Chapter 1

Environmental Issues in Newly Industrializing Economies: A View from North America*

George S. Tolley†

1. Introduction

While one's view of environmental issues in newly industrializing countries is in many ways the same regardless of the observer's country of origin, considering nuances of thinking about the environment that differ among countries can be useful. In addressing this task, the present paper considers environmental issues in two parts.

First, issues are considered that are internal to each country, meaning that concern is with environmental effects that extend only to citizens of a single country. In these situations, externalities do not extend across country boundaries. Much of the concern in this part of the paper is with differences in how countries choose to deal with their internal environmental problems. Countries differ for a variety of reasons that may lead to differences in their actions toward the environment. We consider reasons why countries may differ in their choice of environmental actions, helping to understand international differences. We then consider implications of the fact that more highly developed countries have experience that can ease the burdens faced by newly industrialized countries in dealing with the environment. Technologies that reduce emissions have been developed that reduce costs. These technologies, if transferred, can make dealing with the environment by the newly industrializing countries less costly than it initially was in the more developed countries. Ways for fostering this transfer are discussed. The developed countries have conducted institutional experimentation, such as substituting tradable emission rights for command and control strategies in some cases. These are proving successful in reducing costs of dealing with environmental problems. As with technology transfer, adoption of these newer institutional approaches, if fostered, can be of benefit to newly industrialized countries. The final topic in considering internal environmental problems

*Charlie Parekh and Craig Koerner gave invaluable research and analytical assistance.
† Professor Emeritus, Department of Economics, University of Chicago

of countries has to do with indirect effects between countries. We discuss the fact that differences in the way countries deal with their internal environmental problems may affect competitiveness in international trade. We consider the implications of this phenomenon for world welfare.

The second part of the paper deals with environmental externalities that extend across country boundaries, particularly externalities with global consequences. We consider ecological effects generally and global warming more specifically. All these phenomena involve long-term uncertain effects. The basic problem of what to do about such phenomena is discussed. A seven-point framework is presented for dealing with these phenomena. Difficulties in valuation of effects, probabilistic considerations, discounting in an intergenerational context and irreversibilities figure in the discussion. Superimposed on the problem of how to deal with such phenomena are distributional and political considerations, including problems of achieving international cooperation.

2. Differences Among Countries in Dealing With the Environment

A. The Inverted U Revisited

Much attention has been given to the tendency for pollution to increase in the early stages of economic development and then to fall as development progresses further. An inverted U shape is obtained when pollution is plotted against time or when pollution in a cross section of countries is plotted against country real income. The major explanation has been that increases in production, including production from polluting industries, raise pollution in the early stages of economic development, while pollution is lowered in the later stages of development due to control efforts as rising incomes lead to greater demand for environmental quality. A very large literature has been devoted to the inverted U phenomenon, as reviewed by Selden and Song (1994).

Meanwhile, numerous studies have investigated influences other than income on differences in behavior toward pollution among nations. The additional influences make up a lengthy list and include education, property rights, nature of the political system and economic openness. For original work on these additional influences and a review of previous work, see Coursey and Hartwell (2000). Of relevance to the present paper, Yoonae Jo (1999) finds that high school education reduces conventional air pollution but not green house gas emissions. She attributes this result to the fact that the damages from greenhouse gases fall importantly on nations other than the polluting nation, constituting an externality to which a nation has limited incentive to respond.

B. Role of Benefits and Costs in Explaining Country Differences in Environmental Policies

The inverted U literature and the other literature discussed above deal with differences in aggregative measures of environmental quality. One way of viewing this literature is to suggest that it attempts to explain how the demand for environmental quality varies among countries.

For example, with regard to effects of income, the most common interpretation is that the income elasticity of demand for environmental quality is low at early stages of development and becomes high at later stages. Underlying this interpretation is the idea that a country at a lower level of income may decide that the sacrifice of other priorities that would be necessary to reach the environmental quality levels of the highest income countries is not justified. Environmental budgets and costs of expensive regulations of the highest income countries if followed in lower income countries would require giving up a gamut of urgent needs ranging from basic public programs on the government side to private goods given up such as food when consumers pay the costs of taxation to pay for environmental programs or higher costs of goods whose prices are raised by compliance with regulations.

For aesthetic, ecological and other effects whose benefits are subjective or extremely difficult to verify in the present state of scientific knowledge, this explanation may suffice, though it would be helpful to undertake more surveys of opinion in various countries to gain quantitative insights on the strength of the effects.

On the other hand, much if not most of the impetus to environmental policies comes from scientifically verifiable effects of pollution. These include diseases and symptoms caused by pollution. A great deal of mounting evidence links pollution to increased mortality and morbidity. Why, specifically, are more vociferous actions taken toward these scientifically verifiable effects in high income countries than lower income countries? Consideration of this question can further our understanding of, and attitudes toward, country differences in environmental policies and can be of help in adapting evaluation techniques to situations in countries whose experience with environmental controls is limited.

The question of whether to undertake a policy that will reduce mortality involves deciding how many resources to devote to reducing life-threatening risks to a population. As an example, a policy may reduce the risk of mortality by two hundredths of one percent, which is a significant amount for a single policy. The death rate in the absence of the policy is, say, 100 in ten thousand i.e. ten per thousand or one

percent=10^{-2} per person. The death rate will be lowered by .02 of this amount or by two in ten thousand, i.e. two per thousand or .02 percent per person. As is well known, evidence on how much people are willing to pay for small changes in the probability of survival can be obtained from premiums people demand to work in risky as opposed to safe occupations and by governmental expenditures on life saving activities such as improving road and fire safety, to name some of the sources that have been used. Suppose that the sources indicate a willingness to pay $48 per year to increase the probability of survival by one in ten thousand. Then the willingness to pay for the policy that reduces the incidence of mortality by two in ten thousand, expressed on a per person basis, is $96 or twice the willingness to pay for a one in thousand reduction. If the policy being considered pertains to pollution reductions for a city of ten million people, then the estimate of the willingness to pay is ten million times $96 or $960 million.

Another way of arriving at the result is to note that the lives saved will be $2x10^{-5}$ or.00002 of the population of ten million or $2x10^{-5}x10x10^{6}$ which equals 200, which is to say that there will be a saving of 200 lives. One can divide the $48 willingness to pay for a one in ten thousand or 10^{-5} increase in probability of survival by the 10^{-5} probability increase to obtain $48/.00001 which equals $4.8 million dollars and is the amount if, hypothetically, there were an increase in one, or from zero to unity, in the probability of survival. The calculation extends the numbers far beyond the range to which they actually apply since the exercise is valid only for small changes in probability, not to a change from probability of zero of survival, or certain death, to unity probability of survival, or certain survival. The willingness to pay is $4.8 million for a unity increase from zero to one in probability of survival if it were valid to extend the calculations to such extreme changes in probability, which it is not. However, since real policies involve only very small changes in probabilities, the hypothetical willingness to pay for a unity change in probability can be multiplied by the very small change probability, i.e. extremely small fraction of unity, to obtain the estimate of willingness to pay for the policy. The hypothetical willingness to pay for a unity change in probability of survival is called the value of a statistical life. Multiplying the value of a statistical life, which is $4.8 million in this example, by the change in probability due to the policy of $2x10^{-5}$ gives a willingness to pay for the policy of $96 expressed on a per person basis. Multiplying by the ten million people whose probability of survival is affected by the policy gives willingness to pay for the policy of $960 million. This is the same result as arrived at dealing entirely with small probabilities without ever having to use the concept of the value of a statistical life.

The foregoing considerations go over ground that is familiar to all who have even passing acquaintance with the value of life literature. The considerations have been repeated here to re-emphasize that evaluation of policies affecting the incidence of mortality involves no connotation of putting a dollar amount on the value of an identified human life. Rather, the evaluation is part of risk analysis that is logically required in deciding on any risky human action, given the inescapable necessity to make choices that affect risk in a world of less than perfect certainty.

An argument can be made that it would be better to abandon the calculation method involving the value of a statistical life. It raises a barrier to skeptics of objective evaluation, who say, and in some sense rightly so, that human life is priceless and who view the evaluation of mortality risk reduction as repugnantly putting a dollar value on human life. It gives fodder to writers of newspaper editorials and others who publicize the superficially repugnant idea of putting a dollar value on a human being's life, rather than recognizing that nothing more is involved than the essentials of analyzing inevitable risks faced by large groups of people, none of whom is identified individually.

A major point for the present paper is that the willingness to pay for small changes in survival probabilities, which as we have just noted is often expressed as the value of a statistical life, varies according to income level of a country. In this regard, consider further the example of the value of a statistical life of $4.8 million, which is a value that has been used by the Environmental Protection Agency of the United States. Suppose the yearly earnings of an individual are $24,000, which capitalized at an interest rate of 10 percent per annum over a lifetime gives a present value of foregone earnings on the order of $2.4 million, which is only half the $4.8 million value of statistical life based on willingness to pay and is reasonable. As is well known, the value of life can be expected to substantially exceed value of foregone earnings due to the decreasing marginal value of consumption, reflecting a surplus utility from living over and above consumption made possible by earnings, due to the fact that people care about things other than just the amount of goods and services they consume. In this example, the value of a statistical life is twice the present value of foregone earnings. If this same ratio applies to a country with one-third the per capita income of that in the United States, which is still a relatively high income by world standards, the value of a statistical life in the country would be $1.6 million compared to the $4.8 million for the United States. A subject deserving further investigation is whether the value of a statistical life varies less than in proportion to income due to lesser variation in the things that people care about other than goods and services.

The foregoing example is for the valuation of increases in mortality caused by pollution. Similar comparisons could be made for morbidity i.e. non-fatal illness. The valuation of non-fatal illnesses involves medical costs, time lost from work and willingness to pay to avoid pain and suffering. While most attention traditionally has been given to mortality, much progress is being made in valuing morbidity through contingent valuation and other techniques. For more on health values, see Tolley, Kenkel and Fabian (1994). For a general discussion of contingent valuation technique, see Smith (1999).

As with mortality, the valuation of morbidity can be expected to differ among countries. An hypothesis is that, on net, the values attached to reductions in non-fatal illnesses tend to vary positively with income of a country. M.I Zukarnain Duki, in dissertation work at Gunma University, has initiated studies on morbidity, with consideration being given to contingent valuation surveys in Indonesia, Japan and China.

Just as the willingness to pay for mortality and morbidity reductions varies among countries, so do the costs of environmental policies that bring them about. Most importantly, labor costs vary among countries and are almost inevitably lower the lower is the income of a country. Reduced willingness to pay for life saving programs is then accompanied by reduced cost of achieving the life saving, but not necessarily in the same proportion. Environmental measures require capital in addition to labor, and the skilled labor required for the environmental measures may be relatively more expensive in the lower income country due to scarcity of skilled labor there.

These remarks indicate the need to adapt the analysis of environmental measures to each individual country and bring home reasons why environmental quality chosen by a country may vary with level of income.

In dealing with comparison of the benefits and costs of environmental actions, there is no intention to suggest that a strict comparison of benefits and costs is or should be the sole basis of decisions. Distributional effects impinging on particular parts of the population, public perceptions about the environment and political considerations are, among others, well known influences on environmental decisions.

Two points may be made about these influences other than strict comparison of benefits and costs. The first point is that their existence in no way means that the quantifiable benefits and costs are irrelevant to policy. They simply mean that other considerations must be brought to bear to fully understand environmental policies. The benefits and costs still remain among the influences. Environmental actions require bearing costs, to which decision makers managing budgets and the body politic at large

are quite sensitive. The increases in well being from environmental actions, which is what the benefits are, remain an important consideration in justifying the bearing of the costs. Through all the distributional, perception and political considerations which make for a departure from decisions based solely on the benefits and costs, people want to know that the value of what they are getting from environmental improvement justifies giving up hard earned income valuable in other uses. While strict comparison of measured benefits and costs does not solely guide environmental policies, it remains a powerful, often unspoken, influence. For further views on the role of economic evaluation in a policy context, see Stavins (forthcoming).

Benefit and cost considerations could have a greater weight in decisions, the lower the income of a country. As noted, the urgency of needs for the resources given up, running a gamut from food to basic governmental functions, is greater in lower income countries.

A second point about the role of measured benefits and costs is that the distributional, perception and political considerations vary from country to country. The result is to give greater or lesser weight, and in different ways, to the comparison of benefits and costs in different countries. This point reinforces the contention that environmental policies can be expected to vary from country to country.

This point is reinforced by noting an additional reason for differences among countries that has received less attention than the differences in benefit-cost comparisons and in the distributional, perception and political considerations mentioned so far. The additional reason is cultural differences, or, technically speaking, differences in tastes toward the environment. Cultural differences are particularly relevant to aesthetic features of the environment and to effects on the environment not quantifiable, or at least not yet quantified, in scientific terms. In this connection, characteristics of areas and communities, including unique environmental characteristics, contribute to sense of place that differs among people. Sense of place is being increasingly recognized as important to satisfactions people obtain from living in that place. See Tolley, Rudzitis and Baden (1999). Within the United States, perhaps the most serious cultural difference is between Native American Indians and the majority of the population regarding basic attitudes toward nature. The conflict is notable in disputes over respect shown to American Indian religious sites including burial grounds.

While it is beyond the scope of this paper to deal extensively with cultural differences, it may be noted that what is considered aesthetically desirable in the environment undoubtedly varies among countries with different cultures. Many

differences could be cited including greater emphasis given to tranquility and contemplation in Eastern as opposed to Western cultures, possibly leading to different criteria for environmental preservation.

The above considerations of level of country income, distributional, perception, political and cultural differences suggest that a one-size-fits-all approach to the environment is not appropriate. To the contrary, country differences are to be tolerated and even encouraged as a matter of self-determination and legitimate exercise of sovereignty.

Macro environmental indicators have a place in policy discussions, both in considering a nation's progress over time and in making comparisons among nations. The advancing state of the art in environmental sustainability indexes is reflected in the recent report by the World Economic Forum (2000). Kang, Kim, and Lee (1999) have made important contributions for Korea.

In addition to environmental indicators, the possibility of integration of the environment into national income accounts is receiving serious study. The integration would allow more accurate measurement of a country's overall level of well being, adding environmental effects to the usual measures of market output. A report edited by Nordhaus and Kokkelenberg (1999) sponsored by the National Research Council in the United States analyzes the conceptual approaches and empirical needs for accomplishing integration. While there is agreement that it would be premature to undertake full integration at the present time, the foundation has been laid for continued promising work leading to comparable numbers on national income and the environment.

C. Transfer of Technologies for Dealing with the Environment

The world has clearly not stood still in dealing with the environment. Much has been learned, particularly within the past generation as more active environmental policies have been instituted. Knowledge gained from this experience has spread around the world. Individual country characteristics undoubtedly have influenced the spread.

In their time series, cross section analysis of 130 countries for the years 1960 through 1992, Coursey and Hartwell (2000) find that time trends are one of the most powerful variables explaining environmental progress. These trends are fixed effects of time indicating that they apply to all countries. They are operative in addition to income and the numerous other independent variables in the analysis. Almost surely, the negative time trends reflect in part discovery of new technical means for reducing

environmental degradation in the form of pollution control devices, energy conservation and, to some extent, switches to less polluting fuels. Many, if not most, of these discoveries have originated in the higher income countries in response to their environmental control policies. The fact that the time trends have extended pervasively throughout the world indicates that, through technology transfer, lower income countries have benefited from these advances.

One of the thirteen indicators analyzed by Coursey and Hartwell is emissions of the chief green house gas, carbon dioxide. Its strong negative time trend is one of the most significant time trends found. This finding suggests that, through technology transfer, much progress has already been made throughout the world in controlling green house gases.

The time trend findings are suggestive of the prominent role that can be played by technology transfer in improving the environment. What facilitates such technology transfer? Instructive in this regard is the performance of "openness" in the Coursey and Hartwell analysis, where openness measures "whether certain kinds of institutional arrangements, rules of law, or regulations are more or less conducive to economic dynamism, technological innovation, and by extension environmental or public health improvement." The findings are that openness has highly significant effects in reducing carbon dioxide emissions and in decreasing another measure related to greenhouse gases, namely, electricity use per capita. While openness reflects several considerations, its relation to technological innovation can occur through several channels. These include greater economic linkages with other countries as a result of trade and foreign investment, as well as generally less inhibited transfer of knowledge.

A study of the opening of the power sector in China to foreign direct investment, as reported by Allen Blackman (1998), throws light on some of the specifics of technology transfer in electricity production affecting environmental damages internal to the country as well as greenhouse gas emissions. Energy efficiency in foreign wholly owned or joint venture power plants in China, as measured by coal consumption per kilowatt hour of electricity generated, is found to be substantially greater than in previously existing plants. The major contributor to the greater energy efficiency is the use of technologically advanced combined-cycle gas turbines and circulating fluidized bed boilers.

It may be noted that these technological transfers reduce greenhouse gas emissions without direct incentives toward these emissions as such. The reductions occur because it is economically efficient to producers to make the reductions. Beyond this type of technology transfer, countries that directly try to control the environment

through environmental measures have an interest in doing so bearing as little cost as possible. Indeed, they may undertake the measures if they have sufficiently low cost and will not undertake them at all if the cost is high. Technology transfer extends to measures aimed directly at reducing emissions, both those that largely affect environmental damages within a country, such as particulates, and those that affect the world at large, such as carbon dioxide. The cost and availability of particular devices and techniques for reducing emissions in countries around the world has undoubtedly fallen because they can be obtained at progressively lower cost through purchase or by copying other countries where they originated.

More analysis is clearly needed of the extent to which technology transfer is reducing environmental control costs, of the extent to which it is likely to occur in the future, and of the means for fostering it. The work by Professor Arayama on environmental control costs in China is an example of needed work in this area.

D. Transfer of Institutional Techniques of Control

In addition to physical technologies considered so far, transfer of knowledge about institutional approaches to control is occurring and can increasingly occur in the future.

Tradeable Emission Rights

The experience of the United States with environmental policies has seen a progression through universal command and controls, where the devices to be used are rigidly decreed from the top, to gradually more flexible approaches, reaching their greatest degree of flexibility in tradeable emissions rights which have been introduced for some pollution sources. With tradeable emission rights, each pollution source is given an emission quantity limit, which it may either exercise or sell to someone else. An advantage is that the firm engaging in the polluting activity can decides how to comply, choosing between an array of alternative control devices or possible output or input changes, in this way helping to find least cost ways of complying which may be substantially less than costs encountered in using a particular uniform control method decreed from the top.

A firm that has to bear high costs of emission control has its profits reduced substantially by the controls, while other things being equal, a firm with low control costs does not have its profits reduced as much by controls. The firm with low control costs would be willing to pay a relatively high price for the right to additional emissions, which would be equal to the net profit on the additional production made possible by the

emissions. The amount per unit of emissions that the firm with low control costs is willing to pay is greater than the profit being made from a unit of emissions by the firm with high control costs. The firm with high control costs will gain from accepting the offer of the low cost firm, making more on the sale of its emission rights than is lost by giving up the production made possible by the emission rights it is giving up. The situation gives an incentive for a trade between the two firms. In the process, production moves to the place where costs of compliance are least, reducing the overall costs of environmental controls.

An advantage of the emission trading feature is that it allows production to migrate to places where control costs are low, thus helping to reduce the costs of an environmental control program. A related advantage of the approach is that allowing flexibility in how to control emissions gives incentives to develop new less costly technologies for compliance, so that control costs will tend to go down over time.

Learning about emissions trading is still taking place. Indeed, emissions trading is still in its infancy. The traditional command and control approach still reigns for many, if not most, pollution sources. Further advances can be expected as trading is extended and more experience is acquired, that will be of use to countries in the future who come to controls later than is now occurring in the highest income countries. Countries coming to controls later will not have to go through as much learning.

Important as is the promise of tradeable emission rights, they should not be the exclusive focus. It is easy to over-estimate the cost reductions they can achieve. This occurs if it is assumed that the gains will fully exploit the differences between high and low control costs sources. Problems of measuring emissions, geographical differences in contributions of sources to pollution damages, specification of time duration, enforcement costs and uncertainties about emissions rights are among the reasons for slippage from theoretical maximum cost savings. See Tietenberg (1985) and Tolley, Wentz, Hinton, and Edwards (1993). Dealing with these problems and trying to minimize them should, and undoubtedly will, receive attention as experience with tradeable emissions rights accumulates in the countries where they are now being introduced. There is promise of extending their use to additional pollutants.

Flexibility Through Local Autonomy

Beyond tradeable emissions rights as an institutional approach, the history of controls has generally featured moves toward greater flexibility, acting to reduce controls where they are less needed and reducing the costs of achieving a given amount of control. In the United Sates, environmental standards are set by the national government, but the

basic approach is to allow each of the 50 states to determine how controls are to be used to achieve the standards. Each state formulates its own State Implementation Plan. The approach allows differences in costs of control measures between states to be taken into account, reducing the costs and onerousness of controls over what they would be if a rigid command and control approach emanated from Washington, DC. Further flexibility is introduced in the distinction between so-called attainment and non-attainment areas. For example, in the case of local ozone affecting health more severely in some areas than others, stricter controls are mandated for the severe areas.

Emission Taxes

Another question is whether to use a price versus quantity approach, that is, whether to price emissions through emission taxes versus establishing quantity controls with setting emissions limits and allowing trade in emissions. The United States has favored the latter, where it is called "cap and trade" and is essentially the classical emissions trading solution. Not all countries will necessarily choose this path. The price or emissions tax approach remains a possible option. Emissions taxes are often called Pigovian taxes because the idea is associated with the nineteenth century British economist A.C. Pigou, who was one of the earliest serious analysts of environmental problems. The approach has its pros and cons. These have not yet been fully aired, partly because practical, as opposed to theoretical, concern with emissions taxes is fairly recent. The pros and cons will take on different weights in different countries.

Emission taxes share with tradeable emission rights the advantages of allowing firms to find least cost ways of complying and of encouraging the development of less costly technologies to be used in complying. Beyond these similarities are differences. An advantage of emissions taxes is that they can be equated directly to pollution damages. The ideal Pigovian tax is one that equates the tax to the marginal pollution damages caused by an extra pound of pollutant. An emission tax can get directly to the link between controls and the benefits of controls, which emission quantity controls do not. It is all too easy to set emissions quantity limits and proceed with them essentially fixed for all time, not questioning what the real reason for them is. An emission tax calls attention to the reason for controls and allows them to vary from place to place and, even more, to vary over time as pollution damages change. A proviso is that emission taxes actually be set to try to approximate damages. At least two problems with doing so may be noted. First, taxes are sometimes favored by activists who see them as ways to punish polluters, leading to attempts to set the taxes too high with a view to a punishment goal rather than a true environmental goal. Second, it can

be difficult to estimate marginal damages accurately. The same can be said of the difficulty of estimating the optimum amount of emission quantity controls, when the quantity approach is followed, and indeed it is probably easier for quantity controls to stray farther from the optimum than it is for emissions taxes to do so. Nevertheless, taxed entities may object to payments based on less than exact estimates of what the taxes are for. Meanwhile, for those who tend to favor environmental controls generally without serious consideration of what they achieve, the divorce of quantity controls from necessity to face up to their benefits is seen as an advantage of quantity controls. Then there are those who see the curbing of any revenues of government as being desirable to limit what they view as wasteful and unneeded government programs of many kinds for which they fear the tax revenues would be used. They fear that pollution tax revenues will increase the coffers of government and lead to undesired expansion of government. Politically, forces from a number of different quarters can become arrayed against emissions taxes. The various considerations affecting the choice between emissions quantity controls and emission taxes may play out differently in different countries, and could lead to the choice of the emissions tax approach in some countries.

E. Effects on Commodity Trade Between Nations

Fears are often expressed that adoption of environmental control policies in a country will raise the costs of producing goods for exports. It is said that countries will have incentives not to adopt environmental improvement policies and will instead "race to the bottom" degrading the environment in order to reap gains to their economies from engaging in exports of goods whose production degrades the environment. Sometimes the argument is that international sanctions are needed to induce all countries to adopt similar environmental standards. A dispassionate view can call this argument into question.

In the first place, the fear can be over-emphasized. The extent to which exports are lost because of domestic environmental policies depends on the importance of trade to a country, the relative importance within trade of products whose cost of production is raised by environmental controls, and the magnitude by which the costs are raised. Giving attention to these magnitudes, much more serious attention is needs to be given to the effects of domestic environmental control policies on international competitiveness and, through this, on a nation imposing the controls. For some countries, a change in competitive advantage will be more important than for others, and this importance may affect the degree to which international competitiveness is a

consideration in choosing the extent to which environmental controls are imposed in the country.

Beyond sheer magnitude of trade affected is the cost involved in shifting to alternative production if some exports are lost. If the country has ready substitutes for the production that is lost through reduced exports, the costs will be less than if, for example, it is a one-product country for whom costs of producing alternative commodities are great.

A fundamental point is that a change in competitive advantage in international trade is only one consequence of an environmental policy. If a cost to a country is involved because of some loss in international advantage, this international trade cost needs to be weighed against the excess of the benefits over the costs of the environmental policies in the country. Countries may quite rationally choose to bear these costs and give up some international trade, or they may not. It depends on the circumstances in each individual country.

An objective view is needed taking account of the total context of a country, considering the phenomenon not as a race to an environmental bottom, but rather as a race to what is best for an individual country in view of all effects.

3. International Environmental Externalities

A. Framework for Considering Long Term Uncertainties and Cross Border Effects

When the effects of one country's actions on other countries occur in the same year as the action and the effects are known with reasonable certainty, the amelioration problem is more complicated than in the absence of the inter-country externalities. But the problem becomes far more complicated when the effects occur only after a long period of time and are highly uncertain. Several environmental problems of international concern involve both of these characteristics of producing inter-country externalities and having effects that are long term and highly uncertain.

Dealing with long-term uncertain effects is a conceptual area with many difficult twists, as reviewed for example by Chichilnisky and Heal (1993). While a full exploration of these twists would take us too far afield, certain key features may be noted that help guide the discussion of world environmental problems. The long-term uncertainties surrounding these problems are of two types: 1) effects of polluting actions on the physical environment, and 2) effects of the changes in the physical environment on valued outcomes.

The degree of uncertainty about both of these effects must be assessed. Next, what action to take in the face of the uncertainties depends in part on 3) whether favorable and unfavorable departures from the most likely outcomes have asymmetric likelihoods and whether effects are irreversible.

For example, a disaster may not be the most likely outcome, but its probability may still be greater than the probability of a favorable outcome that would make things turn out as much better on the good side as the disaster does on the bad side. This situation increases the desirability of taking action now, as a form of insurance.

What action to take also depends on 4) how the future is valued relative to the present. The question here is what discount rate to use over an intergenerational time horizon. Finally, what action to take is influenced by 5) the costs incurred.

The costs of the actions are influenced by the time at which the actions are taken, generally being higher if they are taken immediately than if they are delayed or spread out over a longer period. The lower costs from spreading actions into the future result from such reasons as replacement of capital equipment that will not have to be scrapped if actions are delayed until the equipment wears out. Another cost consideration is development of technologies that through learning by doing and R&D may be lowered over time in response to incentives to take the actions. The development of technologies has favorable positive international effects, if new technologies developed in one country are transferred to other countries.

Once the problem of deciding what actions are best taking account of the foregoing five major considerations, 6) practical considerations arise even if the consequences occur only within a single nation. Distributional and more general political considerations alter the action to be taken and may preclude taking any action at all. The practical considerations are compounded by 7) difficulties of achieving international cooperation to deal with inter-country effects.

The above seven points must be faced in dealing with any environmental problem involving long term uncertain outcomes, including point 7 if international externalities are involved. We will briefly discuss how the seven points apply to ecological problems, including species protection, and then turn to global warming.

B. The World Environment Generally

We are in the midst of unprecedented concern over environmental problems of all kinds. Much of the concern is devoted to raising consciousness, with only rather sporadic efforts to deal concretely with the phenomena of concern. That concern spreads widely is

reflected in the lead article by Rosenblatt in *Time* magazine's 2000 Earth Day edition, which extends concerns widely to rural over urban values and states that "There is no concern these days more important than the environment—not gun control, violence in the media, war, refugees or the curing of fatal diseases. We are not even aware of the full dimensions of the problem. Fewer than two million species of animals, plants and microorganisms have been identified. Yet tens of millions more may exist."

While statements of this kind are useful in calling attention to possible problems, not all will agree with the priorities implied by putting concern over species protection ahead of society's most pressing social problems. Here we have one consequence of uncertainty in evaluating long-term effects. Uncertainty gives room for strongly held subjective beliefs based on little available reliable information, whose interpretation can accentuate, and in many cases lead, to strong differences in opinions.

If we view the quoted statement in light of the seven-point framework in the preceding section, we see that considerations related to the first two points are raised, pertaining to uncertainty of knowledge about effects. We see that there is 1) uncertainty about the state of the environment and human effects on it and 2) uncertainty about the importance of human effects on species preservation. The statement seems to be implying that human activity is having extremely serious and widespread effects on a number of species and ecology in general (point 1), and that the consequences of these effects are of great consequence (point 2). Most will accept the idea that some effects are occurring, but the rhetoric of the statement suggests a worst-case scenario. In the absence of good knowledge of effects, the possibility of a worst case scenario deserves to be a part of the analysis, but it needs to be put into perspective as only one scenario whose likelihood should be considered along with the likelihood of less dire scenarios. Even more important, the reasons why the effects matter deserve serious attention. Surely they matter, but how much? Framing the problem in terms of seeking optimal action under uncertainty taking account of all scenarios and the extent to which they matter—rather than discussing or implying that a worst case scenario with consequences unspecified justifies drastic conservation efforts at any cost—is an important step in arriving at a reasoned response to the phenomena.

Further progress in assessing the state of knowledge is represented by a $4 million assessment of ecosystems undertaken as a U.N. effort carried out jointly by World Bank, the U.N. Development Program, the U.N. Environmental Program and the World Resources Institute. The assessment has been described by Linden (2000). The full findings have been scheduled for publication in September 2000. The assessment covers the earth's five major ecosystems, namely, forests, freshwater systems, coastal

and marine habitats, grasslands, and agricultural lands. The report documents effects of human activity on these ecosystems and finds significant physical effects in the aggregate on all of them, as well as sometimes dramatic stories of effects in individual situations. The report is mainly about what has happened to date. Partly because of the poor state of ability to predict ecology, it does not concentrate on projection. Implications seem to be that ecological systems are being degraded and by inference will continue to be degraded, and that therefore action to preserve them is needed.

Valuable as the report is, it has an alarmist flavor because it concentrates on unfavorable outcomes and does not deal seriously with the importance of consequences of further degradation. For example, the report does not seriously attempt to add up what the economic effects of the degradation are, which would a step moving toward evaluation of actions that might be taken. Though it is thorough in dealing with past ecological effects, the report considers only a part of point 1 of understanding physical effects in the list of seven considerations listed in the preceding section that need to be faced in dealing with environmental problems which feature long term uncertain effects.

One would have to move on to point 2 on the importance of the consequences and then to the remaining points having to do with point 3 on asymmetric probabilities of good and bad scenarios, point 4 on discount rate to be used in deciding how to trade off the present versus the future, point 5 on costs as considered in relation to the benefits which could be done in an expected value sense, point 6 on distributional and political considerations affecting what actions are possible and, finally, point 7 on achieving international cooperation for those ecological effects having important cross-border implications. Since relatively little work has been done on these remaining points for most ecological systems either world-wide or in particular local contexts, the seven-point list helps get a sense of how far we have to go to arrive at a reasoned approach to dealing with most ecological effects.

The U.N. report does consider in a small partial way actions that could be taken. These include suggestions to eliminate water subsidies that encourage wasteful use, eliminating pesticide subsidies offered in some countries that have deleterious ecological side effects and eliminating corruption that permits illegal logging. Note that these suggestions are desirable in their own right on economic efficiency grounds, apart from any ecological effects. They would probably have little effect in the aggregate on the world's ecological systems. It still remains for future work to seriously confront what a truly optimal approach to dealing with ecological effects would be. While there are

international ramifications, it would be premature to consider what form international cooperation might appropriately take.

Moving on to the somewhat narrower topic of species preservation and biodiversity as a goal, while we are still far from being able to adequately deal with all seven points in the list of considerations that need to be faced, we are closer than for the broader ecological considerations just considered. The total number of species is unknown, but counts of many known species exist. The processes of creation and extinction of species have received extensive study. In short, much progress has been made on point 1 on effects of human actions on the physical environment, which in this case are effects on species survival.

Attention is beginning to be given to point 2, which is why diversity matters. Many discussions are in general terms, but they provide a basis for deeper and more systematic investigation. Mention is often made of the role of diversity in science, providing gene pools for development of new or enhanced types of agricultural crops and providing a source of pharmaceuticals. While not quantifiable with certainty, these benefits would be amenable to scenario analysis that quantifies alternative possible outcomes, attaches some kind of likelihood to them and begins to get evidence on how much we should be willing to sacrifice to get the benefits. There have been some efforts along these lines, as reported by Simpson (1997).

Other reasons for considering biodiversity to be desirable are more subjective but still amenable to analysis. These include the satisfaction that people derive from knowing that species exist. They also include valuing the existence of variety for its own sake, and ethical considerations such as desire not to destroy other living things we share with the planet. Weitzman (1993) has demonstrated an ingenious method for choosing which of a related set of species to concentrate preservation on. It relies in part on the degree of endangerment of the individual species as reflected in fairly reasonably quantified estimates of probabilities of extinction. It also relies on the degree of similarity between the related species, as quantified in a distance function he develops for measuring similarity. One will obtain more future diversity by preserving an individually different species than one that is similar to other existing species. The approach is quantitative and promising. It goes beyond the attitude that all preservation is desirable to the harder question of framing intelligent approaches to how much effort to devote to which species.

We still have the issue of what people are willing to give up to achieve diversity. Coursey (1998) conducted contingent valuation studies to elicit people's preferences for preservation of different kinds animal species, and he compared the results with

priorities given in government programs to preserve species, finding essential consistency. The findings throw light on what attributes influence people's preferences for saving particular species. Animal size is found to be important. According to Coursey, "Birds, mammals, reptiles, and clams and mussels receive different treatment than received by other animals" (page 432).

With regard to species preservation, then, promising progress has been made on point 1 on actions that influence degree of preservation and on point 2 on the problems connected with how to value preservation, which is the main way that progress in dealing with species preservation shows advances over efforts to deal with broader ecological problems. There have also been some advances related to point 5 on costs of achieving preservation, as reflected in suggestions that efforts be concentrated on a few major hot spots around the world, that have a particularly large number and variety of species of many kinds. The hot spots are facing degradation due to human actions. In addition to direct efforts, Sedjo (1999) points to the example that increases in forest productivity can result in less market demand to encroach on ecologically important forestlands.

Regarding point 6 on distributional and political considerations, Ando (1998) has analyzed the role of interest groups in specifying which species are to be protected. Preservation is clearly a world concern, as reflected for example in calls for action originating in countries—especially high income countries—to protect rain forests around the world which are found predominantly in lower income countries. This is an international externality leading to point 7 on international cooperation. While formal international cooperation is not taking place, individuals from around the world are contributing through various channels. As an internet example, by clicking on http://www.therainforestsite.com, any individual anywhere in the world with access to the internet can preserve a few square feet of rainforest by prompting commercial sponsors to donate to The Nature Conservancy.

C. Global Warming Issues

Assessing the State of Knowledge

The planet-wide ecological phenomena considered in the preceding section have illustrated how the seven considerations to be faced in dealing with long-term uncertain environmental effects are manifested differently according to the phenomenon being considered. The discussion gives perspective on similarities and differences in the way the considerations are manifested and on differences in degree of progress in dealing

with the problems. Further contrast is provided, as we turn to global warming, where we find that considerably more progress in analysis has been made.

In a more extended discussion, we would also consider experience in international cooperation on acid rain in Europe and on the successful actions involving nations on several continents to control the ozone layer culminating in the Montreal Accord. It had seemed that the ozone layer problem was abated, partly because of the Accord. However, recent news is that depletion is again occurring. Rather than being attributed to CFC and related emissions, the occurrence is now being attributed to the effects of increases in polar temperatures resulting from global warming. The ozone layer problem becomes a part of the global warming problem.

Global warming, resulting largely from carbon dioxide emissions, is the international externality problem that has received most attention. It has been the focus of unprecedented attempts to deal with all seven points arising in attempting to address international externalities.

Much work has been done by physical scientists on point 1 on the possible effects of human actions on global temperatures. A great deal of effort has been devoted to developing carbon sink models and related models of the environmental effects of greenhouse gases. The models continue to be improved, and monitoring is improving as well. Based on accumulating evidence, there seems to be a consensus that the most likely situation is that global temperatures are increasing. There is less agreement but still a substantial body of opinion that the warming is due to the effects of human activity. There is unanimous agreement that enormous uncertainty attaches to prediction of future climate change and its causes. Even the degree of unreliability remains in doubt. For further discussion, see Toman, Firor and Darmstadter (1996) and Kerr (2000).

Point 2 on the effects of global warming on valued outcomes has received much attention. Ambitious modeling efforts have been made combining physical and economic relations to predict and value long-term efforts, as for example in Nordhaus and Yang (1996). At a lower degree of aggregation, studies have noted such effects as seacoast flooding and agricultural changes. In one important series of studies, models of agricultural adjustments to temperature change allowing for shifts and substitutabilities have found both favorable and unfavorable effects of global warming. The net impact is estimated to be much more favorable than in studies not allowing for full agricultural adjustment. Estimates have been made for the United States by Mendelsohn, Nordhaus and Shaw (1994). The work has been extended to Brazil and India by Sanghi (1998).

Regarding point 3 on asymmetric likelihoods, there is much *qualitative* discussion of the possibility of unforeseen highly unfavorable consequences of global warming. Much of the public support for measures to curb greenhouse emissions is motivated by this qualitative discussion. In spite of 200 years of the most remarkable and continued increases in incomes in human history, the fear is expressed that it will all come to an end due to global warming of a very few degrees. Perhaps the greatest neglect in the great attention given to global warming is sparseness of dispassionate *quantitative* analysis of dire consequences. The fact that these consequences appear to have a low probability of occurring in no way justifies this neglect. Irreversibility of dire consequences could be a particular concern. Among a few refreshing exceptions to the neglect of quantitative analysis of dire, unforeseen consequences is the collection of essays on assessing surprises and nonlinearities in greenhouse warming edited by Darmstadter and Toman (1993). Nordhaus' very elaborate modeling of intergenerational effects combining scientific and economic relations formally uses the expected utility approach we will discuss in the following paragraph. Nordhaus' analysis sets the stage conceptually and represents a daring attempt at quantification involving dozens of parameters.

Among the many facets of attempting to control global warming, the specific probabilities and estimated costs of various unfavorable outcomes have tended to be lost sight of. A great deal more attention is needed to these relations. What, specifically are the disaster outcomes in physical terms? They need to be listed and made real in terms that will be conducive to public discourse. What can we say based on scientific opinion about the true likelihood of these events? The great uncertainty surrounding the probabilities needs to be discussed, emphasizing ranges in terms amenable to policy discussion. What specifically are the losses from the disasters? The losses to the maximum extent possible should be expressed in dollar terms to enable deciding how much it is worth to give up other things to avoid the disasters. As a minimum, the losses should be described fully, in physical terms. It is not, for example, just that global warming may foster the spread of certain kinds of diseases or even that there will be a certain number of additional cases. We must proceed to the question of how much it is worth giving up in terms of direct economic output as well as pain, suffering, and psychic effects, to avoid the additional sickness. It is clearly not worth giving up everything. The heart of the global warming question in the end is how much it is worth giving up to avoid the effect, which requires serious attention to valuation-type issues that have scarcely entered public discussion. Still, these considerations have not worked

their way into the mainstream of the large amount of effort being devoted to global warming.

Indications from assessments based on most likely outcomes are that the benefits from attempts to curb greenhouse gas emissions may well not be sufficiently great to rouse the present generation to much action. In view of this type of finding, the lack of more concerted investigation of less expected, but dire, consequences and their incorporation into assessment of greenhouse gas policy strategies takes on more importance.

One reason for the neglect may be the difficulty of becoming quantitative about dire unlikely events, especially when their exact nature is not known. Another reason is analytical complication involved in specifying optimal strategies in the face of small probability high loss outcomes. An expected utility approach will carry one far, if one is willing to bite the bullet at least in a contemplative way, by daring to conjecture some numbers on probabilities and on losses connected with them. With symmetric probabilities of losses and gains of any given amount, and with no risk aversion, maximizing expected utility is achieved by the usual calculus of comparing most likely benefits with most likely costs.

As a simple illustration of the complications raised by asymmetry, consider a situation where there is a symmetric probability distribution for all outcomes, except for one very small probability event that will reduce income to a small fraction of its expected amount. If we consider only most likely outcomes, we will calculate the most likely effects of changes of various increments of changes in global temperature. Suppose the loss in income avoided by the reductions is proportional to the temperature increases avoided. The estimates of losses avoided would be based on usual estimates of the type that have become quite prevalent in global warming analyses of effects on agriculture, flooding and the like. The reduced damages are the expected benefits. The expected benefits would be compared with costs of bringing down temperatures by incremental amounts from levels expected in the absence of efforts to curb greenhouse gases. On this basis, it may be found that the benefits are sufficient to justify bearing costs to bring down global temperature by one half of one degree from what it would otherwise be, which is a large change in terms of usual discussions of reasonable controls to impose. Given the proportionality assumption, the benefits would be $.005Y_0$, or one half of one percent of income Y_0, in the absence of efforts to curb greenhouse gases. The figures assume greater effects on global temperature and greater benefits from reduction than in extant analysis. We are not promoting any particular estimates and are using numbers only for the sake of illustration.

The calculations considered so far for the completely symmetric case are still relevant in the example admitting a disaster event, because the figures considered so far can be used to obtain expectations for the symmetric events in the example. In our example, these events will now account for, say, 98 percent instead of 100 percent of the probability space. Suppose that the disaster event occurring with 2 percent probability will reduce income to only a quarter of its most likely value, or by 75 percent. We will not speculate seriously on the specifics of the disaster, but as a fanciful case, ecological changes might take place that lead to lethal air borne viruses along the lines of AIDS but more serious and with less possible behavioral defenses and less possibility of developing curative remedies. If this event were to occur with certainty, the utility loss from the 75 percent reduction in income would not be 75 percent, because of the diminishing marginal utility of income. The prospect that utility will approach zero at very low levels of income will mean that utility goes down more than in proportion to income. The outcome depends on the shape of the utility function determining degree of risk aversion. Suppose that the disaster event would cause utility to go down to one tenth of its amount in the absence of the disaster or by 90 percent. Then the benefit measured in terms of loss avoided is 90 percent of present income. This compares with one half of one percent income loss avoided if the most likely events occur. Strictly the one half of one percent loss in income would be accompanied by some change in marginal utility which, however, at this small percentage loss is a second order effect whose inclusion adds nothing to the point of the analysis. Suppose further that the disaster can only be avoided if the earth's temperature is prevented from rising 2.5 degrees less than what it would in the absence of greenhouse gas controls, which would be confining global warming to only a half degree more warmth than at present. The expected benefit from a policy confining temperature rise to this amount is the probability weighted average of benefits taking account of both the most likely and the disaster states of the world and is $.98x.005\ Y_0+.02x.90xY_0$, which equals $.01899xY_0$, or approximately 1.9 percent of income.

The expected benefit of 1.9 percent of income taking account of the probability of disaster is almost four times as great as .5 percent of income in the symmetric case that ignored effects of potential disasters on the probability distribution. The example indicates that a much greater level of control would be justified than under assumptions of symmetry. A maximum loss in expected benefits due to disaster occurs when the human race is destroyed giving zero utility if the disaster occurs. Then the loss due to disaster, as a percent of income, is equal to the probability that disaster will occur. Greater losses could be obtained if the disutility of discontinuing the human race is

considered greater than loss in utility from zero income. The example could and should be made more complicated in a number of ways.

The simple example that has been presented suggests two hypotheses. First, a low probability of disaster limits the effect of disasters on expected benefits. Expected benefits will be limited to only a very modest fraction of present income. Second, even so, the benefits from avoided disaster can be substantial and in our example wagged the benefit dog. The case for more systematic attention to disasters in planning global warming strategies is strong.

In the absence of availability of exact numbers, contemplation of orders of magnitude, even with very wide ranges, can give insights on desirable strategies. Even the most extreme assumptions about probabilities and losses associated with them can help set limits and indicate where further refinement efforts are needed. It is to be emphasized that inclusion of asymmetric probability distributions of outcomes is entirely different from sensitivity analyses often carried out to find the effects of varying parameter values from base case assumptions in the symmetric case, which is the usual sensitivity analysis carried out. The procedure being suggested here is to include asymmetries in the base case, which may make the asymmetries the chief determinant of actions. This result will most likely continue to hold as parameters are varied from the base case of the asymmetric model.

Some may object to expressing values of importance to the survival of the human race in dollar terms. One can still go ahead and think the unthinkable about what, in whatever terms one likes to use, one would give up to avoid the disaster. If one says one would give up everything, the implication is that present life is worth nothing compared to future life. One needs to pursue this thinking to decide what to do. The thinking is no more fantastic than needed thinking in objective terms about real possibilities for low probability disaster scenarios.

The discussion here has followed an expected utility approach. Examples of more sophisticated approaches emphasizing irreversibilities, information and stochastic decision theory are found in Anthony Fisher's work as exemplified in Fisher and Krutilla (1995) and Albers, Fisher and Hannemann (1996).

Regarding point 4 on how the future is valued relative to the present, the long time horizons involved in deleterious effects of global warming and strategies to combat it has led to greatly increased concern over what discount rate is appropriate for comparing outcomes at different times. Use of ordinary discount rates for time periods within a generation, based on the opportunity cost of investing funds to earn a going rate of return on capital in an economy, has enormous effects on benefits 50, 100 and

more years in the future. The procedure easily reduces valuation of them to almost negligible amounts. Thinking has come around to acceptance of the idea that effects between generations can appropriately be valued at lower discount rates. A basic concept is that such effects involve primarily valuations of income distribution between generations rather than opportunity costs of investment. Issues are explored in the proceedings of a symposium on discounting and intergenerational equity edited by Portney and Weyant (1999). The symposium emphasizes such phenomena as effects of preference uncertainty, possible use of discount rates varying through time, multiple discount rates and political acceptability.

Breaking the link between discounting and investment opportunities requires abandoning the representative consumer approach to analyzing inter-temporal decisions where the consumer is assumed to live forever. With discrete generations recognized as being different actors, if no one ever passed on anything to their children, the link would easily be broken. More work is needed on the relation of intergenerational discounting to the determinants of bequests, limitations of lending institutions, and the unwillingness of parents and children to borrow and lend to each other on perfect market terms. With income rising between generations, the marginal utility of consumption will be less for future than present generations, suggesting the possibility frequently put forward of a discount rate based on intergenerational difference in marginal utility, leading to a positive intergenerational discount rate determined by the rate of decline of marginal utility of consumption.

In the disaster scenarios discussed above, the marginal utility of income could well be greater for future generations experiencing the disaster. The discount rate would vary with the state of the world being considered and could differ within the same analysis. An egalitarian approach to distribution between generations would weight each person the same no matter what generation he or she lives in. Differences in consumption would lead to differences in utility but each person would be given equal weight. Present value would be the unweighted sum of the utilities of each person regardless of the person's generation. But the weights need not be considered equal. Some people may selfishly not consider the welfare of their children to be an important as their own. Less weight would be given to their children's utility function than their own. More altruistically, the evidence that many parents strive to give their children opportunities and make sacrifices so that their children can be better off than themselves, suggests that in many cases the utility functions of their children are given greater weight than their own. Some people may attach value to the idea of providing

continued progress of the human race, obtaining satisfaction from knowing that future generations will be increasingly better off, and being willing to make sacrifices for it.

Cultural differences may make the appropriate intergenerational discount rate differ among countries. Possibly the long view often attributed to Asian cultures reflects a preference for a lower inter-generational discount rate than western cultures.

Regarding point 5 on costs, a number of issues arise. There are so many sources of greenhouse emissions and so many different technologies and control incentives that might be applied, that agreement does not exist on the magnitude of various levels of controls. There are differences in control costs among countries, which incidentally might be lessened by technology transfers. As mentioned earlier, time frame is important with costs generally being less the longer the time is given for imposing controls. A literature exists on the value of delay to acquire more information and develop new technologies, as for example Peck and Tiesberg (1992).

In the case of global warming, a truly unprecedentedly large amount of attention has been given to point 6 on practical considerations, such as distributional and political considerations and point 7 on difficulties of achieving international cooperation. The attention centers on the 1997 Kyoto Protocol that established greenhouse emission limits, and on the follow-up international conferences that have occurred and are still occurring aimed at implementing the protocol.

Distributional considerations as between higher and lower income nations have been one of the concerns. The setting of quantity goals on emissions rather than a price or tax approach divorces the protocol from serious consideration of benefits. One does not know whether the goals are anywhere near what would optimally be called for. The facts that existing studies show only fairly modest benefits even in the long run and that for most nations the yearly costs exceed the yearly benefits until nearly 2100 act as deterrents to participation. Some have pointed out the advantages of going slower, which would allow the emissions reductions to be achieved at less cost for reasons we have already cited. Allowance for flexibility and experimentation has been recommended.

International emissions rights trading has become central in negotiations. Problems of monitoring, enforcement and encouraging private sector participation have been dealt with. Emissions trading would take the form in part of higher income nations purchasing emissions rights from lower income nations. Interest has emerged in a special form of trading called the Clean Development Mechanism (CDM). Higher income nations would directly finance reductions of greenhouse emissions in lower

income nations. They would gain emission rights, while the lower income nations would receive benefits from improvements in their technologies.

A source of further information on global warming analysis is Resources for the Future, Inc. in Washington, DC, which carries on activity on all of the seven points on global warming and keeps track of progress by others. See Toman (2000).

Regardless of how fully the Kyoto Protocol is implemented, the great interest in global warming serves to call attention to potential problems, leading, as a minimum, to closely watching it in the future and leading to ways of dealing with it which could occur with or without the Protocol. These include experimentation with institutional mechanisms like CDM and development and transfer of technologies that will reduce greenhouse gas emissions, among others.

Policies in Addition to International Protocols

Valuable as is the attention to possibilities for international protocols for dealing with global warming, room is left for many additional activities. They take on special importance in view of the fact that the form and indeed the very future of multi-nation agreements remains in doubt. In closing, we turn to other policies.

The "one n^{th}" principle of incentives to contribute to the cost of a public good applies to the world public good of reducing greenhouse gas emissions. The United States will benefit from its own effort to curb emissions even if it is not the only recipient. Each nation has some incentive to curb emissions even if other nations do not. If the perceived benefits are great enough, they will act on their own. A problem is that perceived benefits apparently do not appear that great. Still, the larger the economy, the more the emissions effects are internalized, so if perceptions change, something could be done unilaterally.

Considerable interest has centered on carbon taxes within a nation as a mechanism for reducing greenhouse gas emissions, taxing the carbon content of fuels used in energy and process heat production as in Poterba (1993). Parry (1997) has considered the interaction of carbon taxes with other taxes, finding that carbon taxes will have magnified effects in the presence of other taxes. The added costs can be avoided by reducing other taxes, so that there is no net revenue increase to the government. The carbon taxes could be used as a way of meeting international commitments to reduce emissions, or they could simply be used unilaterally.

Among the many avenues other than international protocols for achieving reductions in greenhouse gas emission is private foreign investment. Policy changes to reduce impediments to foreign investments leading to greater energy efficiency are to be

encouraged. While private investment is gaining prominence over donor loans, still donor lending exists and could be turned to some extent to fostering technologies that help reduce greenhouse emissions. Countries can take unilateral actions toward other countries to induce them to reduce greenhouse gases. Possible approaches include subsidies to foreign investments that foster reductions in greenhouse gases and, possibly more appealing, less direct approaches such as joint public-private partnerships in overseas energy production investments with public role taking the form of supplying low interest rate loans. Additional possibilities include research and/or tax credits for R&D aimed at developing: greenhouse emission control technologies, increased efficiency in producing energy from fossil fuels and non-fossil technologies that will make non-fossil sources commercially viable. Still further possibilities include cooperation in research and in actions to foster transfer of existing technologies in the foregoing areas that are now more efficient in some countries than others.

The role of improvements in energy efficiency is to be stressed. These provide a vehicle for foreign investment which could be profitable to firms in high technology countries, directly increase incomes in the receiving countries, and have environmental benefits that are both internal to the country (such as particulate reduction) and, at the same time, reduce greenhouse gas emissions. In addition to the key role of electricity production, other policies for increasing efficiency and reducing energy consumption exist that can be the focus of urban policies where most energy production occurs, as considered by Tolley (1998).

Automobiles and trucks as a source of greenhouse gas emissions deserve special consideration in view of the prospective increases in automobile use, particularly in rapidly developing nations. Increased mileage efficiency helps many goals in addition to reducing greenhouse gas emissions.

Possibilities for substitutes for fossil fuels as a source for either point source or transportation energy so far appear limited. No real R&D breakthroughs have yet been made. Though not necessarily to be counted on as a large-scale solution, continued R&D is to be recommended and could be a focus of bilateral international cooperation.

4. Conclusion

We have considered environmental problems internal to nations, as well as those involving international externalities. We have taken a broad view of how to deal with the environment, considering many tools and needs for improvements.

We have called attention to differences among countries in dealing with the environment. We have pointed out reasons why fear of a beggar thy neighbor race to the bottom, which avoids environmental controls that increase production costs of export goods in order to gain competitive advantage in international trade, may be exaggerated. Nations may rationally find that the gains from environmental controls exceed the gains from trade given up and so may choose not to race to the bottom. Whatever choices are made, the result of each nation balancing gains from environmental control against gains from trade tends to maximize world welfare.

With regard to ecological and global warming policies, we have given attention to how to deal with problems in which there are long-term uncertain effects. We have presented a seven-point framework for dealing with the problems and have evaluated progress within the framework, pointing out areas that particularly remain to be addressed.

We pointed out the need to deal more dispassionately and systematically with asymmetric probabilities and irreversibilities. Alarmists have played up disaster possibilities qualitatively, possibly exaggerating their importance. Objective economic analyses on the other hand have concentrated on most likely outcomes and have given relatively little attention to low probability disasters. We have shown that asymmetric disaster events, even if they have a small probability, can have non-negligible effects on optimal actions. The objective economic analyses have tested sensitivity to parameter changes of a base case consisting only of a most likely scenario. This is not the same thing as including a low probability disaster in the base case. Our point is that a base case should include as a minimum a most likely scenario having a high probability and a disaster scenario having a low probability. Optimal curbing of greenhouse gas emissions may be affected a lot or a little by inclusion of the low probability disaster scenario. We are not prejudging the magnitude of the effect. To get insights on the magnitude is the purpose of the analysis.

Among other considerations that stand out, the very process of economic development in a world economy, by increasing linkages between countries, facilitates the transfer of technologies, improving capabilities of nations around the world to deal with environmental problems. Another consideration that stands out is that facilitating foreign investment in energy producing industries will particularly foster transfer of those technologies most important to global warming, as well as contributing to solutions of environmental problems internal to each nation and raising incomes to boot.

At various points, we have emphasized the role of efforts concentrating more directly on technology and international transfer of technology. The discussion has called attention to many possibilities that exist for international exchanges of information, as well as study and design of environmental actions, and cooperation both bilateral and among small groups of countries aimed at sustainability.

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