ECONOMIC INCENTIVES AND THE CONTAINMENT OF GLOBAL WARMING

Wallace E. Oates
University of Maryland
and
Resources for the Future

and

Paul R. Portney
Resources for the Future

INTRODUCTION

It is hard to imagine a policy problem more daunting than global warming. To begin with, we are not sure what we are up against. The problem is shrouded in uncertainties of the most difficult sort. Actions today to reduce emissions of greenhouse gases will have their effects on global climate many years down the road, and the magnitude and timing of these effects are the subject of much dispute. Point estimates of possible changes in temperature, rainfall, and other dimensions of global climate come with large confidence intervals, and the estimates are themselves often based on relatively simplistic extrapolations that do not allow for potentially frightening changes in climate should we set off some nonlinear, self-reinforcing processes of which we are currently unaware. Our imperfect knowledge has led to sharply contrasting policy positions: at one extreme are those suggesting that we wait until we have a firmer understanding of the global warming process before adopting costly preventive measures; at the other are those urging rapid action to forestall some possibly catastrophic outcomes.

But uncertainty is not the only aspect of global warming that makes it so difficult to address in the policy arena. Effective policies to reduce emissions of greenhouse gases are likely to be very expensive. William Nordhaus [1991], for example, estimates that the cost of cutting greenhouse gas emissions in half, *if* done efficiently on a worldwide scale, would be on the order of 1 percent of world output, and could easily cost more. We could find ourselves in the United States spending as much on such policies as we spend on all other efforts to control pollution combined! Broad support for such costly policies will be hard to find.[1]

Moreover, global warming is an international public good. Emissions from one country are essentially a perfect substitute for emissions elsewhere. The issue then is one of total planetary emissions of these gases. And no one country is of sufficient size to "go it alone." It has been estimated, for example, that even if the OECD countries (the source of most of the world's *current* emissions of greenhouse gases) were to eliminate all such discharges over the next 15 years, the effect would be insufficient to obtain a 20 percent reduction in total world emissions by 2005 if the USSR and Eastern Europe only stabilize their emissions at current levels and if the developing countries undertake no measures to control their emissions of these gases. Effective policies to address global warming will have to be international in scope--they must enlist widespread participa-

Eastern Economic Journal, Vol. 18, No. 1, Winter 1992

tion if there is to be any hope of success. We are all-too-familiar with the various public-goods or free-rider problems that put obstacles in the path of such cooperation.

These obstacles might not seem so formidable if we could assume a broad similarity in the positions and views of different countries. But this is emphatically not the case. Global warming is projected to have dramatically different effects on the well-being of populations in different areas. Some countries are likely to be net beneficiaries from global warming, as their present cold climates become milder. Others will suffer from changes that promise agricultural ruin. In addition to differences in projected effects, there are widely differing *perceptions* of the seriousness of the problem. There are important North-South differences here. The push for policies to contain global climate change is coming largely from the wealthier, industrialized countries. Many developing countries, in contrast, have what they see as more pressing issues of economic growth. They are slow, quite understandably, to consider seriously policies that would impede development efforts. It thus appears that the industrialized countries are going to be asked to *assist* the developing countries with programs to control emissions of greenhouse gases if their participation is to be expected. A consensus on global policy is not going to come easily!

Our purpose in this paper is not to present a blueprint for policy, or even to advocate a general policy approach. Indeed, the issues here are so formidable and complicated that we are far from clear in our own minds about the appropriate policy response. But a wide ranging and heated debate is underway. More than this, some countries are taking the lead in introducing policy measures unilaterally as a spur to more widespread participation. Sweden, Finland, and the Netherlands, for example, have already introduced "Green Taxes" to reduce emissions of carbon dioxide.

Our more modest aim is to try to sort out some of the policy issues in a systematic way. We begin in the early sections of the paper by returning to the basic literature in environmental economics and reviewing what we have learned about the properties and use of various policy instruments in a domestic context. With this as background, we then venture into a global setting and explore how we must restructure the analysis to incorporate the additional complexities that "openness" introduces for the design and implementation of effective policy. Our primary objective is to provide an overview of the policy debate that will help both to channel the debate in constructive directions and to suggest a research agenda that poses the questions that we must answer to make sensible policy decisions.[2]

A REVIEW OF POLICY INSTRUMENTS

The literature in environmental economics has drawn a sharp distinction between the so-called "command-and-control" (CAC) approach to environmental regulation and the use of economic incentives, or incentive-based (IB) approaches, to pollution control. Under the CAC rubric are policies where the environmental authority specifies, often in great detail, the regulations for each of a very large number of sources or group of sources. These regulations typically go well beyond establishing discharge limits for individual sources: they often specify the form of pollution-control technology that the source must employ, the pollutant content of the fuels to be used, certain features of the products to be produced, and so on. Such measures are characterized by their inflexibility: they typically allow little latitude for innovative responses on the part of sources.

Incentive-based approaches, in contrast, establish a set of penalties for emissions (or rewards for reductions in discharges) but allow the source wide scope for choosing both the form and magnitude of its response. A central theme in this literature is the large cost-saving potential of IB as compared to CAC. At a theoretical level, it is straightforward to show that various economic-incentive instruments have the capacity to achieve *any* desired level of environmental quality at the least cost to society [Baumol and Oates, 1971]. Moreover, there now exists a substantial body of empirical work that produces estimates of the magnitude of these cost-savings, estimates that range from roughly 50 to over 90 percent relative to CAC outcomes.[3]

In addition to these potentially large savings based on the more efficient deployment of existing control technologies in the short run, the literature emphasizes the longer-term savings that IB approaches provide through continued research and development of new control technologies. In short, environmental economists have established a powerful case for the use of economic incentives to achieve our environmental objectives at much lower cost than the more widely used CAC measures.

From the perspective of the containment of global warming, the cost-saving properties of the IB approach to environmental regulation take on real significance, for (as we noted in the introductory section) it could be a very expensive enterprise. With this in mind, we turn first to a consideration of the two major economic instruments emerging from the literature on environmental regulation: emissions taxes and systems of transferable emissions permits.

Emissions Taxes

Under the tax approach, the environmental authority would levy a fee on each pound of carbon (or other greenhouse gas) discharged, and the source would have a tax liability equal to the fee times the number of pounds of carbon that it chooses to emit. Since carbon emissions are equally damaging irrespective of the particular place where they are emitted, there is no need to tailor the tax rate geographically. A single tax rate applicable to all sources is what is needed. And, if the environmental authority is committed to the attainment of some target level of aggregate reductions in carbon discharges, it can adjust the tax rate until this target is achieved. Cost-minimizing behavior by individual sources will ensure that marginal abatement cost is equated across all sources so that the aggregate reduction is achieved at minimum overall cost. Decentralized decisions in the presence of the tax lead to the least-cost outcome.[4]

Transferable Emission Permits

The basic alternative to the tax approach is a system of transferable emissions permits. In a simplified setting, it is easy to show that the two are, in a fundamental sense, equivalent. Under the tax approach, the environmental authority raises the tax to the level needed to achieve the target level of emissions reductions. Under the permit approach, the agency simply issues permits that, in total, equal the target level of emissions. Sources are then free to buy and sell these permits. In the first case, the authority sets "price" and the sources respond by choosing quantities of emissions; in the second case, the agency sets quantity directly and sources bid the price of permits up to their market-clearing level.

While this basic equivalence exists in principle, these two approaches have some important differences in a policy setting. Three of these differences appear to have disposed regulators in the United States to the permit, rather than the fee, approach. They explain to some extent why regulators in the U.S. have chosen the transferable-permit approach under the Emissions Trading Program rather than a system of effluent charges, and also why the 1991 Clean Air Act Amendments included such a permit system to achieve the mandated reductions in national sulfur-dioxide emissions to address the acid-rain problem.

First, the permit approach gives the environmental regulator direct control over the quantity of emissions. This is a very important advantage since environmental goals are typically formulated in quantity terms, e.g., in terms of specified levels of emissions or pollutant concentrations. The new amendments to the Clean Air Act, for example, call for a 10 million ton (roughly a 50 percent) reduction in annual sulfur emissions by the end of the next decade. A regulator will thus prefer having direct control over the quantity of emissions through the issue of permits, rather than indirect (and uncertain) control through the manipulation of the tax rate. In contrast, and especially in a changing world, a regulator would find it necessary periodically to adjust the rate of an effluent tax to prevent emissions of pollutants from rising with a growing economy. No such problem of adjustment exists under permits in the sense that quantity will remain fixed. The price of permits will simply rise to clear the market in the face of increased demand from new sources wishing to discharge the pollutant.

Second, the permit approach offers a way around some of the political opposition that has blocked the introduction of emissions taxes. It is true, of course, that permits *could* be issued through an auction so that sources would have to pay directly for all their emissions, much as they do under a system of effluent charges. But there is another way to set a permit system in motion. The regulator can simply distribute the permits free of charge to existing sources who can then trade among themselves or sell them to new sources. The granting of a valuable asset will obviously encounter much less resistance from polluting firms than will the levying of a tax. This is, in fact, what has been done under the Emissions Trading Program in the United States for the control of air pollution.

And third, the permit approach promises much more ready acceptance simply on the grounds of familiarity. Regulators have experience and are comfortable with the permit instrument. It seems a much less radical move to make permits transferable than to replace an existing permit system with a scheme of emission taxes.

Transferable permits, for all these reasons, have real appeal. They appear to share all the desirable properties of a system of effluent fees, but to avoid certain administrative and distributive problems that have made fee systems unattractive to environmental regulators. The experience over the past decade with Emissions Trading does, however, raise one potentially serious problem with the permit approach: the operation of permit markets. As we have indicated, it is easy to show in theory that a competitive equilibrium in the permit market has all the nice economic properties, including aggregate cost minimization, that we wish for our system of emissions control. The difficulty is that, in practice, markets for air pollution permits haven't worked as smoothly as envisioned. In particular, these markets have been quite thin, especially on the supply side. Robert Hahn [1989] contends that this has been largely the result of unfortunate restrictions on trading that have clouded definitions of property rights and raised serious uncertainties about the ability to obtain these rights in the marketplace when needed. Even so, the

number of potential participants in these markets is often small with certain large sources in a position to exercise monopolistic price-setting powers [Hahn, 1984]. The thinness of these markets and infrequency of transactions suggest that sources may not observe a clear, well defined price signal to indicate the opportunity cost of their emissions. The absence of such a clear price signal is likely to impair the functioning of the permit system, unlike a regime of emission taxes where the tax itself gives a clear and clean measure of the cost of emissions.

While market thinness has been a real problem under Emissions Trading, it seems unlikely that this would be a significant problem in a market for carbon emissions. The markets for Emissions Trading relate to specific air pollutants in particular areas. The markets are highly localized, and this limits the number of potential participants. In contrast, the market for carbon emissions would presumably be national or international in scope. In such a setting, there should be plenty of active buyers and sellers so that competitive conditions would prevail.

POLICY CHOICE IN AN UNCERTAIN WORLD

The formal equivalence of systems of emission taxes and transferable permits exists in a world of perfect information. We find in the more realistic setting of imperfect knowledge that there are some important asymmetries between these two policy instruments. If we are uncertain about the benefits and costs of emission control, then, in hindsight we will tend to make errors in our choices of values for tax rates or quantities of permits. And, as Martin Weitzman [1974] and others have shown, the errors can be of very different magnitude depending on the policy instrument in use. If we are going to make mistakes (and we surely will), we want these mistakes to involve as little damage as possible.

The Weitzman theorem shows that it is the *relative* steepness of the marginal benefit and marginal abatement cost curves that determines which of the two policy instruments, pollution taxes or a system of transferable permits, promises the larger expected welfare gain. The basic idea is straightforward. Suppose that the marginal benefit curve associated with pollution control is quite steep while marginal abatement costs are relatively constant over the relevant range. This would represent a case where the benefits from changes in environmental quality vary dramatically with changes in pollution levels. Such a case might involve crucial threshold effects, where, if pollutant concentrations exceed some critical level, disastrous consequences take place. Under these circumstances, we want to be sure that we have reliable and precise control over the quantity of polluting waste emissions. It is clear that in a setting of uncertainty concerning true levels of abatement costs and, perhaps, benefits, we would use the tax instrument at our peril. If the environmental authority were to set the tax too low (which could easily happen where we are uncertain of the response of sources to a particular level of the tax rate), then emissions would turn out to be higher than planned. Were they to exceed the critical level, an environmental catastrophe would result. It is best in such instances to employ a permit system under which the regulator has direct control over the quantity of emissions and can avoid the threat associated with too low a tax rate. In Weitzman's words, "Our intuitive feeling, which is confirmed by the formal analysis, is that it doesn't pay to 'fool around' with prices in such situations" [1974, 489].

In contrast, under other circumstances, the marginal damages from additional polluting emissions may not vary significantly. The effects from more emissions will, in

such cases, be fairly constant. There will not exist any serious threshold effects over the relevant range of emissions. However, it may be that the marginal costs of control vary dramatically. There exist, in fact, many careful estimates of the marginal costs of emission control which indicate that, after a relatively constant range, marginal costs begin to increase sharply. In this setting, the more pressing danger from a policy-making perspective is one of excessive costs. If, for example, the regulator were to set too tough a standard for emissions reductions, he might impose enormous costs on sources. The danger in this case is greater under the permit instrument, for if the supply of permits is set too low, excessive control costs will be forced upon sources. Under a fee regime, this danger is avoided, since sources can always opt to pay the fee and avoid the more costly control activities.

Uncertainty and imperfect information thus introduce another set of quite important considerations in the selection of the preferred policy instrument. In which direction is this argument likely to cut in the case of carbon emissions and the problem of global warming? The answer is not entirely clear, but it is worth some thought.

Is the problem of global warming characterized by critical threshold concentrations of greenhouse gases, the violation of which sets off a catastrophic reaction? Most projections of the process of global warming involve a gradual, continuous process, but this is because that is the way in which the problem has been modelled. There are fears that significant *non-linearities* might be present in the processes of global change - that at some point the process of global warming could suddenly become self-reinforcing and take off [Peck and Teisberg, 1991; Chao, 1991]. But, at this point, such fears are no more than conjectures about the range of possible courses that global warming might conceivably take. In truth, we don't know if there are significant threshold effects, and, if there are, we don't know what the critical levels of carbon-dioxide concentrations are. We are thus not in a position to build our policies around avoiding certain critical concentrations of atmospheric greenhouse gases.

On the cost side, there are good reasons to believe that the costs of additional increments of emissions reductions will rise, and probably quite rapidly, after some point. There are certain measures that can be undertaken relatively inexpensively to reduce carbon emissions. After these measures are taken, we will have to turn to more expensive options. *If* existing studies of abatement cost functions are a guide, we should expect these rising costs to set in quite sharply as we attempt to decrease carbon emissions yet more dramatically [Jorgenson and Wilcoxen, forthcoming; Nordhaus, 1991, forthcoming]. This suggests that there is a real danger in setting purely quantitative targets for emissions reductions; such targets could involve enormous costs, much higher than those envisioned at the outset.

This danger could be avoided by selecting a price rather than a quantity instrument, that is, by using emissions taxes instead of a system of transferable permits. Taxes could be set at the level which will call forth those control activities that we can *reasonably afford.* Note that such a policy choice implies uncertainty as to just how much emission reductions we would get. But in return for this uncertainty, we would protect ourselves against the potentially large costs that could be incurred to get some (perhaps quite small) additional reductions in carbon discharges.

For the case of global warming, the uncertainty argument would thus seem to favor the use of emissions taxes over transferable permits. But there are some important qualifications. First, if, as our scientific knowledge concerning global warming expands, we find that there are, in fact, some critical threshold values of carbon concentrations

that we must not violate, then the case would swing back to support the policy instrument that gives us a firmer control over levels of emissions, namely, a permit system. Second, the force of this particular argument for taxes should be seen in the proper perspective. In the use of a permit system, if it were found that the supply of permits had been restricted to excessively stringent levels with unjustifiable cost implications, adjustments could be made over time to increase the supply of permits and alleviate somewhat the cost pressures. However, such adjustments take time, are not always accommodated easily in a regulatory system, and involve other costs of their own. But it is important to recognize that these policy instruments, be they transferable permits or tax rates on carbon emissions, can be adjusted over time to produce more satisfactory results. There is, in short, some room for the correction of "mistakes." But we would do well to try to avoid the larger mistakes at the outset.

POLICY DESIGN IN A GLOBAL SETTING

Although we have examined briefly certain general aspects of the major policy instruments for the control of global carbon emissions, we turn now explicitly to the issue of policy choice and design in a global environment. The existing literature on environmental regulation presumes that there is a central environmental authority that is empowered to introduce and enforce policy measures. In a global setting, things become more complicated. Most important, there typically does not exist an international agency with the authority to introduce and ensure compliance with global policies. Such an agency can only come into being upon the agreement of all the countries involved, and even then its powers are likely to be significantly more circumscribed than those of a national or regional authority.[5]

As we discussed earlier, problems of international coordination loom large for the containment of global warming because of the widely differing positions and perspectives of various countries. The examination of policy alternatives must be seen in this context.

Economic Incentives for the Containment of Global Warming

The discussion in this paper has focused on two primary incentive-based policy measures: emission taxes and transferable permits. In view of their tremendous cost-saving potential, they are strong candidates to play a central role in containing global warming and deserve careful consideration.

The debate over the relative merits of these two policy instruments for the control of carbon emissions is already underway. Several thoughtful studies have addressed the issue and, interestingly, reach quite different conclusions. Darius Gaskins and Bruce Stram [1990], for example, contend that carbon taxes are the more promising approach, while Michael Grubb [1989] and Joshua Epstein and Raj Gupta [1990] opt for systems of transferable permits.

The central issues in this choice do not revolve around the basic economic properties of the two policy instruments, but around their feasibility and effectiveness in the existing international setting. In order to achieve the least-cost allocation of abatement efforts under the tax approach, cost-minimizing sources must all face a *single* tax rate per unit of carbon emissions. This will result in the requisite equating of marginal abatement cost across all sources. This would require, in a strict sense, that every source of carbon emissions on the planet face the *same* tax per unit of emissions.

Designing, instituting, and managing such a regime is a tall order to put it mildly. The problems of determining the rate and administering the tax are formidable. Would a single international agency manage the system and collect the revenues? This would seem highly unlikely: the potential revenues from such taxes are enormous, and as Thomas Schelling has observed [1991], no country is likely to give over control of such a major revenue source to an international agency. Moreover, there are other tricky issues to be resolved: How would tax rates be adjusted over time in response to changing exchange rates? Should the taxes be levied at the point of production or consumption of fossil fuels? Do all countries have the "administrative capacity" to operate such a tax system effectively? Finally, there is the troublesome issue of widespread distortions in existing price structures in many countries, notably the developing countries, such that a single, uniform carbon tax would not, in fact, result in equating the true marginal abatement costs across nations. We will return to these last two issues shortly.

The obstacles to the introduction of a "pure" global emissions tax may well be insurmountable. But this certainly does not mean that the tax approach should be abandoned at this point. There are various compromises that deserve careful study. The use of carbon taxes that are designed and administered by each of many countries (perhaps with some coordination) has real appeal. While such a system admittedly would forgo some of the cost-saving potential of the tax approach in terms of intercountry pollution "quotas," it would promote a cost-effective pattern of abatement within individual countries and would provide a powerful incentive for R&D efforts to find new ways to reduce carbon discharges. As James Poterba [1991] finds, such taxes are likely to be regressive in their pattern of incidence, but this regressivity can, if desired, be offset by adjustments in the rest of the tax system and/or with transfers. We need to investigate carefully the ways in which such taxes could be introduced on a national scale with, perhaps, some degree of coordination across countries. Such studies are already underway in many countries, e.g., for the United States, the study by the Congressional Budget Office [1990].

One potential peril in the design of such tax measures and their management concerns their enormous revenue potential. Not only can they be a source of considerable macroeconomic disturbance [Jorgenson and Wilcoxen, 1990; Poterba, 1991], but it will be easy to lose sight of their primary objective of environmental regulation: as they become a significant element in the revenue system, there will be pressures to use them for other purposes such as reducing the federal deficit. Interestingly, it is unclear whether an attempt to maximize revenues from this source would involve higher or lower tax rates than would be appropriate for purposes of environmental management. This depends on the elasticity of the carbon tax base [Oates, 1991]. But what is clear is that the attempt to achieve two objectives - regulating carbon emissions and raising additional tax revenues - with a single policy instrument can pose conflicts. The revenues from carbon taxes can provide a welcome addition to the public treasury, one that can be used to replace revenues from other distorting taxes that impair the functioning of the economy [Terkla, 1984]. But these revenues are best regarded as a kind of *bonus,* a serendipitous inflow into the treasury, whose level is determined independently by the need to control emissions of greenhouse gases.[6]

The use of transferable permits for the containment of global warming must also involve compromises relative to a *pure* system that would have sources around the globe trading entitlements to carbon emissions in a single international market. There are various ways that this could work [Grubb, 1989; Epstein and Gupta, 1990]. At one level,

permits could be used basically as a mechanism to allocate entitlements across countries with trading limited to transactions between national governments. Countries which found abatement (at the margin) especially difficult and expensive could then negotiate for purchases of permits from other countries for whom abatement efforts come more easily and cheaply. Within each country, national authorities would institute systems to keep carbon emissions within the national allowance. Such national systems could make use of transferable permits but need not.

Instituting a transferable permit system requires agreement on an initial allocation of permits among countries, potentially a very contentious matter. Grubb [1989] and Epstein and Gupta [1990] suggest that some kind of per-capita allocation (perhaps modified by population age structure) could serve as a reasonable and acceptable basis for this allocation. With the initial allocation in place, countries could proceed with trading.

Epstein and Gupta regard the explicit quantity restriction associated with a permit system as a compelling advantage over a tax regime; taxes, they fear, could have little effect on levels of emissions, resulting in "toying with basic parameters of a complex system whose sensitivities are not fully understood" [1991, 17]. While this is a danger, we remain uneasy with the potential cost "errors" under a permit system. Jorgenson and Wilcoxen [forthcoming], along with others, find that, after some point, marginal abatement costs for controlling carbon emissions rise quite rapidly. This makes the selection of a particular quantity target a delicate matter. Too stringent a target could prove very costly and disruptive.

Gaskins and Stram [1990] raise important issues related to the visibility and flexibility of the regulatory instrument. They contend that the tax approach has important advantages on these counts. Once permits are issued and traded, they argue, the cost of curtailing carbon emissions becomes hidden in product prices and is less apparent to the public and its representatives than a tax that is paid over and over again. Moreover, entitlements tend to create vested interests, making adjustments in the supply of permits difficult to bring about. For example, if after some time we learned that the atmosphere could accommodate significantly more greenhouse gases than earlier had been believed, we would want to increase the number of permits. But existing permit holders (like those owning taxi medallions in New York City) would object since this would devalue their permits for which they may have paid a sizeable sum. For these reasons, Gaskins and Stram contend that "political-economy" considerations favor the tax regime. While there may well be some force to their contention, we point out that it is not always that easy to change tax rates either!

Abatement Versus Adaptation

The literature in environmental economics demonstrates that the optimal response to a "detrimental externality" is a unit tax on the source of the externality, equal to marginal social damage, accompanied by *no* payments (compensation) to victims of the damaging activity [Baumol and Oates, 1988, chs. 3 and 4]. The latter part of this prescription addresses the need for appropriate levels of *defensive activities.* Victims of pollution often have at their disposal various kinds of defensive measures through which they can alleviate to some degree the damages they suffer. They may, for example, be able to locate away from the sources of the pollution or alter their daily pattern of activities to avoid harm. If, however, victims are compensated for whatever damages

they absorb, they will not have the proper inducement to engage in such defensive activities. Compensation of victims thus results in distortions: too little in the way of defensive activities by victims and too much in the way of abatement by sources. This analysis, we stress, assumes that all defensive activities are private in nature. They provide benefits only to the individual that undertakes them. In such a setting the damages that victims experience provide precisely the correct incentive to engage in defensive activities. No additional incentives in the form of payments or taxes are appropriate.

It is important in finding the least-cost response to environmental externalities to get the appropriate balance of abatement and defensive efforts. In the context of global warming, these defensive efforts, or "adaptation" as they are called in the emerging literature, are likely to play an important role in addressing the global warming problem [Rosenberg et al., 1989]. Many forms of adaptive response are private in nature, involving relocation decisions or changing patterns of tillage, irrigation, and crop selection. For them, we can presumably rely on individual decisions over time to make the appropriate adjustments.

But there are potential forms of adaptation to global warming that do not involve purely private benefits. To cite only a few:

1) The construction of sea walls to prevent inundation with rising levels of the sea;
2) The protection of natural ecosystems;
3) Agricultural research to identify, for instance, new plant cultivars suitable for expected alterations in climate.

Adaptation to global warming thus involves some important activities that have dimensions of *publicness* and will presumably require public programs. It is important that such forms of adaptation be identified and provided for.

Administrative Capacity and Distorted Prices

The cost-saving properties of the two IB policy measures considered above depend in fundamental ways on the presence of two conditions: the "administrative capacity" of governments to introduce and manage these policy measures effectively, and the operation of reasonably competitive markets that are not characterized by serious price distortions. If the latter condition is not satisfied, then existing prices obviously will not provide accurate signals to users of the true opportunity costs of resources.

While the assumption of *roughly* efficient markets may be a reasonable one for the advanced industrialized economies, it is far from clear that it is legitimate for many of the developing countries. Quite pervasive and sizeable price distortions appear to exist in many developing economies, and they are frequently present in the energy sector where prices are often maintained at well below free-market levels. Kosmo [1989], for example, cites petroleum and natural gas prices in Egypt of, respectively, one-third and from ten to twenty percent of world levels. In China, a two-tiered structure of prices for coal exists with "in-plan" coal in Beijing selling for about $50 per ton in the late 1980s, while the "out-plan," or negotiated, coal price was over double this figure [Wang, 1988]. More generally, the developing countries tend to make much wider use of excise taxes and subsidies that distort prices across broad classes of commodities.

Even if price distortions were not such a widespread phenomenon, it is not clear that the administrative capacity always exists in the developing countries to operate a system

of effluent taxes or transferable permits. Such policy regimes require a substantial level of regulatory sophistication and experience. (Of course, most forms of CAC regulation also require some administrative sophistication for both their design and effective enforcement.) Our concern here is that certain *institutional* realities must be faced up to in the design of global policy measures. And the problems of price distortions and administrative capacity are important ones that will require careful study in the analysis of the international response to global warming.[7]

Recognition of these kinds of constraints on feasible policy suggests a somewhat broader frame of reference in terms of the most effective *mix* of policies on a global scale. This is admittedly a formidable problem of the "second-best." But it may well be that the most effective global policy strategy will be one that involves the introduction of some fairly sophisticated IB policies in the industrialized countries alongside the use of various more *blunt* measures in some of the developing countries.

This leads to one further observation. We noted in the introduction the sharp distinction that the environmental economics literature makes between economic incentives and CAC policies. While useful, perhaps, for certain pedagogical purposes, this lumping of all "other" policies into the CAC class is quite misleading. In fact, it is sometimes unclear just where this dividing line is. A program under which the regulator specifies precisely what treatment technology is to be used clearly falls in the CAC class. But what about a program under which the regulator assigns an overall emissions limitation, but leaves the source to find the most effective method of compliance? Such flexibility clearly allows some scope for cost-saving efforts on the part of the polluter. Moreover, some studies have found that cost-sensitive CAC measures can stack up reasonably well relative to their IB counterparts [Oates, Portney, and McGartland, 1989].

This is not to suggest that IB policies will not have a central role to play in an efficient system for the containment of global warming. They surely will. But at the same time, we must be sensitive to the wide array of potential policy instruments and the existing constraints on their use if we are to fashion a policy *mix* that addresses the problem in an effective way.

On the Need for Global Participation

We stressed in the introduction the need for widespread participation in global efforts to reduce emissions of greenhouse gases. This reflects largely the simple fact that in the future no country (or even select group of countries) will account for the vast bulk of carbon emissions. Nations in all parts of the world and in varying stages of development must become partners in this effort if we are to have any realistic hope of effectively controlling emissions of these gases.

Grubb [1989] and others have argued that in the absence of an effective global agreement, much can still be done through regional or select group (e.g., OECD) agreements, or even through unilateral action. Such efforts can provide leadership, create a co-operative environment conducive to broader participation at a later time, and set in motion efforts to develop substitute technologies. While there is surely some merit to these arguments, it is important to recognize their limitations. One especially serious issue arises. Suppose, for example, that the OECD countries were to form an effective alliance to reduce carbon emissions. One result of such an effort is likely to be a dramatic decrease in the world demand for fossil fuels with a consequent fall in fuel prices. This

fall in price would *encourage* other countries to increase their consumption of fossil fuels. To some extent, then, the efforts of the co-operating countries would be offset by natural market responses elsewhere. The extent of this "displacement" would depend on the relative price elasticities of demand, but it could be a substantial offsetting effect. This is a troublesome obstacle to effective action by a limited number of countries. And how to avoid it is not entirely clear. Perhaps the co-operating countries could use some of the revenues from their emission taxes to bolster the demand for fossil fuels and simply build up reserves of these fuels. This issue requires further attention [Bohm, 1991].

A COMPREHENSIVE APPROACH TO REGULATION OF GREENHOUSE GASES

The discussion throughout the paper has run primarily in terms of the control of carbon emissions. Carbon dioxide, however, is but one, albeit the most important, of several greenhouse gases. Others include chlorofluorocarbons (CFCs), methane, nitrous oxides, and ozone. The control of carbon dioxide will likely be the centerpiece of any policy to regulate greenhouse gas emissions, but the other gases are far from insignificant. As Richard Stewart and Jonathan Wiener [1990] emphasize, a comprehensive program to address global warming must incorporate the whole class of greenhouse gases.

The extension of the basic IB instruments to encompass these other gases does not, *in principle*, create any serious problems [Morgenstern, 1991]. The contribution to global warming of the different greenhouse gases varies quite dramatically. Methane, for example, is estimated to have twenty-one times the "radiative-forcing" effect (i.e., capacity to trap heat in the atmosphere) of an equivalent amount of carbon dioxide. The Intergovernmental Panel on Climate Change [1990] has estimated the global warming potential for numerous gases, and from these estimates we can express the warming effects of different gases in terms of a common metric: "carbon equivalents."

Systems of effluent taxes or transferable permits can address this issue by tailoring tax rates or trading ratios to reflect the carbon equivalents of the various gases. The tax, for instance, per unit of methane emissions would, under this approach, be twenty-one times that on discharges of carbon dioxide. This is admittedly a further complication in such systems, but it will be important to build these distinctions into any IB policy measures.

To conclude, we return to the theme of identifying regulatory instruments that can achieve our global environmental objectives in a cost-effective way. To this end, we should look to policies that allow wide flexibility on the part of sources to seek out and adopt the most inexpensive means of reducing their greenhouse gas emissions. Incentive-based measures are obviously strong candidates, and ways of structuring them to function effectively in the global arena rank high on the policy-research agenda. But where we find it necessary to turn to the command-and-control class of policy instruments, it is essential to keep this theme before us. As we emphasized, there exists a wide range of CAC approaches to regulation, and some are much superior to others. In particular, regulatory approaches that involve government officials specifying the precise ways in which sources are to comply with emissions limitations are likely to be extremely inefficient. They provide no flexibility in the short run to adopt less expensive means of compliance and little incentive over the longer haul for research and development activities for new and less costly technologies. A sensible mix of policies should allow

wide flexibility in the response of sources and provide incentives for the development of improved methods for controlling emissions.

We are grateful to Lee Friedman, James Kahn, and Jonathan Wiener for helpful comments on earlier drafts of the paper and to the National Science Foundation for its support of this work.

NOTES

1. There is, incidentally, some controversy over the likely costs of reducing emissions of greenhouse gases. Some studies find that the costs cited above are greatly exaggerated. For an excellent survey and assessment of these cost studies, see Joel Darmstadter [1991].
2. For a useful treatment of greenhouse warming, including both a description of the process and its effects and analyses of the various economic aspects of the problem, see Rosenberg et al. [1989].
3. See Tietenberg [1985, ch. 3] for a useful survey of these empirical studies.
4. The literature has also explored unit subsidies for emissions reductions as an alternative to taxes. While such subsidies can establish the same incentives for pollution control by individual sources as unit taxes, they have the serious problem of encouraging entry into polluting industries by making these industries more, rather than less, profitable. Subsidies thus distort the entry-exit decisions of polluting firms. On this, see, for example, Baumol and Oates [1988, ch. 14].
5. The United Nations occasionally tries to play this role, and did so with some success for the Protocol leading to the phasing-out of CFC use among the signatories. Likewise, the European Community has some powers to enforce environmental and other agreements in the member countries. But the many-nation character of these programs makes them much more complex and delicate than national measures for environmental management.
6. In principle, under an optimal-taxation approach, we can determine a second-best tax rate on waste emissions that optimizes the tradeoff between environmental gains and the gains from an improved tax system that places reduced reliance on distorting taxes [Lee and Misiolek, 1986]. While such a result may be unimpeachable in principle, it makes enormous demands in terms of information *and* in terms of institutions. It would require a public decision-maker who is not only informed but is in a position to transcend competing environmental and revenue needs and reach the proper compromise. The dangers here, since there are many other tax bases available, would seem to lie largely on the side of reduced effectiveness in environmental regulation. For this reason, it seems to us that the determination and management of taxes on polluting waste emissions should fall under the aegis of an environmental regulator, rather than the tax authority [Oates, 1991].
7. We do not mean to imply that regulatory structures for environmental management are absent in developing countries. China, for example, has an extensive and fairly sophisticated system for administering its environmental laws (even including economic incentive mechanisms).

REFERENCES

Baumol, W. J., and Oates W. E. The Use of Standards and Prices for Protection of the Environment. *Swedish Journal of Economics*, March 1971, 42-54.

_____. *The Theory of Environmental Policy*, 2nd ed. Cambridge: Cambridge University Press, 1988.

Bohm, P. Incomplete International Cooperation to Reduce CO_2 Emissions: Alternative Policies, unpublished paper, 1991.

Chao, H. Managing the Risk of Global Climate Change. Electric Power Research Institute, unpublished paper, 1991.

Darmstadter, J. The Economic Cost of CO_2 Mitigation: A Review of Estimates for Selected World Regions. *Resources for the Future Discussion Paper ENR91-06*, 1991.

Epstein, J. M., and Gupta, R. Controlling the Greenhouse Effect:Five Global Regimes Compared. *Brookings Occasional Papers.* Washington: The Brookings Institution, 1990.

Gaskins, D., and Stram, B. A Meta Plan: A Policy Response to Global Warming. Vienna Workshop for Cooperative Research on Climate Change, unpublished paper, 1990.

Grubb, M. *The Greenhouse Effect: Negotiating Targets.* London: Royal Institute of International Affairs, 1989.

Hahn, R. Market Power and Transferable Property Rights. *Quarterly Journal of Economics*, November 1984, 753-65.

_____. Economic Prescriptions for Environmental Problems: How the Patient Followed the Doctor's Orders. *Journal of Economic Perspectives*, Spring 1989, 95-114.

Intergovernmental Panel on Climate Change. *Climate Change: The IPCC Scientific Assessment.* Cambridge: Cambridge University Press, 1990.

Jorgenson, D. W., and Wilcoxen, P. J. Global Change, Energy Prices, and U.S. Economic Growth. *Harvard Institute of Economic Research Discussion Paper No. 1511*, August 1990.

_____. Reducing U.S. Carbon Dioxide Emissions: The Cost of Different Goals, in *Advances in the Economics of Energy and Natural Resources*, edited by J. R. Moroney. Greenwich, CT: JAI Press, forthcoming.

Kosmo, M. Economic Incentives and Industrial Pollution in Developing Countries. *Policy and Research Division Working Paper #1989-2,* Washington: Environmental Department, The World Bank, 1989.

Lee, D. R., and Misiolek, W. S. Substituting Pollution Taxation for General Taxation: Some Implications for Efficiency in Pollution Taxation. *Journal of Environmental Economics and Management*, December 1986, 338-47.

Morgenstern, R. D. Towards a Comprehensive Approach to Global Climate Change Mitigation. *American Economic Review*, May 1991, 140-45.

Nordhaus, W. D. A Sketch of the Economics of the Greenhouse Effect. *American Economic Review*, May 1991, 146-50.

_____. The Cost of Slowing Climate Change: A Survey. *The Energy Journal,* forthcoming.

Oates, W. E. Pollution Charges as a Source of Public Revenues, unpublished paper, 1991.

Oates, W.E., Portney, P. R., and McGartland, A. M. The *Net* Benefits of Incentive-Based Regulation: A Case Study of Environmental Standard Setting. *American Economic Review*, December 1989, 1233-42.

Peck, S., and Teisberg, T. Exploring Optimal Intertemporal CO_2 Control Paths. Electric Power Research Institute, unpublished paper, 1991.

Poterba, J. M. Tax Policy to Combat Global Warming: On Designing a Carbon Tax. *National Bureau of Economic Research Working Paper No. 3649,* 1991.

Rosenberg, N. J., et al., eds. *Greenhouse Warming: Abatement and Adaptation.* Washington: Resources for the Future, 1989.

Schelling, T. C. Economic Responses to Global Warming: Prospects for Comparative Approaches, in *Global Warming: Economic Policy Responses,* edited by R. Dornbusch and J. Poterba. Cambridge: MIT Press, 1991, 197-221.

Stewart, R. B., and Wiener, J. B. A Comprehensive Approach to Climate Change. *The American Enterprise*, November/December 1990, 75-80.

Tietenberg, T. H. *Emissions Trading: An Exercise in Reforming Pollution Policy.* Washington: Resources for the Future, 1985.

Terkla, D. The Efficiency Value of Effluent Tax Revenues. *Journal of Environmental Economics and Management*, June 1984, 107-23.

U.S. Congressional Budget Office. *Carbon Charges as a Response to Global Warming: The Effects of Taxing Fossil Fuels.* Washington: Congressional Budget Office, 1990.

Wang, Y. Coal Prices in Beijing, unpublished paper. Washington: The World Bank, 1988.

Weitzman, M. Prices vs. Quantities. *Review of Economic Studies*, October 1974, 477-91.