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ECONOMIC GROWTH, SUSTAINABILITY, AND THE ENVIRONMENT

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ECONOMIC GROWTH, SUSTAINABILITY, AND THE ENVIRONMENT

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d'Arge: Good afternoon, ladies and gentlemen. This afternoon's session is on economic growth, sustainability, and the environment, and we have a distinguished panel to address this issue.

Before we begin, I want to call your attention to the 20 flags in the background here. They represent the various sovereign nations—including California here on my left—from which the participants at this 65th annual conference come.

Sustainability has become a popular buzzword in the economic development field during recent years. But I think that if we take a broad view of the 20th century and ask how many serious global common property resource problems we have had, we actually have had only two. One has been the problem of nuclear winter—essentially, the possibility that a limited or an unlimited nuclear war would push the climate into a cold spell and then humankind would suffer the consequences. The other problem, which has been around for about 15 years, has been that we might experience a greenhouse-induced warming of the global climate. If atmospheric scientists are correct—and I am not sure they are—then within 100 or 150 years we will see a change in the climate, particularly a temperature rise exceeding the bounds of climatic change during recorded history.

This is rather striking. We must go back about 8,000 years—to the alta-thermal period—to find a period indicating what the earth's climate could be like within the next 100 or 150 years. Essentially, then, we have a substantive potential impact outside the boundaries of any existing or conceivable econometric models.

The atmospheric warming of these global commons gives rise to a second fundamental problem. During the 20th century, we have established a set of institutions that have responded well to problems that cause limited international damages. However, we have yet to see the emergence of an institution to deal with sustainability issues that involve impacts on everyone and that have causes attributed essentially to everyone.

But I want to make a couple of points regarding our current institutional mix. During the early 1970s, the U.S. Congress responded to the question of subsidizing supersonic transports (SSTs) by examining the effects of SSTs not only on the United States but on other countries in the form of climatic change and possibly skin cancer.

In 1977, the U.S. Environmental Protection Agency administrator quite literally removed 50 percent of chlorofluorocarbon (CFC) use by banning on the basis of nonessential use. We have seen similar unilateral actions by European nations associated with global commons problems. Most recently, we have the protocols established at Montreal providing for worldwide control of CFC use and for subsidies to the developing nations that lose due to their inability to use CFCs. These are examples of institutional arrangements for dealing with the severe problem of global common-property resources.

*This is an edited transcription of a general session at the Western Economic Association International 65th Annual Conference, San Diego, July 1, 1990. The panelists, in order listed, are Professor of Economics, University of Wyoming; Professor, Energy and Resources Group, University of California, Berkeley; Distinguished Professor of Economics, University of Maryland, College Park; and Professor of Meteorology, Scripps Institution of Oceanography, University of California, San Diego.

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Today we start with Professor Richard Somerville, who is with the Scripps Institution of Oceanography. He is a professor of meteorology and also is director of the Climate Research Division, which specializes in long-range climate models and the greenhouse effect.

Considerable controversy still exists in the atmospheric sciences over the exact impacts of global warming as well as over the global models themselves. Luckily, we have someone here who is in the middle—that is, he is not at either extreme of the climatic community. Professor Somerville.

Somerville: Thank you. For a long time, I have thought that meteorologists and economists have a great deal in common. Both must forecast systems that are too complicated to understand, and both must put up with users' reactions when the forecasts are wrong. But I have always thought that meteorologists were a little better off because we simply forecast a physical system that is beyond comprehension, whereas economists also must predict human behavior. Now that is changing. The subject I will summarize for you is one in which human behavior has begun to affect the global atmosphere.

Greenhouse warming is a topic of interest at the same time as are the topics of the ozone hole and acid precipitation. That is no accident. All three are examples of global environmental problems with the same fundamental cause: Enough people now populate the earth, and we now use enough energy, so that we are affecting the environment. We are doing so not just on a local scale—which has been going on for centuries—but on a global scale.

The greenhouse effect is the most difficult of the problems. In the case of the ozone hole, we have a smoking gun. We know that CFCs (such as Freon) are responsible and we have a technological fix. We are developing substitutes for them. Just as in the case of acid precipitation, the science essentially has been done. The question is how to muster the political will to do what is necessary to solve the problem.

The greenhouse effect is a much more difficult problem. It is harder to understand and is more long term. That increases the difficulty of bringing it to the forefront of the political process. We must think about today's actions, the costs of which are immediate but the consequences of which do not arise for a long time. We have no easy technological fix.

Carbon dioxide, an absolutely essential and natural product of fossil fuel combustion, is increasing in the atmosphere. Its concentration is rising due to human activities. Several other gases—some of which also have anthropogenic causes—are also increasing in concentration, and they have the same ability to contribute to the greenhouse effect.

During the next few minutes, I will try to make clear which aspects of this subject are on solid ground—that is, those aspects on which we agree or of which we think we are sure. Then I will discuss where the hypothetical and conjectural and less certain aspects come into play. I will begin by leaning on the podium and making no gestures at all while I tell you things of which I am sure. Then, gradually, I will wave my hands a little more—in increasing amplitudes—until, at the very end, I will be telling you things of which I am not sure at all. If I can calibrate the present state of the scientific consensus in the climate research community, then perhaps I can provide a framework for the discussion to follow.

That the greenhouse effect is real is beyond doubt. It has been said that the greenhouse effect is as firmly established as the theory of gravity. It is not at all hypothetical. People who do not believe in the greenhouse effect are in the same class as are flat-earthers or creation scientists. The greenhouse is what keeps the planet habitable. It is what makes the climate of the earth different from the climate of the moon. Both the earth and the moon get

their energy from the sun. The moon is about 60 degrees Fahrenheit colder and has very harsh day-to-night differences. The reason for this is that it has no atmosphere. The earth's atmosphere contains mostly gases that do not affect radiation from the sun or from the earth. Nitrogen and oxygen, which make up 99 percent of the atmosphere, are not radiatively active. But trace gases, of which water vapor is the most variable and important, and which are present in very small quantities, have critical effects on radiation and hence on climate.

Carbon dioxide (CO_2) is next on the list. Today, on an annual average, the CO_2 content of the atmosphere globally is 350 parts per million, or 0.035 percent. It is a very small gas in terms of its absolute abundance, but it is a powerful gas in terms of its contributing to the greenhouse effect. Carbon dioxide is relatively transparent to incoming sunlight. Most sunlight that hits the earth comes through the atmosphere unimpeded and is absorbed by the ocean and the land. They warm, and this warms the air.

The CO_2 traps some of the heat that the earth gives off. So does water vapor. So do methane, nitrous oxide, ozone, and CFCs. The heating that these gases provide helps keep the earth warm. They act as a type of blanket.

Would you like a clear everyday example of the greenhouse effect? When you go camping on a clear night, things are chillier than they would be if clouds were there. Overcast nights are warmer than clear nights, other things being equal, because the clouds are contributing to the greenhouse effect.

Just as the greenhouse effect is real, the rise in the CO_2 concentration is beyond any doubt. The CO_2 concentration is readily measurable due to the efforts of one scientist named C. D. Keeling, who has been measuring it for more than 30 years. Now many other people are measuring it.

When Keeling (1960) began measuring the CO_2 concentration, it was about 10 percent less than it is today. During the 30-odd years that scientists have accurately measured the concentration, it has increased by about 10 percent. (See Firor, 1990, for graphs indicating findings of Keeling and others regarding increasing concentrations of CO_2, methane, and CFCs.) The reasons for that increase are fossil fuel combustion, deforestation, and a few other minor causes. Cement making is on the list.

We know what the concentration was 100 years ago because we can measure it in pockets of air trapped in ice and in other places where geology has provided a record. In the slightly more than 100 years since the industrial revolution began, the concentration has gone up by roughly 25 percent. So it is about 25 percent higher than it was during the last century and about 10 percent higher than it was during the 1950s. It is going up today at about one-half of 1 percent per year.

That is rock solid. People argue about the greenhouse effect. They argue about the climate of the future. They question our ability to predict and the veracity of the scenarios. But nobody questions these data. At the same time, other gases also are rising—and some are rising more rapidly. One is methane, which has a lot of peculiar sources. It comes from oil and gas production, from natural gas pipeline leaks, from combustion, from swamps, from rice paddies, from termites, and from cows doing unspeakable things. Methane is rising at about twice the rate of carbon dioxide—at about 1 percent per year. And part of that is due to anthropogenic activities such as rice cultivation.

Among the other gases that are rising are CFCs, which are very powerful greenhouse gases. These are entirely man-made products. They were invented in 1930, incidentally by the same man who earlier had invented tetraethyl lead, which helped the gasoline and automobile indus-

tries enormously. The CFCs he invented are a wonderful refrigerant. They are non-toxic and non-corrosive. But now we know that lead and CFCs both have unanticipated side effects, and that is why they are being phased out. No one doubts that CFCs are causing the ozone depletion in Antarctica, and no one doubts they are powerful greenhouse gases. The CFCs, pound for pound, are incredibly efficient at trapping heat.

Next, in order of importance, are nitrous oxides, certain other industrial chemicals, and ozone—all of which have greenhouse properties. The combined effect of all gases other than CO_2 is roughly comparable with that of CO_2. We talk about CO_2 concentrations doubling their pre-industrial levels by the middle of the 21st century, depending on what happens to the energy mix when readily available coal and readily available oil and natural gas become scarcer. Perhaps sometime around the year 2030 or 2040, CO_2 concentrations will be about twice their pre-industrial levels. I will wave my hands a little bit—that is an economic forecast. Before that happens, the equivalent of CO_2 doubling already will have occurred, since the other gases will have increased as well.

The equivalent greenhouse properties of the atmosphere increase faster than does CO_2, but the climate change occurs more slowly due to a delay. The climate change occurs long after the gas is introduced. This is not like the ozone hole. The delay is caused mainly by the oceans, which have an immense heat capacity. Warming the temperature of the oceans only slightly takes a lot of heat for the same reason that boiling water on the stove takes a long time. Even though the burner is very hot and only a quart of water is in the pan, raising the temperature 1 degree takes a great deal of heat. Raising the vast amount of water in the oceans by 1 degree takes an enormous amount of heat, and most observers believe the delay will be several decades.

We scientists in the climate field talk about "committing" the earth to a climate change in the future because of gases already emitted into the atmosphere today. This is due to a natural lag. We cannot determine the result of the experiment with certainty until the change occurs.

Roger Revelle, a pioneer in this field, has said that mankind is conducting a one-time geophysical experiment. We are putting back into the atmosphere a substantial fraction of the carbon that had been stored up in fossil fuels over geological time. At the same time, I note that we, too, are performing a one-time forecasting experiment. So those of you who actually make forecasts should sympathize with those of us who must make one forecast of the greenhouse effect. We have no track record. This forecast is not like the daily weather forecast, which we can carry out every day and then improve and refine the model on the basis of success or failure.

That about wraps up the things on which people agree. The next step is predicting the likely consequences of these extra gases. As the moderator just said, the consequence that seems most certain is a global warming. The nature of global warming is complicated, and the climate models used to estimate global warming are unrealistic and idealized in many ways. For example, they treat the effects of clouds simplistically, and they treat the effects of the oceans in a very crude way.

A basic physical understanding of these processes is still lacking, as are the observational data that we need to validate the models. These models basically are mathematical expressions of physical laws and are closely related to the models used to forecast the daily weather. They involve equations relating variables such as pressure, wind, density, temperature, humidity, and cloud cover, and they require supercomputers to solve these equations.

At best, the models give us a broad brush outline, a hint, a look across a foggy field, a type of scenario or prospectus, a

glimpse at what the climate of the future plausibly might be. They give us no hard and firm forecasts on which we can rely comfortably. In my view, we should take them seriously but not literally.

We often run these models simply by doubling the CO_2 and then looking at the new equilibrium. Therefore, we are not solving the time-dependent problem—the problem that interests people—as to what the climate will be this year, next year, next decade. Instead, we are looking at the sensitivity of the climate system to carbon dioxide by running the model twice—once with, say, present-day CO_2 and once with doubled CO_2. We are sophisticated now. We know that doubled CO_2 is shorthand for an increase in all gases that add to the property of trapping heat. When we do that, we really are conducting an experiment symbolizing a thought experiment in which a malevolent Martian comes by in a spaceship, instantaneously doubles the CO_2 in the atmosphere by dumping CO_2 onto our planet, and then rides off and watches the new climate develop.

The new climate takes time to evolve, but the resulting climate differs from today's climate in several respects. First, the new climate is warmer by about 3 degrees Celsius or about 5 degrees Fahrenheit on a global average. That figure is uncertain within a factor of at least 3 since the leading climate models differ by about a factor of 3 in the sensitivity that they show. Those models—about a dozen are in use around the world today—have the biggest computers and the most sophistication and make the most ambitious attempts to include all the physical processes. Consequently, 3 degrees Celsius might really be 1.5 or 4.5 degrees Celsius. But these still are big numbers. They are comparable to the difference between the present climate and Ice Age climates.

The temperature itself does only part of the damage. The other aspects of the climate, of which temperature is a measure, do the damage. Temperature here measures the climate in the same way that body temperature measures health. Your body temperature can be only a little different from normal, but you can be a lot sicker than normal.

When the temperature changes, many other things change as well. For example, concurrent with a temperature rise of 3 degrees Celsius, a large fraction of the sea ice melts in the Arctic and a considerable fraction of the fresh water stored as ice in Greenland, in Antarctica, and in continental glaciers melts as well. This raises the sea levels. Most observers believe that sea levels presently are rising but are doing so very slowly—perhaps 10 inches per century. That rate of rise could double or triple or quadruple and thus endanger low-lying areas—coastal areas of the United States, the Netherlands, Venice, Bangladesh, some Pacific island nations. That is a very serious concern.

The rise in the oceans takes time to occur, but it seems inevitable. The rate of rise is uncertain for many reasons. I will provide an example of feedback processes that make this game difficult. When the climate warms, the hydrologic cycle speeds up. Warm oceans evaporate more water than do cold oceans. More water falls as rain and snow. Glaciers gain mass by snowfall just as they lose mass by warming. So, accurately forecasting how much water will melt requires that we know these two components, which may nearly compensate for each other. Aside from that, the oceans warm by simple thermal expansion. Warm water occupies more volume than does an equal mass of cold water. A rising sea level, then, is one serious consequence.

On firmer ground is the likelihood that the strongest hurricanes will have greater intensities. That will affect not only life and limb and property but the water supply as well.

A big hurricane, such as Hugo or Gilbert, can make a big difference in the water supply and thus affect weather-sen-

sitive sectors of the economy in its path, such as agriculture. Japan gets much of its water from hurricanes. That the path of storms and thus the patterns of precipitation will be altered seems likely. And all models seem to agree that the breadbasket of our nation—the grainbelt in the center of the North American continent—and the grainbelt in Eurasia also will receive less precipitation.

Year-to-year variability always will occur. We always will see wet years, dry years, cold years, warm years. So I am talking about a difference in odds—a difference in probabilities. Droughts may be more severe and more frequent, on average, in these regions. That does not mean that rain will never fall or that Kansas will be transformed into the Sahara. We are taking dice and loading them differently from how they are loaded today, and so the chances of heavy rainfall now considered normal will likely be reduced.

In California, for example, much of the water supply comes from the spring melt, and summer water usage is from water stored as snow pack during the winter. In a warmer world, more of that snow will fall as rain. The snow line will be higher, on average, and so the system for storing and recovering that water must change.

Precipitation predictions are more difficult and are more subject to error than are temperature predictions, but the former will likely be more important. Another problem is that we presently have no means of predicting the regional or transient aspects of climate. I cannot predict with certainty—and you should not trust anyone who says he can—what the San Diego climate will be like in the year 2020. Nobody knows.

We can predict in a broad brush sense—within a few hundred miles horizontally—things such as whether the climate will be wetter or dryer. And even that is somewhat uncertain. But we cannot make accurate forecasts of year-to-year or decade-to-decade changes. Politicians who want to know what their districts will be like when they are up for re-election are just out of luck.

I will close now by saying that we are asking very important and sensible questions of this science. At this stage, however, the science cannot yet answer the questions. But our being unsure of climate forecasts does not mean that we should ignore the problem. We must get used to making decisions under conditions of uncertainty. I know that is not unfamiliar in your field. To say that we need more research on climate is simplistic, and to say that the research has been done and all we need are policy actions is inaccurate. However, I must say that although the media hypes every bit of controversy on this subject, a remarkable degree of scientific consensus exists. One may find a few outlyers, but the bulk of informed scientific opinion generally would agree with the viewpoint I have presented this afternoon. And even the areas of disagreement would tend to be quantitative.

The scientific community agrees that the problem is serious, but questions remain as to when, where, how much, and at what rate the problem is worsening. So if you hear a scientist suggest that doubling carbon dioxide might not be too bad for his industry in his part of world, ask him what he thinks about tripling carbon dioxide, or quadrupling it.

The problem is inherently global, and the solutions must be global. No single country or state or city can solve the problem alone. Even if we shut down the United States tomorrow and went back to eating nuts and berries and living in trees, we would not solve the problem. China, even on its low-growth scenario, eventually will surpass the United States as a net producer of carbon dioxide simply because of its huge population. That may happen in a relatively few years.

Now I am ready to hear some economics. One can spend money foolishly, but I think people can agree on policy actions

that make a great deal of sense. I hope to hear some discussion about things such as energy efficiency and conservation. I also hope to hear what will happen with the fuel mix of the future due to the necessity of stabilizing emissions, of trying to return the climate of our planet to its more natural state, and of coping with the climate change that we think is inevitable.

d'Arge: Thank you, Professor Somerville.

Our next speaker is Professor Richard Norgaard of the University of California at Berkeley. Professor Norgaard has been involved with problems of externalities and environmental economics and with problems of institutions for the past 20 years. He has made countless numbers of rather fundamental contributions to this field. During the past few years, he has written several papers on sustainability and possible ways that economists might consider the long run. I welcome Professor Norgaard.

Norgaard: Thank you. I wish I could describe a series of scenarios—and specify the economic benefits and costs of pursuing such scenarios—so as to cope with or avert global climate changes. A proper economist should be able to do so following a very clear presentation by a climatologist. However, I will not fill out the stage that has been set in quite that way. Instead, I will argue that some fundamental transitions have occurred in our accepting the idea that development is not sustainable.

Neoclassical economics coevolved during the past two centuries with three western progressive beliefs. The first progressive belief was that technological advance would dominate history and improve opportunities for future generations. Both the theoretical elaboration of economics and the practice of economics reflect a faith in progress—that technology would provide access to new resources and, hence, that we could ignore questions of resource distribution over future generations. The second progressive belief was that all peoples eventually would rise to a common understanding about the world and that this understanding would eliminate the irrational differences responsible for conflict among peoples, cultures, and nations. The third—and closely related—progressive belief was that scientifically informed experts could frame technical decisions on the public's behalf—identifying the true nature of problems, the possible solutions, and the trade-offs among them—and thereby help avoid the irrationalities of politics. A fourth progressive belief--that social justice and equality should be advanced deliberately—has played a defining role in the evolution of Marxian and socialist economics but has had little influence on neoclassical economics. The first three progressive beliefs, however, have had as much influence on neoclassical economics as Newton had on physics.

The end of the 20th century represents a watershed in western beliefs. Widespread concern over assuring the sustainability of development marks the demise of faith in progress. Global unity is threatened as individual westernized nations reformulate how to chart their progress while the unity of nations themselves—the Soviet Union, Yugoslavia, India, and Canada, for example—is threatened by revitalized cultural differences within their own boundaries. Our inability to foresee and correct the environmental and social consequences of development is challenging the idea that we are merging to a right way of knowing. Different disciplines are blindly describing different parts of the elephant. The consensus that seemingly has existed within western science has not emerged with respect to our broader environmental dilemmas. Progressive agencies no longer are effectively framing problems and solutions.

Economists have been exploring the meaning of sustainability by tinkering with the economic models and assump-

tions that coevolved with the social organization established around progressive beliefs. The present juncture in beliefs and experimentation with new social orders indicates that economics must change to survive. The underlying model on which economics is based probably will survive this shift in world beliefs since basic patterns of thinking are few. However, most existing elaborations of the model will prove unfit since they are rooted in understandings that the general public no longer holds.

Environmental and resource economics strongly reflects a coevolution with progressive western beliefs more than do the other economics subdisciplines. It has interfaced more directly with western understandings of the natural world and with the progressive institutions through which we relate to the natural world. The elaborations on the basic economic model that occurred within environmental and natural resource economics clearly reflect a technocratic framing of environmental problems and the decision-making process of the institutions through which these problems were to be resolved. Thus, the rich legacy of arguments within this subdiscipline no longer synchronizes with current understandings. I think that as economists begin addressing the concern over the sustainability of development, ultimately they must address the broader shift in understanding that accounts for the present incongruities.

While Malthus and Ricardo elaborated the basic scarcity models that gird the environmental world view, economics during this century firmly embraced the idea of progress and the implication that resources do not matter (Schultz, 1951). Development economists, as the new overseers of progress, felt particularly compelled to defend technological optimism. Thus, Barnett and Morse's (1963) famous analysis of the relationship between scarcity and growth described a "progressive world" and concluded that new technologies were outpacing the niggardliness of nature. Economists were the most vociferous in proclaiming a bright future (Beckerman, 1972; Kaysen, 1972) and in criticizing growth models that specify limits of growth (Meadows et al., 1972). During the past two decades, economists have become more cognizant of the possibility that resources might become increasingly scarce over the long run (Slade, 1982; Hall and Hall, 1984) in consonance with the public's becoming convinced of that view. Interestingly, flaws in the logic of economists' empirical analyses of whether resources are scarce have become increasingly clear (Norgaard, 1990).

Economists, by implicitly assuming that technological progress would assure future generations' access to resources, have ignored the distribution of rights to resources and environmental services across generations. Thus, economists have reduced the economics of intertemporal resource use to questions of efficient allocation. During the past 15 years, resource economists have analyzed myriad variations on Hotelling's (1931) original model of allocation. They consistently have concluded that markets allocate resources "optimally," but they have considered only the case in which the present generation has all resource rights. As one can readily show and as basic theory posits, the efficient allocation of resources over time is a function of the distribution of environmental and resource rights across generations. Optimality of use depends on whether the assignment of rights accords with social preferences. But the profession repeatedly has argued, for example, that energy resource markets work optimally so long as externalities are internalized or that the extinction of some species is optimal, while it has given no consideration as to whether an underlying equity issue is involved. Clearly, in the environmental world view, these are equity issues. These transformations of equity concerns to efficiency questions follow earlier transfor-

mations of public concern with resource conservation and later with wilderness preservation. Economists also reduced these questions to matters of efficient investment and use once the externalities were internalized (Howarth and Norgaard, 1990).

To the extent that economists have worried about whether future generations will have a sufficient share, they have worried that the rate of discount used in benefit-cost analysis and by private investors may be too high. How can one discount the values of benefits received and costs borne by future generations and be concerned with sustainability at the same time? Are not low interest rates more consistent with sustainability than high interest rates since a zero interest rate treats generations equally? And yet, low interest rates would encourage many investments, such as those in the capital necessary for mineral extraction or those in projects that transform environmental systems on which the well-being of future peoples may depend. This long-standing concern over the interest rate and the welfare of future generations becomes manifest within an efficiency framework only after economists already have decided that thinking about the future involves choosing good investments. If we transferred to future generations rights to the services of resources and environmental systems, then both the present supply of savings and the present demand for investment funds would change and would determine a new discount rate (Howarth and Norgaard, 1990). Thus, the discount rate controversy is an artifact of never taking future needs seriously due to historic faith in progress.

Just as the interest rate or discount rate is a function of how rights to environmental and resource services are distributed across generations, the value of these services also is a function of how they are distributed. This is straightforward economics, but the profession has assisted in protecting these services in a roundabout manner. The argument has been that this generation over-exploits many resources since we do not realize—or market signals do not tell us—the full nature of these resources' value. Thus, environmental economists have tried valuing non-market attributes of resources so as to help design appropriate management policies that would avoid using resources too rapidly or destroying environmental systems. The history of valuation efforts is another contradictory relic of our beliefs in progress and progressive social organization—beliefs that have facilitated our failure to take seriously the rights of future generations.

Economists soon joined the applied scientists who manned the federal and state agricultural agencies established after the Civil War, the water and forestry agencies established at the turn of the century, the soil and land management agencies established during the Depression, and the environmental and energy agencies established during the 1970s. Economists filled a critical niche in these agencies. Their estimates of the true costs of inputs and of the values of non-market products related to environmental and resource management facilitated weighing alternatives and trading off one objective for another. Economic reasoning allowed the agencies to go beyond mere technical expertise and to make decisions on the public's behalf without needing to return constantly to legislative bodies for advice. Indeed, governments eventually mandated that decisions be made through economic reasoning (Nelson, 1987).

To fulfill this progressive mandate, economists have retained positivism and other "modern" assumptions about the nature of science long after philosophy and the other social sciences abandoned them (McCloskey, 1985). In addition, economic thought and practice have coevolved around several fundamental contradictions.

As neoclassical economists, we espouse

using the market mechanism since it systematically links complex phenomena. Demand and supply curves for each good are a function of the prices of numerous other goods. Prices constantly are changing in response to changes in tastes and in key substitutes and complements, and in response to changes in key inputs, technology, and resource availability. This property of the price system—that is, everything is connected to everything else by an invisible hand—is the one that accounts for the market economies' success and the one that central planners have had such difficulty matching. Of course, if the relative values of goods simply were fluctuating randomly, then planners could use an average and perhaps could even improve on the performance of a market economy. Or if relative values were moving systematically in accordance with phenomena that the central planners could identify, then planners possibly could speed the adjustment and avoid overshooting the new equilibrium. The problem is that the movements are neither random nor knowable. This vision of the price system's success, which was critical to my education at the University of Chicago, gained widespread acceptance during the Reagan-Thatcher era. And this is the miracle now sought in the Soviet Union and Eastern Europe.

As neoclassical economists, we also present quite a different story. We argue that we can weigh one thing against another according to their economic values and that we can sum and compare benefits and costs. The problem is that when we undertake benefit-cost analysis, we forget our other story regarding the constantly changing nature of economic forces. If demand curves are constantly changing, then values are constantly changing. And if values are changing in ways that are neither random nor predictable, then one cannot determine values over the period of economic decisions. When we engage in benefit-cost analysis, we assume the burdens of the central planners we chide.

A second contradiction extends the "theory of the second best" (Lipsey and Lancaster, 1956). This extension bases valuations of non-market goods and services on the assumption that the absence from the market of these goods and services is a marginal problem. However, if such goods' absence significantly distorts how people perceive opportunities and behave, then we can neither ask nor observe how people value things. The fact that attendance at national parks is not rationed by the price mechanism may not significantly distort the economy or people's perceptions and actions. But if the price of gasoline does not reflect its true market cost, then one cannot determine the value of national parks through the travel cost method. If non-market goods and services comprise a small portion of the total economy, then including these goods and services in the market would not significantly change behavior or change the relative prices among existing goods and services. However, if non-market goods and services comprise a significant portion of the total economy, then the problem of dealing with them is significant and the need for economists is greater. At the same time, valuation is not possible (Norgaard, 1989b).

A third contradiction in economists' progressive role involves public decisions regarding the use of resources and environmental systems. These decisions entail redistributions of use rights among people. One legacy of progress was some economists' argument that resources and environmental systems—and hence rights to their use—did not matter over the long run. Welfare economics plays a similar role as a legacy of progressivism. Welfare economics is a history of unsuccessful efforts to derive rationales for distributive decisions based on allocational reasoning.

A fourth contradiction, though not within economics, places economics on one side of an ongoing public debate.

Economists assume that social value is the sum of individual values. If individuals do not in some way express their values for sustaining environmental services and amenities, then society need not worry about sustainability. On the other side of the debate are environmentalists, those concerned with sustainable development, those concerned with justice, and a large portion of the general public who assume that values are formed—not given—and that we can solve many problems through the value formation process of political discourse.

One can view these contradictions as an artifact of economics being run backward. For each distribution of rights to resource and environmental services, an efficient set of prices exists. The initial distribution among peoples is a social decision. Historically, however, progressive societies and dominant world powers—through international agencies—instead have asked economists to make these distributional choices. And economists have readily assumed this position of social power. Economics lives with these contradictions so as to fulfill this role in progressively organized societies—to make equity decisions and to place values on different social objectives independently of legislative bodies. The belief in progressive social order is collapsing as diverse publics are harnessing expertise of their own. These publics are challenging centralized authorities and are beginning—albeit insufficiently to date—to assume responsibility themselves at local levels.

Speculating as to why neoclassical economics became so theoretically rigid while the other social sciences remained conceptually pluralistic is interesting. Both the success of marginal analysis and the adoption of market theory as a secular religion partly explain the conceptual monism. Hirshleifer's (1985) article on the expanding domain of economics reflects a strong faith in the eventual unity of knowledge of which economics surely will be a part. Without such a faith, one has difficulty explaining how environmental economists have been able to accommodate the contradictions between economic and ecological theory.

If people continue to accept their responsibility for sustaining the future, to reclaim their diverse cultures, and to democratize science, then economics will be coevolving under very new circumstances. If this transition continues and economics survives it, then economics will be very different during the decades ahead.

The following forward-looking conclusion is speculative and reflects my own biases and hopes for the economics profession as it grapples with the demise of progressive beliefs.

I think economics will become more participatory in that economists and economic reasoning will be used more broadly. I do not predict the demise of economists working within progressive bureaucracies on the public's behalf, but I do predict the trend will continue whereby these economists will be challenged by economists working with interest groups (Nelson, 1987). This contention will force decisions back into legislative bodies, where economists from different interest groups will explicate different arguments and viewpoints. This situation will reflect more honestly the fact that economics cannot within its logic determine what society's objectives should be or how trade-offs should be made. This situation also will reflect more honestly the fact that economies are complex and not interpretable by any single form of reasoning (Norgaard, 1989a). Economic reasoning can, however, shed light on the extent to which one can achieve various objectives most effectively. Economic reasoning can be extremely helpful in implementing the public's equity choices efficiently.

The participatory economics that likely will coevolve with the transition to sustainable development, reculturation, and

democratization of science probably will be more contextual due to greater attention to the peculiarities of local ecosystems and cultures and the desire for further diversification of both. Under these new conditions, only a few elaborations of the present-day economic model—spun during the coevolution of economic thought with progressive beliefs—will prove fit. And because applications of economics will be contextual, economic arguments will not tend to accumulate and build on each other as much as they did in the past. One will apply the basic pattern of economic logic again and again but with new twists and innovations appropriate to the issue at hand. Because no accumulation of economic arguments or mystification of mathematics and econometrics will exist, more people will be able to participate in using economics. At the same time, I expect some grand masters to emerge. An example would be economists who may learn how to interpret the influence of economic thinking on the evolution of the social and ecological systems that economists study and for which economists formulate advice (Norgaard, 1989a).

d'Arge: Thank you, Professor Norgaard.

Our next speaker is Professor Mancur Olson, who really needs no introduction here. He certainly has made many substantive contributions, which quite some time ago commenced with a book on the logic of collective action. I can think of few economists who, during the 20th century, have had a wider scope of interests and contributions than has Professor Olson.

Olson: Thank you. I was taken by Richard Somerville's nice analogy between meteorologists' making forecasts and economists' making forecasts. He also talked about the fundamental issues on which the meteorological experts continue to differ—about professional disagreements rather like those arising so often in our field of economics.

Normally, we think of the physical and natural sciences as areas in which knowledge is definite and in which a high level of professional consensus exists. We contrast these "exact" sciences with economics and with the other social sciences. Nonetheless, when global climate change is at issue, the uncertainties and professional disagreements among meteorologists are as striking as those among economists. Why are these areas of the physical and natural sciences plagued by limited knowledge and conflicting schools of thought?

The difference between microeconomics and macroeconomics will, I believe, help answer this question. We all know that economists have reached a high level of consensus in microeconomics: Virtually all skilled economists accept approximately the same microeconomics. But we have different schools of thought in macroeconomics. After many decades of research, we still have failed to reach professional consensus even about what general paradigm we should use. Some macro-economists advocate monetarist or new classical models, and others espouse Keynesian-type models.

Where professional consensus is lacking, ideology plays a large role and sometimes animates scientific debates. This is evident in political science and sociology as well as in macroeconomics.

What do macroeconomics, political science, meteorology, and global climate change have in common that makes them more difficult to understand and more likely to generate conflicting schools of scientific thought? What do certain other areas of the physical and natural sciences—and even microeconomics—have in common that enables them to get results that virtually all researchers find compelling?

The answers to these questions emerge when we remember that we cannot get a decisive answer about the greenhouse effect without an experiment on the plane as a whole. If we burned a colossal amoun

of fossil fuels over Pittsburgh, for example, we could not learn whether a greenhouse effect would result by watching the climate in Pittsburgh. Many products of combustion ultimately reach the stratosphere and disperse over the whole globe. So no experiment or historical observation that really settles the question can occur except an experiment on the whole world.

By contrast, many other areas of science can obtain solid answers with a few compact and inexpensive experiments. Thus, the chemistry of combustion is well understood at the same time that global warming is not. Over a given amount of time, scientists learn less about the greenhouse effect than they learn about some other things. Though scientists get one observation per test tube on many problems they study, they get only one observation per world on the greenhouse effect.

Now let us examine macroeconomics from this perspective. If one wants a clean test of a new classical model or Keynesian model, then one should have a closed economy. And if one desires really well-grounded empirical results, then one needs a sample of closed economies large enough for results with statistical significance.

But no really closed economies exist, and only a few economies are big enough even to resemble closed economies. So very few economies exist from which we can get decisive observations about what really determines macroeconomic outcomes. And that is why macroeconomics remains a discipline in which considerable professional dissension exists—much more than exists in microeconomics.

Suppose we ask about systems—economic systems, political systems, constitutional systems—or about foreign and defense policies and most of the things discussed in the fields of collective choice and political science. Here again, as in macroeconomics, the units that one can observe—the countries—are relatively few in number. Often only a few countries are suitable for testing a given theory or hypothesis. Consequently, scientific knowledge is limited, and ideology plays a depressingly large role in the study of political science and public choice—just as it does in macroeconomics.

For the same reason, scientific knowledge is limited and ideology plays a large role in discussions of ecological systems. Only a limited number of ecosystems exist. And from our planet, we can observe only one meteorological system. Thus, we learn about global warming very slowly, and we have difficulty resisting the temptation to obtain relief from uncertainty through one ideological faith or another.

At the same time, one must not push too far the argument I have made here. The hypothesis that global warming will occur has been around since the 19th century. Observing even a single planet for that long generates *some* knowledge. I have dealt with these matters more carefully in an article (Olson, 1986) and in a forthcoming book. Thus, I shall now leave aside both the development of the foregoing argument and its qualifications, and turn to Richard Norgaard's presentation.

* * *

Perhaps the most notable feature of Professor Norgaard's presentation is his uneasiness about what he sees as the prevailing technological optimism. His own view about the ecological future—at least as it emerged from the emphasis in his oral presentation—is pessimistic. The type of development going on in the world today apparently is not, in his view, sustainable. Our environmental problems are not simply the result of a narrow set of market failures. He views the problem in a more global fashion—in a fashion that is supposed to be less likely to involve mistakes from suboptimization. On this broader view, he seems to conclude that the problem is not simply a specific set of externalities or market failures. Rather, he perceives a society that is moving in utterly

the wrong direction. He comes very close to objecting to the motivating spirit of our age—to the idea of progress itself.

How can we even begin to answer the question of whether the pessimists like Richard Norgaard are right—or, alternatively, whether the technological optimists are right? For example, should we be terrified by Richard Somerville's conclusion that, despite overwhelming uncertainties about most aspects of the matter, a change in our planet's climate eventually is inevitable? Or should we instead take comfort from the fact that global warming also has some favorable effects—such as longer growing seasons and greater agricultural output in higher latitudes—and from modern man's impressive capacity to adapt to a wide variety of conditions?

These sweeping questions about technological optimism and ecological pessimism have so many aspects that even to discuss them intelligently might seem impossible. How could one get any quantitative feeling at all about such gigantic, many-sided, and uncertainty-laden matters?

The logic behind our national income statistics offers a surprisingly good way to think about these huge matters. These statistics provide a framework that can, in principle, encompass both positive and negative developments. Analyzing the sources of bias in these statistics can give us more insight than one might expect.

We can best begin by examining the pessimists' belief that the "development" now occurring in the world is not "sustainable." Those who are the most concerned that modern development is not sustainable emphasize, in their most sophisticated arguments, that our statistics on real per capita income are giving us a misleadingly optimistic picture of what is happening.

They correctly point out that our national income statistics do not properly account for the changes over time in the value of a country's capital stock. Calculations of national income for any period count as output the value of the business investment during that period and estimate the depreciation that has occurred. But the calculations do not take into account the change in the total value of a nation's capital stock.

Notably, the calculations do not take into account the damage to a nation's environmental capital and the depletion of its mines, oil wells, agricultural land, and other natural resources. The calculations subtract depreciation of business plant and equipment to obtain the net national product, but they make no subtraction for environmental degradation or natural resource depletion. To the extent that the planet's future productivity and habitability would be diminished by the greenhouse effect, for example, this would be a reduction in the value of the world's capital. Some of the measured output in the national accounts obviously is due to our consumption of the stock of depletable natural resources and to our general exploitation of the natural environment. Thus, other things equal, drawing down the stocks of depletable natural resources and degrading the natural environment must reduce future income.

No one doubts that our statistics on real national income fail to take proper account of the natural resource depletion and of the environmental degradation that occurs each year. To the extent of that failure, the statistics overstate the growth of our real incomes. Those who hold that contemporary economic development is not sustainable must believe that the increases in real incomes that the statistics show are totally illusory.

If the nation's statistics perfectly measured the value of both the additions to and subtractions from the capital stock and if they fully and comprehensively defined the capital stock, then these statistics already would have taken account of both the bad news and the good news. The quantity and value of the capital stock al

ready would have reflected these events, and the change in the capital stock's real value over a year then would have been part of calculating the net national product for that year. But the government does not produce any measure of the change in the value of the nation's capital stock.

So one way of dealing with the pessimism in Richard Norgaard's talk is to ask, "Is the value of the total capital stock—including both our bequest from Mother Nature and our man-made capital—tending to increase or decrease over time?" The judgment of the ecological pessimists—that the present-day pattern of world development is not sustainable—is that, all things considered, the world's capital stock is getting smaller.

Is that a reasonable conclusion? In discussing that question, I shall take for granted the proposition that many of the ecosystems are suffering serious damage. I shall assume not only that the greenhouse effect exists but that it also is unreservedly bad and that its bad effects are large. I also shall lean to the pessimistic side with respect to other environmental problems.

These assumptions would seem to imply that no economic progress has occurred for some time, or even that society has been moving backward. This conclusion would be much too hasty because the national income statistics contain another very different bias.

* * *

Let us think about the characteristics of technological knowledge and useful ideas in general. An idea is not the type of thing that will wear out when it is used more often or that will lose its value when it is used by more people. Knowledge is a nonrival public good—a good whose value does not diminish as more people use it. Knowledge also is a non-depreciable good. The ideas of Newton, for example, are no less valuable to each of us now than they were in his own day, even though the world's population has increased manyfold and the ideas have been used and reused over the centuries. Thus, ideas are inherently non-depletable and non-depreciable.

The most important ideas also tend, with rare exceptions, to be passed on from generation to generation. When really important new ideas arise, they usually are written down and taught in schools and universities so that subsequent generations can use them. Perhaps some of the artists' and humanists' insights die with them. But in all of the natural sciences, as in our own field of economics, knowledge is cumulative. Possibly a slight exception to this rule occurred in some fields in Europe during the Dark Ages, but even then the total stock of technological knowledge continued to grow. Thus, as long as human civilization survives, each generation year by year preserves and augments the stock of knowledge.

So the stock of knowledge not only is a non-depletable and non-depreciable good but also expands over time because new discoveries are added at the same time that the old knowledge is retained. These remarkable properties of the intellectual capital stock are overwhelmingly important. They imply that the total value to the world of the intellectual capital stock increases over time—and often increases very substantially.

Let us combine this salient truth with the bad news that Mother Nature does, alas, lose some of her beauty, energy, and vitality as she nurtures us. Our capital in the form of natural resources and environmental quality depreciates over time in ways that are not generally accounted for in the national income and product accounts. This consideration certainly is a cause for concern. It provides whatever basis exists for the dark pessimism that Richard Norgaard has expressed.

On the other hand, the national income statistics also fail to measure the changes in the value over time of that marvelously

undepletable and undepreciable and constantly improving public good: the intellectual inheritance of mankind. Each successive generation is inheriting an ever more glorious bequest in the form of a good-as-new and always growing stock of useful knowledge. Since the national income and product accounts contain no measures of the overall capital stock, the national income statistics fail to add the increased value of this capital stock to the value of the yearly production of consumption and investment goods. In other words, the statistics fail to take into account the *permanent* increase in our productive capacity resulting from this increase in our intellectual capital stock.

When we conceive of the matter as I just have, we realize that we need to compare the losses from the important resource depletion and environmental degradation not captured in the national income statistics with the also important and also unmeasured gains from the growth in our stock of useful knowledge. If we do not do this, we cannot come to any sensible judgment about whether current development is sustainable or whether the pessimists or the optimists are right.

* * *

How can we get some insight, and preferably even some numbers, on whether the bad news regarding natural resources and the environment or the good news regarding the accumulation of knowledge is more important? When we structure the problem the way I have, we may have the basis for a sound conclusion on a large part of the problem by looking at what has happened over time to primary products. The secular changes in the prices of primary products provide us with a valuable statistical test.

We know that the depletion of natural resources over time, other things equal, is reducing the world's productive capacity and that this depletion has been occurring at a rapidly increasing rate since the industrial revolution began during the late 18th century. This bad news shows up mostly in the prices of primary products. It tends to raise the prices of primary products compared with the prices of those goods and services that are not depletable natural resources. So a main argument of those who believe current development is not sustainable implies rising relative prices of primary products over time.

One type of knowledge that accumulates over time is knowledge about mining and farming—about how to produce, transport, and handle primary products. So the growth of knowledge affects the prices of primary products as well as the prices of other things. This means that if we consider the *relative* prices of primary products and remember that depletion tends to raise the prices of these products compared with the prices of other products and services, then we can test for the relative strength of resource depletion, on the one hand, and of the stock of knowledge, on the other. If those who believe that current development is not sustainable and that the idea of progress is nonsense are correct, then the relative prices of primary products should have been rising secularly.

For timber and for some other primary products, that is what has happened. But as many fine studies—such as those by Barnett and Morse (1963) and by Manthy (1978)—have shown, the relative prices of primary products generally have had no tendency at all to rise. If anything, they have on average tended to fall, and many of them have fallen substantially. Farmers, for example, are all too aware that the prices of farm products have tended to decrease over time.

Over the past 100 years for which relatively good price data exist, the growth of knowledge has reduced the relative prices of primary products by at least as much as depletion and environmental degradation have raised them. This finding cer-

tainly does not support the doomsday prophecies. To conclude that we are going backward is, at the least, premature.

Important as the relative price test is, we must not read too much into it. The past pattern has been quite persistent and goes back a long way, but the future could, of course, be different. Let us suppose that the suffering from poverty in populous developing countries such as China and India will be alleviated by economic growth at the rates that Hong Kong, Korea, Singapore, and Taiwan have enjoyed. Since the choice of economic policies and institutions seemingly provides the main explanation for economic growth rates, other developing countries—including countries as populous as China and India—conceivably could grow at similar rates.

If a couple of billion people were to experience the per capita income growth rates of the most successful developing countries, then that would lead to a colossal increase in the demand for primary products. The increase in productivity that caused the increase in per capita income also would imply considerable extra production of food and other primary products, but this increase would not necessarily be proportional to the increase in demand: Some extractive activities in some poor countries already are handled in a modern and efficient manner by multinationals from the advanced countries. Thus, very optimistic assumptions about economic development throughout most of the developing world might justify relatively pessimistic assumptions about the relative prices of some natural resources. And even if one assumes the relative prices of primary products will fall throughout the future, avoiding resource waste and protecting against environmental degradation still is appropriate.

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Nonetheless, I would argue that the expression "sustainable development" in the title of this session leaves much to be desired. Sustaining development might not be difficult at all due to the great importance of the accumulation of knowledge. Therefore, treating the *sustainability* of development as the problem with the highest priority is a mistake—a mistake that can cause a lot of human suffering in a world with billions of poor people.

In some respects, paradoxically, focusing on sustainable development could even *harm* the environment. It could lead to policies that do too little to protect the environment. The income elasticity of demand for environmental quality apparently is high and certainly is positive. Looking at the areas where high-income people live and at the areas where low-income people live immediately teaches us that high-income people buy more environmental quality than do low-income people. In almost every city, for example, the more prosperous tend to live upwind of the less prosperous. Rich nations also buy more environmental quality than do poor nations. Thus, as people and nations get richer over time, they will want to buy relatively more environmental quality.

That is the natural and the economically appropriate course. Why should richer people not buy more of something as important as a wholesome environment? Why should they not also buy more security against ecological hazards? Such hazards are considerable due to the uncertainties I described earlier.

The claim that current development is not sustainable may well, due to the arguments set out here, come to be ridiculed almost universally. If unfolding history refutes the predictions implicit in this claim, then complacency about environmental quality and ecological hazards could result. If environmentalists claim that our pattern of development is unsustainable and if future experience and research demonstrates that this claim is wrong, then friends of the environment will tend to be dismissed as foolish prophets of doom.

People then will think that society should do less—perhaps much less—to protect the environment and to insure against ecological hazards.

But if we are getting richer over time and if the optimal allocation for our descendants is to have more environmental quality than we have since they will be richer than we are, then we should place a higher value on preserving environmental amenities for the future. If the uncertainties are as great as my earlier argument suggests, then devoting some resources to insure against ecological disasters is prudent. As per capita income goes up, society should spend more on such insurance and on environmental amenities.

In short, if we follow those who claim current development is not sustainable, then we may well politically discredit sensible policies to protect the environment and to reduce the risks of ecological disasters. If we claim that sustaining current incomes is difficult or impossible, then we are not likely to plan for the levels of environmental amenity and ecological safety appropriate for people with growing real incomes. We do not protect the environment by crying "wolf" every day.

d'Arge: Thank you, Professor Olson.

In a moment, we will have comments and questions from the audience. But first, the panelists may have about two or three minutes to respond to each other.

Norgaard: Professor Olson had the opportunity to comment on my talk. I guess I should comment on his. First, I should point out that I premised my talk not on whether we should or should not believe in progress but on whether the global population believes in progress. My premise was that the general public is believing less and less and perhaps almost not at all. That transition is driving the political changes that are demanding economists to step in. My observations of that transition and of the state of economics drove me to say the things I said.

I could simply step back and say this is just my interpretation of the public's beliefs regarding progress and the environment. Whether or not economists believe in progress will be irrelevant. We must work with the system we have.

However, I should point out that no matter how wonderful knowledge may be, global climate change is forever. It is not just something that will affect the next generation. Global climate change, like Newtonian mechanics, will be passed on forever.

I should point out that I agree 100 percent with all the discussion of national income statistics. The difficulty is that national income statistics are just that. They are mere statistics—mere accounts. Making up the accounts is difficult and making up a global climate account, in particular, would be incredibly difficult. For example, how would we measure the asset value of global climate services to future generations? If we attempted to construct such an account, then we would wind up right back where we started and would have to go through the whole process we are going through now anyway. What is the nature of global climate? What is the nature of changes that are under way? What things are driving the changes? How do we put all of this into a national account so that we can say, for example, this year we depreciated the account by this particular amount?

Regarding scarcity and growth, how much do we know about whether resources are becoming more or less scarce? We face many problems in dealing with these analyses. For a start, I suggest you read my article (Norgaard, 1990) in the *Journal of Environmental Economics and Management*.

d'Arge: You characterize the impact of climate as necessarily bad, but apparently different areas will experience different effects. The temperate nations will gain. The nations along the equator will lose. And apparently, we almost are back to an old North/South dichotomy.

The developed nations contribute a substantial amount of the CO_2 and in a relative sense—or, in some cases, in an absolute sense—they will gain from the climate warming. The poor countries that have not yet burned their fair share of fossil fuels will be negatively impacted, for two reasons: (i) The warming will hurt them directly in a physical sense. (ii) They lack the adaptive capabilities of responding in the manner that the developed countries can respond.

Tullock: I am Gordon Tullock from the University of Arizona. This question is directed to our climatologist. Just before you mentioned the global warming, you mentioned the great nuclear winter scare. We certainly could lower the air temperature quite readily by putting dust in the upper atmosphere, and we know much simpler ways of doing it than having a nuclear war. If we are worried that the world is getting too warm, then nothing is preventing us from just cooling it off.

Somerville: Professor d'Arge, and not I, mentioned nuclear winter. However, I will happily respond to that.

I am terrified by most proposed large-scale interventions in the climate system—including that one, since it would be in the nature of taking medicine we do not understand for a disease we have not diagnosed. Fortunately, most such interventions are technologically impracticable. Today we are uncertain of the large-scale consequences of dumping chemicals or particles into the atmosphere or ocean.

In weather modification, only a few limited examples exist of our ability to make the atmosphere do what we want. These include clearing clouds from airport runways and seeding clouds. Predicting the consequences of putting particles in the atmosphere is extremely difficult. The biggest volcanos—not pikers such as Mount St. Helens but monsters such as Agung and El Chichon, which put tons of material into the high atmosphere—seem capable of altering the climate by only a few tenths of 1 degree for only a few years at most.

So that particular suggestion is technologically difficult to manage. Other suggestions are technologically more feasible, but predicting their consequences is difficult. In my judgment, the search for a technological fix to this type of global environmental concern is dangerous and somewhat misguided. It is somewhat like trying to develop a pill that will keep you from getting fat or getting kidney and liver disease so that you can eat and drink as much as you want rather than modifying what you are eating and drinking. I am worried about that approach.

I also will respond to Professor Olson's analogy of buying environmental quality. As he stated, rich people do live in nicer neighborhoods than do poor people and rich people do put more of their income into improving their local environment. But we are talking about a greenhouse effect change that is global and, in many senses, may be irreversible. We are talking about enormous changes—for example, loss of biodiversity and loss of forest, which in practice are not susceptible to technological fixes and are irreversible. In many cases, we cannot let them occur today and then buy our way out of them tomorrow.

Buckwalter: My name is Charles Buckwalter and I am a consultant with Western Pacific Consulting Associates in Montana. I deal in natural resource policy issues, and I have an observation for Professor Norgaard.

I would submit that the decline of progressive institutions has nothing to do with the decline of progress. Many people might think that the opposite is true. I think that your comments help clarify the issue since you appear to be a true progressive yourself.

My impression is that when individuals speak of looking out for the best interests of future generations, they bring up the concept of scientific management and pla-

tonic despots for which the progressives became known. Consequently, when you talk about the decline of progressivism, you must feel lonely. In that regard, I feel sorry for you since that concept seems to be on its way out.

And as you observed, we must look at the global population and try to figure out what they are saying. I submit that we now are seeing an appeal for free-market processes and the sanctity of private property rights. That is what is coming back. And I will conclude with just an observation that you seem to be making the issue much more complex than it really might be. Many people maintain that the real problem is the need to generate more markets in this environmental area. Then the free-market process would effectively mediate and allow us—the population—to put these resources to their highest-valued use.

Norgaard: First, I did not link the observations between the decline of progress and the decline of progressivism. I am sure they are linked somehow, but I did not say they are linked. I do not feel lonely at all. I have a University of Chicago Ph.D. and know something about markets. I would love to set up a market between generations. In a sense, that is all I am asking to do in the models I have constructed to illustrate the points I have made.

These models are purely market analogies. But they are market analogies where you assign property rights to future generations and then let the market work, and you see the changes I described. So I have no conflict at all with your interest in free markets. And when you say "the population," I think I am just talking about a bigger conception of the population.

Davis: My name is Larry Davis, and I am an Associate Professor of Business at Northern Montana College. I have questions to direct to each of the three panelists. Because they were in the order of Somerville, Norgaard, and Olson, I will ask them questions in that order.

My first question concerns the pessimism I heard so much about regarding the global warming. Temperature data from the 1980s do not particularly reflect general agreement that the temperatures are rising, as you said. I think some recent evidence suggests that the temperatures are not rising. If they are rising, then they are not rising so rapidly as they were hypothesized to have risen during the 1970s. Would you want to comment on that?

Somerville: Yes, I will be glad to comment. We cannot tell from the recent temperature record whether the enhancement of the greenhouse effect is observable as yet. And whether we *should* be able to tell also is unclear. You are absolutely right about the current temperature record, which in the United States shows a rather level temperature but globally shows a weak warming over a period of many years. From this current record, we cannot unambiguously attribute the warming to an increase in the greenhouse effect—or to any other single cause.

As far as we can tell, the recent warming is perfectly compatible with the idea of simple natural variability. We expect that during coming decades, a signal gradually will emerge out of the noise and we will see clear evidence of warming, an increase in the rate of sea level rise, and the other features that I mentioned superimposed on the natural year-to-year variability. As I mentioned, the change is in the odds. Just because the odds favor global warming does not mean that we can prove or disprove the theory by observing a few years. Overall, we expect a warming to occur. However, you can get a run of tails even with an honest coin, and you can get a stretch of cool years even during a long-term warming trend. We will just have to wait to see.

As Professor Olson mentioned, we have a problem here that may be analogous to a macroeconomics problem. We have only one planet. We are doing the experiment only once. And if we want unambiguous

confirmation of our theory, then we must wait and watch.

You certainly are correct in saying that the present-day record is not the basis of these forecasts. We are not extrapolating the time series of past climates. We are making the predictions from models based on physical laws imperfectly understood and imperfectly modeled rather than on any extrapolations of observed data.

Davis: Professor Norgaard, I also am concerned, and I echo my fellow Montanan's view. I have a question regarding the characteristics of the negativism toward economic growth. The U.S. economy has grown quite successfully for the past seven years, and world economies are not in decline but are in stages of economic progress. Certainly, the Club of Rome data of the 1970s have not been verified. To some extent, the Ricardians have more empirical evidence on their side during the 1980s, as you suggested in your discussion. I was wondering whether you would continue to portray, as you stated, that a large number of people believe we are in a declining economy as opposed to a growing economy.

I believe that is what you stated. I think that a large body of people believe that the world's economies—and, in particular, the U.S. economy—are in relatively slow growth but are growing, not declining, and have sustainability.

Norgaard: Let me plead the same answer as did my colleague in climatology. I am not extrapolating the last decade nor the last century. I am saying that if people in fact believe climate change will occur, if the concerns over biodiversity and accumulation of toxics are real concerns, and if the people concerned over these things are right, then how should economists view the problem? That is what I tried to address.

Davis: Regarding that, yes, market failures do occur, and I am sure that this economy probably needs some additional modeling in those areas.

This question is for Professor Olson and deals with a topic with which I tend to agree—a verification of Dennison's model of economic growth. I agree that the missing ingredient in all our discussions regarding sustainability is the non-rival public good characteristic of knowledge. And I applaud you for quite correctly identifying this important ingredient that is missing from our national income accounts. I also emphasize the view that not just during the past decade but since before the time of Plato, society has been building a tremendous stock of knowledge that we continue to possess. That knowledge will continue to grow and to provide a basis for maintaining growth.

As we move even further into an information society, can we gain some further insights into the institutional structure for growth, as opposed to the dismal views of the negative scenarios, and how might we best address these issues in the future?

Olson: My personal hunch is that our biggest problem is the slow growth of our knowledge about institutions and the inadequate use of such knowledge as we do have. As I look across national borders, I see poor economic performance and serious environmental problems in many of the developing countries. And as I study these countries, I learn that the problem is not anything inherent in these countries' natural resources or in their peoples or in factors such as that. The problem is that the institutions and policies are even worse in the developing countries than they are in developed countries.

If I had to guess whether things will or will not work out well, then my guess would depend mainly on how well we come to understand things such as economics and collective choice and how effective we are in passing on that knowledge to the population. If public understanding of economics—and especially of the economics of collective choice and institutions—improves enough, a good outcome will result.

d'Arge: During the past several months, I have talked with a group of Soviet economists and with Eastern European economists, and their solution to this problem—the climatic problem—is that all we need to do is identify the relevant Pigouvian tax and charge it to fossil fuels. They say that is the way we will achieve efficiency. That is nearly a uniform view from Eastern Europe.

Chapman: I am Duane Chapman from Cornell University. I think this question should be addressed primarily to the economists.

This is a simple but large question: What do you think about the respective roles of designing market incentives and institutional regulations so as to deal with global environmental problems?

Norgaard: That is a very broad question. It deals with a very broad problem. The ways in which we use energy, generate carbon dioxide, and, more important, generate all the other greenhouse gases are different in different countries since not all countries employ the same technologies. So we are not going to have one great solution. I think we can start with a carbon tax, which seems to be an obvious solution. But the problem involves many other things, such as CFCs. In that case, just regulating to make the transition was much easier than trying to deal with a tax. Therefore, the solution will be case specific.

Olson: My view is that any good policy to deal with these problems must create an efficient structure of incentives. Also, the basic ideas that economists have been developing over a couple of centuries are absolutely indispensable to a good solution.

However, we must not confuse the point that we need to improve the structure of incentives with some notion that we just need to leave things alone. A good structure of incentives always results from a process of creating appropriate institutions.

For example, the institution of private property did not exist during early history and does not exist in any reliable way in a large part of the world today. The institution of enforceable contracts did not emerge from the Garden of Eden. We certainly could not even work out a system of property rights that would deal with the greenhouse effect. We would have to give an unambiguous property right to someone for the whole of the world stratosphere. Then we would have a rather unpleasant world-wide monopoly problem. So we cannot just shout *laissez faire* or property rights. But with good research and good thinking, we always can improve the incentives.

Wilkins: My name is Reggie Wilkins. I am a graduate student at Claremont Graduate School.

Dr. Norgaard suggested that perhaps economists will have to think in a different light. Perhaps our standard of thinking will not solve this problem very well. In my view, our concept of value has problems because environmental scientists have difficulty accepting the idea of a market's solving this problem.

How do you value someone's life? More people are going to die from skin cancer caused by ozone depletion. Saying someone's life is worth, say, $20,000 seems rather perverse. We have a market solution that comes out of this if we can only value a life. How much are spotted tree owls worth in the North? How will we deal with the value of life? How will we let a market solve this unless we have some really strange notion of how much I am worth? What is my market value? Neal Southly could answer that, I guess, but how do we solve that?

Norgaard: I am fundamentally at odds with many assumptions behind the idea of valuation. In my understanding of economics, if property rights are assigned and if rights to take action are assigned, then prices come out of it. And if we want to assign rights to live or extend our concept of rights to live, then we should extend

that concept of rights to live through whatever political processes we have. Then let us see how the market prices change.

At least to me, market prices are the equilibrating mechanism that makes things work efficiently. They give the signals to the actors. Society, through the political processes, decides the system of rights around which the market generates prices.

d'Arge: One fundamental problem is the rights of future generations and, obviously, we dictate those rights. How we should respect those rights or whether we even should allocate them in any reasonable way certainly is an unanswerable question at this time.

I thank the panel for a good session.

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