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How Useful Is Environmental Economics?

In 1992, the Quality of the Environment Division at Resources for the Future (RFF), with the help of the Alfred P. Sloan Foundation, began a research program to renew and enlarge economists' and others' investigations of the application of welfare economics theory to environmental and natural resource policy. Such investigations seem timely, as some economists and noneconomists have recognized that traditional assessments of the benefits and costs of exploiting natural environments are somewhat deficient. Philosophers and environmental advocates, for example, have pointed out that such assessments focus on use values, ignoring the ethical values individuals hold with regard to natural environments. While some economists contend that ethical values lie beyond the purview of economic analysis, others assert that they can be brought to bear in quantitative analyses of proposed environmental programs and policies.

Although the notion of self-interested utility is not about to be abandoned in such analyses, researchers at RFF suggest that welfare economics would become a more useful tool for decision making if the utilitarian model of human behavior is broadened to include behavioral motivations of an ethical character. By integrating insights concerning human behavior from other disciplines—

philosophy, sociology, and psychology—into the welfare economics paradigm, they seek to provide research that will better guide public policy.

In recognition of the potential contributions of other disciplines to its research, RFF invited Dr. Mark Sagoff, director of the Institute for Philosophy and Public Policy at the University of Maryland, to articulate his views on environmental economics, the discipline that applies the theory of welfare economics to environmental and natural resource policy. In a lecture at RFF on June 3, 1992, Sagoff argued that the concepts that define the approach of environmental economics have outlived their usefulness as ways to evaluate such policy. In doing so, he presented a libertarian critique of the discipline—one that many economists find unconvincing.

Given that environmental economics is increasingly used in policy analysis, the debate between philosophers and economists over the discipline should not be restricted to the halls of academia. Because the debate involves issues of ethical values and freedom of choice, and therefore is of importance to many, RFF asked Sagoff to summarize his critique of environmental economics in this issue of *Resources* and invited Dr. Raymond Kopp of RFF to respond to it.

Melissa Edeburn

Environmental Economics: An Epitaph

Mark Sagoff

In his critique of environmental economics, Dr. Sagoff focuses on the discipline's approach to resource allocation. He argues that environmental economists, by basing this allocation on the theory of welfare economics, substitute preferences or hypothetical choices for actual choices, replace free markets with centralized planning, and indulge in paternalism. This leads Sagoff to question whether achieving allocative efficiency by correcting market failures is a more important goal than preserving the freedom of choice that markets afford us. He denies that preferences, as economists conceive them, constitute the basis for rational choice, and he doubts that the satisfaction of preferences contributes meaningfully to social welfare. Because environmental economists study the relation between preference satisfaction and resource use rather than macroeconomic matters such as employment, Sagoff contends that they have little to say about the relation of the economy to the environment. He concludes that the concepts of property rights, knee-of-the-curve thinking, and place (nature as it exists in community with human beings) are more useful than any concepts found in environmental economics for formulating environmental policy.

Candidate Clinton ran his successful 1992 campaign for the presidency of the United States on a platform of strengthening the U.S. economy. Given that platform, how should the Clinton administration approach environmental policy? In this essay, I propose that the new administration will find little that is helpful in the vocabulary of mainstream environ-

mental economics (or resource economics). I shall argue that the concepts that define the approach of environmental economics—concepts such as allocative efficiency, social cost, market failure, and welfare—have outlived their usefulness as ways to understand or to evaluate environmental policy.

By "mainstream environmental economics," I refer to the discipline that applies the theory of welfare economics to natural resources and to the environment. Its goal is to allocate resources efficiently—that is, to deploy them on the basis of what individuals are willing to pay for them. Under certain ideal conditions, markets will achieve allocative efficiency. In other words, they will put resources into the hands of those willing to pay the most for them. Yet because these conditions generally fail to hold in respect to the environment, economists argue that the government may often succeed better than the market in allocating resources to the would-be highest bidders.

Four arguments

I shall offer four arguments to suggest that the theory of welfare economics as a basis for allocating resources should be given up as no longer useful. My first argument is that the theory abandons choice for preference. People make choices in markets; however, markets are thought to be the problem, since they pervasively fail to allocate resources to those who, under ideal conditions of exchange, would pay the most for them.

Markets fail—resulting in the need for government managers to allocate resources—for several reasons. One is that the costs of getting information and

striking bargains keep people from making the exchanges they would make in the absence of those costs. Another is that no one can be charged a fee for the use of unowned goods, such as oceans and the atmosphere. Yet another is that each member of a group may try to exempt himself from paying his share for goods or services that every member of the group desires. This is known as the "free-rider" problem. For these reasons and many others, the story of "market failure" is the only story besides "I love you" that has no end.

Allocating resources on the basis of the theory of welfare economics entails substituting preferences (hypothetical choices) for actual choices; however, preferences, as economists understand them, are simply constructs of the theory itself and, outside of that theory, do not provide a foundation for "rational choice."

In view of the pervasiveness of market failure, environmental economists advise the government to hire experts such as themselves to identify the allocations people "would" choose under "ideal" conditions and substitute those allocations for the outcomes that result from the choices people actually make. Since ideal conditions are never found—one can so easily tell stories to "show" how and why they fail to exist—this strategy substitutes hypothetical

choice for actual choice and replaces free markets with centralized planning.

My second argument against using the theory of welfare economics as a basis for allocating resources has to do with the nature of choice. We ordinarily explain the choices we make by referring to the reasons, beliefs, character traits, habits, hopes, fears, principles, promises, values, and many other factors that influence and justify our decisions. Occasionally, we may explain a choice in terms of a preference. In the ordinary or intuitive sense, "preference" refers to an inclination or an idiosyncratic desire as distinct from a principled or objective basis for a decision. Economists do not use the term "preference" in an ordinary or intuitive sense. Rather, they have in mind what they call "preference schedules" or "preference maps" that are supposed to obey formal rules or requirements and that explain every "rational" choice we make. Preferences (or hypothetical choices) of this sort should not be confused with inclinations in the ordinary sense; rather, they are simply artifacts or constructs of economic theory itself.

The priests at Delphi read the entrails of chickens to determine the preferences of the gods. To find out what mortals "prefer," economists interpret market and survey data. Preferences discerned by either priesthood are equally useful in making predictions, as the social science literature abundantly illustrates. This literature, which attempts to elicit preferences in experimental situations, has produced a long list of technical problems with names like "preference-reversal," "inconsistency," and "intransitivity," which attest to the intractable difficulties that beset efforts to make scientific sense of the shadowy world of preference maps.

My third argument against using the theory of welfare economics as a basis for allocating resources is that, even if preferences did exist as a foundation for "rational" choice, economists offer no plausible reason why environmental policy should seek to satisfy them. Econ-

omists use the term "social welfare" as a proxy for the "satisfaction of preferences," and then trivially and speciously argue that "the satisfaction of preferences" produces "social welfare." However, empirical evidence confirms what common wisdom suggests: not the satisfaction but the content and quality of desires correlates with what people mean by welfare or well-being.

My fourth argument against allocating resources on the basis of the theory of welfare economics is that the vast literature of environmental economics deals exclusively with microeconomic questions—that is, with problems of market failure or allocative efficiency—rather than with macroeconomic matters, such as employment, inflation, trade, interest rates, and savings. Economists generally understand that no clear relationship holds between microeconomic efficiency and macroeconomic performance or prosperity. The literature of environmental economics says little, then, about the relationship of the environment to the economy.

Once we discard environmental economics, we can make room for concepts that give us a better analytic purchase on environmental and natural resource issues. For example, freedom of choice is a more helpful concept than the satisfaction of preference, and the protection of property rights is a more meaningful norm than the pursuit of "optimal" levels of pollution. As I shall propose, anyone wishing to understand environmental policy will find ethics, aesthetics, cultural history, religion, and other fields to contain concepts far more useful than any discovered in environmental economics.

The libertarian critique of environmental economics

Environmental economists posit maps of preferences, which preferences they then develop methodologies to measure. They urge society to respond to those preference maps by overriding the out-

comes—or, as they would say, "correcting the failures"—of legitimate institutions of social choice, including representative legislatures and free markets in which people may respond to suggestions, reasons, and arguments, not just preexisting preferences. The appeal to hypothetical choices (choices people would make under "ideal" conditions) to "correct" outcomes that result from choices people make under actual conditions is characteristic of collectivist planning. That is why libertarians see no reason to distinguish mainstream environmental economics from socialism.

Environmental economics deals with microeconomic rather than with macroeconomic matters; because economists understand that no clear relationship holds between microeconomic efficiency and macroeconomic performance, the literature of environmental economics says little about the relationship of the environment to the economy.

Environmental economists recommend that the government empower experts, presumably themselves, to second-guess the choices people actually make in order to install outcomes that satisfy their "true" preferences. This sort of paternalism—giving people what they "would" choose, not what they do choose—is also characteristic of collectivist planning. Marxists in the former Soviet Union empowered a politburo to allocate assets as the people themselves would choose to allocate them if they were able to overcome their corrupt, bourgeois ideology. Environmental economists similarly allocate resources as the people themselves would if they

could overcome bargaining costs. Whether Marxist or neoclassical, these economists develop methodologies that give them paternalistic power to determine the "true" preferences people "would" reveal under "ideal" conditions. To base policy not on actual but on hypothetical choice is to set out on the road to serfdom.

Markets, libertarians tell us, make choice possible; even if they are not efficient, markets enhance virtues such as freedom, responsibility, accountability, cooperation, self-reliance, and consent. Allocative efficiency through centralized planning, in theory, maximizes the satisfaction of preexisting preferences. Which is more important—freedom of choice or efficiency in allocation? To answer this question, we must know what preferences are and why it is important to satisfy them.

Are preferences real?

When we speak of preferences in an intuitive or ordinary sense, as I noted above, we refer to desires and inclinations, which—along with factors such as reasons, principles, and beliefs—help explain what people do. In contrast, economists use the term "preferences" to refer to mental entities or to dispositions that behave in a rule-governed way to determine all the "rational" choices we make. We would expect, then, that economists would be able to show that their preference maps predict and, in that sense, explain our decisions. However, the literature on public choice theory reports the results of a number of psychological experiments that show predictions based on hypotheses about preferences to be worthless. Take a simple example: you resolve after breakfast to diet but you pig out at night. How good is your morning preference as a predictor of your evening performance?

Since economists cannot observe preferences "in themselves," or directly, they have no way to test the inferences

they draw from market, voting, survey, and other data. These data permit many competing interpretations. When a person gives to a worthy cause, for example, does he act selfishly and altruistically, or does he seek a benefit for himself, such as the "warm glow" of giving? Likely stories are so easy to tell that one assessment of a person's preferences is as good as another. Thus it is clear that preferences do not exist in the mind of the individual; rather, they exist in the eye of the beholder.

The problem with preferences, then, resides not so much in the failure of preferences to predict and therefore explain behavior as in the impossibility of falsifying hypotheses about what a person's preferences are. No matter what a person does, you can tell a story to reconcile the person's actions with any reading of his prior preferences. A trip to Atlantic City, for example, can "reveal" a preference for virtually anything; what a person does there might "reveal" any number of values, interests, or goals. Even the simplest choice might involve many complex motivations, or so psychoanalysts tell us. If they cannot explain what a person does, how can economists? Attempts to account for behavior on the basis of

The problem lies not so much in the failure of preferences to predict and therefore explain behavior as in the ease of telling stories to account for behavior and thus the impossibility of falsifying hypotheses about a person's initial preferences.

prior preference have produced a burgeoning literature about preference change, preferences concerning preferences (or "second-order" preferences),

preferences that motivate and preferences that evaluate, "public citizen" and "private citizen" preferences, and so on. Every new conundrum produces a new distinction or some other ploy to maintain the faith that preference maps account for all we do.

Centuries ago, social scientists posited demons that made you act as you do; they recommended ritual exorcisms to get rid of them. Today, they posit preferences and, like true scientists, obtain grants to develop methodologies to measure them. These methodologies, however, have succeeded only in creating anomalies and difficulties, and still more grants and methodologies to try to resolve *them*. Major academic disciplines have arisen to try to figure out how to figure out preferences. I can only hope that some day preferences, like demons, will be discarded as useless theoretical entities. This is what scientific progress now seems to demand.

Efficiency and welfare

Mainstream environmental economics, a branch of welfare economics, is normative insofar as it lays down in advance of the political process the principal goal that society should pursue in dealing with the environment—namely, social welfare. "Welfare" is defined as the satisfaction of preferences as measured by willingness to pay and as determined independently of the process of satisfying them.

By allocating resources to satisfy the preferences of those who are willing to pay the most for those resources, society will, of course, maximize social welfare, since social welfare is itself defined in terms of the satisfaction of those preferences. Social welfare is just another name or a proxy for allocative efficiency. The question we must ask is whether "welfare" has anything to do with happiness, well-being, or any goal that appeals to common sense, morality, law, or culture.

Ordinary wisdom suggests that happiness is not what money can buy—that one attains well-being not by satisfying one's capricious desires but by learning to overcome or master them. Parents know this: they do not want children to experience instant and constant gratification; they want them to learn through some frustration and defeat to discipline and elevate their desires. The literature of moral philosophy shows us that we improve our stature and well-being more by criticizing than by satisfying arbitrary inclinations. The philosopher and economist John Stuart Mill wrote that Socrates dissatisfied was better off than a pig satisfied. He thought it obvious—as it is—that happiness depends more on the quality of our desires than on the degree to which we satisfy them.

Social research confirms what common wisdom suggests: preference satisfaction and well-being have no clear relation to each other once basic needs are met. Thus people frequently report that they become *less* happy as their income rises and they thus satisfy more of their wants. Indeed, studies have found, overall, no stable relationship between satisfaction and changing economic conditions once basic needs are met. (These studies do not assume any particular conception of happiness or well-being; they leave that to the individual subject.) Amusingly, people who win large sums of money—in lotteries, for example—do not report being on the whole more happy afterwards.

Environmental economists must concede that their theory of resource allocation rests on a conceptual rather than on an empirical (therefore testable) relationship between "willingness to pay" and "welfare." They may reply, however, that this conceptual relationship is based on an assumption that the individual prefers what he thinks will increase his well-being. This reply defends one tautology by appealing to another. What the individual thinks will improve his well-being is defined beforehand as whatever it is the individual wants.

Most of us seek outcomes, especially with respect to the environment, for intrinsic ethical rather than self-serving reasons. We may have the good of the community or of future generations in mind; we may seek outcomes that are simply good in themselves. However we may define it, our personal well-being is not what we necessarily seek. We debate public policy in terms of the values and goals of the community itself. Our political choices, in particular, may express our commitment to objective values and to social norms—not simply to our personal well-being.

Values not grounded in considerations of personal benefit cannot be included in the social welfare function that determines how goods should be allocated, since that would render incoherent the relation between preference satisfaction and personal welfare; yet they cannot be excluded, since public policies are usually debated in terms of the good of the community.

Environmental economists confront a dilemma. Ethical and community-regarding values not grounded in considerations of personal benefit must either enter into or be excluded from the social welfare function that determines how goods should be allocated. It is impossible to include these "commitment" values, since that would render incoherent the relation between preference satisfaction and personal welfare. (These values, once again, are not based on considerations of personal benefit.) However, it is also impossible to exclude commitment values from the

welfare function or calculation, since people usually argue for public policies in public terms—that is, in terms of the good of the community rather than in terms of what benefits them personally.

To overcome this dilemma, environmental economists have invented "existence," "stewardship," "bequest," and other kinds of values to capture what is essential about moral commitments—namely, that they rest on objective ethical beliefs rather than on the expectation of personal benefit. At the same time, economists understand that these values must be based entirely on considerations of personal satisfaction or well-being, for otherwise they could not fit into a welfare function. Thus moral commitments to protect nature are both utterly independent of and completely dependent upon considerations of personal benefit or well-being. That is the reason they are so important.

Economists elicit ethical and other "commitment" values in surveys by asking people how much they are willing to pay, for example, to protect whales. These surveys do not ask how much individuals are willing to pay for a personal benefit, such as a warm glow or a psychic satisfaction, that they might experience as a result of contributing to that cause. Yet economists interpret their surveys as if that were the question they had asked. They assume that paying to protect whales and paying for psychic satisfaction come to the same thing. Thus they interpret moral commitments to preserve nature for its own sake as preferences based on considerations of personal benefit or welfare. For environmental economists, this kind of double-think "solves" the dilemma of not being able to exclude ethical values from or include them in the social welfare function.

Microeconomic efficiency and macroeconomic performance

The approach in mainstream environmental economics that I am criticizing

deals entirely with microeconomic issues—principally, efficiency in the allocation of resources. Environmental economists primarily study the relation between resource use and preference satisfaction, particularly in the context of prices at which goods trade in individual transactions. Macroeconomic issues, in contrast, have to do with large aggregates—such as the amount of employment, inflation, and trade—that determine the state of the economy as a whole. The question arises whether environmental economics has anything to do with the economy that concerns ordinary people—for example, jobs, inflation, deficits, and interest rates.

No consensus exists among economists about what relation, if any, holds between microeconomic efficiency and macroeconomic performance. Some theorists accept Marx's argument that efficient market competition—by driving down prices—eliminates profit, which is not a good or service anyone wants to pay for. Efficient market competition would then lead to involuntary unemployment. Others contend, on the contrary, that involuntary unemployment is impossible within efficient markets, since wages will fall sufficiently to clear the labor pool—that is, will fall low enough so that markets will create jobs for everyone who wants to work. Incompatible stories like these are all too easy to tell about how the microeconomy does or does not affect the macroeconomy.

If you turned to the index of any textbook in macroeconomics, you would not find an entry for natural resources, nor would you find one for the environment. At present, environmental or resource economics is exclusively a branch of microeconomics and thus is concerned with microeconomic efficiency. Microeconomic efficiency has no clear relation to macroeconomic performance. That is why environmental economists say so little about the relation of the environment to the economy.

A better approach to formulating environmental policy

I have space here to describe briefly three concepts that I believe are more useful in formulating environmental policy than the concepts I have criticized. They are the concepts of property rights, knee-of-the-curve thinking, and place.

Knee-of-the-curve thinking offers an appropriate context in which to consider the costs of environmental protection; it suggests that we make the least expensive reductions in pollution first and that we implement pollution reductions until we reach the point of rapidly diminishing returns.

As libertarian Murray Rothbard points out, the way to keep polluters from polluting is to enjoin them from doing so and thereby invading property rights. With this in mind, we should treat pollution not as a social cost but as a legal nuisance or trespass. This is in fact the way most of our environmental statutes intend pollution to be treated. The preponderance of these statutes require industry to minimize emissions it cannot feasibly eliminate in order to protect property rights while avoiding the extreme consequence of closing down the economy. The point of the statutes is not to allocate resources efficiently, to "optimize" levels of pollution, or to maximize social wealth. Rather, by ratcheting pollution levels down to the lowest economically and technologically feasible minimums, the statutes seek to prevent torts and to protect personal and property rights.

In setting priorities for reducing pollution, we should rely on knee-of-the-curve thinking, which offers an appropriate context in which to consider the costs of environmental protection. Knee-of-the-curve thinking compares the price of purchasing and maintaining one technology to achieve a given reduction in pollution with the price of purchasing and maintaining an alternative technology to achieve the same reduction. This approach attempts to achieve cost-effectiveness by comparing the actual market price of competing technologies and by stimulating the development of those technologies that can bring down the price still further.

According to knee-of-the-curve thinking, we should make the least expensive reductions in pollution first, and we should continue to implement pollution reductions until the price of doing so rises dramatically—that is, until the point of rapidly diminishing returns is reached. To illustrate, imagine a graph in which the horizontal axis represents pollution reduction and the vertical axis represents price. The law of diminishing returns suggests that at some point the price of the next marginal reduction in pollution will rise considerably; this point is the knee of the curve. The aim of environmental law is to use means such as technological innovation to push the knee out as far as possible on the pollution-reduction axis; it is not to "optimize" pollution, as I noted above, or to balance benefits and costs.

To understand the value and purpose of environmental protection, we should look to another concept. Those who are eager to save treasured landscapes have introduced the concept of place—of a natural scene as it is understood in relation to local human culture and history or, more generally, of the environment as it exists in community with human beings. The concept of place brings together human, environmental, and natural history; it is particularly valuable in helping us understand what we deplore about the human subversion of nature and what we fear about the destruction

of the environment. Indeed, much of the discussion about preserving resources might be better understood in terms of protecting places.

As technology makes us economically less and less dependent on nature, we become aesthetically, culturally, and ethically more attached to nature. We begin to think of nature less in terms of utility and more in terms of permanence. (One might compare this to gentrification—the process in which urban areas come to be perceived as a cultural

heritage.) The concept of place applies to landscapes that do more than satisfy the consumer preferences of individuals. Protecting landscapes for their ethical and cultural significance is not the same thing as protecting them to satisfy consumer preferences.

The economy was the message of the Clinton campaign; to get “on message” we need a macroeconomics, not a microeconomics, of the environment. Our environmental policy should reflect first and foremost our shared and public

values about nature and about the many places we care about in common. The Clinton administration may look to ethics, history, literature, religion, science, and art to find concepts that are useful in devising environmental policy. It cannot express its message of hope, however, in the worn-out vocabulary of environmental economics.

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Environmental Economics: Not Dead But Thriving

Raymond J. Kopp

In responding to Dr. Sagoff's critique, Dr. Kopp focuses on the philosophical attack on preferences. He rejects the notion that preferences are hypothetical expressions of choice under ideal conditions and that choice and preference are substitutes for one another. Rather, Kopp argues, human actions are a result of choice based on preference, and it is the choices of individuals that environmental economists use to infer underlying preferences. He also rejects the idea that ethical values not grounded in considerations of personal benefit cannot be included in economists' definition of individual welfare. Kopp contends that preferences include preferences for characteristics of the social state that could be associated with ethical concerns. Kopp rebuts the claim that satisfaction of preferences has nothing to do with individual well-being by pointing out that, for economists, the ultimate criterion for deciding what is good and what is bad for a given individual is his or her own wants and preferences. The root of the disagreement between philosophers and economists regarding the concept of individual well-being and

what makes a person better off or worse off, Kopp suggests, is not really related to the satisfaction of preferences but to economists' rejection of paternalism. Economists and philosophers, Kopp says, can agree on a list of elements that give rise to well-being; where they part company is on the weighting of each of the elements on the list.

Mark Sagoff argues forcefully that decision makers will find little that is helpful in the vocabulary of environmental economics as they wrestle with questions of environmental and natural resource policy, and that the concepts that define the approach of environmental economics have outlived their usefulness. His critique of environmental economics is provocative and, if his assessment of the discipline is valid, it is damning as well. I think it can be shown, however, that his assessment is not valid.

Is environmental economics (or resource economics) dead, as the title of Dr. Sagoff's article suggests? It would not appear to be. Indeed, it is more popular in policy analysis and policy formulation today than at any other

time in its brief history. The Clean Air Act Amendments of 1990, for example, incorporate novel provisions for reducing sulfur dioxide emissions from coal-fired power plants through a system of marketable emissions permits—a system advocated by economists for at least twenty years and supported by the Environmental Defense Fund during congressional debate. Moreover, the amendments themselves carry a statutory provision that benefit-cost studies of the regulations required by the act be conducted at periodic intervals, with the results presented to Congress.

Perhaps the most far-reaching use of environmental economics is found in the natural resource damage provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA, also known as Superfund) and the Oil Pollution Act of 1990. Both acts stipulate that parties responsible for damages to natural resources or the environment due to the release of hazardous substances or oil must pay to restore the resources and pay the “value” of the natural resource services lost as a result of the injury. These acts use an explicit economic paradigm to define value. Moreover, the

promulgated regulations defining the manner in which values are to be estimated rely on techniques developed over the last twenty years by environmental economists.

In contemporary environmental policy, environmental economics appears to be thriving. The discipline's development of the concept of nonuse value (also known as existence value and passive use value), introduced more than twenty-five years ago by John V. Krutilla of Resources for the Future, has changed the manner in which Congress and the courts view environmental protection and damages to natural resources. The ability of environmental economists to estimate nonuse values—for example, the values individuals may derive from the mere knowledge that an unspoiled natural area exists—allows the ethical concerns of individuals with respect to natural resources to be explicitly incorporated into quantitative analyses of environmental programs. This innovation represents more than a simple enhancement of analytical capability; it represents a significant broadening of the scope of issues open to economic analysis, including issues in other disciplines previously closed to economic analysis.

An overview of Sagoff's critique

The thrust of Sagoff's critique of environmental economics comes in two parts. In the first, which concerns the philosophical underpinnings of the discipline, he suggests that the inadequacies of environmental economics are a result of the abandonment of choice for preference, the artificial nature of preferences in general, and the disassociation between preference satisfaction and individual welfare. In the second part, which concerns the use to which the discipline is put in policymaking, he argues that decision makers should discard environmental economics as a source of relevant information and rely instead on ethics, aesthetics, cultural

history, religion, and other fields. If Sagoff reserves any room for economics in the environmental policy debate, it is in the realm of macroeconomics; however, he states that environmental economics, being basically microeconomics and concerned with allocative efficiency, has nothing relevant to say.

I believe the first part of the critique to be the more substantive and will devote most of this article to my response to Sagoff's philosophical attack on preferences. First, however, I will briefly respond to his notion that environmental economists have little or nothing to say about the macroeconomic implications of environmental policy, and address his misconceptions about the association between allocative efficiency and macroeconomic performance.

Allocative efficiency and macroeconomic performance

I suppose that, in Sagoff's eyes, I am a macroeconomist when I write about the effect of environmental regulation on employment, economic growth, prices, and the like, and that I am an environmental economist when I write about the benefits to agriculture of ambient air quality standards (for example). Much of the work that has been done on the macroeconomic consequences of environmental regulations—most notably on the cost of these regulations—has been done by microeconomists, myself included, using general equilibrium microeconomic models of the U.S. economy.

To be fair, Sagoff is really not asserting that environmental economists ignore macroeconomic implications, but rather that allocative efficiency, which he takes to be the Holy Grail of environmental economics, has nothing to do with macroeconomic performance. However, allocative efficiency is not the goal of environmental economics, as Sagoff suggests it is. Rather, its goal is to maximize social welfare.

Allocative efficiency is a necessary but not sufficient condition for welfare maximization, and no economist would ever suggest that it is. In order to maximize welfare, resource allocations must not only be efficient but equitable. For economists and others, the concept of equity encompasses everything from individual rights to the distribution of wealth and income.

Even if allocative efficiency were the goal of environmental economics, one would still not expect to see a link between the allocative efficiency of environmental regulation and macroeconomic performance. The reason is quite simple. Allocative efficiency means allocating resources to maximize some objective. One can imagine a small environmental program (small in terms of resources consumed by the program)

Allocative efficiency is a necessary but not sufficient condition for welfare maximization; economists' concern with allocative efficiency is not about macroeconomic effects but about waste and the attainment of goals.

that is very inefficient, but due to its small size has virtually no effect on the larger economy. On the other hand, it is just as easy to imagine a very efficient, even perfectly efficient, mammoth project that has a considerable macroeconomic impact. The economist's concern with allocative efficiency is a concern about waste and the attainment of goals—it is not about macroeconomic effects. If our goal is environmental improvement and the chosen policies do not lead to the attainment of that goal, they are inefficient, wasteful, and socially undesirable, regardless of their macroeconomic effects.

Preference and welfare theory

The substance of Sagoff's critique lies not in his desire to emphasize macro implications but rather in his philosophical attack on the economic concept of preference. How should one assess the validity and thus the importance of this attack? A logical approach would begin with the identification of the precise elements of environmental economics that are being questioned. It is clear that Sagoff does not question all the activities performed by environmental economists, but only a small portion of those activities—specifically, benefit-cost analyses. Moreover, he notes that it is the application of the theory of welfare economics to environmental and natural resource policy that is at the root of his concern. I would conjecture that Sagoff would be just as critical of the use of the theory in any decision-making process involving the provision of public goods, whether the decisions involve federal tax policy, construction of space stations, local expenditures for sewer systems, or environmental policy.

It would be unfair to say that Sagoff opposes the balancing of costs and benefits in public decision making. Rather, he criticizes the use of a welfare-theoretic paradigm in the quantification of the costs and benefits of contemplated actions.

What is it about the welfare-theoretic paradigm that so irritates Sagoff? He argues that economic theory "abandons choice for preference," that "preferences . . . are simply artifacts or constructs of economic theory itself," and that "even if preferences did exist as a foundation for 'rational' choice, economists offer no plausible reason why environmental policy should seek to satisfy them." The substance of the critique seems to boil down to the role of choice and preference in welfare theory. But if this is true, we are left with the realization that Sagoff's critique extends far beyond welfare theory, and in fact encompasses all of economics proper. Since his critique is focused on choice, preferences, and

the relationship of preference to social welfare, I shall respond by addressing each of these issues in turn.

Economics is about the choices made by businesses and consumers. In its purely objective form, economic theory seeks to explain the actual choices businesses and consumers make. The sub-area of economics known as welfare theory is a theory of optimal choices. It is a positive theory when it describes the optimality properties of actual choices and is a normative theory when it specifies how optimal choices might be made given politically specified objectives. There is simply no support for the argument that economics has abandoned choice in favor of preference—the study of choice is the economist's *raison d'être*, and preference is the attribute of individuals that gives rise to specific choices. Choice and preference are not substitutes for one another as Sagoff seems to think, nor are they names for the same thing, or alternative theories. Choice is a process economists endeavor to understand; preference, combined with a posited behavioral objective (often termed utility maximization), is the reigning theory for explaining choice.

Sagoff is correct when he states that preferences as employed in welfare theory are theoretical constructs and are not observable. However, when he states that "preferences do not exist in the mind of the individual; rather, they exist in the eye of the beholder," he implies that individual preferences are somehow illusions of economists and nonexistent in the real world. Moreover, he implies that observation of individual behavior can say nothing about a person's preferences even if they exist. Sagoff should realize, however, that in economics introspection goes a long way toward casual verification of theory. I know, for example, that I prefer coffee to tea, silver cars to black cars, and hiking to fishing. Readers of *Resources* could easily assemble a similar preference list. Because individuals can articulate their preferences and anyone observing an individual's behavior can infer those preferences, one cannot dis-

miss preferences as the inane creation of economists. Two of Sagoff's high priests may see different things in chicken entrails, but people display the indelible mark of their preferences in their daily actions. Any two environmental economists looking at the same data on individuals' recreational activity, for example, will draw the same general conclusions about their recreational preferences. Moreover, on the basis of these conclusions, economists can endeavor to predict the recreational behavior of these same individuals under different circumstances. If the predictions are reasonably accurate, one can have some confidence that economists' description of preferences is reasonably correct.

Economics has not abandoned choice in favor of preference; choice is a process economists endeavor to understand, while preference, combined with a posited behavioral objective, is the reigning theory for explaining choice.

The preferences that economists infer from the behavior of individuals are not hypothetical expressions of choice under ideal conditions, as Sagoff seems to believe. There is nothing hypothetical about the reduction in beach recreation one might observe after the beach has been contaminated by an oil spill. Nor is there anything hypothetical about the outcome of local elections in which citizens vote to tax themselves in order to protect specific aspects of their environment. Each of these acts is a result of choice based on preference, and made freely under real-world conditions. It is such choices that environmental economists use to infer the underlying preferences of individuals. Sagoff is simply wrong to suggest

that economists reject the actual choices of individuals and impose their own paternalistic views. Rather, economists build their entire empirical theory of value upon such actual choices. As I shall argue below, for a philosopher to term economics paternalistic is surely the pot calling the kettle black.

I shall make one further point about the notion of preferences. Economists posit that individuals define their preferences for states of nature and society. This implies that I not only prefer coffee to tea, but also have preferences with respect to the manner in which I behave and the manner in which I like society to behave. These latter preferences may be characterized as codes of conduct or personal ethics but, regardless of their characterization, they define preferred modes of individual and social behavior. The point emphasized here is the breadth of preferences employed in economic theory; preferences extend beyond those that exist for goods, services, and activities to include those for characteristics of the social state that one might associate with broader ethical concerns.

Sagoff would argue that the contamination of preferences by ethical concerns makes it impossible to define personal welfare on the basis of such preferences. This argument derives from his assumption that individual welfare, as defined by economists, is coincident with personal benefit and that ethically based preferences are not grounded "in considerations of personal satisfaction or well-being." I will say more about the economic notion of individual welfare below, but here it is sufficient to say that much of human behavior can be explained by treating individual welfare as synonymous with personal benefit, thereby excluding ethical concerns, or what the economist Amartya Sen refers to as "commitment." However, when considering the range of human behavior that includes choices among public goods—such as education, humanitarian aid, local welfare programs, environmental protection,

and the like—preferences based on individual ethics become relevant. Under a general view of individual welfare, it is certainly true that individuals can benefit

Because individuals can articulate their preferences and anyone observing an individual's behavior can infer those preferences, one cannot dismiss preferences as the inane creation of economists; nor can they claim that preferences are hypothetical expressions of choice under ideal conditions.

personally from choosing to act in accordance with their ethical preferences and can be made personally worse off by acting in a manner inconsistent with such preferences. The individual acts in accordance with these ethical preferences or commitments because of the personal well-being he or she enjoys as a result of the action, or because of the loss in well-being he or she would suffer from acting otherwise.

Sen, in "Rational Fools: A Critique of the Behavioral Foundations of Economic Theory" (1977), cites an instructive example: in George Bernard Shaw's *The Devil's Disciple*, the character Richard Dudgeon, denying that his willingness to be hanged for another man was due to sympathy or love, explains to a woman that "What I did last night, I did in cold blood, caring not half so much for your husband, or for you as I do for myself. I had no motive and no interest: all I can tell you is that when it came to the point whether I would take my neck out of the noose and put another man's into it, I could not do it." While Richard's act was surely heroic and self-sacrificing, it was the result of his choice to act

in a manner he preferred and for his own personal benefit.

Acting in accordance with one's ethical preferences enhances one's personal welfare, but I am willing to make an even stronger statement: one will act in a manner that violates some of one's individual ethical codes when the price of obedient behavior becomes too high. For example, I give to various charities because I have an ethical preference for doing so. However, the amount I give fluctuates with my economic circumstance. Making large charitable contributions in hard economic times means I would not be able to provide for my children, for which I also have an ethical preference. The fact that individuals are capable of and willing to trade one action for another on the basis of preferences, even when those preferences include personal ethical codes, is a hallmark of "economic" behavior that we have come to know as rational choice.

Satisfaction of preferences and individual well-being

In my view the most serious of Sagoff's philosophical criticisms is his insistence that satisfaction of preferences has nothing to do with individual well-being. Since Sagoff has no compunction about delving into economics, let me explore what I believe to be the philosophical argument underlying Sagoff's view, as articulated by Harvard philosopher Thomas M. Scanlon, who has given us one of the most accessible philosophical critiques of preference satisfaction. Scanlon's critique provides a rare clarity of insight into the differences that exist between economists and philosophers regarding the fundamental concept of individual well-being and what it is that makes a person better off or worse off. I hope to convince readers that the difference that divides philosophers and economists is really not about the satisfaction of preferences, but rather is focused on economists' rejection of paternalism.

I begin by making a concession that may weaken my credibility among some economists, but which nevertheless seems unavoidable: when one speaks about those things that make an individual better off, one is necessarily making a value judgment. Some economists will no doubt be uneasy with this concession and would rather have well-being defined in a purely objective fashion, but I believe that such a definition would simply represent fanciful thinking. Scanlon, in his paper "The Moral Basis of Interpersonal Comparisons" (1991), suggests that the value-judgment nature of a definition of well-being can be mitigated to a degree by constructing "a more concrete conception of welfare in terms of goods and conditions that are recognized as important to a good life even by people with divergent values." The idea is to formulate a list of things that give rise to well-being based on "a shared conception of the important goods and bads in life." There are potentially, of course, a large number of such lists. The issue that concerns us here is not the specific elements of the list, but how the elements are aggregated to define a measure of well-being that may be used to compare alternative social states.

Philosophers and economists are willing to define a set of elements that give rise to well-being; moreover, they wish to aggregate the elements so that social states may be compared.

Scanlon's answer to the problem of aggregating the elements of a list is to utilize an index—an index that would not "consist simply of exchangeable goods and institutional prerogatives"

but could "refer as well to levels of development of personal capacities . . . or even to states of consciousness." According to Scanlon, such an index must pass a test of adequacy and a test of practicality. An index would be inadequate if it contained only a subset of those elements that were deemed important to a good life—for example, if it contained only wealth.

Economists have no quarrel with Scanlon up to this point. Like philosophers, economists are willing to define a set of elements that give rise to well-being. Their list would obviously include material goods and services as well as intangibles such as friendship, love, self-esteem, and religious and ethical views. As it turns out, this list looks very much like the list of items one might find in a generalized microeconomic utility function. Moreover, economists, like their philosophical colleagues, wish to aggregate the list's elements so that social states may be compared, and economists would agree that an arbitrarily short list could very well be deemed inadequate. Where, then, is the controversy? Where is the indictment of preference satisfaction?

Controversy begins to arise when we examine the second of Scanlon's index tests—practicality. On its face, practicality seems just like more microeconomics. Scanlon notes that the question of practicality takes account of the fact that an index of well-being will be used by legislators and others in assessing the contributions of institutions to welfare. He has described an instance in which institutional decisions (on environmental policy, for example) are made by comparing levels of individual well-being. We should all recognize this for what it is—cost-benefit analysis. And while even economists routinely reject cost-benefit analysis as a sole decision-making criterion, it seems the philosophical view of public decision making is very close indeed to that of welfare economics.

We now come to the root of the disagreement concerning practicality. For

an index approach to be practical, we must be able to aggregate the elements that give rise to well-being. In the simplest case, which will suffice here, aggregation is accomplished by weighting these elements and summing them; but where do the weights come from? In welfare economics, the weights are derived from the observed choices of individuals, which economists attribute to underlying preferences. In "Morality and the Theory of Rational Behavior" (1982), the welfare economist John Harsanyi articulates the economists' view of the derivation of weights most directly in stating that the ultimate criterion for deciding what is good and what is bad for a given individual is his or her own wants and preferences. This

In welfare economics, the weights given to the elements that give rise to well-being are derived from the observed choices of individuals; what matters for economists is that individuals apply the weights and that the weights are permitted to be specific to each individual.

so-called principle of autonomy does not depend on the reasons one has for particular preferences. What matters for Harsanyi and other economists is that individuals apply the weights and that the weights are permitted to be specific to each individual.

What weights does Scanlon suggest? Unfortunately, he is not forthcoming on this point. However, he appears to believe that people do not know what is good for them and that someone or some body must decide for them when he says that there are circumstances in which the satisfaction of people's mani-

fest preferences would not serve people's true interests. Instead of an index of well-being formulated in terms of preference satisfaction, Scanlon proposes an index formulated in terms of the availability of goods and conditions deemed important for a good life. The question economists naturally ask is, who will determine the goods and conditions important for a good life and their relative weights?

Up to the point at which one must weight the constituent elements of well-being, Scanlon's approach to defining and even quantifying well-being is virtually identical to that of the economist. It would be unjust to suggest that Scanlon is recommending that weights be developed by philosopher-kings; however, it is clear that the weights we as individuals would apply are unimportant in his scheme.

If, as I assert, the defining difference between an economist's view of well-being and Scanlon's boils down to paternalism, then the debate can proceed no further on the basis of economics or philosophy, but needs to be decided by each individual. It seems the remaining question to ask is not, Do people act in their own best interest? but, Are we more willing to live with our mistakes than we are willing to give up our freedom to make mistakes?

Infeasibility of Sagoff's approach to environmental policymaking

In closing his article, Sagoff suggests a better approach to the problem of formulating environmental and natural resource policy. This approach would utilize the concepts of property rights, knee-of-the-curve thinking, and place. As bases for policymaking, two of these concepts—property rights and place—are untenable, at least for the present.

Sagoff suggests that people should be enjoined from polluting and thereby

invading property rights. This is neither a new idea nor a very useful one. The problem with common property, such as the environment, is the fact that the property rights are held in common. Those who advocate a property rights approach to environmental policy want the rights assigned more specifically. This ultimately means engaging in a futile political process to redistribute the rights among individuals—a process in which rights are taken away from some and given to others.

If one rejects preference as the motive for economic choice, one must also reject market prices as a measure of cost; if prices hold no meaning, one must then reject knee-of-the-curve thinking, since the cost curve is based on price information, and then reject the whole of microeconomics and macroeconomics.

The concept of place—which Sagoff suggests is our understanding of a natural scene in terms of how the scene is related to local human culture and history—is even more problematic as a basis for policymaking. If Congress and the regulatory agencies can figure out how to define environmental policy on this basis, more power to them. I believe that the concept of place will have to be much further developed before it can be shown to be a practical concept on which to formulate environmental policies, not to mention a useful one.

Thus we are left with Sagoff's knee-of-the-curve thinking, which he suggests can be used to set priorities for reducing pollution. According to such thinking, we should implement the

least expensive reductions in pollution first and stop making pollution reductions when the cost of doing so begins to rise substantially. This has some intuitive appeal; however, it means that we should ignore high-cost environmental policies even when we acknowledge that the benefits of those policies are considerably greater than their costs! More important for our present discussion is the fact that costs of environmental programs are just as dependent upon the preferences of individuals as are the benefits.

The cost of an environmental program is dependent upon the prices one must pay for the program's components—for example, prices for capital goods, labor services, and energy. Prices are determined in markets where the buyers' preferences are reflected in the amount they are willing to pay and the sellers' preferences are reflected in the amount they are willing to accept. If one rejects preference as the motive for economic choice, one must also reject market prices as a measure of cost. If prices hold no meaning, one must then reject Sagoff's knee-of-the-curve thinking, since the cost curve is based on price information. And one must then reject the whole of microeconomics and macroeconomics, which of course is based on market prices. Thus Sagoff's argument with preferences leaves us with no viable, internally consistent prescriptions—economic or otherwise—for setting priorities in environmental policymaking.

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Cleanup Decisions Under Superfund: Do Benefits and Costs Matter?

Shreekant Gupta, George Van Houtven, and Maureen L. Cropper

The high cost of cleanups of hazardous waste sites under the Superfund program has prompted critics of the program to question whether the benefits of cleanups are worth what the U.S. Environmental Protection Agency (EPA) says should be spent to achieve them. Recently, researchers at Resources for the Future and the University of Maryland examined the agency's decisions regarding the cleanup of 110 Superfund sites in order to determine whether the factors that influenced the agency's choice of target risk level (the lifetime cancer risk posed by a site after cleanup) and choice of cleanup option (how permanent the cleanup should be) for each site were related to benefit and cost considerations. Their study reveals that EPA balanced benefits and costs to the extent that it was legally entitled to do so. Other factors being equal, the cheaper the cost of a cleanup option, the more likely it was that the agency chose it. However, EPA clearly preferred more permanent remedies to less permanent remedies. The question remains whether the benefits of more permanent remedies warrant the costs of obtaining them.

Passage of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly referred to as Superfund, brought about what has become the best-known program for cleaning up hazardous waste sites in the United States. One of the most controversial of all U.S. environmental pro-

grams, Superfund has been widely criticized for the slow pace at which remedial actions at such sites are undertaken. It has also come under fire for leading to lengthy and costly litigation as a result of its liability standards, which many parties potentially responsible for cleanup costs consider unfair.

Not least among the criticisms of Superfund, which is administered by the U.S. Environmental Protection Agency (EPA), is the high cost of cleanups under the program. To date, it has averaged \$27 million per site. Estimates of the costs to clean up all sites currently on EPA's National Priorities List (NPL) and those likely to be put on the NPL range from \$60 billion to \$90 billion. In light of these estimates, many question whether the benefits of the Superfund program justify the costs of the program. At issue is how EPA determines the amount of money that should be spent on the cleanup of each Superfund site. Does the agency make this determination on the basis of risks to human health and the environment, or on some other basis?

To answer this question, we recently examined EPA's decisions regarding the cleanup of contaminated soils at 110 Superfund sites. Specifically, we examined the factors that influenced the agency's decisions about how much soil to clean up and how the cleanup was to be effected at each of the sites. In doing so, we investigated whether these factors were related to the benefits and costs of cleanups and whether political variables, as measured by the socioeconomic characteristics and racial composition of the population living near a

site, influenced the choices of cleanup strategy at the 110 sites.

If those choices reflected the benefits of cleanup, it would be expected that cleanups at sites where these benefits were great would be both more comprehensive and more permanent. Other factors being equal, the benefits of cleanup should be greater at sites located in densely populated areas than at sites located in sparsely populated areas, for the simple reason that more people are potentially exposed to contaminated soils in the former. To the extent that society considers it important to clean up sites that pose the highest risks, the benefits of cleanups should also be greater at sites where such risks are higher than at sites where they are lower.

If EPA's choices of cleanup strategy reflected the costs of cleanup, it would be expected that, other factors being equal, cleanups at sites where these costs were great would be both less comprehensive and less permanent.

The cleanup process under Superfund

When EPA learns of abandoned hazardous waste sites, it enters them into a computerized database called CERCLIS (Comprehensive Environmental Response, Compensation, and Liability Information Service), which currently contains entries on more than 33,000 sites. The agency then undertakes a preliminary assessment of each site in which it attempts to determine how the site was used and which hazardous substances were disposed of there. In many cases, this assessment indicates that no remedial action is required. In about one-third of the cases, it indicates the need for a site investigation, in which a more detailed assessment of the site is made on the basis of a visual examination and a laboratory analysis of materials found at the site. After a site investigation, many sites are judged harmless enough to warrant no further action.

Sites not so judged go through a formal hazard ranking process in which they are evaluated on the basis of their potential to inflict damage through three pathways—groundwater, surface water, and air. Using its hazard ranking system, EPA assigns each site a numerical score on a scale from 0 to 100. If a site's score is greater than 28.5, the site is put on the National Priorities List. At the end of fiscal year 1991, there were more than 1,200 sites on the list.

Once EPA has selected cleanup goals and remedial actions that protect public health and the environment and that comply with state and federal environmental standards, it is allowed to balance the cost of cleanup against other evaluation criteria, such as the permanence of remedial actions.

Each site on the NPL is subject to a formal Remedial Investigation/Feasibility Study (RI/FS). RI/FSs may be conducted for individual portions of each large site. In the Remedial Investigation, the wastes at the site are identified and the risks they pose to human health and the environment are assessed. In the Feasibility Study, remedial alternatives are developed and screened.

In most cases, the Feasibility Study must address two pollution problems: surface contamination—contamination of soil, sludge, or surface water—and groundwater contamination. The cleanup options for contaminated soil include capping, in which materials such as clay and asphalt are placed over the soil; in situ treatment, in which the soil is not excavated but treated in place with chemicals or microorganisms that detoxify contaminants; or excavation. Soils that are excavated can be disposed

of in a landfill or can be treated by some method such as incineration. The most common cleanup option for contaminated groundwater is to pump the water to the surface, treat it to remove contaminants, and either reinject it into the aquifer from which it was pumped or discharge it into a river or stream. In some cases the use of an alternative water supply is considered.

Following the Feasibility Study, EPA issues a proposed remedial action plan, which describes and justifies the remedial alternative selected. The public, private parties, and state and local governments are then given thirty days to comment on the proposed plan, after which the plan is issued as a Record of Decision. At this point, the actual cleanup of the site can begin. Once the cleanup is completed, the site can be deleted from the NPL.

It is important to note that EPA must not only protect public health and the environment but comply with state and federal environmental standards—the “Applicable or Relevant and Appropriate Requirements”—in selecting cleanup goals and remedial actions. After these standards have been met, the agency is allowed to balance the cost of cleanup against four other evaluation criteria: (1) permanence of remedial actions; (2) short-term effectiveness of the actions; (3) reduction of toxicity, mobility, or volume of waste; and (4) feasibility of the cleanup strategy.

Scope of study

In studying the role that cost and benefit considerations play in the choice of cleanup strategies at Superfund sites, we limited our investigation to EPA's cleanup decisions at sites for which one or more Records of Decision (RODs) had been signed. By the end of the 1991 fiscal year, 945 RODs had been signed. We further limited our investigation to EPA's cleanup decisions at sites where soil contained chemicals used in the treatment of lumber (wood-preserving

sites) and at sites where soil contained polychlorinated biphenyls (PCBs) at concentrations in excess of ten parts per million (PCB sites). Thus our study was restricted to cleanup decisions at 110 sites—32 wood-preserving sites and 78 PCB sites. Because EPA chose different cleanup strategies for different parts of some of these sites, we examined 127 cleanup decisions in all—40 at wood-preserving sites and 87 at PCB sites.

We chose to investigate cleanup decisions at two types of sites in order to determine if the influence of cost and benefit considerations was the same at one as at the other. Our decision to focus on wood-preserving sites and PCB sites was prompted by the similarity of their contaminants. Like PCBs, creosote and pentachlorophenol—one or both of which are found in the soil at wood-preserving sites—are organic chemicals. Therefore, the menu of treatment options is similar for wood-preserving sites and PCB sites. Because all three contaminants are suspected human carcinogens, we were able to collect quantitative estimates of health risks in order to determine whether these risks were reflected in the choice of cleanup strategy.

In our study, we examined EPA's two major decisions with respect to the cleanup at each site: how much of the soil should be cleaned up and how the cleanup should be effected. The first decision—how extensive the cleanup should be—involves determining how much of the site to cap, or, if excavation is chosen, how much of the soil to excavate. This decision is usually stated in terms of the maximum concentrations (in parts per million) of toxic substances that will be left at the site once the cleanup is completed. These concentrations place an upper bound on the lifetime cancer risk arising from exposure to contaminated soil at the site. Choosing maximum concentrations of contaminants is therefore tantamount to choosing a target health risk. In choosing a target risk level, EPA is to protect the health of persons living near the site, regardless

of cost. It is free to decide how low the target health risk should be at a site, although guidelines suggest that lifetime cancer risk should lie between 1 in 10,000 and 1 in 1,000,000.

As noted above, the second decision involves choosing one or more of three options: capping the soil, treating it in situ, or excavating it. If the last is chosen, EPA must then decide whether the excavated soil will be put in a landfill or treated in some way (such as incineration). This decision is essentially a determination as to how permanent the cleanup will be. If the contaminated soil is capped rather than excavated, for example, the cleanup will last only as long as the life of the cap. If the excavated soil is put in a landfill rather than being incinerated, the cleanup will last only as long as the landfill liner remains intact.

Choice of target risk level

EPA quantified the post-cleanup level of lifetime cancer risk it wanted to achieve in 61 of the 127 decisions we examined. Parties potentially responsible for cleanup costs (so-called potentially responsible parties, or PRPs) paid for RI/FSs on which 29 of these decisions were based. State funds or federal tax revenues earmarked for the purpose were used to pay for RI/FSs on which the remaining 32 decisions were based. Since it is sometimes thought that the party who pays for an RI/FS can influence the menu of cleanup options considered at a site, we examined whether the factors that affected the target risk level chosen for enforcement-lead sites (where RI/FSs were paid for by potentially responsible parties) differed from those that affected the level chosen for fund-lead sites (where RI/FSs were paid for by government funds).

As stated earlier, at least two factors might influence the choice of target risk level at a site if benefits mattered in deciding which cleanup options to implement. One factor is baseline

risk—that is, the risk that a site poses to an individual living near the site prior to cleanup. The other is the size of the population exposed to contamination from the site. Other factors being equal, EPA might be expected to choose lower target risk levels for sites with a high baseline risk than for sites with a low baseline risk. Likewise, the agency might be expected to choose lower target risk levels for sites in densely populated areas than for sites in sparsely populated areas, because more people would benefit from a reduction in risk in densely populated areas.

Baseline risk (the risk to health posed by a site prior to cleanup) influenced EPA's choice of target risk level only at enforcement-lead sites, where remedial investigations and feasibility studies were paid for by parties potentially liable for cleanup costs.

In our study, we approximated the size of the population living near a site by noting whether the site was located in an urban, a suburban, or a rural area. We found that the influence of population on the choice of target risk level was no different at enforcement-lead sites than it was at fund-lead sites. Somewhat surprisingly, we did find that the target risk levels selected for sites in urban areas were higher than those selected for sites in suburban or rural areas. One possible explanation for our finding is that residents living near the sites perceived some health threat arising from the excavation of soil—a remedial action that is usually entailed by the choice of a low target risk level. If so, EPA may have chosen a higher rather than a lower target risk level at sites in urban areas so as to

avoid a cleanup strategy that involved soil excavation.

While the influence of population on the choice of target risk level was the same at enforcement-lead sites and fund-lead sites, we found that the influence of baseline risk was not. EPA chose high target risk levels at enforcement-lead sites that posed a low baseline risk. This risk had no effect on the choice of target risk level at fund-lead sites. At these sites, however, the target risk level was related to a site's hazard ranking system score: the lower the score, the higher the target risk.

As noted above, EPA is supposed to ignore costs in setting target risk levels. It appears to have done just that. At both fund-lead sites and PRP-lead sites, target risk levels were unrelated to either unit excavation costs or to the size of the site. Target risk levels were also unrelated to political variables, as measured by the racial composition of and the median income in the county where a site is located.

Choice of cleanup options

At the sites, EPA had three choices regarding cleanup options: whether or not to excavate soils; whether or not to treat soils; and whether to dispose of excavated soil off site or on site. These choices can be combined to yield six distinct remedial alternatives: on-site treatment of soil that has been excavated (on-site treatment), off-site treatment of soil that has been excavated (off-site treatment), disposal of excavated but untreated soil in a landfill off the site (off-site landfill), disposal of excavated but untreated soil in a landfill on the site (on-site landfill), on-site treatment of soil that has not been excavated (in situ treatment), and containment of soil that has been neither excavated nor treated (containment) (see figure, p.16).

We estimated the parameters of a model that explains the likelihood that EPA would select each of the six

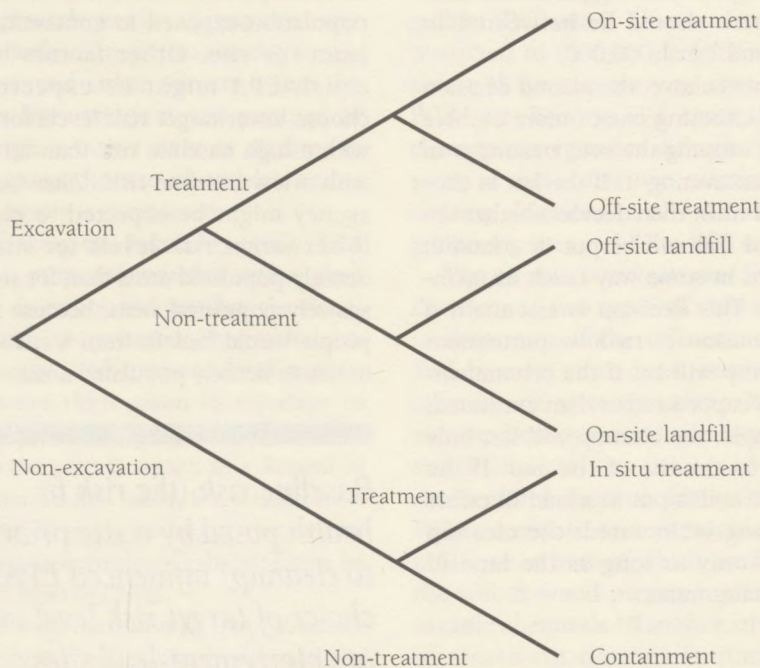
cleanup options. The model describes how much more likely the agency is to select one option rather than another as a function of the cost of the options and the characteristics of the site—its location, the baseline risk it poses, and the volume of contaminated waste it contains. One reason for estimating the parameters of the model is to determine if variables such as cost and baseline risk can explain the cleanup option chosen. The model also enables us to compute, in dollar terms, how much more valuable EPA considers one option to be than another. For example, we can estimate how much more EPA would be willing to spend (or have PRPs spend) to incinerate a given volume of waste rather than to cap it.

When we estimated the parameters of the model for wood-preserving sites and then for PCB sites, we found that costs were significant in explaining the choice of cleanup option at both types of sites. Other factors being equal, we found in both cases that EPA was likely to choose less expensive cleanup options. Unlike costs, baseline risk and the location of the site appear to have

Other factors being equal, EPA was likely to choose less expensive cleanup options at sites contaminated with polychlorinated biphenyls (PCB sites) and at sites where chemicals had been used in the treatment of lumber (wood-preserving sites).

had little effect on the agency's choice of cleanup option at either type of site. However, we found that higher hazard ranking scores were positively correlated with a preference for more permanent treatment options—incineration, for example—at PCB sites.

Remedial alternatives for soil contamination



By law, EPA is supposed to show a preference for treatment options, as opposed to containment options, and for on-site remedies, as opposed to off-site remedies. Our study revealed that it chose on-site treatment of excavated soil more often than the five other cleanup options. Moreover, it revealed that the agency was willing to pay (or have PRPs pay) at least twice as much for on-site incineration of contaminated soil than for capping of the soil at both PCB sites and wood-preserving sites.

If a PCB site were to contain 10,000 cubic yards of contaminated soil, we estimated that EPA would be willing to spend (or have PRPs spend) \$12 million (in 1987 dollars) more to incinerate the soil than to cap it. If a PCB site were to contain 100,000 cubic yards of contaminated soil, we estimated that the agency would be willing to spend (or have PRPs spend) \$36 million more to incinerate the soil than to cap it. It is interesting that EPA appears to be willing to spend (or have PRPs spend) almost as much for

off-site incineration as for on-site incineration at PCB sites, suggesting that it finds little difference in the utility assigned to the two alternatives at PCB sites.

For wood-preserving sites, as for PCB sites, we estimated that the agency was willing to spend (or have PRPs spend) more for on-site incineration than for capping. At a typical wood-preserving site, we estimated that EPA would be willing to spend an additional \$12 million (in 1987 dollars) to incinerate the soil. However, EPA did not demonstrate a willingness to spend nearly as much for off-site incineration as for on-site incineration at wood-preserving sites. Its willingness to pay for off-site incineration at these sites was not significantly different than its willingness to pay for capping.

Interpreting the results

From the perspective of public policy, it is important to ask whether the benefits

of Superfund cleanups justify the amount of money EPA is willing to spend (or to have PRPs spend) on cleanups. Because the information collected in RI/FSs is insufficient to conduct a conventional benefit-cost analysis of EPA's cleanup decisions, we attempted to determine whether benefits and costs were correlated with the agency's choice of cleanup goal (target risk level) and cleanup option (permanence of cleanup) at wood-preserving sites and PCB sites for which Records of Decision had been signed.

As we have seen, there is no evidence that EPA balanced benefits against costs in selecting a target risk level for these sites. However, it would be incorrect to infer from this that the agency did not do its job. Under CERCLA, the target risk level chosen for a Superfund site must be one that protects the health of the population, regardless of cost. Thus, by ignoring cost in its selection of target risk levels, EPA acted in accord with its mission.

CERCLA does allow EPA to balance the cost of cleanup against other goals, including the permanence of cleanup, once a safe target risk level has been chosen. At the sites we studied, the agency did this. Other factors being equal, the cheaper the cost of a cleanup option, the more likely it was that EPA chose it. However, the agency was clearly willing to pay (or have PRPs pay) more for more permanent remedies than for less permanent remedies. As noted above, it was willing to pay more to incinerate contaminated soil than to cap it.

Variables associated with the benefits of cleanup, such as the location of the site (size of exposed population) and the health risk associated with the site before cleanup (baseline risk), were only weakly associated with the target risk level chosen, and were unrelated to the permanence of the cleanup that the chosen cleanup option would achieve.

In assessing the 127 cleanup decisions considered in our study, we found

that EPA followed its mandate: it reduced baseline health risks without regard to cost, but it was willing to balance the costs of cleanups against the permanence of cleanups in choosing a cleanup option. What must be asked is whether the benefits of more permanent cleanups, such as those achieved by the incineration of contaminated soil, are worth the amount that the agency is willing to pay (or have PRPs pay) for them. To answer this question, it will be necessary to first define and then value the benefits of alternative waste disposal technologies. In view of the size of the resources devoted to Superfund cleanups, this is research that deserves the very highest priority.

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Herbicide-Resistant Weeds May Threaten Wheat Production in India

Leonard P. Gianessi and Cynthia A. Puffer

India is having increasing difficulty controlling weeds in its wheat fields. Weed scientists suggest that this may be due to the evolution of herbicide-resistant weeds. Should such weeds become widespread, wheat yields could decrease enough to threaten India's self-sufficiency in wheat production. Despite this danger, few efforts have been made to determine whether herbicide-resistant weeds are evolving in India. If they are, it will not be easy to manage them. The lack of patent protection in India will con-

strain the importation of other herbicides that might effectively control the weed species found in India's wheat fields as well as the importation of genetically engineered wheat varieties that can detoxify herbicides normally damaging to wheat. Thus India's wheat farmers may have to control herbicide-resistant weeds by changing their tillage patterns or by periodically growing crops other than wheat. The latter strategy must be considered carefully as there are limits on demand for non-wheat crops.

In India, as in many countries, wheat is a staple crop, consumption of which allows people to meet a large portion of their caloric requirements. It has become an increasingly important source of nutrition in India since 1966, when dwarf, high-yielding varieties of the crop were introduced in the country. Cultivation of these varieties has allowed India to meet its domestic demand for wheat and, in recent years, to put a portion of its wheat crops in reserve.

Although India is seeking to diversify its crops, it will be necessary for the

country to increase wheat yields in order to keep pace with the food needs of its increasing population. This may be difficult as there are signs that such yields may be declining in some of India's key wheat-producing states. On some of the wheat farms in these states, there is evidence of diminishing returns to inputs of fertilizer and irrigation and of an increasing problem with weed control.

The weed control problem has attracted the attention of weed scientists, who have become concerned with the same problem on wheat farms in developed countries during the last decade. They fear that in India, as in these countries, weeds are becoming resistant to herbicides applied to wheat crops. They also realize that, if left unchecked, the evolution of herbicide-resistant weeds could seriously reduce grain yields in India. It is estimated that if such weeds become widespread, yields would decline by 30 percent or more. Although such a reduction would threaten the country's self-sufficiency in wheat production, few agricultural experts outside the weed science community have paid much attention to the weed control problem in India.

Potential strategies for slowing the evolution of herbicide-resistant weeds are constrained by economic and policy factors, as well as by lack of knowledge about weed biology. It is clear that international agricultural research organizations and agricultural support institutions in India will have to give priority to weed control research if efforts to make India's wheat production system sustainable are to be successful.

Evolution of herbicide-resistant weeds

Herbicides are widely used in crop production to control weeds, which compete with crops for light, space, nutrients, and water. They typically work by disrupting the metabolism of weeds.

One way they do this is by inhibiting enzymes, which catalyze biochemical reactions such as photosynthesis, within the plants.

Most herbicides are applied at rates sufficient to kill 85 to 95 percent of a weed population. The remaining weeds normally survive because they are shaded by other plants, are missed during spraying, or germinate after the herbicide has dissipated. Because of genetic variability within a species of weed, however, a small number of individual weeds are able to survive the application of a particular herbicide that is effective in controlling the vast majority of the weeds of the same species. If the herbicide is used on one population of the weed species year after year, the weeds that genetically differ from the rest of the weeds in the species will multiply. As the weeds that are susceptible to the herbicide are removed from the population, the resistant strains have more room to grow and to flourish. Without intervention—such as the use of an herbicide that attacks the weeds at a different point of vulnerability—these strains will become a predominant part of the population.

The incidence of herbicide-resistant weeds in wheat crops is a relatively recent phenomenon, but one that is widespread. Such weeds were first observed in the early 1980s in Australia and were later observed in England, Israel, the United States, and Canada. In these countries, the resistant strains do not appear to have proliferated through the spread of seeds. Instead, they seem to have evolved concurrently in a number of locations as the result of the selection pressure exerted on them by herbicides. In the United States, for example, herbicide-resistant populations of some broadleaf weeds common in wheat have appeared in areas where the herbicides chlorsulfuron and metsulfuron-methyl have been applied over a period of four to five consecutive years.

To prevent the increase of herbicide-resistant weeds in wheat crops, U.S. wheat growers have been advised to

alternate herbicides, one year applying a herbicide that targets a particular biochemical site of action, the next year a herbicide that targets a different biochemical site of action, and so on. In some cases, it has been recommended that they use two or more herbicides simultaneously or discontinue use of particular herbicides that may exert too strong a selection pressure on weeds. Such strategies are viewed as sufficient for the short to medium term, or until the problem of herbicide-resistant weeds warrants more drastic action.

To control herbicide-resistant weeds, U.S. wheat growers have been advised to alternate herbicides, use several herbicides simultaneously, or discontinue use of herbicides that exert too strong a selection pressure on weeds.

Such action has been necessitated in Australia and in one area in England, where weeds in wheat crops have acquired tolerance to one or more herbicides not as a result of direct exposure to those herbicides but through exposure to similar herbicides—a phenomenon known as cross-resistance. In Australia, more than 3,000 large wheat farms, comprising nearly one million hectares, have weed biotypes that are resistant to virtually all selective herbicides that can be used on wheat crops. In addition to alternating herbicides or discontinuing their use, Australian wheat farmers have been forced to change cropping systems in order to incorporate integrated weed management strategies, such as using mechanical means to remove weeds from fields or allowing pasture to grow in place of wheat every other growing season. These strategies impose economic

hardships on growers, because they are less cost-effective than the use of herbicides.

Herbicide use in India's wheat production

During the early 1960s, agricultural scientists were experimenting with ways to increase the productivity of India's native wheat varieties. Their research indicated that a substantial increase in the use of fertilizer would result in increases in the vegetative growth of the wheat plants, causing them to fall over and wheat grains to become lodged on the ground. Because the amount of fertilizer used on fields sown with native wheat varieties could not be increased, the maximum yield of India's wheat farms was limited to 11 or 12 bushels of wheat per acre. Such a yield was insufficient to meet India's demand for wheat in the mid 1960s, when two years of drought (coupled with an increasing population and a decreasing amount of

land that could be converted to grain production) forced the country to import food grains in order to avert widespread hunger.

The crisis sparked interest in some high-yielding dwarf varieties of wheat that had been developed in Mexico. These varieties, which were introduced in India in 1966, were superior to India's native wheat varieties in that they had thicker straw and grew no more than two feet high. Thus farmers could increase inputs of fertilizer in order to increase yields without causing the plants to droop and grains to lodge on the soil. Moreover, the new varieties matured earlier and put out a larger number of tillers than traditional varieties do. (Tillers are stems that form from buds below ground on the main stem and that eventually produce heads and increase the supply of seed.)

The adoption of dwarf varieties allowed India to increase its wheat production fivefold in twenty-five years; however, it also necessitated a dramatic increase in the use of herbicides. When

tall varieties of wheat were planted, weeds were not a serious problem. Such varieties grow faster than both grass and broadleaf weeds and thus are able to compete successfully for sunlight. However, grass weeds such as *Phalaris minor* (canarygrass) and *Avena* spp (wild oats) are highly competitive with dwarf varieties of wheat. Canarygrass and wild oats grow faster and taller than the dwarf varieties and broadleaf weeds, and thus block sunlight from these plants. They are also more responsive to fertilizers than dwarf wheat varieties and broadleaf weeds. If uncontrolled, grass weeds (particularly canarygrass) can remove much of the nitrogen from fertilizer applied to wheat fields.

Moderate infestations of canarygrass and wild oats—100 to 250 of the weeds per square meter—reduce wheat yields by approximately 34 percent. On most wheat farms where canarygrass is a serious problem, the ratio of the weed to wheat plants is about four to one. At this level of infestation, wheat yields are reduced by approximately 60 percent.



Photo courtesy of Shreekant Gupta

Manual weeding is not an effective means for controlling canarygrass in India's wheat fields. By the time the weed, which looks like wheat in its juvenile stage, is distinguishable from wheat plants, the damage due to competition has already occurred. Given limitations on manual and mechanical weeding, weed scientists found that the most effective way to rid wheat fields of canarygrass and other grass weeds was to use herbicides.

In some instances, wheat fields have been plowed under or used as green fodder due to severe infestations of canarygrass.

Neither mechanical nor manual removal of weeds is an effective means for controlling grass weeds in India's wheat fields. Mechanical weeding is not feasible because wheat plants are sown very close together. Manual weeding is not feasible because both wild oats and canarygrass look like wheat in their juvenile stages. By the time these weeds are distinguishable from wheat plants, the damage due to competition has already occurred.

With the introduction of high-yielding dwarf varieties of wheat in India, grass weeds became a problem; because neither mechanical nor manual weeding is effective in controlling these weeds, wheat farmers had to increase their use of herbicides.

Limitations on mechanical and manual weeding led weed scientists to conclude in the early 1980s that the most effective way to rid wheat fields of grass weeds and to maintain the potential yield of these fields was to use herbicides. The primary herbicide used by wheat growers in India to control such weeds is isoproturon. Experiments conducted in the early 1980s indicated that the use of isoproturon could reduce populations of canarygrass by 96 percent. Other experiments of the period showed that wheat yields from plots where isoproturon was used to control canarygrass were approximately 33 percent greater than yields from plots where the herbicide was not used.

In Punjab and Haryana, the two states that together account for 34 percent of

India's total wheat production and more than three-quarters of India's procurement of surplus wheat for reserve stocks, approximately 40 percent of the acres planted in wheat are now treated with isoproturon. Farmers who use neither isoproturon nor any other herbicide to control grass weeds in wheat still depend on manual weeding for weed control. These farmers allow weeds to become well established before removing them so the weeds can be used as fodder for cattle. Of course, the delay in the removal of grass weeds means that these farmers are probably losing one-third of their potential wheat yield.

Potential for the evolution of herbicide-resistant weeds

As noted above, the most difficult weeds to control in wheat are grass weeds, which are related to wheat in their taxonomic, phenological, morphological, and biochemical characteristics. Certain grass weeds have evolved morphological and phenological resemblances to wheat during the 8,000 years since its domestication. They may now be responding to the use of herbicides by evolving a biochemical mimicry of wheat's enzyme system that detoxifies herbicides. By producing higher levels of the enzymes in this system, the weeds could detoxify herbicides in the same manner as wheat.

Because herbicide-resistant weeds have been a problem in other parts of the wheat-producing world, it is expected that they will become a problem for wheat farmers in India. Indeed, they may be the cause of the recently observed decline in the effectiveness of isoproturon on some farms where the herbicide has been applied for ten or more consecutive years. On these farms, the use of isoproturon did not achieve satisfactory results in the last two to three of these years, even when it was applied in doses higher than those formerly effective in controlling canarygrass.

In November 1991, an experiment to determine the ability of isoproturon to control the weed was begun by R. K. Malik in India. Canarygrass seeds were collected from six locations in Haryana, where isoproturon had been used continually for ten to fifteen years, and were grown in pot cultures in a laboratory. After the cultures were sprayed with isoproturon, it became clear that the herbicide was not effective in killing one particular canarygrass biotype. An investigation of three of the locations from which the seeds used in the experiment were taken revealed that isoproturon had failed to provide more than 30 percent control of canarygrass at these locations during the winter season of 1991-1992. It also indicated that the poor control could not be attributed to impurities in or the dilution of isoproturon, the method by which it was applied, or the timing of its application.

Some populations of canarygrass may have evolved partial resistance to isoproturon; if so, the selection pressure exerted on weeds by the herbicide, if it continues to be used, might diminish the effectiveness of isoproturon in controlling all populations of canarygrass within a few years.

If some populations of canarygrass in India have evolved partial resistance to isoproturon, wheat farmers must contend with two potential problems. The first is that the selection pressure exerted on weeds by isoproturon, if it continues in use, might quickly diminish the effectiveness of the herbicide in controlling all populations of canarygrass within a few years. The second is that canarygrass

might develop cross-resistance to other herbicides that can be used in wheat.

The evolution of herbicide-resistant weeds is rare in fields where different crops are grown in sequence on the same field; however, it could be occurring in India, where wheat is double-cropped with rice and to a lesser extent with sugarcane and maize. Although wheat and rice are grown in the same field—wheat in the winter and rice in the summer—wheat-rice cropping is essentially a wheat monoculture from the standpoint of grass weed control. This is because rice is grown when fields are flooded with water, and grass weeds such as canarygrass do not germinate in standing water. Thus repeated use of one herbicide could exert the same degree of selection pressure on weeds in a field where wheat alone is grown as it does on weeds in a field where wheat is grown during one season and rice during another.

Strategies for managing herbicide-resistant weeds

Wheat-producing countries in the developed world have demonstrated that the evolution of herbicide-resistant weeds can be slowed by the adoption of strategies that prolong the effectiveness of herbicides. However, these strategies become costly once herbicide-resistant weeds become widespread. Moreover, the kinds of strategies that can be adopted are limited once such weeds make up more than 10 percent of a given weed species. Even when herbicide-resistant weeds make up only a small proportion of a weed population, intensive weed management efforts are required to prevent their increase. These efforts include periodically alternating two or more herbicides, changing tillage systems, and growing different crops.

As noted above, weed scientists in India have begun to conduct both field and laboratory research to determine how tolerant canarygrass is to isoproturon and whether the weed has devel-

oped cross-resistance to other herbicides. Their findings will lead to recommendations regarding the future use of herbicides in India's wheat production. These could include changes in the rates at which herbicides are applied and in the timing of application. As in some parts of the wheat-producing developed countries, they could also include the simultaneous use of several herbicides, each of which targets a different biological site of action in weeds; or the abandonment of some or all herbicides used on wheat crops. Recommendations not involving herbicide use could include changes in tillage practices and in the periodic substitution of other crops for wheat, both of which can sometimes prolong the effectiveness of a herbicide.

Recommendations for controlling herbicide-resistant weeds in India could include alterations in the rates and timing of herbicide applications, the simultaneous use of several herbicides, changes in tillage practices, and the periodic substitution of other crops for wheat.

It may be that the above management strategies will fail to prevent canarygrass from evolving resistance to all herbicides normally effective in controlling the weed. Even if the evolution of herbicide-resistant weeds can be delayed in the short run, it has become evident to weed scientists in developed countries that the problem requires long-term monitoring and research. In light of the potential for widespread evolution of herbicide-resistant weeds, either in the short term or the long term, India's agricultural scientists and

policymakers may want to consider changes in agricultural research agendas in order to focus on the increasingly complex problem of controlling weeds.

If India is to be successful in dealing with the problem of herbicide-resistant weeds in wheat crops, it needs to establish a committee similar to those that have formed in developed countries to study the problem. A group representing India's herbicide manufacturers, agricultural scientists, agricultural extension workers, and wheat farmers could monitor the spread of such weeds, develop management strategies, and facilitate implementation of those strategies.

Setting research priorities

In 1991, the International Rice Research Institute and the International Maize and Wheat Improvement Center began several research efforts aimed at identifying and correcting problems that limit further increases in the productivity of India's wheat-rice cropping system. In their assessments of India's wheat production, these organizations and the World Bank have noted the increasing difficulty of controlling weeds. However, they have made no mention of the possible link between that difficulty and the evolution of herbicide-resistant weeds, even though such weeds could easily offset any gains in the productivity of India's wheat-rice cropping system. Clearly, management of herbicide-resistant weeds should be considered in any international research efforts to enhance that system.

Several national programs aimed at correcting problems with the system are under way. These programs have focused on the problem of soils becoming saline as a result of extensive irrigation. While improving the operation and management of irrigation systems is important, India's policymakers need to give the same attention to weed management problems that they give to irrigation if India is to realize its goal of self-sufficiency in food production.

To successfully manage herbicide-resistant weeds, knowledge of weed ecology and weed biology is essential. Specifically, there is a need for information about the length of time that weed seeds remain viable in the soil, the ratio of weed seeds that germinate after one year, and the effects of alternative crop production systems on the survival and proliferation of weeds.

Other research efforts could focus on the genetic engineering of a wheat plant that could detoxify herbicides normally damaging to wheat. Some genes that could be used in the genetic engineering of wheat would make the plant resistant to the herbicides glyphosate and glufosinate, which cannot be used on wheat fields at the present time because they would kill wheat plants along with weeds. The genes that would make the genetically engineered wheat's enzyme system capable of detoxifying glyphosate and glufosinate are introduced from outside the wheat gene pool. In the foreseeable future, therefore, it is unlikely that weeds that are similar to wheat could evolve a biochemical mimicry of the enzyme system.

Policy and economic constraints

India's policy of domestically producing needed goods guides much of its economic development. Self-sufficiency in food grain production is a particularly high priority for India, which does not want another food shortage crisis like the one it experienced in the mid 1960s. Should herbicide-resistant weeds evolve, strategies to check the increase of such weeds fail, and wheat yields decline as a result, India might have to import wheat from the United States and other countries. Doing so would entail a reduction in the amount of hard currency that India spends on petroleum products and other imports vital to its economy.

Rather than import wheat, India might try to deal with the problem of

herbicide-resistant weeds by importing other herbicides. If weeds in the country's wheat farms are becoming resistant to isoproturon, which is produced in India, the introduction of imported herbicides may play a key role in an effective management strategy. However, it is uncertain that any of the other herbicides would in fact control herbicide-resistant weeds in India's wheat farms.

Given its policy of domestically producing needed goods and given constraints to the importation of wheat, herbicides, and genetically engineered wheat varieties, India may attempt to manage herbicide-resistant weeds by periodically growing crops other than wheat; however, this strategy may be hampered by limits on demand for non-wheat crops.

Moreover, in the absence of patent protection for pesticides used in India, foreign producers of herbicides have a strong disincentive to introduce new herbicides into the country. Lack of patent protection is also likely to deter foreign biotechnology firms from introducing genetically engineered wheat varieties into India.

Given constraints to the importation of wheat, herbicides, and genetically engineered wheat varieties, India may attempt to manage herbicide-resistant weeds in wheat by making changes in crop rotations and tillage practices. Changes in either will prevent herbicide-resistant weeds from completing their life cycles, but changes in crop rotations must be considered carefully. It would be necessary to assess the economic impacts of growing crops other than wheat in order to determine

whether such changes would be prudent. A recent economic analysis of the options for diversifying crops in Punjab revealed that the production of vegetables and fruit were more profitable than wheat-rice cropping. However, increased production of these crops is constrained by limits on demand for the crops and by a lack of facilities for processing the crops before they are brought to market.

It is clear that there are no easy solutions to the problem of herbicide-resistant weeds in wheat. Given that fact, India must act quickly to determine to what extent, if any, herbicide-resistant weeds are evolving in its most productive wheat-growing states. If such weeds are in fact evolving in India, they would likely evolve in several other developing countries. Thus any management strategies that prove effective in India may have to be adopted in Pakistan, Bangladesh, and Nepal, where wheat production practices are similar to those in India, and in China, where the pattern of herbicide use on wheat crops is also similar to that in India. Like India, these countries can ill-afford a decrease in their wheat production due to unexpected weed control problems as they struggle to increase such production in order to feed their growing populations.

The management of weeds in wheat cannot be taken for granted. Weed science research needs to be supported, and policymakers need to be made aware of the prospects for the evolution and spread of herbicide-resistant weeds, as well as the potential impacts of this phenomenon if not anticipated and dealt with in a timely fashion.

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INSIDE RFF NEWS AND PUBLICATIONS

Environment and trade discussed at RFF Council meeting

Representatives of government, industry, and the research and environmental communities addressed the issue of environment and trade at a meeting of the RFF Council—a group of individual, foundation, and corporate supporters of Resources for the Future—in Santa Fe, New Mexico, on April 1. RFF vice president and senior fellow Paul R. Portney introduced the day's talks by noting the controversy surrounding both the most recent negotiations under the General Agreement on Tariffs and Trade (GATT) and ratification of the North American Free Trade Agreement (NAFTA) by the United States, Canada, and Mexico.

Carmen Suro-Bredie, assistant U.S. trade representative for intellectual property and the environment, noted that the environment more than any other factor will change the way the United States formulates trade policy. She said that one of the two events that have most affected the interaction between trade and the environment is the tuna-dolphin case brought by Mexico before GATT. The United States embargoed tuna caught by Mexican fishermen through fishing practices that failed to comply with the U.S. Marine Mammal Protection Act. Mexico argued that the rules of conduct for international trade relations set forth in GATT do not allow one country to impose its environmental standards on another country. The GATT report on the issue agreed with Mexico, indicating that trade measures to protect the environment would best be effected through international environmental agreements, which would reflect the consensus of countries on the use of trade measures as a sanction but would avoid the taint of protectionism. Suro-Bredie said the report is of great concern to the trade and environmental communities because it has left officials without a clear idea

about what other U.S. laws might also be disputed under GATT.

The other critical event, said Suro-Bredie, was the 1991 congressional renewal of fast-track authority for the executive branch of the U.S. government to negotiate NAFTA. Under fast-track authority, Congress can approve or reject, but not amend, any agreements arising from trade negotiations. Fast-track authority was initially sought by the Reagan administration in 1987 to gain credibility in negotiating a trade agreement with Canada. It was later renewed for both the Reagan and Bush administrations so that they could negotiate multilateral trade agreements during the Tokyo and Uruguay rounds of GATT talks.

When fast-track authority was renewed yet again to allow the executive branch to negotiate NAFTA, Suro-Bredie noted, environmental groups and labor unions insisted on the need for safeguards against environmental and labor problems with Mexico. In response, the Bush administration made the so-called May 1st commitment, in which it agreed to such safeguards in return for renewal of fast-track authority. As a result, the United States entered for the first time into trade negotiations under the obligation to consider specific environmental questions—for example, how the trade agreement would interact with international environmental agreements; how it would interact with the right of states to set environmental standards higher than those specified by NAFTA; how costs arising from NAFTA would be paid; and what type of environmental controls would be instituted.

As part of the agreement, Suro-Bredie noted, the United States, Canada, and Mexico pledged to conduct trade in an

environmentally sustainable manner, not to lower environmental standards in order to attract investment, and to organize a North American Commission on the Environment (NACE) to oversee the trade and environment interaction. Among the questions Suro-Bredie posed was how much pressure could be put on a trade agreement such as NAFTA before the agreement becomes untenable. NAFTA, she said, has some strong economic benefits for the United States. The dilemma is how to create the supplemental agreements requested by the labor and environmental communities and still allow the United States to maintain these benefits.

Stewart Hudson, a legislative representative for the International Programs Division of the National Wildlife Federation, outlined a philosophy by which the environmental, trade, and foreign policy communities should



In an address to the RFF Council in Santa Fe on April 1, Stewart Hudson, legislative representative for the International Programs Division of the National Wildlife Federation, spoke about the need to balance the costs and benefits of liberalized trade.

approach trade and the environment. He noted that the approach of trade economists has long been guided by the theory of comparative advantage. While trade has been instrumental in increasing wealth worldwide in the years since GATT was formed, Hudson contended that we are now living in an age in which wealth is not enough. He asserted that economic patterns of development must be harmonized with the natural resource base that sustains development. Given this task, trade and the theory of comparative advantage need to be overhauled.

In the future, said Hudson, trade will be successful when it not only creates wealth but distributes wealth in a way that is just and environmentally and ecologically sustainable. Therefore, the costs and benefits of liberalized trade need to be balanced. One benefit is efficient allocation of resources, underlying which is the internalization of environmental costs. Unless environmental costs are properly internalized in market prices, Hudson asserted, increased trade will only exacerbate environmental problems. Another benefit of liberalized trade is harmonization of standards, yet harmonization could impose unacceptable costs if the price of raising environmental standards in other countries is the lowering of such standards in the United States. Yet another benefit of liberalized trade is increased domestic and foreign investment. However, cautioned Hudson, the economic activity generated by that investment can create environmental damage.

Hudson suggested that the trade and environment issue involves development. The good news for those concerned about trade, he said, is that trade can be a sound engine for generating the kind of growth necessary to meet development needs. The good news for environmentalists is that unfettered trade does not have to be the only way to meet such needs.

Brad Allenby, director of research on technology and environment at AT&T,

discussed some of the lessons emerging from industrial ecology that bear on internationalization of commerce and environmental interactions. One lesson, he said, is the need to focus on the life cycle of materials and of products, keeping in mind that the environmental impacts of that life cycle know no national boundaries. For example, a product designed in the United States may be manufactured in Mexico from components made in Thailand, and disposed of in yet another country. Another lesson is the need to integrate technology and the environment. Countries that can do so, Allenby contended, will be at a competitive advantage. Given that countries' environmental standards vary, the degree to which a product is environmentally benign depends on where the product is made and where the raw materials in the product come from. There is a need, Allenby concluded, for an infrastructure to support efforts by private firms to do the environmentally appropriate thing.

John Wirth, president of the North American Institute, reported on the outcome of a conference sponsored by his organization on the North American Commission on the Environment proposed under the North American Free Trade Agreement. In order for NACE to be politically feasible, he said, the United States, Canada, and Mexico must come to the negotiating table as equals. Wirth asserted that this may be difficult for Americans, given that the U.S. economy is ten times larger than the Canadian economy and twenty-five times larger than the Mexican economy.

Wirth noted that regulation and enforcement are key issues with regard to NACE. Some Americans conceive the commission as an iron fist inside a velvet glove. While this image may not bother Americans, who are familiar with regulation, it may frighten Canadians and Mexicans. NACE would be better conceived, Wirth asserted, as a body that exposes polluters. Environmental standards could be enforced, he suggested, through "intrusive sunshine"—that is,

through vigorous information-gathering and regular reports on polluters.

One objective of the United States in negotiations concerning the commission, said Wirth, is to avoid infringing on the sovereignty of Canada and Mexico. The United States, he said, is prepared to accept a substantial role for citizen participation in NACE activities. For Mexico, the participation of the Mexican private sector was a major concession. However, Wirth cautioned, Mexico will not accept a system of regulatory control that is not salable politically within Mexico. For Canada, the strengthening of economic ties with the United States is problematic. It is possible, said Wirth, to use NACE as a springboard for addressing multilateral issues that are important to Canada. NACE conference attendees suggested that NACE become a regional body that is part of the United Nations Council on Sustainable Development. Such a move might assure Canadians that the commission would not be under United States control.

Wirth concluded that Congress would probably approve NAFTA if Mexican-U.S. border issues are dealt with sufficiently and honestly. It is almost conventional wisdom in the press, he said, that companies in countries with low pollution control standards have a competitive advantage and that firms will move to countries like Mexico in order to take advantage of slacker standards. He asserted, however, that pollution control is a small factor in a firm's decision to move to another country. Much more important are markets, labor, and access to capital.

Paul Portney of RFF proposed that economic and other social science research could help illuminate some of the political and institutional questions that arise in the attempt to integrate environmental standards into trade legislation. He described three RFF research efforts related to environment and trade. One is an attempt to integrate differences among countries' environmental standards into conventional



Brad Allenby, director of research on technology and environment at AT&T, discussed some of the lessons emerging from industrial ecology that bear on internationalization of commerce and environmental interactions. John Wirth, president of the North American Institute; Paul R. Portney, vice president of and a senior fellow at Resources for the Future; and Carmen Suro-Bredie, assistant U.S. trade representative for intellectual property and the environment, also delivered comments on the topic of trade and the environment at the RFF Council meeting.

trade models. Such an investigation is necessitated, suggested Portney, by the fact that much literature on the economic theory of international trade is oblivious to the notion that such differences may affect comparative advantage.

Another RFF project is an investigation of the Porter hypothesis. According to Michael Porter of the Harvard Business School, tighter U.S. environmental regulations should increase the competitiveness of U.S. industries. Porter's reasoning is that the imposition of increasingly strict environmental standards forces regulated firms to innovate technologies to prevent and control pollution and even to stumble upon other innovations in the process. U.S. firms can then make money by selling these innovations to firms all over the world. Because Porter's hypothesis is controversial, RFF is trying to determine whether firms subjected to strict regulation are more innovative than less regulated

industries and whether there is any evidence to suggest that U.S. leadership in pollution control significantly helps the U.S. trade balance.

Another RFF project, in which two professors from the Kennedy School of Government at Harvard University are participating, is a survey of literature on the effects that differences among individual countries' environmental regulations may have on competitiveness or trade. Portney noted that the literature offers little empirical evidence to support the hypothesis that such differences have a big impact on trade in general and on the movement of firms from one country to another in particular. One reason may be that pollution control costs represent a relatively small percentage of many industries' total cost of production. Therefore, differences among countries' environmental regulations may not have as large an impact *ex ante* as thought. Another reason is that environmental

standards are becoming increasingly strict worldwide. As the environmental standards of other countries become increasingly similar to those of the United States, there is less incentive for U.S. firms to move out of the United States. In any case, said Portney, U.S. firms are going to build plants in other countries that are very similar to the plants they build in the United States, even if they are not asked to do so. Even the domestic firms of countries that have less stringent environmental regulations than the United States are building plants that exceed the environmental standards set forth by their own government. These firms realize that they will be required to meet stricter standards in the future, so they are operating now, in many cases, as if those stricter standards were already in place.

Portney cautioned that there are three caveats to his conclusion that differences among countries' environmental standards have little effect on the movement of U.S. firms to other countries. First, data on pollution control costs arising from regulation in each country are difficult to obtain and may not be accurate. Thus ascertaining the differences in firms' pollution control costs from country to country is difficult. Second, countries may have strict pollution control regulations but be lax in enforcing them. Thus an examination of those regulations will not reveal what the competitive effects of the regulations will be. Third, the regulatory climate differs from country to country, even among countries with identical environmental standards. It may be easier for a firm to get a permit to manufacture a product in a country where regulators cooperate with regulatees than in a country, such as the United States, where regulators and regulatees have an adversarial relationship. Therefore, said Portney, it is difficult to quantify the effects of differences among countries' regulatory climates and plug these effects into statistical studies of the effects on trade of differences among countries' environmental regulations.

New book

**Valuing Natural Assets:
The Economics of Natural Resource
Damage Assessment,**
*edited by Raymond J. Kopp and
V. Kerry Smith*

In this collection of papers—originally prepared for a conference held by Resources for the Future in 1988 but rewritten since then in response to rapidly changing developments—the editors and other contributors examine the complex and evolving interactions among economic research on assessing natural resource damages, legislation (such as Superfund) establishing liability for such damages, and the litigation and regulatory processes affecting implementation of damage assessments. Recent court decisions have suggested that among the injuries to publicly owned natural resources for which liability may be claimed are losses of the nonmarket services of the resources; as Kopp and Smith explain, such injuries are seen to diminish people's valuation of these services, and the diminished value is a measure of the economic damage. The challenge to economists—which is the focus of this book—is how to measure such nonmarket values in the context of litigation, regulations, and the damage assessment provisions of Superfund.

Contributors reveal that although existing nonmarket valuation methods, such as contingent valuation, have been used to assess natural resource damages, the damage assessment process itself has dramatically changed the context for applying these methods and has had a major influence on economic research associated with nonmarket valuation of environmental resources. In that context, for example, valuation of nonmarket measures takes place largely in the courtroom rather than in agencies, and the procedure itself changes how the measures are presented, received, and defended.

In their introductory chapters, the editors discuss definitions and concepts

concerning natural resource damages and suggest that damages to natural resources are best understood when the resources are treated as assets that provide a flow of services to individuals. Other contributors examine statutes, rulemaking, and practices concerning natural resource damage assessment, focusing particularly on Superfund, its place in legal history, and the implementation of Superfund and related legislation. Contributors then critically evaluate the range of economic methods and models that are employed to measure the value placed on lost use and nonuse services; their analyses encompass both indirect methods (such as travel cost and hedonic models) and direct methods (with particular emphasis on contingent valuation). Two important conceptual dimensions of damage assessment—the role of time in capitalizing past losses and discounting future losses, and the theoretical bases of nonuse or existence values—are also analyzed. The editors conclude the volume with a look at the impact that natural resource damage assessment will have on future research in environmental and natural resource economics.

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Resources for the Future has recently received several grants from private foundations. The G. Unger Vetlesen Foundation awarded RFF \$50,000 for continued support of research on climate resources. The Esther A. and Joseph Klingenstein Fund provided a \$15,000 grant to help support a workshop co-sponsored by the National Press Foundation to educate journalists about environmental and natural resource issues. The Montgomery Street Foundation made a grant of \$10,000 for operating support for RFF's research and education programs.

The following individuals have recently made gifts of \$100 or more in support of RFF research and education programs: Christopher C. Aitken; Joan Z. Bernstein; Guthrie S. Birkhead; W. V. Bussmann; Henry L. Diamond; Margaret W. Fisher; Luther H. Foster; Roger W. Gale; Darius W. Gaskins, Jr.; Lincoln Gordon; Richard A. Herrett; Charles J. Hitch; Fisher Howe; W. Mitchell LaMotte; Franklin A. Lindsay; Setsuko Mitsuhashi; George G. Montgomery, Jr.; Paul Rodzianko; Larry E. Ruff; Gunter Schramm; Sally A. Skillings; Christopher Sonnesyn; Linda K. Trocki; Kazuhiro Ueta; William A. Ward; and Aaron Wildavsky.

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The following papers have recently been released.

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- "Desirable Attributes of Environmental Regulations," by Fred D. Hoerger. (CRM93-01) Free

Four RFF board members take positions in the Clinton administration

Thomas E. Lovejoy, a current member of the RFF board of directors, and three recent RFF board members have been appointed to positions in the Clinton administration. Secretary of the Interior Bruce Babbitt named Lovejoy, a senior Smithsonian Institution official, as his scientific adviser. John M. Deutch of the Massachusetts Institute of Technology was appointed secretary for

acquisitions at the U.S. Department of Defense. John H. Gibbons, director of the Congressional Office of Technology Assessment since 1979, was named as President Clinton's scientific adviser. Isabel V. Sawhill, a longtime senior fellow with the Urban Institute, was appointed associate director for programs in the Office of Management and Budget.

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