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International Environmental Problems—A Taxonomy

Clifford S. Russell and Hans H. Landsberg

The last few years have seen an explosion of interest in environmental problems among citizens of the developed countries, both East and West. Most of this interest has focused on domestic situations and on possible changes in domestic policies designed to provide remedies. Increasingly, however, the focus has widened to embrace environmental concerns that transcend national borders. A high point may be reached in June 1972, when the United Nations Conference on the Human Environment will be held in Stockholm. Wide-ranging discussions and the signing of international treaties on specific international environmental issues are on the agenda. Even though it will not be the first conference on these subjects (*1*), both the auspices of the United Nations and the publicity that it is bound to receive will give it special importance.

The growth of interest and enthusiasm, however, is not matched by accomplishments. That little action has been taken is perhaps easily explained, since sovereign states are involved in these issues, which are old as a class but essentially novel in degree. So far, it has even proved difficult for concerned parties to discuss the problems (*2*).

A major reason for the lack of communication has been the general failure to look beyond the label, "international environmental problems," to the disparate elements it covers and to limit, in advance, the number of such elements that can be discussed at any one time and in any given group. A second reason may be that environmentalists have sometimes couched their arguments in terms that impugn the morality and intelligence of the parties concerned, thus guaranteeing defensive, hostile reactions (*3*).

A third reason may be that management of international environmental problems is most often thought of in terms of "police actions" and regulatory authorities rather than as a component of growth and development. It should be realized that this component of growth and development, neglected by the now developed countries (and being paid for dearly by them), can still be built into the development of emerging countries, probably with long-lasting benefits. Finally, political problems, in terms of a lack of new institutions and mechanisms, have played a role. For example, the growing pollution of the Baltic Sea involves eight countries, three of which are in the Soviet orbit, and one of which (East Germany) has a sufficiently undefined international status to make any international agreement difficult, at best, to achieve (*4*).

Many environmental problems involve citizens of two or more countries and hence are "international." Confusion and controversy arise easily: an individual or a government is usually concerned with (or even aware of) only one or two specific problems and incorrectly assumes that other individuals or governments are talking about the same problem when they use the same general label. Consider, for example, the prospects for agreement when one group's mind is on the long-term buildup of carbon dioxide in the atmosphere and particulates in the lower stratosphere; another worries over the dangers associated with increasing storage of radioactive wastes; a third focuses on the ecological implications of large-scale hydroelectric developments in the tropics; a fourth is concerned with the effect of domestic air pollution controls on export prices and hence trade patterns; yet another is concerned about a specific regional problem in which one nation's pollution, or attempt at protection against pollution, imposes costs on another nation; and, finally, a group of developing nations views matters through the prism of its overwhelming interest in increasing per capita income.

Some of these situations affect all the world's people, though significant contributors may number only a handful. Others are problems of a particular region and do not concern nations outside that region. To developing nations, all environmental problems may appear to be potential threats to their domestic development. At the least, they seem to be concerns of those nations that have incomes sufficiently high to permit concern with esthetics and that have health standards high enough to permit detection of the effects on morbidity and mortality of concentrations of sulfur dioxide. To lay the basis for more successful discussion, this article suggests a first cut at a taxonomy of international environmental problems and solutions, as well as areas in which further research can

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contribute to this discussion. We take the point of view of the social scientist, since that view is most likely to speak directly to the concerns of those who must ultimately do the discussing and deciding, but the categories we suggest are based on characteristics of the physical world.

A Taxonomy of Problems

International environmental problems may profitably be divided into two broad categories, depending on the nature and scope of the international linkages involved: physical-linkage effects and social-linkage effects. The first may be divided again into global and regional effects, and the second into pecuniary and nonpecuniary effects.

Global problems are those problems that physically involve all or nearly all nations of the world, either as contributing parties (emitters) or damaged parties (receptors) or both. Some of the most widely discussed environmental issues fall into this category. For example, since World War II, persistent pesticides have been used all over the world in programs to control disease vectors and agricultural pests. The residues directly affect animal life and potentially affect human life, not only in the country in which a specific application is made, but also through the actions of wind, water, and living carriers, even in regions remote from the point of origin. Notice that it is the combination of persistence and mobility that makes the pesticide problem a global one. If any significant user remains outside a control agreement and continues application of pesticides, the impact on everyone may still be felt (*5*). Even if they were applied by virtually every nation, highly toxic pesticides that were used in small quantities and that broke down quickly to inert residual chemicals might not constitute an international problem. Each nation could manage its own environmental quality problem by enacting its own laws: It would not be dependent for effectiveness on simultaneous action by all other user nations (*6*).

Two familiar examples of global problems, the balance of carbon dioxide in the atmosphere and the particulate content of the stratosphere, are closely related to man's burning of fossil fuels, and both tend to affect the earth's temperature (*7*). Here again, the essential elements of the problem are persistence in the atmosphere (for carbon dioxide, the extended time scale of the carbon cycle and its components) and the global span of the physical systems involved. Carbon dioxide is relatively stable, and the molecules are not removed from the atmosphere very rapidly. The very small particulates do not settle out rapidly, but tend to remain in suspension in the stratosphere over long periods. Thus global agreement will eventually be needed to assure a long-term solution. However, since the sources of fossil-fuel emissions are highly concentrated now in the developed countries (North America, Western Europe, the Soviet Union, and Japan), an agreement on limitations among this group would probably result in a solution good for several decades at least (*8*).

Carbon monoxide and larger particulates are also produced in great quantities in some forms of fossil-fuel combustion and cause specific environmental problems. Carbon monoxide, however, is not stable; it does not survive long in that form in the air and is not a problem at some distance from the source. Similarly, larger particulates tend to settle out relatively quickly after emission. Thus, even though these products of combustion are as ubiquitous as carbon dioxide and the very small particulates, they create almost entirely intranational or local difficulties.

A fourth example of a global environmental problem is the dumping or spillage of oil on the high seas. Here, a look at the registry of the world tanker fleet makes it clear that relatively few nations are emitters. Through its effects on marine life, however, the dumping affects the much larger group of nations that engage in ocean fishing (or that, by a slightly more remote linkage, depend on another nation's catch). Ultimately, it could affect every nation directly: if, for example, the as yet controversial possibility that continued large-scale dumping could affect the photosynthetic activity of the seas and hence could threaten one of our largest sources of oxygen were to be demonstrated; or if changes in the surface reflectivity of the water affected the earth's heat balance. Once again, the global nature of the problem results from the discharge of a persistent residual into a natural system that spreads the effects of the residual over long distances. For example, Thor Heyerdahl sighted numerous, large globs of oil in a recent Atlantic crossing. The list of global environmental problems, which, prior to the nuclear test ban treaty, also included worldwide transport of radionuclides, may become longer as our ability to measure trace elements and track their movements increases and we are alerted to interdependencies as yet unseen. But for the moment, the issues listed appear to constitute the major, truly global phenomena (*9*).

Regional Problems

Regional problems result from physical, including biological, linkages between two or more nations, with little or no spillover to the world at large because of the particular combinations of relatively low persistency of pollutants and relatively limited scope of the natural systems involved in transporting them. Regional problems often resemble the domestic environmental quality issues now facing most developed nations. That is, because geographic proximity frequently permits identification of "upstream" and "downstream" countries, the *assignment* of costs of control and the benefits from damages avoided presents no difficulty, even if the *estimation* of damages avoided may, in principle, be impossible in many cases. Many of the same analytical techniques developed for dealing with domestic quality issues are directly applicable to regional situations. Examples of such situations are most common in the highly industrialized parts of the world: their natural systems are subject to the most stress, both in quantity and variety of pollution discharges; agriculture tends to be more intensive, with the attendant use of fertilizers and pesticides (*10*); "conventional" pollutants associated with lack of sanitary facilities (toilets, sewers, waste disposal, and so on) are at a low level, thus giving greater visability to the pollutants associated with high technology (detergents, scrapped automobiles, carbon monoxide, and so on); and incomes are high enough to permit people to concern themselves with damages to esthetic values and recreational opportunities.

There is no lack of examples of regional problems of the upstream-downstream variety. The Rhine serves France and Germany as a sewer, but it serves the Netherlands as a part of its water supply. Acid rainfall over western Sweden and eastern Norway has been

attributed by some scientists to sulfur oxide emissions originating in industrial operations in Germany's Ruhr and England's Midlands (*11*). As a result, trout fishing in southern Norway is threatened, and there is a suspicion that the growth of trees is being slowed down. The Environmental Committee of the Organization for Economic Cooperation and Development has been asked to investigate the problem, and management of the resulting project has been entrusted to Norway. The seaborne flow of pollutants from Italy to France along the Riviera is another instance of the upstream-downstream syndrome (*12*). The use of Arctic waters by U.S. oil tankers, should this development occur, would be yet another, involving Canada, the United States, and, depending on the implication of ocean currents and the like, possibly other countries.

In other cases, because of the natural system involved, all parties become both emitters and receptors. This is true, for example, of the Baltic Sea and of Lake Erie. Countries around the Baltic are concerned, above all, about oil transportation and mercury pollution from pulp mills. The narrow link with the North Sea makes much of the Baltic practically an inland sea body, and the results of a major oil spill could bring great harm to any or all of the eight countries involved.

Other cases involve despoliation rather than pollution in the conventional sense, but still present the upstream-downstream pattern of damage. Thus, European conservationists are concerned about the effects that the Italian practice of netting will have on migratory bird populations. Large numbers of birds that winter in Africa and summer in the north of Europe are trapped each year as they migrate up the Italian peninsula (*13*). Finally, there are the major environmental alterations that involve neither pollution nor despoliation. A case in point is the Aswan Dam. By cutting the flow of silt and organic debris in the Nile, it appears to have adversely affected the eastern Mediterranean sardine fishery (*14*) (apart from other consequences that are purely domestic at this time).

Although regional and global problems have many similarities, it is useful to distinguish between them in order to emphasize that not every international environmental problem need—or should—be grist for the mill of the United Nations. It may, in fact, be helpful in seeking a solution to involve only the smallest possible group of nations—generally those directly interested (*15*). This is not, however, to suggest that the distinction between the two classes will always be clear. Realistically, one must expect that some large-scale regional problems will be most conveniently dealt with as global issues, while the interests of a very few powerful nations may so dominate a global problem that its solution rests, at least initially, entirely with them (*16*).

Social-Linkage Effect

Social-linkage effect is the term we use to refer to a second class of international environmental problems in which no physical linkages exist but in which, nonetheless, the policies of one national government impinge directly on the well-being of citizens of one or more other nations. This may occur through established economic relationships between nations (that is, trade and investment, including foreign aid), or in a way that is not, in the first instance, pecuniary. We deal with the second class first and call it, for want of a better term, nonpecuniary linkage.

A classic case of nonpecuniary linkage is that of one country's possessing unique natural or historical gifts that citizens of other nations value as part of the human cultural and natural heritage (*17*). Thus, for example, Uganda's plan to develop a hydroelectric scheme that would involve cutting by 90 percent the flow through Murchison Falls (a very narrow gorge on the Upper White Nile) has aroused considerable ire among conservationists, particularly those in Europe (*18, 19*). The filling of Lake Nasser, behind the Aswan High Dam, stimulated an international effort to rescue a number of tombs, temples, and statues erected along that stretch of the river by early Egyptian civilizations. Similarly, the Italian government's care of remnants of antiquity has postponed the completion of Rome's subway, but has probably prevented it from becoming an international issue (*20*).

Many countries, particularly the developing nations, have been criticized for failing to take effective action to protect animal species that are valued by conservationists around the world. Perhaps the most widely known examples are the African cats, especially the leopard, which are endangered by poachers, and the Ceylonese elephant, threatened by the large-scale clearing of forests for agriculture.

These situations are local phenomena, but they become international problems when citizens of other countries protest and attempt to obtain actions that accord with their own values rather than with those of the country concerned. Aroused citizens implicitly or explicitly involve their own governments in their efforts. Thus, the opponents of the Murchison Falls Dam would persuade the British government to renege on its promise of financing the initial construction phase (*21*). Thus the nonpecuniary interaction can become pecuniary.

It is worth noting that motives are of the highest character in both camps; and, as is always the case when neither side is villainous, the problem appears in its purest and most difficult to solve form.

This is equally true of yet another variety of nonpecuniary interaction—international altruism, in which citizens of one nation endeavor to help citizens of another nation avoid mistakes in dealing with the environment. For example, agricultural experts in the West may be anxious to help African nations avoid exhaustion and erosion of laterite soils. This type of interaction will only lead to problems if the country to be assisted does not agree that the proposal is in its best interests, or if the outside altruists become too insistent or paternalistic.

This situation is apt to arise, above all, in large-scale, agriculture-oriented engineering works. As an example, consider the controversy over the eventual benefits of the Aswan High Dam. Leaving aside the question—often hard to judge—of whether or not some of the effects were or could reasonably have been anticipated, it is useful to distinguish between adverse effects that diminish the chances of success of the primary project objectives, and those that adversely affect some other environmental facet.

In the first instance, decreased soil fertility or increased salinity, for example, if indeed resulting from the changed characteristics of the river, would directly diminish the project's objective—that is, higher agricultural production. Provided there was no dispute on the scientific findings, it would be a straightforward computation to evaluate the size of the loss in dollars and cents. There would be no room for dispute over the consequences. By contrast, the spread of schistosomiasis,

while also damaging to the country, could not, in the same sense, be calculated as a direct offset to agricultural production. Outsiders might view it as part of an ecological horror story and consider it a serious offset to the value of the project as a whole, but the national government, given the already very wide diffusion of the disease in rural Egypt, might view it less severely. Indeed, it might even consider that increased output and income might, in the long run, provide a better basis for a successful battle against the disease *anywhere*.

Weighing of environmental effects is, then, unlikely to lead to controversy in the first instance (direct relation to project objective) but apt to do so in the second (adverse side effects related only tenuously, if at all, to project objective).

Divergences of judgment, as described above, sometimes leading to the attempt to impose some kind of sanctions on another country, are not new. Boycotts, embargoes, and other measures have been used in the past to express disapproval of a country's behavior and force it to comply with more acceptable standards. What is new here is the issue that gives rise to such conflict and pressures; and as that issue gains increased status among the aspirations of mankind, the opportunities for intervention, as well as the felt justification, are bound to rise.

Pecuniary Effects

The issue becomes at once more pedestrian and more pointed when we turn to another class of social linkage —namely, the pecuniary effects upon country B of specific environmental policies followed in country A. Here the cases shade into well-known phenomena in foreign trade, even though the impetus lies in a newly prominent field, the environment.

Thus, when the United States adopts strict automobile emission standards, it raises the costs of European and Japanese auto manufacturers who wish to export to this country. Even if the sales price of U.S. automobiles should rise in proportion, foreign manufacturers will need to make special provisions for cars sold in the U.S. market. This fact, together with the likelihood of a proportionately greater financial burden on smaller cars, will directly affect the income of the owners and employees of foreign firms, and will indirectly affect the income of other citizens of those nations. Similarly, limits on the permissible sulfur content of fuels burned in U.S. and European cities imply gains for those nations that own low-sulfur fuel reserves, and lost markets or decreased profits (because of the costs of desulfurization) for others. These examples are only extensions of long-standing regulations in food imports, for example, where tolerances for specific ingredients or impurities, or observation of stated sanitary procedures, are prerequisites for admission to the U.S. market. They bring us squarely up against trade effects as international environmental problems; and for many people trade effects are the most immediate and important of such problems. Thus, it will be valuable to pause and consider how trade effects fit into the taxonomy we are proposing.

There are generally two kinds of trade effects: (i) loss of export markets as a consequence of the increased costs of maintaining high environmental quality in the exporting country, or (ii) the erection of barriers to imports in line with the importing country's policies on environmental quality (*22*). In the first case, by forcing domestic manufacturers to absorb the costs of disposing of production residuals, environmental quality legislation will tend to diminish the competitiveness of domestic products in the world market. This, in turn, will lead to a decline in domestic income and employment and to losses in the value of invested capital (*23*). The second effect is exemplified by the standards on auto emissions and sulfur content of fuels. Here the major losses will arise through action in the importer's country, which raises the additional specter of retaliation.

There is no doubt that both situations can create friction between nations and be the subject of negotiation, unilateral action, and so on. Hence, both are international problems. This is obvious with barriers to imports, but the implications of the loss of export markets are no less disconcerting. As put by Germany's Minister of the Interior Genscher (*24*):

> We must . . . avoid a situation in which individual countries exclude themselves from making investments for environmental protection, thereby securing competitive advantages for their own economy vis-à-vis those countries who do meet their responsibilities.

What is noteworthy here is the use of the term "responsibility," placing environmental effects in a context beyond voluntary action.

It is important to realize, however, that trade effects are quite different from the direct, physical-linkage effects. The loss of export markets due to action in the exporting country is simply an international facet of the classical adjustment process necessary within an economy when tastes or ground rules shift markedly, causing capital and labor to move out of some industries and into others. Some owners of capital suffer unanticipated losses, and, in the short run, lower incomes and some unemployment will result. But the real cost of producing the same goods (or of obtaining the goods internationally) has increased by what it costs to achieve the higher level of environmental quality. Hence, given government policies designed to maintain aggregate demand, there is no reason that full employment cannot again be obtained (*25*). In the long run, and in the absence of similar environmental policies by other governments, the nation will tend to import those goods that involve the greatest environmental costs and to export those involving the least. It will, in effect, be exporting pollution (*26*).

The emergence of so-called "pollution havens" is not a theoretical consideration. For example, air pollution standards have led to reductions in copper smelting operations in Arizona, Texas, Montana, and Washington, and to an increase in shipments of ore to smelters in West Germany, Canada, and Japan. Japan is reported to be shipping ore to Indonesia for smelting, though on a very small scale. A movement in the opposite direction is our export of coal and lumber to Japan. To the extent that those exports are stimulated by lower prices, made possible by a lack of strip-mining regulation and of control of timber overcutting, the United States is functioning as a pollution haven, suffering land erosion, acid mine drainage, reduction of wildlife stocks, and disruption of natural vistas in order to support domestic employment in export industries.

Environmental policies that act as direct obstacles to trade affect the outside world as do other nontariff barriers such as product quotas or import prohibitions. For the domestic economy of the importing countries, the higher real cost of imports is, again,

simply one facet of the overall cost of attaining the desired level of environmental quality.

Because international trade problems have been dealt with extensively elsewhere, little need be said about them here, even though they arise in a novel context. However, the novelty must be qualified. Nontariff barriers that confer large gains on specific industries are frequently justified in terms of noble objectives—to further health or some other aspect of the well-being of some or all citizens. When environmental objectives act as trade barriers, it is not, therefore, surprising that the motives of those who are responsible for them will be suspected.

It is difficult to predict the effects on international trade of domestic environmental quality policies that are imposed unilaterally. The one attempt with which we are familiar is limited to five major developed countries (France, Japan, West Germany, the United States, and the United Kingdom). The reported results must be interpreted with caution because of the rather strict assumptions and limited data on which they are based (*27*). Nevertheless, this study does indicate the order of magnitude of the short-term impact on national income and the balance of payments of domestic environmental control policies, if it is assumed that each nation, in turn, acts alone while others continue present policies and that the government of the nation imposing the controls does not pursue policies designed to reduce the resulting economic dislocations. In this situation, the predicted effect on the balance of payments and national income of the United States is quite small; on those of West Germany, moderate; and on those of the other three nations, substantial. These results suggest that U.S. environmental policy need not be constrained by fears of serious national income and balance of payments implications, but that other major developed nations will probably be extremely cautious about acting, except in concert with their major trading partners, in such a way as to force domestic industry to take account of environmental damages. There is the additional complication that the degree to which adjustments are borne by society as a whole (for example, through subsidies paid out of general revenue), as against being reflected in the price of the affected commodity, will impinge upon relative prices and thus competitiveness in international markets.

Environmental considerations are equally likely to affect the allied field of investment. We have pointed out the tendency to import, rather than produce at home, goods that have a highly adverse effect on the environment. In addition, some countries do not impose strict regulations, either because conditions (whether natural or otherwise) do not yet require them, or because they wish to attract capital. As a result of these two factors, investments may be shifted to those countries. It is easy to see how such moves can lead to international friction.

These investment effects also appear in the field of foreign aid, whether bilateral or multilateral, except that here the reverse situation obtains. By U.S. law, development projects financed by the U.S. government must now be evaluated for their impact on the environment. In a parallel development, the World Bank has recently established a program designed to look into adverse effects of foreign aid on the environment. From such evaluations are likely to come actions to prevent or remedy adverse environmental consequences. Hence, the cost of a given project is likely to be higher than it would otherwise have been, and the host country will be concerned over the competitive status of the goods and services that will result from the investment. Recipients of aid do not look kindly on the need for additional foreign exchange, perhaps foreign technicians, and further delay in achieving economic independence—all for benefits often little understood or valued.

Shared Experiences

Before abandoning the taxonomy of problems and proceeding to that of solutions, a comment is needed on a range of matters that are not in any real sense international environmental problems but that do relate to them. These are the domestic environmental experiences common to most countries at specific stages in their growth.

Problems of human settlement, especially those of large urban areas, come to mind at once. These are not new problems. Most of them have merely been given a new label. Thus Calcutta, Rio de Janeiro, Lima, Tokyo, and New York all suffer from problems related to large concentrations of population. Similar problems were noted in London 150 years ago. The international aspect lies in the commonality of such problems, not in any interaction. And so it is with matters like soil erosion, poor drainage and resulting salinity (encountered many thousands of years ago in the plains of the Tigris and Euphrates), deforestation to meet the needs of shipbuilders (Rome), or settlers (United States), and a host of other environmental problems. Here the opportunities for international cooperation are greatest: in the exchange of information, technology, and so forth. In short, here is the possibility of progress without conflict. But, by the same token, it is not here that truly perplexing international issues are found.

A final comment is in order on the above taxonomy. A problem in any of the three categories may be—and usually is—complicated by considerations of the income distribution among the nations (and their citizens) involved. These will be particularly obvious and important when one or more of the interested parties are developing nations, but they will also be present when only developed nations are concerned. Any particular solution to an international environmental problem will involve transfers of real income from nation to nation. These can generally be identified and at least partially quantified at a technical level. But the desirable direction and size of such income transfers become two variables for consideration in the political process of choosing between alternative outcomes.

A Taxonomy of Solutions

Solutions to international environmental problems may be either negotiated or imposed. If negotiated, the appropriate group of interested parties will, as we have suggested, be defined by the scale of the natural system involved, although considerable improvement may be obtained over a fairly long period through agreements among the smaller group of nations responsible for most of the problem.

Solutions may be imposed by a single nation or by a group of nations that has the required economic—or, in extreme cases, military—power. The imposition may be directly by force: for example, if one nation invades another to destroy a dam that has changed

the flow of a river (*27*). More likely are impositions based on the terms of foreign aid (as in the Murchison Falls example mentioned above), trade restrictions (as in auto emission standards for imported vehicles and the prohibition against importing certain furs), or by internal law operating as a trade restriction (restrictions on the sulfur content of fuels or prohibitions against the landing of SST's at domestic airports).

An imposed solution generally implies that the costs and benefits have been assessed by the imposing nation from its own point of view. But if negotiation is to be attempted, the problem of evaluating alternative solutions becomes extremely difficult. There are the usual problems of making cost comparisons among nations with different internal factor–cost structures and correcting the nominal rate of exchange to reflect at least the most serious distortions. In addition, the task of getting any real notion of the benefits will be all but impossible. Nations' preferences for the changes in environmental quality being sought will vary in accordance with their stage of economic development, cultural matrix, political structure, and so on. Moreover, these changes are associated not with private goods, where the market provides a test of preferences, but with public goods, which are consumed willy-nilly in equal amounts by all. Therefore, there exists an opportunity, if not an incentive, to conceal true preferences (for a nation as much as for an individual) and report falsely on the evaluation of benefits (*28*). Solutions may be implemented through the setting of standards or through levying charges on contributing nations, although there are tremendous difficulties in achieving either on an international scale.

Standards, in turn, may be "ambient" (that is, applying to the quality of the environment of the receptor nations) or "discharge" (applying only to the contributing nations) (*29*). If the mechanisms of the natural world are sufficiently understood, a set of ambient standards, if attainable at all, can be translated into a set of discharge standards (*30*).

Because demands for "minimum standards" crop up so frequently in proposals for safeguarding the environment, it is well to stress that such minimums are unlikely to be either unambiguously defined or easily agreed upon. For example, is the minimum standard for oil tanker design simply to require hull thickness and tank sizes such that at least tankers won't break up in storms for their first 10 years? Or is it to require some minimum of oil spillage resulting from a design collision or grounding incident? Who chooses the design incident and the minimum acceptable spillage? Or, consider minimum standards for mercury contamination of foods. For any particular food, the level of contamination that a nation will be willing to tolerate will vary with the importance of that food in the diet of its citizens, *and* with the incidence of poisoning it finds acceptable. Since individual susceptibility to mercury undoubtedly varies, any given minimum standard is likely to result in some (albeit very few) cases of poisoning. The only minimum standard that can, with certainty, prevent poisoning is a zero level. Any nonzero level implies choices of probabilities of incidence; and any level high enough to be a minimum (in the sense that no nation would insist that a higher tolerance be agreed on) would undoubtedly lead to significant incidence in one or more nations.

Notice also that *any* standard which changes the status quo will create costs for some nations and benefits for others. Thus, in the tanker example, nations whose citizens own tanker fleets or ship oil will absorb costs if tankers are made more expensive. Nations with coastlines near busy international shipping lanes will reap obvious benefits from stronger construction, smaller tank size, and soon. Similarly for the mercury example, nations producing and consuming a particular food are likely to differ on the desirability of any standard, even a very low one.

The point is that minimum standards are no more objectively determined than would be optimum standards, and attempting to find and agree on a set of global minimum standards will not make the negotiating problems appreciably easier. Any standard that finds immediate and nearly unanimous international support is likely to be quite meaningless.

The term "monitoring" also tends to give rise to much confusion, even though it is a prominent activity apt to draw nations together rather than push them apart. One kind of monitoring is directed toward exploring basic processes and flows in natural systems, setting baselines, discovering what needs to be measured, and assuring compatibility of measurements carried on by different nations. Some of this activity is underway. A second sense of the term refers to compliance with set standards and is used in the context of regulation. In terms of sequence, the second sense follows the first. A clear distinction between the two meanings is helpful for avoiding unnecessary conflict and suspicion.

Other Dimensions of Variation

International environmental problems differ in a number of dimensions other than the one we have chosen for our basic taxonomy. Thus, problems may involve different time scales between cause and effect and, hence, a different level of immediacy for the present population of the world. For example, the buildup of carbon dioxide is a long-term problem, with the possibility of any detrimental global effects many decades in the future, if they occur at all. This is apart from the fact that the environmental effects of fuel combustion and energy conversion and use generally are as yet poorly understood. Thus, any attempts at timing are highly speculative.

The persistent pesticide problem, on the other hand, is much more immediate, with consequences of past applications observable today and with every indication that the situation will worsen unless action is taken now. Related to this dimension of timing is the degree of certainty with which an event will or will not occur. Generally, the further in advance effects are predicted, the more uncertain the outcome; on the other hand, the continuation of presently observable effects is far more certain.

Two other important dimensions of environmental problems are magnitude and degree of irreversibility of effects. Because the effects will be of different types, occur in different places, and affect different facets of human life, the relative magnitude of particular problems is not easily determined, except in the infrequent cases where some estimates of monetary damages can be obtained.

The scope of effects, however, can roughly be compared: For example, a global warming trend is a "greater" effect than is the extinction of a species. However, this approach is too intuitive, and it becomes progressively

less useful as one moves away from extremes.

Reversibility refers to the possibility of returning the world, or one of its subsystems, to the state it was in before some effect occurred. Thus, sulfur dioxide pollution in the atmosphere, because of the speed with which it is scrubbed out, is highly reversible. The construction of a dam, on the other hand, is generally considered to be irreversible. As a matter of fact, many effects are reversible *at some cost*; irreversibility, in everyday parlance, generally means that the cost of returning to an earlier state is very high. True irreversibility can be seen in species extinction, destruction of scenic areas, and changes in global climate and weather (except sub specie aeternitatis).

The dimensions of timing, certainty, magnitude, and reversibility of effects all contribute to the broader dimension of urgency. A situation that produces immediate (thus certain), serious, and irreversible effects is perceived as more urgent than a situation that produces long-deferred (hence uncertain), minor, or reversible effects. There is, of course, no one scale on which all environmental problems may be ranked according to urgency, but individuals and governments make subjective evaluations of this sort all the time, and these evaluations help to determine willingness to negotiate solutions.

The ability to proceed from some mutual willingness to negotiate to an acceptable settlement will depend, in general, on the number of interested parties, the degree of diversity in their development and needs, and the nature of the issues involved. For example, if "national pride" somehow becomes an issue in its own right, negotiation will be far more difficult than if only economic or esthetic questions were involved (though in practice it will be hard to make distinctions). More important, objectives differ. Thus, developing countries will generally desire to exploit their natural resources more rapidly and process more of them at home, in order to earn foreign exchange and raise per capita income. "Some of us would rather see smoke coming out of a factory and men employed than no factory at all. It is, after all, a matter of priority," commented the president of the Consumer Association of Malaysia at the recent meeting of the International Organization of Consumers Unions (*31*). At the same conference, the director of the Consumer Council of India is quoted with this remark: "The wealthy countries worry about car fumes. We worry about starvation" (*31*). Presence or creation of appropriate institutions will also make a difference. The pooling of the Scandinavian countries' research efforts in "Nordforsk" is likely to promote internationally advantageous action, just as failure to do so in the context of the Baltic will retard action. Thus, building institutions is an important element of progress in negotiated settlements.

Some Research Needs

We have attempted simply to outline and categorize the range of issues subsumed in the broad heading "international environmental problems." Solutions to these problems must rest on difficult international negotiations, but social scientists can play a useful role in setting the stage for such negotiations by undertaking research to answer questions that are currently being answered, without sound data or analysis, by advocates of one or another solution. The following are examples of such questions:

1) What are the pitfalls of various types of international agreements as revealed by previous experience, for example, in the field of marine fisheries or international communications via the radio spectrum? What forms and safeguards have proven to be successful in, for instance, international control of uses of nuclear energy? in control of the movement of toxic materials, such as drugs?

2) What are the costs of altering the behavior currently giving rise to the problems? For example, what would be the costs (economic, political, and in terms of additional radiation hazard) of the widespread substitution of atomic energy for fossil fuel in generating electricity, in order to cut down on global emissions of carbon dioxide and particulates (*8*)? What would be the cost of abandoning the use of DDT in specified areas and for specified purposes, and of replacing it with a range of alternatives? What would be the costs of undertaking alternatives to the schemes giving rise to the direct nonpecuniary interactions defined above? As a specific example, what would be the additional costs to Uganda of obtaining the generating capacity of the Murchison Falls project by some other method? Or how valuable is the generating capacity that would be lost in some compromise scheme to preserve a flow through Murchison Falls?

3) What policies could be devised to assure that the cost differences calculated above could be made up by nations voicing concern? As a subproblem, how could one effectively assure the country making the substitution—as one would have to—that the cost difference would not come out of development funds that had already been committed? And how would it be possible to erect safeguards against "ecological blackmail" (that is, the threat of an adverse undertaking as a means of securing financial indemnity for acceptable modifications, or abstention from action)?

4) What are the costs of meeting various objective sets of ambient environmental quality standards in such classic cases as the Rhine and the Baltic? Who would bear these costs in the first instance? And what mechanism could encourage payments from nations deriving benefits to those bearing costs?

This list is not meant to be comprehensive, but to outline a set of specific problems that can be tackled by social scientists with, for the most part, techniques that have already been developed in the context of domestic problems. It is purposely confined to the cost side of the problems and is designed to modify arguments about these problems, at least to the extent that proponents of change know what costs they are imposing on other nations. The task of quantifying benefits is probably beyond the competence of any scientist and must remain a matter for political judgment as exercised in the process of negotiation.

References and Notes

1. Notable examples are the Study on Critical Environmental Problems held at Williams College during 1970, the results of which have quickly become available in an initial report [*Man's Impact on the Global Environment: Assessments and Recommendations for Action* (M.I.T. Press, Cambridge, Mass., 1970)], and the Prague Conference this spring, sponsored by the United Nation's Economic Commission for Europe.
2. The exception has been the increasing activity by international scholarly bodies. For example, the Scientific Committee on Problems of the Environment was formally established late in 1970 by the International Council of Scientific Unions and so far has set up at least three study groups. These have begun to conduct research on matters ranging from the effect of chlorinated aromatic compounds on human tissue to the scope and methods of worldwide environmental monitoring systems and the structure and functioning of ecosystems as influenced by man. Specialized

agencies like the World Meteorological Organization (with its World Weather Watch) or the planned Global Atmospheric Research Program (to be undertaken as part of the World Weather Program) are similar ambitious programs. The International Biological Programme has been functioning for some years now. Others, such as UNESCO's Man and Biosphere, have barely begun to function. Below the global level, study programs are under way in the Organization for Economic Cooperation and Development, at NATO, at the Council of Europe, and others, but none of these are at this time action-oriented.

3. Thus, some scientists appear to feel that the setting of environmental standards is a "scientific" question, like that of understanding environmental mechanisms. One set of standards then is "correct"; others are "wrong." In fact, however, scientific inquiry only furnishes society with the understanding and the data on which to base decisions. Given identical facts, the differing tastes, preferences, and prejudices of different members of society will lead them to advocate different standards. Because of the impossibility of trading the results of environmental standards in a private market, the problem of combining individual preferences to arrive at a social decision becomes a political problem. Politicians make these decisions not by default, but because such decisions are the very substance of democratic government.
4. *New York Times*, 4 October 1970, p. 15.
5. Persistence alone is not sufficient to cause a global problem. A discarded tire is extremely persistent and creates a visual blight that is surely an environmental quality problem. But the tire is not subject to global transportation by the natural system into which it is discharged. Similarly, mobility without persistence would not create the problem discussed.
6. How subtle are the distinctions involved is evidenced by the possibility that even nonmobile, nonpersistent pesticides could have affects beyond national borders if (i) they affected migratory birds, for example, and thus broke the food chain, or (ii) they were used near international boundaries. But control of these cases would require agreement among a much smaller set of nations.
7. For a recent comprehensive survey of the subject, see H. E. Landsberg [*Science* **170**, 1265 (1970)].
8. See W. O. Spofford, "Decision-making under uncertainty: The case of carbon dioxide buildup in the atmosphere," paper prepared for the Study of Critical Environmental Problems, Williams College, July 1970.
9. Dealing with global issues is, in one sense, not a totally new experience. Control of infectious diseases affecting human, animal, and plant life has long been practiced on a worldwide basis with considerable success, since in many instances carriers could be identified and thus isolated. Note also that global "concern," of course, extends far beyond this list, to include population growth, the nuclear threat, and so on.
10. Even this situation is not without its fuzzy edges. Agriculture in the developed countries is conducted with more care for soil erosion: thus, dispersion of nutrients into the environment is lessened. On the other hand, poor farming practices in the less developed countries may be the cause of the major portion of particulates in the atmosphere, according to the Williams College report (*1*). If so, poor agricultural practices would have to be considered a true global environmental issue.
11. *New York Times*, 27 November 1970, p. 64.
12. J. Cornwell, *New York Times Magazine* 21 February 1971, p. 24.
13. *New York Times*, 19 April 1970, p. 17; *ibid.*, 27 December 1970, p. 16. This is not a new phenomenon, but a new attitude, arising in the context of general concern for the environment.
14. C. J. George, "The role of the Sadd El Aali [Aswan High Dam] in the fisheries of the southeastern Mediterranean," paper presented at the conference on Ecological Aspects of International Development, Airlie House, Warrenton, Virginia, 9–11 December 1968. See also C. Sterling, Washington *Post*, 15, 17, 20, and 24 February 1971; *Life*, 12 February 1971, p. 46.
15. Recent work in political theory on legislatures, individual preferences, and social decisions suggests that it is preferable not to have a decision made on an issue by a legislature in which few individual legislators have a direct interest in that issue [see E. Haefele, *Amer. Econ. Rev.* **61**, 217 (1971)]. An analogy between legislators and national government representatives in international organizations does not seem far-fetched.
16. This is true of nuclear disarmament, the extreme case of a threat to life on earth. On a less extreme level, G. F. Kennan has suggested that global problems are best handled by the developed nations in any event—not only because they are the principal polluters but because it will be too much to expect the rest of the world to take an interest in a problem that does not loom large at that stage of economic development [*Foreign Aff.* **48**, 401 (April 1970)].
17. J. V. Krutilla, C. J. Cicchetti, A. M. Freeman, C. S. Russell, in *Environmental Quality Analysis; Theory and Method in the Social Sciences*, V. Kneese and B. T. Bower, Eds. (Johns Hopkins Press, Baltimore, in press).
18. P. Géroudet, *Biol. Conserv.* **2**, 309 (1970).
19. C. S. Russell, *ibid.*, in press.
20. *New York Times*, 23 January 1971, p. 2. The economics of the preservation of unique historical and geological sites is discussed in (*17*).
21. A translation of a public letter from three prominent British scientist-naturalists (F. Darling, J. S. Huxley, and P. Scott) calling for this action is in (*18*).
22. Both manifestations are mentioned in *Bus. Week*, 23 January 1971, p. 72.
23. We emphasize that income, as measured by such market-based indices as gross national product, will decline relative to what it would have been in the absence of the domestic policies. The fact that the policies were adopted, however, shows that the society judged it would be better off with them than without them. Nonmarket income has increased enough to offset the decline in market income.
24. *J. Commer.*, 15 January 1971.
25. Even in the short run, wise government policies may ease the transition considerably. For example, worker retraining allowances and expanded unemployment coverage, as well as subsidized loans for machinery conversions, can cut the frictional costs of the required employment shifts. Such policies to offset trade effects are possible under the current tariff law but have almost never been used. There are signs that this situation is changing. For a discussion of assistance being given the Massachusetts shoe industry, see *New York Times*, 21 February 1971, section F, p. 2.
26. R. C. d'Arge, Appendix F, in A. V. Kneese, "The economics of environmental pollution in the United States," paper prepared for a meeting of the Atlantic Council, Washington, D.C., 1970.
27. It is hard to visualize anything less drastic, such as water pollution, as a casus belli, even though the consequences in the long run may be just as damaging. But, of course, the invocation of an environmental insult may merely mask a more traditional objective of foreign policy, economic or otherwise.
28. P. Bohm, *Swed. J. Econ.*, in press. The fundamental papers in the theory of public goods are P. A. Samuelson, *Rev. Econ. Stat.* **36**, 387 (1954); *ibid.* **37**, 350 (1955); *ibid.* **40**, 332 (1958).
29. We place the words "ambient" and "discharge" in quotes to indicate that the same notions may be used more broadly. Thus, for example, in the trapping of migrating birds, a discharge standard would require that the trapping nation allow some number or percentage of the flock to escape. An "ambient" standard would require the maintenance of some population in each of the host countries.
30. In addition, of course, the ground rules chosen in translating "ambient" to "discharge" standards will make a difference to economic efficiency. If all individual dischargers may be subject to different discharge constraints, an ambient standard may be attained most efficiently. On the other hand, if notions of "equity" seem to require a uniform standard, then some dischargers will be cutting back too far when the ambient standard is just attained. In any event, however, we are a long way from approaching such sophistication in domestic affairs, let alone international conduct.
31. *New York Times*, 3 July 1970, p. 4.
32. We wish to express our appreciation to L. Carter, M. Clawson, J. L. Fisher, A. V. Kneese, and W. O. Spofford, all of Resources for the Future, for useful criticism and comments on early drafts.