.3	+
Species loss	−4.0	−1.0
Sea level rise		
Construction of dikes, levees	−1.2	−0.6
Wetland loss	−4.1	−1.1
Dryland loss	−1.7	−0.4
Energy for heating and cooling residential homes and businesses	−9.9	+12.2
Human amenity		+10.0
Human life	−5.8	+40.0
Human morbidity		+37.0
Migration	−0.5	+0.2
Hurricanes	−0.8	−0.8
Construction		+4.4
Leisure activities	−1.7	+1.0
Water supply	−7.0	+5.6
Urban infrastructure	−0.1	+0.2
Air pollution		
Tropospheric ozone	−3.5	−2.2
[Transportation]		+0.3
[Marine resources]		+
Total	−61.6	+104.8

SOURCE: Information from Cline 1992, 131, table 3.4, and the author's calculations.

In 1996, the IPCC issued a controversial analysis, *Climate Change 1995: Economic and Social Dimensions of Climate Change*, prepared by Working Group III, which identified the damages that would occur under global warming. Several researchers, including William Cline, wrote Chapter 6, ''The Social Costs of Climate Change: Greenhouse Damage and the Benefits of Control.'' Although the chapter pretends to present a balanced picture, it always portrays the most alarming possibilities and plays down any mitigating arguments or evidence.

For example, the section dealing with agriculture discusses a number of studies that find losses and occasionally small benefits from warming. It starts the discussion with an analysis that forecasts a 5 to 40 percent fall in yields in developed countries and a 40 percent rise in food prices worldwide (IPCC 1995a, 190). Nowhere does it mention the work by Mendelsohn, Nordhaus, and Shaw (1994) in the *American Economic Review*, the official journal of the American Economic Association. That research, discussed here, found very small losses or small gains to American agriculture. Nor does the chapter mention any of the other studies that have reported benefits (White and Hertz-Picciotto 1995; Kane et al. 1991; Wittwer 1995). Instead the section relies heavily on Cline's own work, which is biased toward finding damage.

The Effects of Global Warming

As mentioned above, most sectors of modern economies are mainly impervious to climate and consequently to climate change. Agriculture, forestry, and transportation, however, are significantly influenced by climate. People and nations are also subject to rising sea levels, increases in violent weather, energy costs for heating and cooling, and changes in recreational activities. Each of these topics is discussed below.

Agriculture

Food output depends largely on agriculture, an industry that would be particularly sensitive to any climate change. Water availability, soil composition, technology, sunshine, and temperature all affect crop production. Warm climates have longer growing seasons and higher productivity. Wetter areas, holding other factors constant, are more productive than dry, unless the latter are irrigated. Climate change, if it takes place, is most likely to lead to a warmer climate, especially in higher latitudes where it will have a strong beneficial effect on the length of the growing season. Climatologists predict that a warmer world would enjoy more rainfall. Although models are unable to forecast where rainfall will increase, most places should experience at least a little more. The net result of warming and enhanced precipitation would be to boost farm output.

In addition, the concentration of CO_2 in the atmosphere is rising. Carbon dioxide is an essential ingredient for plant growth. It boosts both photosynthetic capacity and water-use efficiency. According

to peer-reviewed research, a doubling of carbon dioxide would on average boost growth by 52 percent (Wittwer 1997, 12). Moreover, the improved water-use capacity of plants means that less rainfall would be needed to grow crops, thereby economizing on irrigation and perhaps offsetting partially any local reduction in rainfall (Baker and Allen 1994). As a consequence, a boost in carbon dioxide would have a strong beneficial effect on food production.

Evidence exists that rising levels of CO_2 have already hiked plant growth worldwide. Tests at Mauna Loa in Hawaii have not only documented a rise in the level of carbon dioxide in the atmosphere, from 316 parts per million in 1959 to 360 ppm in 1996, but shown a marked seasonal pattern that has become more pronounced (Wittwer 1997, 10). The levels of CO_2 in the atmosphere begin to fall in the northern spring as the new growth of plants absorbs the gas and reach a low by early fall. As plant growth ceases and leaves fall in autumn, CO_2 levels rebound to a mid-winter high. The amplitude of this pattern has been increasing, at least since 1960, by about 0.5 percent annually (Wittwer 1997, 11). This would suggest that plant growth worldwide has been on the upswing.

Additional evidence that agriculture has benefited comes from Dr. Ranga B. Myneni, a biologist at Boston University, and his colleagues who have found that, since 1980, plant growth, during the summer months, has become more vigorous north of the 45th parallel (Myneni et al. 1997). Inasmuch as there has been no measurable warming over this period—some areas have warmed while others have not—the result must stem from increased CO_2 concentrations. They report that the growing season has lengthened by 12 days and that plant growth has become 10 percent more energetic. Similar reports have come from Australia, where researchers have discovered that warmer weather, more rainfall, and perhaps greater CO_2 have led to bumper crops (Nicholls 1997).

In 1994 two scientists, Paul Knapp and Peter Soulé, compared a site in central Oregon that had been extensively surveyed in 1960 with its flora 34 years later. The region was almost inaccessible; climate had remained constant; human activity, given its remoteness, was negligible. They reported that the site had become much greener, with large increases in trees, perennial grasses, and western juniper. After systematically excluding all other factors, they concluded that the rise in CO_2 had boosted growth (Knapp and Soulé 1996).

Many studies have examined the relationship between warming and agricultural output. In a cautious report, the U.S. Department of Agriculture reviewed the likely influence of global warming on crop production and world food prices. The study, which assumed that farmers fail to make any adjustment to mitigate the effects of warmer, wetter, or drier weather—such as substituting new varieties or alternative crops and increasing or decreasing irrigation—concludes:

> The overall effect on the world and domestic economies would be small as reduced production in some areas would be balanced by gains in others, according to an economic model of the effects of climate change on world agricultural markets. The mode . . . estimates *a slight increase* in world output and a *decline in commodity prices* under moderate climate change conditions (Kane et al. 1991, emphasis added).

Economists Robert Mendelsohn, William Nordhaus, and Daigee Shaw researched the relationship between climate and land values in the United States (1994, 753–71). After holding land quality, the proximity to urban areas and the nearest coast, and income per capita constant, they found that climate explained over two-thirds of the value of croplands. They concluded that, for the lower 48 states, a rise in average temperature of about 5°F and an 8 percent increase in rainfall stemming from global warming would, depending on the model used, reduce the value of output between 4 and 6 percent or boost the value of output slightly. The result ignored the effect of increased CO_2 on farm output. It is consistent, however, with the Department of Agriculture's study that suggests the United States might see a slight fall in output while production in the rest of the world increased.

Dr. Sylvan Wittwer, a professor of horticulture at Michigan State University, has concluded that, although scientists know little about the effect of climate change on food production, the benefits of increased levels of CO_2 are unambiguous. The distinguished professor emphasizes that

> the effects of an enriched CO_2 atmosphere on crop productivity, in large measure, are positive, leaving little doubt as to the benefits for global food security. . . . The rising level of atmospheric CO_2 is a universally free premium, gaining in magnitude with time on which we can all reckon for the

> foreseeable future. Direct effects of increasing CO_2 on food production and the output of rangelands and forests may be more important than the effects on climate (Wittwer 1995, 236).

Other studies such as those appearing in *Economic Issues in Global Climate Change: Agriculture, Forestry, and Natural Resources* generally find small costs or benefits. Most of those papers, however, fail to take into account the effect of CO_2 on output; those that do find it increases yields considerably. On the basis of those studies, Table 5-3 lists neither a gain nor a loss for the U.S. farming sector, a conservative position. If the effect of carbon dioxide fertilization adds to output and reduces world food prices, as the Department of Agriculture study suggests, U.S. producers may lose; but American consumers, as well as those in the rest of the world, will gain. In any case, I assume that the sum of the gain for consumers and any loss for producers from lower prices would be positive but close to zero.

Forest Loss

Forestry is another sector subject to change as a result of an increase in CO_2 and world temperatures. Canadian agricultural economists, examining the effect of warming and a doubling of CO_2 on forestry production, concluded that increased carbon dioxide would boost productivity by 20 percent and that overall the harvest of timber in Canada would climb by about 7.5 percent (Van Kooten 1990, 704). Although their research applies strictly only to our northern neighbor, it seems reasonable to infer that timber output in the United States could be more than maintained at current levels. If the climate changes, forest managers can shift the types of trees to fit the new environment.

Brent Sohngen of Ohio State University and Robert Mendelsohn of the Yale School of Forestry and Environmental Studies have estimated that the U.S. timber market would benefit from climate change by less than 1 percent to more than 10 percent of the current value of American forests (Sohngen and Mendelsohn 1996). British researcher J. L. Innes, for the Forestry Commission in Surrey, United Kingdom, reports that over the last 100 years, forests have expanded ''in areas as far apart as southern Patagonia and northern Finland. As growth . . . is primarily controlled by temperature, it seems likely

that climatic change is involved'' (Innes 1994, 239). The IPCC has projected that global forest area could increase as much as 9 percent (IPCC 1996).

The total value of all lumber and wood products produced in the United States in 1993 was only $35 billion. If we assume that warming might increase production by 1 percent, the total gain would be less than $1 billion. Actually since the United States imported around $9 billion in that year, a substantial portion of consumption, world prices would affect domestic costs. A worldwide increase in production of 1 percent would reduce prices so that the total dollar value of the increase in U.S. output would be even less than $350 million. To be conservative I have not projected a dollar gain from warming, but timber prices should decline and consumers would benefit.

Species Extinction

Cline's estimate of the economic loss from species extinction is really nothing more than a number pulled out of the air. He asserts that the public was willing to spend $160 million to preserve the spotted owl and therefore might be prepared to spend 25 times that amount or $4 billion to preserve other species. No justification is given for multiplying by 25. Why not 10 or 100?

Moreover, the general public has not spent $160 million to preserve the owl; the timber companies have had losses inflicted on them to save the redwood forests in which the owl lives. The $160 million reflects the estimated value of the timber that was not cut. People like big trees; but in general the public has paid relatively little because timber has been imported from Canada to make up for the shortfall. Timber prices did increase somewhat, however. To the extent that the program to preserve old forests has driven up timber prices, the burden on the public has been hidden. In no way can it be argued that the voters decided that they would spend $160 million to preserve the spotted bird.

Chapter 4 examined the benefits of biodiversity for pharmaceutical research and concluded that, for the production of new drugs, its value was close to zero. It is true, of course, that all of us fancy a world populated with many species of animals and plants. Nevertheless, it would be surprising if the public were willing to pay more than $1 billion annually to preserve an unknown number and unknown types of species. That estimate has no more basis than does Cline's.

The media exaggerate the numbers of species that are becoming extinct. Of the 1,354 species here and abroad that have been listed by the Interior Department since 1966, only 19 have been delisted. Seven did become extinct; eight were listed in error; only four recovered enough to allow delisting. Three of those are native to the western Pacific; the fourth is a plant that grows only in Utah. None of the recoveries appears to have had anything to do with the protections of the Endangered Species Act. The handful of species that did go out of existence represents only .5 percent of all those listed and a much, much smaller proportion of those species identified and monitored. In all, there have been few identified extinctions in recent years, despite the rhetoric about wholesale losses of species, and an informed public is unlikely to pay much to prevent the loss of such small numbers.

Sea Level Rise

The IPCC concludes that a 4.5°F warmer world would lift sea levels by one to three feet, with the central estimate being about one and a half feet by the year 2100 (IPCC 1995c, 188). Cline assumes that the ocean would rise by one meter, about three feet. On the basis of the IPCC's central estimate that the sea will rise only about one and a half feet in the next 100 years, construction costs for dikes and levees are cut in half to $600 million annually from his figure of $1.2 billion.

To calculate the value of the land that would be submerged, Cline assumes that rental values of land would be 10 percent of the value of the land, too high a percentage. Abstracting for risk there is no reason that rental values for land should be higher than the long-run real rate of interest, about 3 percent. Cline also minimizes the discount rate by assuming it to be only 1.5 percent. From these assumptions, he calculates that the annual loss from the land inundated by a rising sea would be $5.8 billion. Adjusting those estimates to reflect a smaller rise in the sea and employing a real rate of interest of 3 percent for both rents and discounting pares his estimates to $1.5 billion, less than one-quarter of his figure.

Heating and Cooling Expenses

Warming will reduce the costs of home and office heating while increasing the costs of air conditioning. Ignoring business costs for heating and cooling and consumer expenditures for oil and gas

heating, Cline considers only the consumer's outlays for electric heating and cooling. By focusing on electricity costs, he biases upward potential expenditures under a warmer climate because air conditioning, which would be used more, requires electricity. Homeowners can heat their homes, a cost that would go down, not only with electricity but with gas, coal, oil, or even wood, the benefits of which he ignores.

The U.S. Department of Energy estimated the savings in energy costs for both a 1.8° and a 4.5°F warming. They calculated that even with added cooling expenses, the gain would be about $12.2 billion for the greater gain in temperature (Rosenthal et al. 1995). I have adopted their estimate as being the most authoritative.

Human Amenities

William Cline argues that human amenity would deteriorate because of hot summers, although he admits that less ice and snow in the winter would be positive. We need only ask the following: ''Do people prefer the summer or the winter?'' ''Do humans enjoy warm weather or cold?'' ''What proportion of vacationers in the winter go south and what proportion go to ski resorts?'' The answer is obvious: people call warm weather ''clement'' and enjoy warm, sunny days.

The previous chapter reported on measures of amenity values. Those results have been confirmed independently by an Environmental Protection Agency staffer who surveyed the literature. The agency bureaucrat reported that individuals prefer climate change and are willing to accept lower wages for such improvements (IPCC 1995c, 201, based on Leary 1994). They also like sunny, mild climates. Those are essentially my conclusions.

My research implies that, assuming minimum temperatures and maximum all rise equally and depending on the statistical model, the gain from a warmer climate could be as little as roughly $30 billion or as much as $100 billion. If we assume that global warming will increase winter and night temperatures most, however, then the gain may be only $10 billion. Although the statistical procedures used to make these estimates undoubtedly underpredict the gains, Table 5-3 lists only the smaller figure.

Migration

Over recent decades, Americans have been moving south. Many retirees have left their cold northern neighborhoods and their friends

and relations to migrate to warmer venues. Between 1984–85 and 1993–94, on net, over 300,000 people each year left the Northeast. The Midwest lost on average some 30,000 souls while the South gained over 250,000 and the West, over 100,000 (*Statistical Abstract of the United States 1995, 1996–97*, table 32). In 1992, revenue of household goods carriers transporting furniture and personal belongings between cities reached $7.4 billion (*Statistical Abstract of the United States 1996–97*, table 1024). That figure is an underestimate of the cash costs of moving, as many families rent vans or trailers. Ninety percent of all migrants from the Midwest and the Northeast in 1993–94 relocated either to the South or to the West. The implication is that about $3.0 billion was spent on commercial movers carting people's personal effects to the South or West. If warming simply reduced the desire of Americans to move south by 10 percent, it might save nearly $300 million annually in the costs of changing residences.

Mortality

Chapter 3 estimates that a warmer climate would reduce deaths by about 40,000 annually. If the lives saved reflect a random sample of the U.S. population, their value would be somewhere between $2 million and $10 million per life saved. These figures come from several studies of how much people are willing to pay to reduce the risk of early mortality (Viscusi 1994; Lutter and Morrall 1994). It may be, however, that the increase in length of life comes from adding a few years at the end. Putting a value on those extra years is problematical.

We know that diseases of the respiratory system, which account for 10 percent of all deaths in the winter, are over 50 percent higher in the cold season than during the summer. Diseases of the circulatory system, which account for about half of all deaths during the winter, are nearly one-quarter higher during December through February. The latter killer takes primarily older people whereas diseases of the respiratory system can sicken all ages. Thus, to be conservative, the 40,000 lives saved will be valued at only $1 million each for a total gain of $40 billion.

Human Morbidity

Not only should warmer weather extend lives, it should also reduce illnesses. A conservative estimate of the gain reflects simply

the wage cost to people with jobs who are not at work because of illness. This neglects the gain to those not in the paid workforce and those who come to work even though they have a cold or the flu. I assume that a 4.5°F warmer temperature would reduce illness by the same amount that it would reduce deaths (1.8 percent). Workers' compensation consequently would fall by the same percentage, producing savings of around three-quarters of a billion dollars (from *Statistical Abstract of the United States 1994*, 404, table 631; 427, table 660).

Chapter 3 presented estimates of the reduction in hospital costs and in medical expenditures generally from a warmer climate. The savings in national expenditures on health care would be roughly $36 billion in a warmer world. Savings on workers' compensation come to nearly $1 billion. On net, therefore, global climate change, if it were to occur, should provide health benefits, aside from reduced mortality, of about $37 billion.

The analysis made of the costs of global climate change for the Department of Transportation in the early 1970s calculated the costs to human health from cooling, especially the costs of visiting a doctor or hospital and outlays for medication (Anderson 1974). Projecting the gains from a warmer climate and adjusting for the rise in medical expenses and the increase in U.S. population suggests a gain of about $22 billion. For the purposes of Table 5-3, the estimate of $36 billion on doctor and hospital costs, plus the savings on workers' compensation, were included for a total of $37 billion.

Hurricanes

Hurricanes develop over warm tropical water that provides both the moisture and the energy to fuel the storms. A warmer climate would lead to a larger portion of the oceans being covered by waters warm enough to support hurricanes. Moreover, a hotter world would also mean that the tropical oceans would remain warm for more of the year, producing longer hurricane seasons. In part, this would be offset by the reduction in the temperature differences between high latitudes and equatorial regions. Since temperature differences between the poles and the equator drive winds, storms overall, especially winter gales, blizzards, and cyclones, should be reduced. Nevertheless, hurricanes may become more common, so Cline's figures have been accepted. A proper accounting, however,

would offset at least partially increased losses from hurricanes with smaller damage costs from other storms.

Construction

The IPCC report on the costs of climate change repeats Cline's strange rainfall results. Although much of the chapter stresses drought, the section on construction mentions that additional rainfall will hamper building activities (IPCC 1995c). Rainfall also is projected to inhibit outdoor activity, and losses to ski areas are again stressed.

Climate change should have only a very small effect on the building industry. Warmer winters, if they develop, will make it possible for construction firms to work more of the year. The longer work year would reduce costs modestly because contractors would be able to employ workers on a steadier basis. Not having to cope with as much snow and ice also should shave building costs. The implication is that the price of housing and other buildings would decline slightly, leading to some expansion of output. Nevertheless, the construction industry probably would build few additional housing units or office complexes, as the small reduction in costs is unlikely to have a noticeable effect on the volume of construction. The net effect, although likely to be small, would be positive, so the savings have been projected to be 1 percent of building costs, or $4.4 billion.

Leisure Activities

Most outdoor activity, with the exception of skiing and snowmobiling, would be helped by a warmer climate. Of 17 outdoor activities listed in the *Statistical Abstract of the United States 1994*, downhill skiing is 14th and cross-country skiing is 17th in popularity (*Statistical Abstract 1994*, 258, table 406). Only soccer and backpacking boast fewer participants than Alpine skiing. Thus the great majority of people who enjoy outdoor activities would find a warmer climate in their interest. The Europeans have estimated that tourism would improve in the European Union by about $4 billion (IPCC 1995c).

Additional spending on equipment and on entrance fees would reflect the minimum value consumers place on the benefits they would reap from being able to enjoy their favorite leisure activity for more of the year. If the amount spent on camping material, hunting gear, and golf clubs and accessories grows by 10 percent

with a longer warm weather outdoor season while spending on ski equipment falls by the same percentage, consumers would, on net, increase their outlays on sports equipment by nearly $1 billion. For a number of activities that would also benefit from a longer season, such as hiking, softball, baseball, and football, outlays for equipment are unknown. Thus the $1 billion underestimates the gain to outdoor enthusiasts. That sum, moreover, does not include the additional spending on items like golf fees or the loss in ski lift charges. Since golf fees appear to be higher on average than lift tickets, the net result should be an additional gain, reflected in higher spending on golf over the loss to skiers. Table 5-3 uses the $1 billion gain, which is no doubt a considerable underestimate of the benefit of a longer warm season to sports participants.

Water Supply

Cline cites the 1990 IPCC report as concluding that world rainfall would increase by 8 percent (Cline 1992, 122). He assumes, however, that U.S. rainfall would decline by 10 percent. He predicates this assumption on two studies of water supplies in California, an area that is hardly typical of the entire country. The chapter Cline helped put together in the IPCC Working Group III report assumes a 10 percent decline in precipitation in 18 major water districts despite the climate model forecasts of increased rainfall (IPCC 1995c, 193). Taking the IPCC estimate of rainfall and employing Cline's methodology, the gain from *increased* rainfall would be $5.6 billion.

Urban Infrastructure

In discussing his forecasts of the effects of global warming on ''urban infrastructure,'' Cline states that climate change will bring both more frequent droughts and more frequent heavy rains. He predicts that such a change will require additional outlays for expanding reservoirs and improving storm drains. The evidence, however, fails to show any such change in the weather over the last hundred years (*World Climate Report*, February 3, 1997 and March 17, 1997). It does show a rise since 1895 in average rainfall, which correlates with improved crop yields, but no increase in heavy rains.

Global warming, if it occurs, is expected to raise temperatures in high latitudes while having little effect on equatorial regions. As pointed out previously, fewer and less violent storms should affect the United States, with the possible exception of hurricanes, which

are related to sea surface heating. Perhaps, between now and the year 2100, some cities may have to expand storm drains, but over such a period, they would have to be upgraded anyway, so the added cost would be minimal. On the other hand, as already mentioned, global warming should increase precipitation. On average, cities would have a more reliable water system and would need to invest less in expanding reservoir capacity, resulting in a net saving. Some areas, of course, could face diminished rainfall, but the majority of the country should gain precipitation.

In addition, winter weather would be less harsh and last for a shorter period, so northern cities should benefit. That would mean less spent on removing snow, salting the streets, heating municipal buildings, and repairing potholes, which are related to freezing. If we consider only those states where the principal cities suffer from average January lows below freezing—a consideration that excludes California and Texas, among others—total outlays by states and local governments in 1992 amounted to approximately $46.7 billion. Assuming that those communities and states would save only .5 percent on streets in reduced plowing, fewer potholes, less ice and snow removal, and less need for police traffic control and accident cleanup, the gain would be more than $200 million.

Air Pollution

Using EPA estimates, Cline points out, correctly, that warmer weather will lead to more smog and ozone. The EPA has concluded that a 7° rise in temperatures would increase peak ozone by 10 percent and has pinned the cost of offsetting the increase at $3.5 billion (Cline 1992, 129). Taking the numbers at face value and assuming a 4.5°F temperature rise, rather than 7°, the costs to mitigate the additional air pollution fall to $2.2 billion.

Transportation

Additional sectors of the economy, which William Cline ignored, might well be influenced by global climate change. In particular, transportation could gain from more clement weather. Less ice and snow would improve driving conditions and reduce weather-related delays for airlines. According to U.S. Department of Transportation figures, airline passengers suffer from greater delays in winter months than in summer. A warmer climate should improve on-time performance.

Currently the fewest delays occur during the third quarter, with the second and fourth quarter being better than the first. I assume that warmer temperatures would improve on-time performance during the cold months to the level of the second quarter (around 84 percent in 1992) from the poor showing during the first quarter (76 percent) and from the less good showing in the fourth quarter (81 percent).* Multiplying the percentage increase in on-time flights during those two quarters by the number of domestic passengers on all airlines operating aircraft larger than 60 passengers during the periods indicates that nearly 1 million people would benefit. Valuing airline passengers' time at a conservative average value of $20 per hour and assuming that average delays would be reduced by 30 minutes, warming would improve the well-being of airline travelers by about $100 million annually.

Airlines themselves would also gain: they would have fewer problems with aircraft being unable to land and diverted to other airports, a costly procedure. Dealing with irate passengers, rerouting them, putting them on later flights, providing meal tickets, and paying their hotel bills are expensive. Although airlines make virtually all their profits in the second and third quarters, thanks to increased numbers of passengers, their costs are slightly higher in the first and fourth, a reflection of poorer weather. If airlines could achieve the same costs in the two cold quarters as they do during the spring and summer, they would reduce their costs by $300 million.

Highway traffic should also benefit from improved weather and less snow and ice. Truck accidents are somewhat more frequent in the winter than in the summer—in 1987, the winter months experienced 6 percent more accidents than did the summer—but this could be ascribed to shorter daylight hours. Private auto travel is considerably reduced in winter months over summer—about 15 percent—and would become more balanced under global warming; that is, more people would visit their friends and relatives during the winter rather than concentrating their travel during the warm months. The result might be less congestion in the summer and an optimal use of the highway network. Although there would be clear

*Airlines in 1992 reported that during the third quarter 84.9 percent of their flights were on time, that is, arrived within 15 minutes of schedule.

gains to surface transportation from a warmer climate, a lack of data precludes any estimate of the benefit.

Marine Resources

Another sector Cline ignored is fishing. The Department of Transportation conference estimated the costs of cooling on fishing, both commercial and recreational. Economist Frederick W. Bell of Florida State University carefully reviewed the literature on the major types of fish caught commercially. Overall he reported (Bell 1974) that the present value of the loss from a cooler and drier world was $93 billion in 1974 dollars, or $138 billion in 1996 dollars.[†] Bell reviewed the effect that temperature, precipitation, and wind velocity would have on groundfish, tuna, salmon, halibut, sardines, shrimp, lobsters, crabs, clams, scallops, oysters, and other food fish, shellfish, and crustaceans. In the case of a decline in sea temperature and a fall in precipitation, the sustainable catch for all of the groups, except halibut, would fall by 1991. The decline in fish caught would be between 0.01 percent for crabs and 1.7 percent for salmon. Some of the loss would come from reduced rainfall, which would cut freshwater runoff in coastal areas. If rainfall were assumed to increase, production of shrimp, crabs, scallops, and oysters would go up in spite of the lower temperatures. Extending the period out to 2025 produced much larger changes.

On the basis of Bell's work, it might be reasonable to conclude that a warmer, wetter world would boost fish yields. Since a number of species thrive within a relatively narrow temperature band, however, this assumption may be unwarranted. Nevertheless, fish can adapt by swimming to cooler or warmer water, so that effect should be small. Although there is some evidence that warmer sea temperatures can boost yields—during the largest El Niño on record, 1982–83, which produced warm surface waters in the Eastern Pacific, fish prices went down—I will assume no overall benefit from climate change.

Total

Even though many potential advantages have not been included, Table 5-3 shows that Americans would benefit from warming by

[†]Adjusted using the food stuff and feed stuff crude materials price index of the producers price index.

Table 5-4
ESTIMATES OF COSTS OF GLOBAL WARMING
EXPECTED LOSS OF GDP

Researcher	U.S.A.	World
Cline (4.5°) 1992	1.1%	n.e.
Nordhaus (5°) 1991	1.0%	n.e.
Frankhauser (4.5°) 1995	1.3%	1.4%
Titus (7°) 1992	2.5%	n.e.
Tol (4.5°) 1995	1.5%	1.9%
Moore (4.5°)	Gain of 1.0%	n.e.

SOURCE: IPCC 1995c, 184, and author's calculations.
NOTE: n.e means no estimate.

over $100 billion per year. It seems almost indisputable that Americans would be better off at the end of the next century if temperatures were 4.5°F hotter than today. For the United States, Europe, Japan, and other advanced countries, it is implausible to assume that climate change would have overall significant negative effects. Thomas Schelling, in his 1991 presidential address to the American Economic Association, reported that for ''developed countries, the impact on economic output will be negligible and unlikely to be noticed'' (Schelling 1992, 6). Most likely, people would be oblivious to any change; they would simply enjoy the reduction in ice, snow, and cold.

Transition costs, such as the building of dikes, the introduction of new crops, or the construction of irrigation facilities, may exist. In part, those costs are included in the estimates of Table 5-3. Despite those adjustment costs, a warmer climate would almost surely benefit most Americans.

Virtually all the other estimates of the damages from global warming to both the United States and the world have been very small. For developed countries, they have ranged generally from 1 percent to 2 percent of GDP (IPCC 1995c, 184), although Nordhaus's original estimate was for one-quarter of 1 percent of GDP (Nordhaus 1991, 932). It is generally agreed that poor countries will typically fare worse than the advanced market economies. Table 5-4 presents some of those estimates as given by the IPCC in terms of the expected loss of GDP.

Some may be willing to grant that rich industrial countries in temperate climates might benefit, yet argue that the poor Third World areas will suffer. The IPCC Working Group III report asserts: ''. . . climate change seems likely to impose greater risks and damage on poorer regions'' (IPCC 1995c, 84). Chapter 3 of that report on ''Equity and Social Considerations'' argues strongly that poor countries are much more vulnerable, hence rich nations should bear the burden. Not only has the West produced most of the greenhouse gases to date—the rapidly growing Third World will soon exceed the output of the OECD countries—but the rich nations can afford to pay the cost of slowing or stopping global climate change and to contribute to any measures necessary to adapt to change. Climate policy has become foreign aid.

Poor countries dependent on agriculture are more sensitive to changes in climate. But the growth of CO_2 should actually help. Many of those nations are in tropical areas and will be largely unaffected because the climate will not change appreciably near the equator. Other subtropical regions should receive more rainfall and may benefit, although farmers may need to learn to grow new crops. Some low-lying countries—Bangladesh, for example—may suffer from more frequent sea flooding as water levels rise. Such places, including low-lying islands, may be the only major losers from warming. Rather than spend resources on a futile effort to slow warming, it might be more humane to help them either to accelerate their growth so they become less dependent on the weather, or to build dikes for protection from rising seas, as the Netherlands has done. Foreign aid should not be confused with environmental policy.