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Sustainable development: principles into practice

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Experts argue over the ability of society to meet the challenge of sustainable development. Will technology continue to satisfy the wants of society without serious resource constraints, or is there a limit to the productivity of resource use? Those who believe there is such a limit ask if the technology behind the optimists' faith in increasingly productive resource use really exists. Perhaps a more important question is whether new principles for allocating scarce resources will be put into practice.

As Woody Guthrie refrain goes, "ain't no country extra fine that's just a mile from the end of the line." His song—"End of My Line," written in 1941—praised the new dams that were bringing cheap electricity to the Columbia River Basin. The line he mentions is, of course, a power line.

Today's songs about the Columbia River are more likely to praise salmon than power lines. Still, Guthrie reminds us of where priorities lay, even in the United States, only two generations ago. As we now face the challenge of a sharply growing and mostly poor world population, it is an instructive reminder.

The 1987 report of the World Commission on Environment and Development, *Our Common Future* (commonly known as the Brundtland Report), is less lyrical than Woody Guthrie, but is equally instructive. It insists that we attend to the economic needs of the world's people, as well as to the quality of their environment. And the report rests on the principle of sustainable development, arguing that we must meet the needs of the present without compromising the ability of future generations to meet their own needs.

This is a tall order, but the Brundtland Report takes it on with a remarkable sense of hope. Thus the report "is not a prediction of ever increasing environmental decay, poverty, and hardship in an ever more polluted world among ever decreasing resources. We see instead the possibility for a new era of economic growth, one that must be based on policies that sustain and expand the environmental resource base."

Not everyone sees it this way. For example, Bill McKibbin, in "The End of Nature," argues that we simply consume too much, and he questions "the industrial basis of our civilization, the need to forever grow in wealth and numbers, and the entire way we live." Paul and Anne Ehrlich focus on the population problem. Some of their sense of gloom comes through in their observation, in *The Population Explosion,* that "if current population trends continue, [they] could bring us essentially to the same sort of

Photo courtesy of The World Bank

Sharing financial and knowledge resources with the developing world, where economic and environmental security are hardest to achieve, seems prudent.

world as would be left after a nuclear war and a nuclear winter—just more slowly." And in "Land, Energy, and Water: The Constraints Govern Ideal U.S. Population Size," David and Marcia Pimentel foresee such impressive resource constraints that if "the U.S. population wishes to continue its current high level of energy use and standard of living and prosperity, then its ideal population should be targeted at 40–100 million people."

This is pretty heady stuff, and makes it worth asking whether the optimism of the Brundtland Report is misplaced. Can we manage our affairs in a sustainable way? And if we can, what are the chances that we will? Unfortunately, the first question has a more promising answer than the second.

The challenge is formidable. Demographers estimate that world population might level out at more than ten billion people sometime in the twenty-first century. More than 90 percent of this growth will occur in developing countries, where the current average per capita income is about one-tenth of that in the member countries of the Organization for Economic Cooperation and Development (OECD). For the developing world to achieve, say, one-third of the per capita income level that the developed nations enjoy, the world economy would have to expand more than thirtyfold over the next one hundred years.

Daunting as this challenge may seem, we have little option but to face it. If meeting the economic needs of the poor is not reason enough, the Brundtland Report stresses that environmental degradation equals the absence of development. In short, neither rich nor poor can have economic or environmental security without economic development.

Nor is it easy to conclude that a doubling of the world's population is a mistake requiring drastic remedy. The world's population is growing in large part because improvements in public health have depressed the mortality rate in the developing nations, a humanitarian effort worthy of some praise. The problem now is to make the predictable lag between reduced mortality and lower fertility as brief as possible. While fertility control is clearly a part of the solution, economic development is also a necessary contributor to the social change that will persuade parents to have fewer children.

Can technology save us?

For these reasons, it seems to me the vision of the Brundtland Report is inescapably correct. But if we accept the need for economic development and the inevitability of some population growth, then we must look to technology as the chief engine of sustainability. The central issue is whether technology—both hardware and the knowledge to use it wisely—will allow us to manage our natural and environmental resources sustainably. And this issue is in dispute.

On one side stand those who believe that technology will continue to satisfy the wants of society without serious resource constraints. These optimists—many of them economists—believe in markets in which incipient scarcity triggers an increase in the price of the affected resources. Responding to this price signal, technology emerges that lets us use scarce resources more efficiently.

History supports this view. According to the Brundtland Report, the global economy multiplied fiftyfold in the last hundred years, four-fifths of this growth coming since 1950. Yet the prices of many natural resources have not risen much in real terms for decades, suggesting that the market has dealt with resource scarcity at acceptable costs. Moreover, economists have shown that markets can also efficiently resolve scarcities of environmental resources, given the right price signals.

The alternative view raises the possibility of ultimate limits. Consumption of material goods cannot forever increase, and in any case we should prefer quality over quantity of consumption. From thermodynamics comes the idea that it takes an ever-increasing amount of work to put nonrenewable resources into usable shape—one cannot recycle the same beer can forever. We are ultimately left to rely on the sun's energy as our sole source of support. When this daily ration of energy falls below that needed to overcome the dissipative use of nonrenewable resources, economic growth ceases.

Of course, growth will end someday, but this conclusion is only a troubling curiosity if technology gives us ample time before the limits are reached. It is on just this point that the skeptics' argument is the most powerful, for they simply insist that productivity of resource use cannot increase forever. Thus the optimists had better be prepared to show that real technology exists to support their assertion. And given the constraint of

sustainability, it had better be the right kind of technology.

This is a heavy burden of proof, as the example of agriculture suggests. The optimist need only assume that agricultural productivity will grow at its historical rate to show that there will be plenty of food and fiber for the population of the next century. But present agricultural technology can do environmental harm by introducing polluting fertilizers and pesticides, and by encouraging the overuse of marginal land and water resources. What is required is not simply more of the same, but new technologies that produce more food and fiber without the environmental consequences of the current ones.

The same situation—a technology that overcame resource constraints in the past but may not do so in the future—exists in regard to other natural resources. Energy analysts argue that we can meet future energy needs and solve the pollution problems that energy creates, but not with yesterday's technology. We need not cut old-growth and tropical forests to have adequate timber supplies, but it will take an approach different from today's. The world's water resources are ample to sustain a much larger population, though not if we manage these resources as we do now.

On balance, the technological possibilities for providing a growing population with at least an adequate level of economic well-being seem encouraging. Still, the optimists have yet to meet the test of showing that there is real technology behind their faith in increasingly productive resource use. Surely, closing on this issue must be one of the chief tasks facing economists and technologists in the immediate future.

From principles to policy

That the available evidence is equivocal leads to a difficult challenge for policy. We have a goal that seems to be inescapable, but our ability to meet that goal is uncertain. Given this dilemma, what policies for allocating our scarce financial, natural, and environmental resources give us the best shot at success?

In an age of sustainable development, new principles for allocating resources apply. These principles are still too unfocused to be called policy prescriptions. Yet their weight is already beginning to be felt, and it is not hard to see their major outlines.

Above all, we must invest heavily in creating the new knowledge we need to increase the productivity of our use of natural and environmental resources. What is required is a long-term technological vision and a corresponding commitment to it—an act that is both financially expensive and politically rare. Still, the payoffs are immense.

Second, we should rely on decentralized decision making to allocate resources—preferably market mechanisms. Markets need the right price signals to work properly, and so, in the language of economics, externalities must be internalized in private markets. We can expect greater interest in getting prices right, as the consideration of carbon taxes to contain CO_2 emissions suggests. Although not an easy task, getting the prices right is infinitely preferable to the prospect of global command-and-control regulation.

Optimists have yet to show that there is real technology behind their assertion of increasingly productive resource use.

Third, global interdependence means sharing scarce financial and knowledge resources. The developing world is the chief battleground for achieving economic well-being and environmental sustainability, but most of the financial and technological weapons exist in the industrialized nations. Inevitably, we must face the issue of transferring these resources from the wealthy to the poor, even at some expense to the former.

Finally, we must be more risk-averse in deciding to use resources. Human activity can now disturb global physical and ecological systems, such as the climate. Until we know more about some of these systems, it is not unreasonable to suspect that they are as likely to be fragile as robust. This situation enlarges the danger of inadvertently and irreversibly crippling a valuable resource. Since the obvious way to avoid irreversible damage is not to use a resource at all, it follows that there will be a rising level of aversion to risk in decisions about resource use.

The obvious difficulty of successfully applying these principles in shaping public policy would seem less formidable if our record of managing scarce resources were not so dismal. Many nations subsidize agriculture at great economic and environmental cost. The United States pays too little for energy, a fact brought home by the recent turmoil in the Middle East. We refuse to manage water according to its true value, and so seem to have too little of it.

Nor are our environmental policies models of careful resource use. The toxic pollution control provisions of the Clean Air Act amendments will cost $5 to $10 billion per year to save at most a few hundred cancer cases annually. It is hard to imagine that this expenditure could not be put to better use even to reduce the incidence of cancer in the United States. More globally, William Ruckelshaus finds "something unsettling about a world where every day twenty-five thousand people die from easily preventable waterborne diseases. And yet we continue to argue in America about ever smaller increments of pollution abatement with diminishing health benefits."

It is surely elementary that, if sustainable development means anything at all, it means not wasting resources. Nevertheless, we seem more often than not to adopt policies that only make matters worse—that create scarcity where none need exist. In the glow of our devotion to the principle of sustainable development, this seems a special hypocrisy.

That the task is hard should not weaken the conviction that we must seek to provide adequately for the growing population of our planet. Old technology that is unsustainable does nothing to diminish the importance of developing new technology that is. And our penchant for making matters worse hardly means that we ought to ignore policies that make matters better. What all this does say, however, is that it is time to put our practice on a par with our principles. ■

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The expanding role of environmental interests in agricultural policy

Katherine H. Reichelderfer

Despite the potential of modern agriculture for harming the natural environment, agricultural activities in developed economies have been regulated quite differently with respect to environmental consequences than have the activities of the mining, manufacturing, energy, and construction sectors from which similar environmental damages arise. Understanding the factors that have influenced how agriculture is regulated to achieve environmental goals provides important clues to the success of future agroenvironmental policy efforts and to the changing role of agriculture in a growing economy.

The contributions of modern agricultural practices to the depletion of natural resources and the degradation of the environment have been well documented. Modern agriculture is associated with depletion of underground water sources, degradation of soil resources, contamination of surface and ground water with substances that run off or percolate from agricultural land, destruction of wildlife habitat, and endangerment to biodiversity. Agriculture is really no different from other industries in that it generates waste materials. But unlike other sectors of the economy—in which pollution has increasingly been controlled through federal standards, fees and fines, restrictions, or (more recently) market-based incentives—agriculture is unique in having engendered relatively less federal government intervention with respect to its environmental consequences. When intervention has occurred, it has been achieved—more often than in other industries—through mechanisms that increase rather than decrease producers' incomes.

Federal agricultural resource and environmental programs have existed in the United States since the 1930s. As originally established and traditionally maintained, these programs have been largely voluntary and have relied on the use of positive incentives to achieve their goals. For instance, agricultural landowners have long had access to the Agricultural Conservation Program, the Soil Conservation Service, and the Great Plains Conservation Program, which, along with similar programs, offer technical and financial assistance for voluntary initiation of soil and water conservation planning and implementation at the farm level. The current Conservation Reserve Program—like its predecessor, the Soil Bank Program of 1956—allows farmers to receive annual rental payments from the federal government for retiring land on which cultivation may pose environmental hazards. Such programs mutually benefit the environment and the farmers who choose to participate in them.

Federal agricultural resource programs have traditionally relied on positive incentives to encourage resource conservation.

Only since 1985 have some penalties been added to the incentives offered to farmers for resource conservation. The 1985 Food Security Act prohibits farmers from receiving benefits through commodity, farm credit, and related farm programs if the farmer drains wetlands or cultivates erodible land without having a conservation plan in place. While involving penalties of a sort, these compliance programs are also voluntary. Any participant in a farm program is free to drop out of the program rather than comply with its environmental requirements. As conditions in agricultural markets improve (making farm program safety nets less necessary) or the level of farm program benefits declines, the penalty for noncompliance with environmental guidelines can rapidly diminish.

Despite the historical tendency for U.S. policy to treat farmers as willing stewards of the land, some environmental legislation since the early 1970s has directly affected farming. In particular, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), under which pesticides are regulated, has reduced the number and variety of alternative substances available to farmers for pest control. FIFRA is unique in two ways: it addresses the safety and environmental effects of the use of products rather than the making of products; and it is among the few federal environmental acts that mandate a balancing of benefits and risks in decisions to ban or restrict a product. As a result of these characteristics, FIFRA has had limited economic effects on farmers. The need to balance the benefits of a pesticide's use against the risks that use poses has meant that, in most cases, uses have been banned only when there were close chemical or nonchemical substitutes available. (For an examination of how the U.S. Environmental Protection Agency [EPA] balances the risks and benefits of pesticides, see the article "An analysis of EPA pesticide regulation" in this issue.) Only those farmers who were especially dependent on a pesticide for a use that was banned have suffered economic losses. The farming sector at large may even have gained from the increases in revenue that come about when a regulatory action decreases the production of only some farmers and subsequently stimulates rises in commodity prices that benefit all producers. Paradoxically, costs have been restricted mainly to consumers, whose public health FIFRA was designed to protect.

Agriculture has thus far been overlooked by or excused from meeting the requirements of most other environmental policies. Federal policy regarding water quality and toxic substances has focused on point

sources of pollution, postponing the more difficult problem of nonpoint sources, mainly agricultural. For instance, the Clean Air and Water Quality acts impose technology-based standards that affect the location, configuration, operating conditions, and costs of virtually all industrial and public utility facilities, yet they place no limits on effluents or emissions from agricultural and other nonpoint sources of air and water pollution. Similarly, industries and municipalities spend an estimated $23 billion to $30 billion annually to comply with the 1972 Federal Water Protection Control Act, yet that act authorizes federal subsidies to help states plan and farmers adopt water quality management strategies for which there are no associated standards.

The unique treatment of agriculture is apparent in a range of resource conservation and environmental policies. During the energy crisis of the 1970s, agriculture was routinely exempted from controls on the price and availability of fuels. At present, agricultural landowners whose practices have rendered land unusable (through accumulation of salts, heavy metals, or other toxic substances in the soil) are not subject to any law equivalent to that which requires land users to return areas scarred by surface mining to their original condition at private cost. Thus, while the centralized or command-and-control approach to environmental policy has been given precedence in nonagricultural sectors, incentive-based and subsidy approaches have predominated in the agricultural sector. Why is this so?

Is agriculture special?

In some respects, unique approaches to minimizing potential environmental damages from farming might seem warranted. First, there is more uncertainty about the nature of nonpoint sources of pollution than there is about readily observable point sources. Contaminants from nonpoint sources cannot easily be traced either to agricultural activities (some could originate naturally or in a golf course or home garden) or to a specific parcel of land or land operator. Thus regulations based on limitations on or requirements for certain agricultural practices—with or without associated fees, fines, or taxes—are more difficult to design than are regulations for point sources of pollution, which can be monitored.

Second, in farming, individuals are making use of privately owned resources. In other industries, where environmental concerns focus on the private use of public goods such as air and water for discharge, there are few counterparts to the property rights issues involved in decisions about how farmers use their own land. Questions about whether farmers' property rights might be violated by environmental regulation that acts upon the public's right to an undegraded environment are also complicated by a pervasive paternalism toward American farmers. The special reverence with which small farms and family farms are regarded is not common to most other groups of producers, especially in the manufacturing sector, and creates a public desire to resolve environmental problems without hurting farmers.

Finally, agriculture in the United States and other developed countries is highly protected through a network of farm income and price support policies. The distortions created in agricultural markets by such intervention can offset regulatory incentives for changes in agricultural technology that are environmentally beneficial. In other words, the maintenance of farm income through production and price controls makes regulations that raise the cost of environmentally damaging farm practices weaker in agriculture than in other markets that remain unregulated.

Despite these constraints, a range of policy options for more efficient control of agricultural sources of pollution is readily identifiable. For instance, the sales price of agricultural chemicals known to pose risks could be taxed at rates consistent with their social costs. Farm income support could be linked to environmental stewardship instead of to commodity production levels. Markets for permits to use certain agricultural chemicals in closed biosystems could be established. The fact that such options have not been implemented suggests that there are other factors influencing the direction that agroenvironmental policy has taken to date. Research at Resources for the Future demonstrates that it is largely broader political and economic trends that have most influenced past patterns and that are likely to change future policy approaches to environmental regulation in American agriculture.

Critical factors

Trends in the value of gains and losses as perceived by public interests on the one hand and agricultural interests on the other, and the subsequent influence of competing interests on the policy process, best explain policy choices for environmental regulation of agriculture. How the public and its representatives view and value the goods arising from agricultural activities depends on many factors, one of which is economic growth.

Rising per capita income in the developed economies increases the level of demand for goods such as environmental quality, recreation, and aesthetics at a greater rate than it does the level of demand for basic goods like food and fiber. Demographics reinforce this demand as an aging population with greater leisure time exerts pressure for clean recreational and retirement sites. Consistent with these trends is a generally increasing valuation by the public of the environmental costs arising from agricultural production. As perceived costs rise, the proclivity to protect agriculture may decline in relation to the demand for environmental regulation of agriculture.

Whether federal legislation favors agricultural or environmental protection depends partly on relative farm income.

At the same time, the size of the agricultural sectors of developed economies tends to decrease as the economy continues to grow. The decline in the number of farmers implied by this phenomenon actually increases rather than decreases the political influence of agricultural interests; as the size of the agricultural community decreases, each member of that community has a larger personal stake in decisions

about agroenvironmental policy. Thus economic growth can create tension and increased competitiveness between groups that have invested in agriculture and those that demand higher levels of environmental protection.

The response of legislators to these ofttimes competing interests is in part a function of how well farmers are faring in relation to the rest of the economy. There seems to be a strong correlation between relative farm income and the passage of agroenvironmental legislation, as well as the form that legislation takes. When farmers are perceived as being richer than the rest of us, it is more likely that restrictive legislation in the manner of FIFRA will be passed. Conversely, when farmers are suffering financially in relation to the rest of the economy, as in 1985, legislation addressing agroenvironmental problems is more likely to take the form of a subsidy that enhances farm income (see figure 1).

Because of farm program payments, fluctuations in the extent to which the capacity to produce agricultural goods corresponds to demand for those goods vary in a different way than does relative farm income over time. Yet the willingness of federal legislators to enact laws protective of agriculture or the environment also appears to be related to the size of surpluses. The larger those surpluses, the more likely it is that legislation favors environmental interests over agricultural ones.

The political strength of environmental interest groups lobbying to represent public interests in agroenvironmental quality is also an important factor in whether legislation favors agricultural protection or environmental protection. The number of environmental groups involved in agricultural policy, their membership, and the resources available to them have grown dramatically over the last two decades. As environmental groups become increasingly efficient at exerting pressure, the degree to which environmental interests influence policymaking may rise. Independent of the activities of these groups, the rapid accumulation of information on the levels and possible consequences of environmental contaminants from agricultural sources is likely to raise the public's demand for environmental regulation of agriculture.

Implications for the future

Many of the factors that have affected the level and direction of U.S. agroenvironmental policies in the past are still in evidence or are gaining in influence today. The long-term outlook for the economy is continued growth, implying a continued general shift of public preference toward environmental regulation of agriculture. Relative farm income is on the rise, reinforcing trends that place greater weight on environmental interests in policymaking. Furthermore, the size and influence of environmental and other public interest groups concerned with agroenvironmental policy is growing.

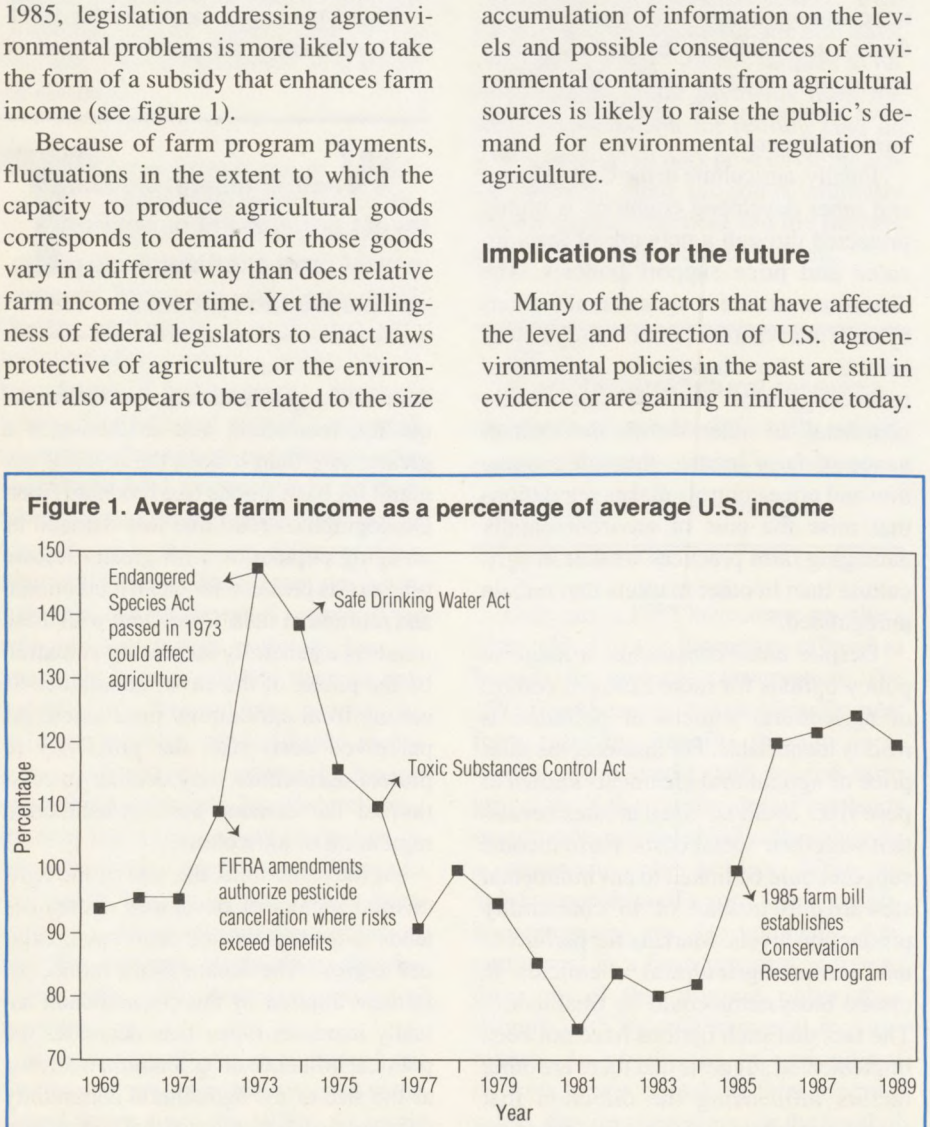
Other factors may accelerate the shift toward regulation of agriculture for the purpose of environmental protection. One is the changing composition of the House of Representatives, which with each redistricting in recent years has lost some proportion of representation from rural and farming-dependent regions. Others include increasing agricultural productivity, shifts in agricultural trade patterns, and the proliferation of environmental regulation at the state level.

U.S. agricultural productivity increased an average of 2 percent per year during the 1980s. As the efficiency of production continues to increase, the costs to the public of agricultural programs will rise (unless demand increases at the same rate—a phenomenon not expected in the short run). These rising costs will likely decrease the political strength of agricultural interests relative to that of taxpayers, implying a future decrease in agricultural protection relative to environmental protection.

As for trade, current negotiations under the General Agreement on Tariffs and Trade (GATT) are attempting to decrease the level of subsidies to domestic agricultural producers while exempting agricultural programs that are oriented toward environmental protection or conservation from similar cuts. If successful, GATT reforms could promote agriculture as an industry that must be more responsive to environmental concerns.

Regardless of the outcome of GATT negotiations, continued or increased reliance by U.S. agricultural producers on the export market will reinforce pressure for reforms in the agricultural sector. This is because the costs to the public of agricultural support tend to be greater in the relatively price-sensitive export market, and because the direct and indirect costs of environmental degradation associated

Figure 1. Average farm income as a percentage of average U.S. income



Note: Laws potentially costly to agriculture are more common when farm income is high relative to average income.

with production are not passed on to foreign consumers.

Finally, the number of environmental standards established, laws enacted, and programs implemented at the state level increased dramatically during the 1980s. This increase was partly in response to federal mandates for states' development of customized environmental protection efforts, and partly a result of public clamor and responsive legislatures in progressive states. At present, a fair proportion of state environmental legislation specifically targets or has direct implications for agriculture. In California, Proposition 65 may restrict some uses of agricultural pesticides otherwise allowed under FIFRA. In Connecticut, liability has been imposed on individuals (including farmers) shown to have contaminated drinking water sources. In Iowa, fertilizers and pesticides are taxed to raise revenues for improvements in water quality.

Great variation in the environmental laws of individual states can create problems for agricultural industries that operate nationally. If and when such variation becomes a serious constraint, the agribusiness industry itself may exert pressure for federal provision of some uniformity—a move that suggests the possibility of increased centralization of agroenvironmental policy in the future.

As the U.S. economy grows, new information on the environmental effects of agriculture is made available, and existing environmental legislation is applied to nonpoint pollution sources, the level of environmentally motivated government intervention in agriculture will begin to approach that in other industries. This is not likely to happen overnight or in a continuous fashion. Just as a generally growing economy experiences periodic recessions and expansions, the influence of economic factors on environmental regulation of agriculture is likely to wax and wane. An example of this is the recent defeat of the Big Green initiative in California, public support for which was seen to diminish in direct response to the developing recession in the state's economy.

There is little chance that agricultural protection will be overrun by environmental protection in the near future; only that the level of agricultural protection relative to environmental protection will decline. The form that new legislation takes will depend on the unique characteristics of agriculture, the public's view of agriculture, and the influence of private interests. However, in the future it is increasingly likely that the agricultural sectors of the United States and other developed countries will be affected by a centralized form of environmental regulation. Moreover, federal budget deficit problems in the United States will make it increasingly difficult to address agroenvironmental problems chiefly through subsidy programs, as has been typical in the past. The choice that farmers, agribusiness, and policymakers face is whether to increase environmental regulation of agriculture through a command-and-control approach or a market-based one. Experience in other industries suggests that the more efficient market-based approach has greater potential for creating a climate under which production that is sensitive to environmental protection is also good for agricultural business. ■

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An analysis of EPA pesticide regulation

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Does the U.S. Environmental Protection Agency balance risks and benefits in regulating pesticide use? A recently completed study of the agency's decisions regarding cancellation of some registered food uses of pesticides suggests that it does. The study also finds that the agency's regulation of pesticides is influenced by special interest groups—a fact that some economists and risk analysts may find discouraging and others encouraging.

Pesticides are at least partly responsible for the large increases in agricultural productivity that the United States has enjoyed since World War II. However, their use may pose risks to the environment—to ground or surface water or to wildlife habitat—as well as to workers who apply them and to consumers who eat pesticide residues on food. It is the job of the U.S. Environmental Protection Agency (EPA) to regulate pesticide use to manage these risks. Specifically, the EPA decides whether a pesticide can be used and, if so, what residues may safely remain on foods. According to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the agency makes the first decision—whether to allow a pesticide to be used—by assessing whether the pesticide imposes "unreasonable adverse effects on the environment." Once it approves a pesticide for use, the EPA must act to "prevent any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of [the] pesticide." This implies that a pesticide should be banned only if the risks of its use outweigh the benefits.

In the past the EPA has been criticized for its decisions to ban or not ban pesticide uses. Environmental groups cite the agency's failure to ban pesticides, such as dicofol, that pose risks to wildlife. At the same time, some economists allege that the agency pays too much attention to pesticide risks to farmworkers and consumers. They claim that the EPA has reduced the risk of cancer to these groups only at very high cost. In the same vein, farmers have been quick to point out that banning a pesticide can be very costly to them, especially when few substitute pesticides are available.

These criticisms raise several questions about the EPA's recent decisions regarding pesticides. First, in deciding whether or not to ban a pesticide, has the agency balanced the health risks of pesticide use against the benefits, as it is required to do under the law? Have the costs of banning a pesticide been considered as well as the risks, or does the EPA always ban pesticides when risks of cancer to farmworkers or consumers exceed some threshold level, regardless of how much such a ban costs? In the area of risk regulation, the notion that substances posing high risks to any one person should always be banned—even if the cost is high—is a common one. The other side of this argument is that substances posing low risks should never be banned, even if it is inexpensive to do so. Has the EPA acted in accordance with this argument in regulating pesticides, or has it balanced costs against benefits at all risk levels?

Second, has the EPA been responsive to the interests of environmental groups in regulating pesticides? When organizations such as the National Audubon Society or the Environmental Defense Fund comment publicly in support of cancelling a registered use of a pesticide, do their comments increase the chances that the EPA will ban the pesticide? In light of the history of U.S. pesticide regulation, the EPA's responses to such comments are particularly interesting. Before the EPA was created, pesticides were regulated by the U.S. Department of Agriculture. Transfer of responsibility for pesticide regulation to the EPA was prompted in part by the view that the Department of Agriculture was not sufficiently responsive to environmental and consumer groups.

Third, what other political considerations have influenced pesticide regulation? Has participation in the regulatory process by growers' organizations or their representatives decreased the likelihood that a pesticide will be banned? Are pesticide decisions sensitive to political concerns, given that the administrator of the EPA is a political appointee?

In an attempt to answer these questions, researchers at Resources for the Future and the University of Maryland undertook a study of the EPA's decision to ban or not ban each of the 245 registered food uses of the nineteen cancer-causing, food-use pesticides that went through the agency's special review process between 1975 and 1989 (see table 1). The EPA cancelled 39 percent of these food uses. The study explains the pattern of cancellations as a function of the risks and benefits of pesticide use, as well as of political variables.

Registering pesticides

If the EPA suspects that use of a pesticide imposes unreasonable adverse effects to human health or the environment, it must subject the pesticide to a special review before banning it. During this review, the agency examines the risks and benefits of the pesticide's application for each crop on which the pesticide is used. The EPA next makes a preliminary judgment, crop by crop, regarding cancellation of the pesticide. Then follows a period during which members of the public, including environmental groups and growers' organizations, may comment on the proposed decision. At the end of the comment period a final decision (Notice of Final Determination) is issued.

During the special review process, the EPA considers not only the ecological effects of pesticides, such as whether a particular pesticide is toxic to wildlife or is likely to contaminate ecologically fragile environments, but also the risk of cancer to persons who mix and apply pesticides and to consumers who ingest pesticide residues on food. Evidence that a chemical is carcinogenic usually comes from tests on animals; these tests produce an estimate of the relationship between dosage of a pesticide and lifetime risk of cancer. This estimate is extrapolated to humans and multiplied by an estimate of human dosage (exposure) to calculate the incremental lifetime risk of cancer to a farmworker or consumer from that exposure.

Incremental lifetime cancer risks are typically much higher for pesticide applicators than for consumers of food products. For example, for the pesticides studied by researchers from RFF and the University of Maryland, the highest lifetime cancer risk for pesticide applicators is 0.10 for ethylene dibromide (EDB) when used in spot fumigation—that is, as a result of applying this pesticide, the applicator's lifetime risk of cancer in-

Table 1. EPA Pesticide-Use Decisions Studied by RFF/University of Maryland

Active ingredient (generic names)	Year of decision	No. of food-use registrations	No. of final cancellations
Dibromochloropropane (DBCP)	1978	12	12
Amitraz	1979	2	1
Chlorobenzilate	1979	3	2
Endrin	1979	8	4
Pronamide	1979	4	0
Dimethoate	1980	25	0
Benomyl	1982	26	0
Diallate	1982	10	0
Oxyfluorfen	1982	3	0
Toxaphene	1982	11	7
Trifluralin	1982	25	0
Ethylene dibromide (EDB)	1983	18	18
Ethalfluralin	1983	3	0
Lindane	1983	8	0
Silvex	1985	6	6
2,4,5-T	1985	2	2
Dicofol	1986	4	0
Alachlor	1987	10	0
Captan	1989	65	44
Totals		245	96

creases by one-tenth. (In other words, according to the EPA's estimate, one out of every ten pesticide applicators would die of cancer.) For half of the crops on which the use of pesticides was studied, however, the increase in cancer risk to applicators is much lower—only 1 in 100,000 or less. For consumers, the increase in lifetime risk of cancer from eating pesticide residues on food is even lower—only 23 in 1 billion, or less, for half of the crops studied.

In addition to cancer risks, pesticides may have adverse reproductive effects: they may cause miscarriages and fetal deformities or may lower the sperm counts of applicators. While there is human evidence for the latter two effects, information on fetal deformities usually comes from animal tests, and the extent of such effects in humans is generally difficult to quantify. Against these risks, the agency must weigh the costs to consumers and producers of banning the use of a pesticide on a particular crop. Losses will occur if producers must switch to a more costly substitute for a pesticide, or if a substitute is an imperfect one that will reduce yields when used. Decreases in yield may in turn lead to increases in food prices to consumers.

As calculated in the EPA's special review process between 1975 and 1989, losses to producers from the cancellation of uses of pesticides on foods varied widely. The highest loss expected during the first year following a cancellation was $227 million (in 1986 dollars) for the ban on alachlor for use on corn. Average first-year losses, however, were considerably lower—only $9.1 million. In 35 percent of all the cancellations considered, losses were calculated to be negligible because of the availability of substitute pesticides.

The roles of risks and benefits

To explain the EPA's decisions regarding cancellation of a pesticide for use on a particular crop, RFF and University of Maryland researchers constructed a database on the risks and benefits of pesticide use as reported by the EPA in official documents. They also assembled a record of comments entered in the public docket (following a proposed decision) by environmental groups, growers' organizations, and persons from universities. This database was used to develop a model for predicting the influence of risks, benefits, and comments in the public docket on cancellation of a pesticide for use on a crop.

The results of the RFF/University of Maryland study indicate that the EPA has balanced the benefits of pesticide use against the health risks at all levels of risk. Although the researchers found levels of cancer risk for consumers and pesticide applicators above which all pesticide uses were banned, a model that assumes that cancellations are based on a risk threshold does not explain the decisions the EPA made as well as one that asserts that risks and benefits are balanced even at high risk levels. The theory that substances with low risks are never banned simply does not hold for the pesticides studied. For example, some uses of captan were banned even though they posed negligible cancer risks.

Given that the EPA balanced risks and benefits, how important were each of these factors in arriving at a decision? Analysis indicates that an increase in producers' losses of $1 million in the first year after cancellation reduced the chances of cancellation by one percentage point. With regard to health risks, those of greatest concern to the EPA appear to be risks of cancer and adverse reproductive effects in pesticide applicators. The value the agency attached to reducing risks of cancer to applicators is large: $35 million for a 1/10,000 reduction in cancer risk for each of 10,000 applicators. In the terminology of risk management, the value of saving one "statistical life" among pesticide applicators was $35 million. The size of this figure may reflect the fact that applicators are a well-defined population that faces large risks relative to the risks to persons who consume pesticide residues on food.

Environmental groups, economists, and farmers have all criticized the U.S. Environmental Protection Agency for its decisions regardng pesticide bans.

Risks of adverse reproductive effects in workers who mix and apply pesticides were also important in banning both EDB and dibromochloropropane (DBCP). Overall, the presence of adverse reproductive effects increased the chances that a pesticide was banned by about 15 percentage points.

By contrast, risks of cancer to consumers of pesticide residues on food were not very important in decisions to ban food uses of the pesticides studied. However, it is important to note that, with the exception of toxaphene, which was banned for use on field crops, none of the pesticides studied posed large cancer risks to consumers of food products.

Influence of special interest groups

In addition to considering the risks and benefits of pesticide use, the Environmental Protection Agency appears to have been influenced by environmental groups and users of pesticides in making decisions to cancel food uses of pesticides. Comments by environmental groups increased the chances that a pesticide would be banned for use on a particular crop by 49 percentage points. Comments by growers' organizations and by academics acting on behalf of users and manufacturers reduced the probability of cancellation by 27 and 19 percentage points, respectively. This seems to imply that growers and academics offset the influence of environmental interests in the regulatory process; however, the three groups did not always comment on the same decisions. Environmental groups commented on 49 percent of the proposed decisions to cancel or not cancel a food use of a pesticide, growers' organizations commented on 10 percent of the decisions, and academics on 28 percent. All three groups commented on only 17 percent of the proposed decisions between 1975 and 1989 to cancel food uses of pesticides.

This last point raises the question of what prompted special interest groups to comment on the EPA's proposed decisions. In analyzing the behavior of grow-

Photo courtesy of the Southern Agricultural Chemicals Association

Health risks to pesticide applicators appear to weigh heavily in decisions by the U.S. Environmental Protection Agency to ban a pesticide use.

ers' organizations and environmental groups—the two special interests having the most clearly defined objectives—it is clear that growers were more likely to comment when losses to producers from pesticide cancellation were high, while environmental groups were more likely to comment when a pesticide posed a danger to wildlife. In addition, whether or not special interests commented on proposed decisions was influenced by who the current administrator of the EPA was. When Anne Burford was the agency's administrator, no environmental groups commented on the 75 food-use decisions proposed during her tenure, possibly because they thought they would not receive a sympathetic hearing. By contrast, growers' organizations, anticipating more sympathetic treatment, were more likely to comment during Burford's tenure. In fact, half of all comments by growers' organizations occurred during the two years that Burford was administrator of the EPA. Thus Burford's tenure at the EPA seems to have had a negative effect on the likelihood of pesticide cancellation, due to the fact that no environmental groups intervened during her administration, whereas grower organizations were more likely to have intervened.

An RFF/University of Maryland study indicates that the EPA has balanced the benefits of pesticide use against health risks at all levels of risk.

Cause for comfort and concern

The results of the RFF/University of Maryland study offer both comfort and concern to persons interested in environmental regulation. With respect to comfort, it appears that the EPA is indeed capable of making decisions that balance risks and benefits, as the law requires. The study demonstrates that risks to human health, the environment, or both increased the likelihood that a particular food use of a pesticide would be cancelled by the EPA, while the larger the benefits associated with a particular use, the lower the likelihood of cancellation.

On the other hand, the study's results provide some cause for concern. For instance, researchers found that the implicit value of a statistical life in the 245 regulatory decisions studied is $35 million. This value is based on a risk estimate that, by design, is much more likely to be too high than too low. In other words, the value that the EPA implicitly placed on reducing risks to pesticide applicators may be considerably in excess of $35 million per life saved. Since there are a variety of policy measures, environmental and otherwise, that are capable of reducing cancer cases at much lower costs, it might be possible to reduce the cancer rate through a reallocation of resources.

It is less clear how to view the study's findings concerning the influence of interest groups on the cancellation of uses of pesticides on food. Clearly, intervention in the regulatory process—by both business and environmental groups—affects the likelihood of restrictions on pesticide use. Other factors being equal, intervention by environmental groups has about twice the impact on the likelihood that a pesticide will be banned as intervention by growers does; however, the combined impact of growers and academics acting on behalf of growers is approximately equal to that of environmental groups.

To those who view pesticide regulation as the proper province of economists and risk analysts alone, these findings may be discouraging. On the other hand, those taking the view that regulation—like government taxation or spending—is inherently a political act may find it encouraging that affected parties not only participate actively in the regulatory process but do so quite effectively. ■

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The disappearing Aral Sea

Kenneth D. Frederick

Once one of the world's largest lakes, the Aral Sea in the Soviet Union, is now the site of one of the world's greatest ecological disasters. Conversion of the area around the sea to cotton production has resulted in contamination of water by pesticides and in large water diversions from the rivers that feed the Aral for irrigation. Effects on the region's ecosystem and on human health have been devastating, and plans to increase water supplies to the Aral might create severe ecological problems elsewhere. Fundamental changes in the institutions that now distort incentives to efficiently manage water resources are required.

For most of the last ten thousand years the waters of the Amu Dar'ya and the Syr Dar'ya rivers have flowed through the deserts of south central Soviet Asia to the Aral Sea—actually a lake having no outlet. Formed in the high mountains to the southeast of the Aral, these rivers have a combined average annual flow of 111 cubic kilometers (km^3), or 90 million acre-feet (maf). (In comparison, the Colorado River, which is formed in the Rocky Mountains and drains some of the most arid areas of the United States, has an average annual flow of only about 13.5 maf.) Until around 1960, about half of this water replenished the Aral Sea; the rest evaporated, transpired, or filtrated into the ground either naturally as the rivers flowed through the deserts and their deltas or as a result of diversions for irrigation and other human uses. During the preceding half century, inflows to the sea were just sufficient to offset the desert's high net evaporation rates. The size of the Aral remained relatively stable at about 68,000 square kilometers (km^2), making it the world's fourth largest lake in area.

The region's relatively flat topography and easily tilled soils are conducive to irrigation, which purportedly dates back several millennia. Indeed, irrigation in this region supported one of the world's earliest civilizations perhaps as early as six thousand years ago. By 1900, more than 3 million hectares (7.4 million acres) were irrigated. By 1960, about 5 million hectares (12.4 million acres) had been brought under irrigation.

The size of the Aral Sea was little affected by this increased water use; the level of the sea fluctuated less than 1 meter between 1910 (when accurate measurements were first made) and 1960. Increases in the consumptive use of water for irrigation and other uses up to that time were largely offset by reductions in evaporation, transpiration, and filtration from the rivers and their deltas.

Over the last three decades, however, the balance that had maintained the level of the Aral Sea has broken down under a relentless drive to expand cotton production in the area around the sea. The Karakum Canal, for which construction started in 1954 and which now extends 1,300 km westward from the Amu Dar'ya, was a centerpiece of Soviet plans to expand cotton production in the central Asian republics. Diversions of water to this canal alone, all of which were lost to the Aral, rose from 1 km^3 in 1956 to 14 km^3 in 1986. By 1987 aggregate diversions through the Karakum Canal totaled 225 km^3, equivalent to 60 percent of the water currently stored in the Aral Sea. (Annual diversions to the canal are now equivalent to nearly 85 percent of the virgin flow of the Colorado River.)

Due to low levels of inflows to and the increasing salinity of the Aral, some fish and animal species in the area around the sea have disappeared.

The increase in water use since 1960 has come largely at the expense of inflows to the Aral Sea. Average annual inflows to the sea dropped from about 56 km^3 during the period from 1911 to 1960 to only 5.2 km^3 from 1981 to 1985. In 1986, a relatively dry year, virtually no river water reached the Aral. Between 1960 and 1989 the level of the sea declined 14 meters, its area declined 45 percent from 67,000 to 37,000 km^2, its volume declined 68 percent from 1,064 to 340 km^3, and the salinity of the water increased from 10 to 28 grams per liter (g/l). By 1990 the Aral had divided into two parts (see map).

The Aral will continue to shrink until evaporation from the sea is equal to total inflows from precipitation and surface and groundwater flows. As the Aral recedes, evaporation losses decline in proportion to the diminished surface area. If inflows to the Aral remain at the low levels of the 1980s, the area of the sea would eventually decline to about 6,000 km^2. Even if flows increase to 10 km^3 (about twice the rate of the past decade), the area of the sea would decline to about 16 percent of its 1960 size, the sea would become further partitioned, and salinity would rise to 140 g/l (four times the level of the oceans). To maintain the Aral at its current size, annual inflows would have to be increased to about 30 km^3.

The low levels of inflows to and the increasing salinity of the Aral Sea are having devastating impacts not only on the sea but on the people once dependent on its rich productive system. Just three decades ago the sea supported an important fishing industry; in 1957 Muynak and Aral'sk were thriving ports processing a commercial catch that totaled 48,000 metric tons of fish. It has been seven years since the last commercial catch was taken from the Aral Sea. Muynak and Aral'sk now lie many kilometers from the sea's edge, and their canneries are kept open only at high cost with fish brought in from the Barents and Caspian seas. By the early 1980s, 20 of the sea's 24 native fish species had disappeared.

Similarly, the once-productive ecosystems of the Amu Dar'ya and Syr Dar'ya deltas have suffered enormously. The deltas were once described as oases of flora and fauna that provided a natural

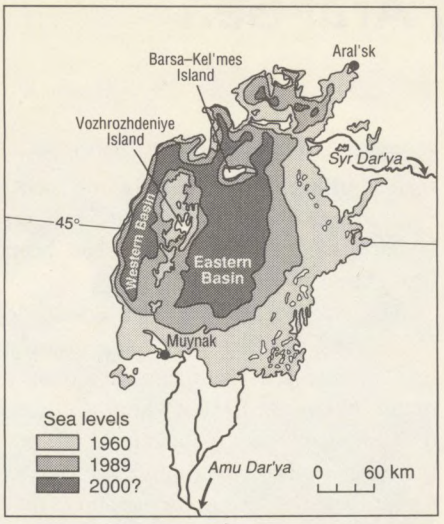
feeding base for livestock, a source of reeds for industry, spawning grounds for fish, and sites of commercial hunting and trapping. As the deltas have dried up, the deserts have encroached on them, livestock raising has declined sharply, and fish and wildlife habitat has been degraded. Only 38 of the 173 animal species once supported by the deltas have survived. Commercial hunting and trapping in the area have dwindled to a tiny fraction of their former levels.

Ecological and health effects

Soviet planners recognized that their efforts to expand irrigation would adversely impact the Aral Sea. They failed, however, to anticipate other consequences of their actions that have precipitated one of the greatest ecological disasters in history. Expansion of irrigation and the recession of the Aral Sea have resulted in huge dust storms, declining agricultural productivity, and sharply rising mortality and morbidity rates. Even the region's climate is apparently becoming less hospitable to crops and humans.

As the sea recedes, large areas of the former lake bottom have been exposed. The concentration of toxic salts in the upper layer of the exposed seabed and the lack of water and nutrients make it extremely difficult to establish a stabilizing plant cover. Without such a cover, dust storms blow up. These storms, which appear to be increasing in frequency and magnitude, transport an estimated 43 million metric tons of salts per year over vast areas, including the area's irrigated lands. Sodium chloride and sodium sulfate, which are particularly toxic to plants, are among the salts being carried from the former seabed.

High salt levels in the region's soils and water are also affecting agriculture. Although the soils are naturally saline, if there is adequate drainage salts can be leached from the soils by applying water in excess of that needed by plants. While the quantities of water applied to crops in the area are well in excess of crop requirements, the drainage is often very poor. Consequently, excess water, which is much more saline than the irrigation water applied, accumulates and raises the level of the groundwater table. As the water table rises into the root zone, the crops suffer from curtailed oxygen supplies. Moreover, capillary action draws salts from the shallow groundwater tables upward toward the surface. As the water evaporates, high concentrations of salt are left near the surface, largely destroying the agricultural potential of the land. Soviet research suggests that 60 percent of the irrigated soils in Uzbekistan, 80 percent in Turkmenistan, 35 percent in Tadzhikistan, 40 percent in Kirghizia, and between 60 and 70 percent in Kazakhstan suffered moderate to strong salinity problems in 1985.



Decreases in inflows to the Aral Sea since 1960 have resulted in a decline in the area of that sea.

Increasing salinity is an important factor in the recent decline in cotton yields. Reported average cotton yields in the five central Asian republics declined from 2,840 kilos (k) per hectare for the period 1976–1980, to 2,610 k for 1981–1985, to 2,400 k in 1986, and 2,300 k in 1987. Despite efforts to boost yields by increasing the amount of fertilizer applied, yields in 1987 had dropped to 81 percent of the average annual yield for the years 1976 through 1980. In 1987, 7 percent less cotton was produced on 15 percent more land compared with the 1976–1980 averages.

Perhaps the greatest sacrifices associated with the development of cotton have involved the health of the area's population. Drinking water supplies, especially in the lower reaches of the river basins, are contaminated by pesticides used in cotton production and by high salt concentrations. Pesticides have even been detected in mothers' milk. The deterioration of health conditions is evident in statistics: over the last fifteen years, the incidence of typhoid fever increased almost 30 times, hepatitis increased 7 times, and kidney disease, gallstone ailments, and chronic gastritis have all increased markedly. The incidence of cancer of the esophagus is 50 times the world average, and tuberculosis has reached epidemic rates. Infant mortality is more than 50 per 1,000 in the region as a whole, more than twice the reported rate of 23 per 1,000 for the Soviet Union. In one region of the Karakalpak Republic, located in the lower reaches of the Amu Dar'ya, child mortality is 110 per 1,000. One survey found 80 percent of the women suffering from anemia and 70 percent of the children ill.

As the Aral Sea recedes, the climate of the surrounding region is also being affected. Large water bodies have a moderating effect on the neighboring climate. Studies indicate that the decline in the size of the Aral Sea has been accompanied by more extreme temperatures—summers have become hotter, winters colder, and growing seasons shorter. Average May temperatures at Kungrad, currently located about 100 kilometers south of the Aral in the Amu Dar'ya Basin, were 3.0 to 3.2 degrees Celsius higher during the 1960–1981 period than during the previous twenty-five years. October temperatures, on the other hand, were 0.7 to 1.5 degrees Celsius higher during the more recent period. The growing season, the period between the last spring frost and the first fall frost, declined by ten days in the northern reaches of the Amu Dar'ya Basin.

Proposed solutions

The problems confronting the Aral Sea region were the subject of an international symposium entitled The Aral Crisis: Causes, Consequences, and Ways of Solution, held in October 1990 in Nukus in the Karakalpak Autonomous Soviet Socialist Republic. The author was a participant in these discussions. One result of the symposium was that participating scientists from the central Asian republics unanimously approved a resolution requesting

the Supreme Soviet of the USSR to declare the lower reaches of the rivers in the Aral Basin to be ecological disaster areas, and urging immediate measures to improve the health of the region's population and to stabilize the level of the Aral Sea.

Improving the quantity and quality of potable water supplies and restricting the use of pesticides and fertilizers in the region are among the priorities of these Soviet scientists for improving health conditions there. Drinking water supplies in Nukus and Muynak should improve when a 200-kilometer pipeline, to cost an estimated 200 million rubles (about $350 million at the official exchange rate), is completed. The pipeline will bring water from a reservoir located above the irrigated lands that contribute most of the chemicals to the water.

To this participant in the symposium, an important part of any program to improve the health conditions should be a reduction in the use of pesticides—especially the defoliants used to facilitate cotton harvesting. Continuous cotton production has depleted soils and encouraged larger chemical applications in a futile effort to maintain yields in the Aral region. Rotation of crops might be one way to maintain yields and reduce the use of agricultural chemicals. Since cotton requires much higher concentrations of pesticides than any other crop, permanently shifting some of the land now in cotton to other crops would also reduce the use of agricultural chemicals.

In their resolution, the scientists at the Aral crisis symposium concluded that ecological restoration of the region is impossible unless the area of the Aral Sea is stabilized. Their proposals for increasing water flows to the sea include the imposition of strict limits on the water diverted by each republic, the introduction of water-conserving techniques in all areas of the economy, limiting the production of rice (a crop that uses particularly large quantities of water), removal of low-yielding land from cultivation, and reassessment of the use of reservoirs and drainage-collection ponds that lose 5 km^3 or more of water annually to evaporation.

The resolution of the scientists was also notable because it did not support many of the costly structural proposals of some of the symposium speakers. One such proposal called for lining the dirt irrigation canals—which often lose 20 percent or more of their water to filtration—with concrete. This would save water (albeit at a high cost) where the seepage ends up collecting in and evaporating from local depressions and desert lakes; however, in other locations water seeping from an unlined canal may return naturally to the river and to an irrigation system downstream, or to a usable aquifer. Where filtration from canals and high water-application rates are raising groundwater tables and causing waterlogging, the conjunctive management of surface and groundwater might reduce salinity problems and improve overall irrigation efficiency. Soviet assessments suggest that groundwater use could be increased by about 10 km^3 annually without reducing river runoff. Detailed knowledge of the region's surface and groundwater hydrology is needed to target where the lining of canals or other schemes might be useful in improving water-use efficiency.

Proposals for stabilizing the Aral Sea include limiting water diversions, introducing water-conserving techniques, and removing land from cultivation.

Some Soviet engineers have proposed increasing water supplies to the Aral Sea through transfers from other basins. Under these proposals, rivers that now flow northward to the Arctic would be reversed so that the water would flow south to the Aral; alternatively, water from the Caspian Sea or the Ural River could be diverted eastward to the Aral Basin. The resolution of the Soviet scientists criticized as scientifically unfounded the existing proposals for interbasin transfers. Yet even if the scientific questions were resolved, economic and environmental objections to interbasin transfers would remain. Any transfer large enough to have a significant effect on the Aral Sea would cost many billions of rubles, and the environmental costs on the exporting basin would also likely be high. It is also probable that water could be conserved within the Aral Basin at costs much lower than would be required to bring in new supplies. Moreover, unless fundamental changes are made in the institutions that now distort the incentives to those allocating and managing the water resource, bringing more water into the basin might permit an expansion of the current inefficient and environmentally damaging water-use practices.

Lessons from market economies

The Aral crisis symposium resolution identifies problems and needed changes but provides little insight as to how water-conserving technologies, altered cropping patterns, and other proposed reforms are to be brought about. Misguided central planning is cited as the cause of the Aral crisis. Yet the symposium scientists seem to expect that this same system, with adjustments in planning strategies, will solve the region's problems. Such expectations appear to be unrealistic; more fundamental changes in the economic system may be required.

Microeconomic planning and resource allocation by government fiat have rarely been successful, and some of the Soviet Union's biggest failures have been in the agricultural sector. Dictating what crops to grow and how much, and when water is to be applied, is a proven recipe for low productivity and wasted resources. One of the most persistent lessons to be learned from agricultural studies worldwide is that farmers tend to be efficient managers of their own resources within the context of the incentives, institutional constraints, and technologies by which they operate. Government policy is best directed to changing incentives to better reflect broad social directives and resource scarcities, to removing unnecessary constraints on farmers' decisions, and to expanding the available technologies rather than attempting to micromanage farms.

Unfortunately, market economies such as the United States do not provide an ideal model for the Soviet Union to emulate. Market and centrally planned economies alike tend to treat water as a free resource, and fail to internalize the

full social costs of using environmentally damaging inputs such as pesticides. Underpricing of water, uncompensated environmental costs associated with its use, and wasted opportunities for transferring scarce supplies to higher-value uses in response to changing conditions underlie most water problems worldwide.

Nevertheless, there are fundamental differences between the two systems, and the Soviets could learn some important lessons from market economies. Although producers' costs in the United States may not fully reflect social costs, at least most irrigators here pay something for water (based on delivery and treatment costs) and chemicals. Moreover, production decisions in the United States are motivated by profit incentives and are usually based on an intimate knowledge of local conditions. In the Soviet Union, on the other hand, the expansion of irrigation, the selection of crops, and the allocation of water within the Aral Basin have been dictated by planners far removed from the basin and the outcome of their decisions. Soviet farmers are motivated by production targets. They apply more water and chemicals, which apparently have been readily available to the region's collective and state farms, as long as these inputs are expected to increase production. The people who actually manage the water, plant the crops, and apply the chemicals have little or no incentive to adopt more efficient and benign practices.

Soviet leaders have recognized the failures of their system and are debating how to introduce market incentives. Farmers in the Aral Basin have recently been permitted to lease small plots for their own use. Although a step in the right direction, this will have little impact on the region's basic problems as long as the majority of the land stays in huge collective and state farms subject to centrally established production goals.

Extreme poverty and abysmal health conditions characterize the Aral Sea region. And conditions continue to deteriorate as the sea vanishes, crop yields decline, salts and pesticides accumulate in the water and soil, and the region's population of nearly forty million increases rapidly. Structural approaches alone will not solve these problems, and the depressed state of the Soviet economy suggests that large new infrastructure investments will not be forthcoming soon. Major institutional reforms are needed to provide farmers of the Aral region with more latitude in selecting the crops they grow and the farming practices they employ, as well as to provide greater incentives for farmers to conserve water and to reduce chemical inputs in crop production.

One such reform could be the privatization of land. The government could give land, along with some short- and medium-term credit, to farmers. In return, the farmers would have to pay for the water and chemicals used and repay the loans within some reasonable period—say five years. Successful farmers would soon be in a position to purchase more land from those unable to repay their loans. Gradually, the region's natural resources would move into the hands of the most able and enterprising managers, and its human resources would have greater opportunities and incentives to prosper. ■

Note: This article is based on information obtained from participation in the international conference held in Nukus, USSR from October 2 to 5, 1990; from the article "Desiccation of the Aral Sea: A Water Management Disaster in the Soviet Union," by Philip P. Micklin, in Science *vol. 241 (September 2, 1988); and from unpublished papers by V. M. Kotlyakov, director, and N. F. Glazovsky, deputy director, of the Special Research and Coordination Center Aral, and by Peter Rogers, professor of applied sciences at Harvard University.*

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Risk communication and attitude change: Taiwan's experience

Jin Tan Liu and V. Kerry Smith

Can risk communication efforts narrow the distance between the public's perception and the experts' assessment of various risks? In 1989 Taiwan's state-operated power corporation sponsored a national debate on nuclear power to promote greater public consensus on the need for a proposed nuclear power plant. In surveys conducted before and after the debate, citizens in Taiwan were asked about their perception of risks posed by nuclear power and their attitudes toward the proposed plant. Their responses suggest that the debate did not bring about a convergence of public perception and expert judgment about the risks involved.

Many analysts and policymakers now appreciate that environmental problems are unlikely to be eliminated with some technological fix. Instead, they are beginning to describe environmental goals in terms of risk management. With this reorientation

comes a growing recognition of the disparity between experts' assessment and the public's perception of what constitutes serious risks. This disparity is particularly evident for the risks posed by hazardous and nuclear materials.

During the 1980s several surveys of peoples' attitudes toward different land uses revealed that facilities for producing, using, or disposing of nuclear or hazardous substances were considered the least desirable land use. People surveyed in different countries consistently rated nuclear power plants or nuclear waste disposal sites as the most serious among a number of sources of risks. In spite of these surveys, many scientists remain convinced that if people are given the facts, their perception of the risks posed by hazardous substances will begin to align with scientific judgments about these risks. However, the results of a nationwide effort in Taiwan to disseminate the facts about nuclear power plants suggests that this convergence of public perception and expert assessment is unlikely to occur.

In December 1984, Taiwan's state-operated power corporation, Taipower, announced plans for the nation's fourth power plant, to be constructed on the northeastern coast of Taiwan. In Taiwan public concern over the safety of nuclear power had been heightened by the Three Mile Island accident in the United States. The accident raised interest in and public awareness of the safety records of the three existing nuclear plants in Taiwan. (The record of leaks and shutdowns for these Taiwanese plants has not been good by U.S. standards. From 1984 to 1988, the radiation leaks in each plant were substantial, averaging more than twenty per year at two of the three plants.) The Soviet Union's Chernobyl accident in 1986 also increased concern about the proposed fourth plant.

Because Taipower had agreed to delay planning another nuclear power plant until it established a greater degree of public consensus on the plant's merits, the company sought to change public attitudes about the safety of nuclear power by organizing a national debate on the safety of nuclear power and the need for a fourth plant. A national risk communication program on nuclear power and the proposed plant was announced in February 1989. A budget of more than $460,000 was allocated to the program. The program included one hundred debates and discussion-group sessions at universities and cultural centers in Taiwan's major cities, fifty lectures on the safety of and need for the proposed plant at high schools and cultural centers in these same cities, and a series of television programs and articles in local newspapers that emphasized the merits of the fourth plant. In addition, Taipower announced a program that would provide a fund of more than $6 million per year for compensating people residing near the proposed facility during the ten-year construction period, and another $4.6 million per year for compensation after the plant begins operation.

Two surveys of 404 households in Taiwan—one made in March 1988 (before the nuclear power debates) and one made in July 1989 (after the debates)—provide evidence about how attitudes toward the proposed plant have changed as a result of Taipower's risk communication initiative. Analysis of the surveys suggests that, in general, the debates increased respondents' perception of the seriousness of risks from the proposed plant.

The disparity between the public's perception and experts' assessments of risk is particularly evident with respect to risks from nuclear materials.

The changes in respondents' reported attitudes toward the fourth plant are not clear-cut, however. For example, no substantial change occurred in the percentage of people favoring the plant. Before the debates, 42 percent of those surveyed favored a fourth plant and 31 percent opposed it, while 27 percent voiced no opinion. After the debates, 46 percent favored the plant, 34 percent opposed it, and 20 percent voiced no opinion. The relatively small increases in the percentages of those in favor of and opposed to the proposed plant would seem to indicate that the respondents' views were fairly stable, yet substantial shifts occurred in and out of all three groups: those opposed to, in favor of, and undecided about the plant. Thus it is important to evaluate individual changes in attitude.

The influence of experience

Peoples' perception of risks can be influenced by experience. In fact, the influence of experience on perceptions is an important element in a rational theory of behavior given uncertainty about risks. One of the most successful empirical risk perception models describes how people use information to update their initial perception of risk. The model maintains that current risk perceptions, usually elicited using a simple index, are a weighted average of a person's perceptions prior to receiving new information combined with his or her understanding of this information. The message that a person receives about risk from new information may be different than that intended by the information.

Most of the existing applications of this model involve one of two types of situations. The first consists of interviews in which individuals are asked about their risk perceptions, given information about a hypothetical situation that could affect their risk, and then asked what their new perceptions of risk would be for that situation. While this approach is consistent with the basic framework of the empirical risk perception model, it does not represent a strong test of the process by which people update their risk perceptions. Because each interview lasts a short period of time (usually less than one hour for personal interviews and twenty minutes or less for telephone interviews), the model must assume that responses to new information given within the space of the interview offer a reasonable description of how people would respond to new information over the longer periods of time usually available for actual decisions.

The second type of application of the empirical risk peception model overcomes this limitation. This type was used in a study of how 2,300 homeowners in the state of New York who had their homes monitored for radon (an indoor air pollut-

ant considered to be a serious source of lung cancer risk) updated their risk perceptions as they received new information about radon readings for their homes and about the health risks of radon. The study was designed to control the information study participants received about risks associated with radon and to observe each person's reaction to new radon readings over nearly a twenty-month period.

Two aspects of the study's findings are especially relevant to how perceptions of risks associated with nuclear power plants changed in Taiwan. First, like the Taiwan study, the New York study found that prior beliefs were important in each participant's current perception of risk. The application of an empirical risk perception model in the New York study confirmed that as individuals updated their initial perception of risk with progressively refined information about radon levels in their homes, the weight they attached to their prior perceptions of risk increased about sevenfold.

Second, the information explaining how to interpret radon readings in quantitative terms was found to be influential in participants' first update of their perception of risk, but not generally influential when supplementary radon readings were received over a longer time span and for different parts of each person's home. However, to the extent that this information encouraged people to think in terms of radon thresholds—that is, a reading below a specified radon exposure level would indicate an acceptable level of risk, and one above it would indicate an unacceptable level—this framing did appear to affect how people responded to new readings that exceeded the threshold.

These findings suggest that the estimated parameters of models for describing how people use new information to update risks over time may provide approximate gauges of the confidence people place on their prior perceptions. Empirical risk perception models therefore offer the potential for evaluating whether programs to disseminate information about risk induce changes in the public's perception of risk.

Impact of Taiwan's nuclear power debates

To evaluate the impact of the nuclear power debate in Taiwan on the public's perception of risks from a proposed nuclear power plant, researchers from the Institute of Economics at Academia Sincia (Taiwan) and North Carolina State University employed empirical risk perception models to analyze changes in attitude indicated by responses to the pre- and post- debate surveys mentioned above. The first survey, sponsored by the government of Taiwan in March 1988, elicited attitudes toward the proposed plant through personal interviews with 2,001 households in two cities and two counties in Taiwan. Using a mail questionnaire, the researchers conducted a second survey of these same households in July and August 1989. Of the households participating in the personal interview, 22.6 percent responded to the mail survey. Of the 404 households that returned the mail survey, 286 responded to a question (first asked in the personal interview) that solicited a rating of the risk from nuclear power plants in Taiwan, and 398 provided sufficiently complete information on their attitudes toward the proposed power plant to describe how these attitudes changed.

By comparing the results of the mail survey with those of the personal interviews, it is possible to track the evolution of attitudes toward Taiwan's proposed nuclear power plant. In the personal interviews and the mail survey, people were asked to rank the risks posed by nuclear power plants on a scale from 1 to 5, with 1 indicating the risk as very slight and 5 indicating it as very serious. Before the debate, 48 percent of those who answered this question rated the risk as slight. After the debate, the percentage of those who reported they did not know the risk from nuclear power plants dropped from about 29 to 8. Moreover, the percentage of respondents who rated the risk as very serious increased from 8 percent before the debate to 39 percent after it.

Data from the mail survey indicate that the proportions of respondents with the two opposing views on the plant increased slightly after the nuclear power debates. These increases were not simply the result of those previously undecided taking a position on the plant. Changes in attitude were evident among those previously opposed to, in favor of, or unde-

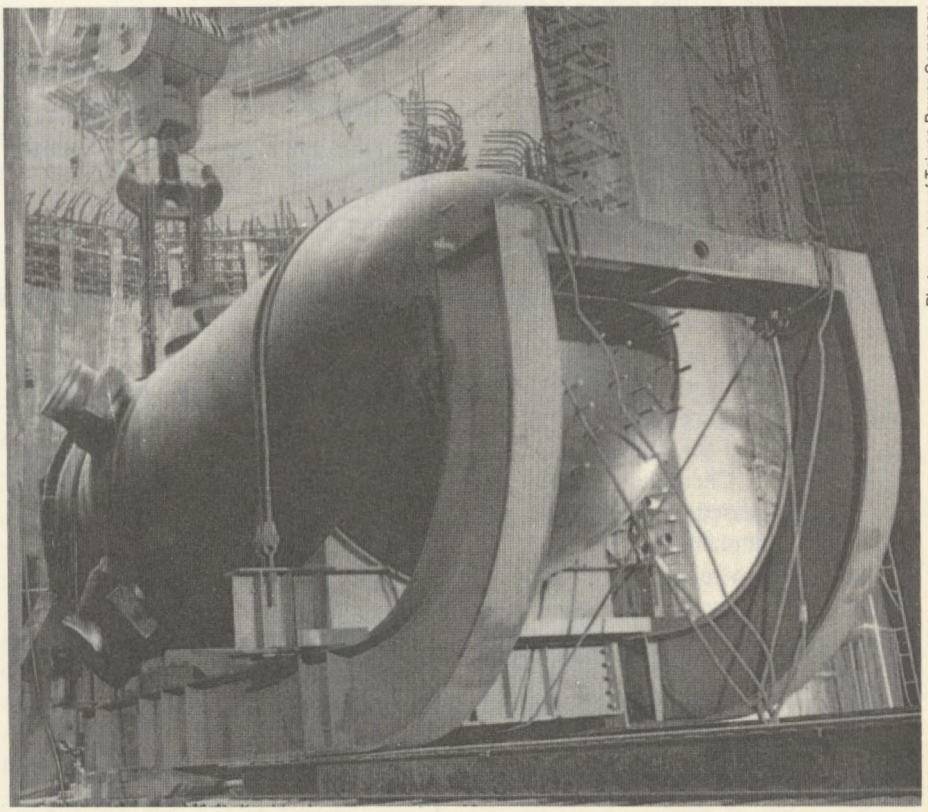

Photo courtesy of Taiwan Power Company

Taiwan's nuclear power debate raised people's perception of the seriousness of risks posed by nuclear power plants. This is one of three such plants in Taiwan.

cided about the proposed plant (see table 1). More than half (55 percent) of those who favored the plant in 1988 (before the debates) continued to favor it in 1989 (after the debates); however, 27 percent of those who favored the plant in 1988 opposed it in 1989. Of those who opposed the plant in 1988, 48 percent remained opposed to it in 1989. However, 52 percent of those previously opposed to the plant changed their views. After the debate, 31 percent favored it, and 21 percent reported no opinion. These shifts indicate that attitudes are variable.

However, this aggregate summary can be misleading as a guide to the influence of the debate on individual decisions to favor or to oppose the proposed plant. Because other factors may have affected changes in individual attitudes, the researchers investigated whether changes in respondents' attitudes could be explained by eight other variables: the location of a respondent's residence in relationship to the site of the proposed plant, the respondent's perceived risk from nuclear plants, age, education, sex, family income, family size, and origin (local Taiwanese or Chinese).

For this investigation, the researchers employed a model that measures the effects of each variable on the probability of observing a particular attitude change in relationship to a base case. For this analysis, the base case involved a situation in which a respondent is opposed to the proposed plant in 1988 and remains opposed to it in 1989. Because the model used could only measure the influence of proposed determinants of attitude change in relative terms, it could not indicate how much a particular variable contributed to the chance a person would switch from opposing to favoring the proposed nuclear power plant—the attitude change the government and Taipower hoped to encourage. However, the analysis of survey data using the model did indicate that none of the variables hypothesized to affect attitudes had a clearly significant influence on this change compared with their influence on consistent opposition to the plant. Stated perceptions of risk that were heightened by the debate seem to have had a negative (and marginally significant) effect on this attitude change. Thus to the extent that the debate raised people's perceptions of the seriousness of the risks posed by nuclear power plants and this perception reduces the chances for the desired attitude change, the debate did not accomplish Taipower's goals. A pattern consistent with this response can be found in the change from no opinion before the debate to opposition after.

Table 1. Attitudes Before and After the National Debate

	1989 Attitudes			
1988 Attitudes	Against	Favor	No opinion	Total
Against	59	38	25	122 (31)
Favor	45	93	31	169 (42)
No opinion	31	52	24	107 (27)
Total	135 (34)	183 (46)	80 (20)	398

Note: The numbers in parentheses below the totals represent the percentage of the total reporting each attitude for each year.

Ironically, the major effect of the debate may have been to erode support for Taiwan's proposed plant. After the debate, survey respondents were less likely to consistently favor the proposed plant, becoming either opposed to it or undecided, and were more likely to shift from an undecided to an opposition stance. Even in cases in which the debate appeared to reinforce an attitude favorable to the plant, its effectiveness depended on the perception, prior to the debate, that the risk from nuclear power plants was low. Generally the debate appears to have increased respondents' perception of the risk from nuclear power plants. This perception has the potential to further reduce support for the proposed plant.

Effective risk communication?

Risk communication efforts usually serve one or more of four objectives: conveying information to and educating the public, encouraging change in behavior and protective action, warning the public about potential disasters or emergencies, and facilitating the solution of problems and the resolution of conflicts. Taipower's national debate on nuclear power sought to inform people about the experts' appraisal of the risks posed by nuclear power plants and to resolve conflicts about the efficacy of a proposed plant. Analysis of the surveys in which 404 households in Taiwan participated suggests that the debate was not effective in attaining the latter goal.

The nuclear power debate in Taiwan highlights the difficulty of treating risk management as a two-way process between experts and the public when the intention is to ensure public acceptance of the experts' judgments concerning risk. However, inferences drawn from that debate for other risk communication efforts should be limited. Clearly, the design of a risk communication program is an important factor in its success, as is the source of risk it addresses. Equally important is the degree to which citizens believe they have access to some governmental entity, such as the courts, that can evaluate administrative rulemaking and decisionmaking. These and other factors must be considered in assessing how the findings on Taiwan's national debate on nuclear power contribute to our understanding of the potential for risk communication efforts to narrow the gap between the public's perception and experts' judgments about various risks. ■

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William S. Paley, 1901–1990

Not surprisingly, the flood of comments on the life and achievements of William S. Paley have concentrated on his role in the world of communication and entertainment. But there was another Bill Paley, the corporate executive who in early 1951 accepted President Truman's invitation to head a commission charged with assessing the nation's material resources and peering two decades into the future. Driven by his energy, enthusiasm, and organizing talent, he was able to lay on the president's desk a five-volume report by mid-1952. Labeled "Resources for Freedom," it set a high standard of scholarship for undertakings of such complexity and for many years influenced both the national research agenda and public policy. The pleasure he took in this association is well illustrated by a comment he made not many years ago that on visits to Europe he was more often identified as the man who chaired the president's Materials Policy Commission than the man who created and headed CBS. That, of course, is the Bill Paley we at RFF knew best.

The report has long been out of print, but in a reprint of the summary volume, published by RFF in 1987, Mr. Paley wrote in a foreword that "the task of objectively and comprehensively assessing the relationship between national resources and society is not done, and never will be." It was in that spirit nearly thirty years ago that he founded a nonprofit corporation named Resources for the Future. He chaired its board of directors for many years and took an active part in setting its research agenda. RFF mourns the passing of its founder and friend. ■

Hans H. Landsberg

Documentary on global warming completed

In a joint venture with Resources for the Future, Marilyn and Hal Weiner and their Washington, D.C.-based film company, Screenscope, Inc., have completed production of a new documentary called "Future Conditional: Global Warming." The thirty-minute program presents an accurate and balanced overview of the greenhouse problem, examining the causes of global climate change, its policy aspects, and two strategies for dealing with it—abatement and adaptation.

The documentary will be broadcast on public television stations, and is also designed for educational use by general audiences, high school and college students, environmental and scientific organizations, industry groups, policymakers, and the press. Foreign language versions of the program are planned.

RFF's involvement in the documentary stems from its interest in helping to fill a major gap in public understanding of the complex problem of climate change. Norman J. Rosenberg, director of RFF's climate resources program, served as scientific adviser on the film.

For a VHS cassette of "Future Conditional: Global Warming," write a check for $95.00 payable to Resources for the Future and send to Documentaries, Resources for the Future, 1616 P Street N.W., Washington, D.C. 20036. ■

Book orders: new procedures

To order books, add $3.00 for postage and handling per order to the price of books and send a check made out to Resources for the Future to:

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Summer interns sought

Every summer Resources for the Future offers a number of paid internships to students. Interns assist RFF staff with a variety of projects ranging from technical studies to applied policy analyses. Interested persons are invited to apply for RFF internships at this time. Applicants should have outstanding academic records in the undergraduate or graduate programs in which they are enrolled, and have undertaken course work in one or more of the following fields: microeconomics; statistical and quantitative methods; agricultural, environmental, or natural resource management; or environmental sciences.

The deadline for applications is March 15, 1991. The internships begin on or about June 1, 1991 and last from two to three months. Stipends are commensurate with experience and length of stay. For further information about applying for internships, contact the Office of the Vice President, Resources for the Future, 1616 P Street, N.W., Washington, D.C. 20036. Telephone (202) 328-5022. ■

New appointments

Two new members recently joined the staff of the Center for Risk Management. H. Keith Florig was appointed a fellow in the center on December 17. Florig was most recently on the staff of the U.S. Arms Control and Disarmament Agency, Office of International Nuclear Affairs. On January 1 Dominic Golding was also appointed a fellow in the center. He comes to Resources for the Future from the Hazard Assessment Group at the Center for Technology, Environment, and Development (CENTED), from Clark University, and from the Department of Urban and Environmental Policy at Tufts University. Both Florig and Golding will be working on the center's program on Rational Risk Reduction: Defining National Goals, Exploring National Strategies. ■

Recent corporate contributions, grants

Resources for the Future has recently received corporate contributions from the following corporations and corporate foundations: Aetna Life & Casualty; Baltimore Gas and Electric Company; BankAmerica Foundation; BP America Inc.; Browning-Ferris Industries, Inc.; Carolina Power & Light Company; The Coca-Cola Company; Crum and Forster Corporation; Dominion Resources, Inc.; E. I. du Pont de Nemours & Company; Georgia Power Company (Southern Company); The Mead Corporation; Monsanto Company; Pennsylvania Power & Light Company; The Prudential Foundation; Southern California Gas Company; Stout & Teague Company; Union Carbide Corporation; Uniroyal Chemical; and Valent U.S.A. Corporation.

In addition, The Henry M. Jackson Foundation awarded a grant to the Quality of the Environment Division for the Visiting Fellows Program for Chinese scholars, and the Montgomery Street Foundation awarded $7,500 for general support. The Ford Foundation awarded the International Policy Council a $29,000 grant for travel and living expenses for East/Central European and Soviet conference participants. ■

Photo courtesy of Arnold Sachs

RFF senior fellow Allen V. Kneese (center) and former senior fellow John V. Krutilla (left), co-recipients of the 1990 Volvo Environment Prize, at the award ceremony for Kneese at the National Academy of Sciences, Washington, D.C., on November 20, 1990. Krutilla received the prize at a ceremony at the University of Gothenburg, Sweden, on November 8, 1990. Claes Beyer of AB Volvo is at the right. The international committee that awarded the prize observed that Kneese and Krutilla were the first to combine economics with ecology, systematically analyzing environmental impact in relation to the prevailing economic system, and that their pioneering work is the basis of advances to date in environmental economics.

Discussion papers

RFF discussion papers convey the early results of research for the purpose of comment and evaluation. They are available at modest cost to interested members of the research and policy communities. Price includes postage and handling. Prepayment is required. To order discussion papers, please send a written request, accompanied by a check, to the Publications Division, Resources for the Future, 1616 P Street, N.W., Washington, D.C. 20036-1400.

The following papers have recently been released.

Quality of the Environment Division

- "Electric Vehicles and the Environment: Consequences for Emissions and Air Quality in Los Angeles and U.S. Regions," by Hadi Dowlatabadi, Alan J. Krupnick, and Armistead Russell. (QE91-01) $2.25

- "'Black Mayonnaise'" and Marine Recreation: Methodological Issues in Valuing a Cleanup," by Yoshiaki Kaoru and V. Kerry Smith. (QE91-02) $2.25

- "The Impact of Pricing Rules on Electric Utility Emissions," by Hadi Dowlatabadi and Robert W. Hahn. (QE91-03) $2.25

- "Diversification by Regulated Monopolies and Incentives for Cost-Reducing R&D," by Karen L. Palmer. (QE91-04) $2.25

- "Health Capital, Risk Aversion, and the Variance of Income: Assessing Some Welfare Costs of Alcoholism and Poor Health," by John Mullahy and Jody L. Sindelar. (QE91-05) $2.25

Energy and Natural Resources Division

- "Designing Price Caps for Gas Distribution Systems," by Thomas P. Lyon and Michael A. Toman. (ENR91-01) $5.00

- "Lessons from Other International Agreements for a Global CO2 Accord," by Peter M. Morrisette, Joel Darmstadter, Andrew J. Plantinga, and Michael A. Toman. (ENR91-02) $5.00

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