6 Trading in Greenhouse Permits: A Critical Examination of Design and Implementation Issues

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CONTROL OF GREENHOUSE GAS EMISSIONS

The desirability of taking immediate action to curb greenhouse gas emissions may be open to question, but it is important that the design and evaluation of policy options for addressing potential global change issues begin.1 Negotiators of future global warming treaties may examine a variety of international and domestic instruments to reduce greenhouse gas emissions. Among the approaches most likely to be considered are those that rely on command-and-control policies, which prescribe performance levels or technologies for specific sources, and those that use market-based instruments to provide economic incentives for achieving stated goals and standards. Two market-based instruments that are likely to receive great attention are tradeable property rights and taxes.

This chapter explores the possibility of nations using some form of tradeable property-rights approach to limit the level of greenhouse gases in the atmosphere. Although trading in greenhouse gas reduction permits has the potential to achieve a given level of reduction in emissions at least cost, there are many practical problems in design and implementation. This chapter frames these issues by examining the strengths and limitations of trading as a means of achieving a desired emissions limit for greenhouse gases both nationally and internationally. Thus, the central purpose of the chapter is to illuminate major design and implementation

From *Shaping National Responses to Climate Change*, Henry Lee, Ed., Harvard Global Environmental Policy Project, Island Press, 1995

issues, not to advocate any particular type of permit system or even the use of such systems in general.

Tradeable permits could be used collectively by the community of nations, or individual countries could adopt permit-trading schemes to allocate control responsibilities domestically.[2] Trading could thus be used either on its own or in conjunction with some of the other policy mechanisms considered in this volume, including carbon charges. One issue that is critical for the success of any policy is the problem of how to allocate control responsibilities in a way that will allow negotiating parties to reach agreement. In this regard, we investigate how policies for trading in greenhouse gas permits can facilitate, or hinder, the likelihood that countries can reach agreement.[3]

In the next section, we propose a set of criteria by which alternative environmental policy mechanisms can be assessed. Then, following a brief review of conventional command-and-control regulatory approaches to environmental protection, we introduce the concept of incentive-based policy mechanisms and present the basic theory of tradeable permit systems. Next, we provide a review of actual experiences with these systems in the United States for air pollution control. We assess tradeable permits as a potential mechanism for addressing global climate change, describe some necessary conditions for successful permit markets, and highlight some crucial design issues that must be faced if a workable system is to be developed. Finally, we compare tradeable permit and charge mechanisms for the control of global climate change and offer some conclusions concerning the practical application of tradeable permits to the climate change issue.

To assess whether the trading of greenhouse gas reduction permits is likely to result in real advantages over alternative approaches, we consider the following criteria.[4]

- Will the policy achieve stated environmental goals?
- Will the policy approach be cost-effective? That is, will it meet environmental goals in the least costly manner?
- Will the strategy provide governmental agencies and private decisionmakers with information needed to implement the policy?
- Will monitoring and enforcement costs be reasonable?
- Will the policy be flexible in the face of changes in tastes, technology, resource use, and information?
- Will the policy give private industry incentives to develop new environment-saving technologies, or will it encourage firms to retain existing inefficient plants?

- Will the effects of the policy be equitably distributed?
- Will the purpose and nature of the policy be understandable to the general public?
- Will the policy be feasible? That is, can it be enacted, and can it be implemented by appropriate international agencies?

BASICS OF THE SYSTEM

As international deliberations consider various actions related to the threat of global climate change, policymakers will be faced with two tasks: the choice of the overall goal and the selection of a means, or instrument, to achieve that goal.[5] The two tasks are often linked in practice. For example, the goal might be to freeze carbon dioxide emissions levels at 1990 levels by the year 2000. The instrument used to achieve this goal could be tradeable permits, taxes, subsidies, conventional regulatory approaches, or some combination of these policies. Thus, market-based environmental policies are a means for achieving policy goals. Such policies are largely neutral with respect to the goal selected, though they can affect whether a particular goal is chosen.[6] Before investigating market incentives in general and tradeable permits in particular, we find it useful to review the regulatory approach most frequently used—that is, command-and-control regulations.[7]

CONVENTIONAL COMMAND-AND-CONTROL REGULATORY APPROACHES

A fundamental principle behind command-and-control regulations is that all firms should bear the same share of the pollution control burden, regardless of the relative costs of doing so. This regulation is typically implemented through the creation of uniform standards for firms, the two most prevalent of which are technology-based standards and performance standards. Technology-based standards identify particular equipment that must be used to comply with a regulation.[8] For example, electric utilities may be required to use electrostatic precipitators to remove particulates, or all firms in an industry must use the "best available technology" to control water pollution. Performance standards, on the other hand, set a uniform control target for each firm, while allowing some latitude in how the target is met. Such a standard, for instance, might set the maximum allowable units of pollutant per time period but be neutral with respect to the means by which a firm reaches this goal.

In contrast, by requiring firms to meet a specific standard, command-and-control regulations may result in unduly expensive means of a nation's achieving an environmental target.[9] The reason is simple: the costs of controlling pollutant emissions can vary greatly among and even within firms. Technology appropriate in one situation may not be appropriate in another. Indeed, the cost of controlling a given pollutant may vary by a factor of one hundred or more among sources, depending on the age and location of plants and the available technologies.[10]

A second shortcoming of this regulatory approach is that it tends to freeze the development of technologies that could provide greater levels of control. Because little or no financial incentives exist for firms to exceed their control targets, a bias exists against experimentation with new technologies (explicitly in the case of technology standards and implicitly in the case of performance standards). In fact, the reward to a firm for developing a new technology may be that it will subsequently be held to a higher standard of performance. Hence, dollars that could be invested in technology development are diverted to legal battles over what are or are not acceptable technologies and standards of performance.[11]

In terms of the performance criteria for good environmental policy presented above, command-and-control regulations can be designed to perform well on most of the criteria, except for cost-effectiveness and the incentives to develop new technology. Moreover, while it may be possible for command-and-control approaches to meet some stated environmental goals, the use of these regulatory approaches may slow the general rate of environmental progress.

Incentive-Based Policies

The primary motivation behind incentive-based policies is to save resources by encouraging more economical and effective use of scarce private and public funds. If it is possible to save money by lowering the costs of achieving an environmental goal, this action leaves extra funds that can be spent on other activities. Economists tend to support the use of these policies because they allow citizens and firms to satisfy more of their individual and social needs by enhancing the efficiency with which they use resources.

Incentive-based policy instruments save resources by equalizing the incremental amount that firms spend to reduce pollution—that is, their marginal costs of reducing pollution—as an alternative to equalizing the amount that firms pollute.[12] These instruments achieve the same aggregate level of control as a uniform standard, but with the control burden shared differently among firms. Firms that can control pollution at lower cost control their pollution more (emit less); those that have relatively high costs to control pollution control their pollution less (emit more). This situation results in a cost-effective outcome in which fewer economic resources in total are used to achieve the same level of pollution control.

Theoretically, the government could achieve such a cost-effective solution by setting different standards for each individual firm in a way that equated all firms' marginal costs of control. To do this, however, the government would need detailed information about the costs faced by each firm—information that the government clearly lacks and that it could obtain only at great cost, if at all. Fortunately, there is a way out of this impasse. Economic-incentive systems have the potential to produce the least costly allocation of achieving a given level of pollution control. By linking environmental performance with financial performance, these systems create incentives for firms to find cleaner production technologies.

While the precise mechanics of economic-incentive systems vary by type, they share a simple underlying principle. By making it costly for firms to pollute, the government makes it in the interests of firms and individuals to prevent pollution. The central role of government is to establish the incentives so that costs incurred by firms are sufficient to achieve the desired level of aggregate pollution control and (as in any regulatory system) to monitor compliance and enforce the law. Thus, economic-incentive systems do not represent a laissez-faire, free market approach. Instead, these systems recognize that market failures are typically at the core of pollution problems: the activities of firms and consumers have consequences for society (such as pollution) that are not adequately reflected in their own decision making. At the same time, incentive-based regulations reject the notion that such market failures justify scrapping the market system and dictating firm or consumer behavior. Instead, they provide freedom of choice to businesses and consumers to determine the best way to reduce pollution. By ensuring that environmental costs are factored into decision making, incentive-based regulations harness rather than impede market forces and channel them to achieve environmental goals at the lowest possible cost to society at large. In the language of economists, these systems internalize the externalities.

Most incentive-based approaches fall within five major categories: pollution charges, tradeable permits, deposit-refund systems, market-barrier reductions, and government-subsidy elimination. The first two categories—charges and tradeable permits—have received substantial attention as possible means of controlling global climate change.

With the charge approach, producers of pollution are charged a fee or tax on the amount of pollution they generate. This approach works on the assumption that producers will reduce pollution up to the point at which their marginal costs of control are equal to the pollution tax rate. As a result, firms will control to different degrees, with high-cost controllers controlling less and low-cost controllers controlling more. An effective charge system can thus minimize the aggregate costs of pollution control and give firms incentives to develop and adopt newer and better pollution control technologies.[13] However, pollution charge systems that are linked to emissions can impose significant monitoring burdens on governments.[14] Also, it is difficult to estimate in advance how large a charge will be required to obtain a desired level of pollution reduction, and it may be difficult, in a political context, to establish charges large enough to achieve given environmental objectives.[15]

In terms of the performance criteria for good environmental policy specified above, charges can be designed to perform well on most of the criteria, except for meeting specific environmental goals and, possibly, for monitoring and enforcement costs. In general, monitoring and enforcement costs may increase because firms can be expected to introduce a wide range of existing and new technologies to reduce pollution.

The Basic Theory of Tradeable Permits

Unlike a charge system, a system of tradeable permits allows the government to specify in advance an overall level of pollution that will be tolerated. This total quantity is allotted in the form of permits among polluting firms.[16] Under the most common type of system—that of emissions permits—firms that keep their emissions below the allotted levels may sell or lease their surplus allotments to other firms or use them to offset excess emissions in other parts of their own facilities. In this way, tradeable permit systems tend to minimize the total societal costs of achieving a given level of pollution control.

There are many points in the product cycle at which pollution can be regulated, whether with tradeable permit systems or otherwise. The simplest systems to organize and monitor (whether in the case of tradeable permits or other instruments) may focus on inputs to the production process, such as the lead content of gasoline or the carbon content of fossil fuels.[17] One step toward greater sophistication, but also substantially greater administrative complexity and transaction costs, is represented by emissions permits, which are tied to the quantity of pollutants actually emitted. Further in the same direction are ambient or concentration permits, which are tied to the effects that individual sources have on pollutant concentrations at specified receptor points. And further still are exposure permits and, finally, risk permits, the former referring to human or ecological exposures and the later referring to the consequences of such exposures.[18] Each successive system on this continuum may come closer to a theoretical ideal, but each system is also likely to bring greater public costs associated with monitoring and enforcement and greater private transaction costs. Indeed, these practical considerations help to explain why only input trading and simple emissions trading have actually been adopted or seriously considered by public authorities.

To see why tradeable permits are less costly than command-and-control approaches, consider the simple case of an industry with only two firms—one with a high marginal cost of control and the other with a low marginal cost of control. If permits are initially allocated uniformly to the two firms, it will be in the interest of the high-cost firm to purchase additional emissions permits and to increase its emissions as long as the price of the permits is less than the firm's marginal cost of pollution control. Likewise, it will be in the interest of the low-cost firm to sell additional emissions permits and to decrease its emissions as long as the price of the permits is more than the firm's marginal cost of pollution control. These competitive forces will tend to lead to an equilibrium permit price and distribution of permits (and pollution control responsibility), in which each firm equates its marginal cost of pollution control to the prevailing permit price. Therefore, the pollution control responsibility will be allocated in such a way that the two firms are controlling pollution at the same marginal cost of control (rather than at the same level of control). Hence the tradeable permit system, in theory, achieves the most cost-effective allocation of the pollution control burden among firms.[19]

In terms of the performance criteria for good environmental policy specified above, tradeable permits can be designed to perform well on most of the criteria, except, possibly, for monitoring and enforcement costs and accessibility to the general public.

U.S. Experience with Tradeable Permit Systems

Tradeable permit mechanisms have previously been applied in the United States, including the EPA's Emissions Trading Program, the nationwide phasedown of lead in automotive fuel, CFC reduction, point-nonpoint source trading for water quality control, and, most notably, the 1990 amendments to the Clean Air Act, which include a permit trading system for sulfur dioxide emissions and the control of acid rain.[20] In the following section, we review four of these programs—the EPA's criteria for air pollutant trading, the phasedown of leaded gasoline, the trading in

CFCs, and the new sulfur dioxide trading system—to highlight lessons that can be learned about design and performance.

The EPA's Emissions Trading Program

In 1974 the EPA began to experiment with emissions trading as part of its efforts to improve local air quality. Under the various programs, firms that reduce emissions below the level required by law receive credits usable against higher emissions elsewhere. Under programs of "netting" and "bubbles," firms are permitted to trade emissions reductions among sources within the firm, so long as total, combined emissions comply with an aggregate limit.[21] Under the "offset" program begun in 1976, firms that wish to establish new sources of pollution in areas that are not in compliance with ambient standards are required to offset their new emissions by reducing existing emissions by an amount greater than the amount of pollution the new source will generate. This offset can be achieved through the firms' own sources or through agreements with other firms. Finally, under the "banking" program, firms may store earned emissions credits for future use, either to allow for internal expansion or for sale to other firms.

These programs were codified in the EPA's final policy statement on emissions trading in 1986, but their use to date has not been extensive.[22] States are not required to use the programs, and uncertainties about their future course have made firms reluctant to participate.[23] The programs appear to have been handicapped further by bureaucratic infighting and by opposition from environmental organizations.[24] Nevertheless, companies such as Armco, DuPont, USX, and 3M have traded emissions credits, and a market for transfers has arisen.[25] Even this limited degree of participation is estimated to have saved between $.5 and $12 billion since 1976.[26]

Lead Trading

The EPA's lead trading program contrasts with the emissions-trading program for other air pollutants and much more closely approximates the economist's ideal of a freely functioning market. The lead trading program was created to allow gasoline refiners greater flexibility during a period when the amount of lead in gasoline was being reduced to 10 percent of its previous level. Interrefinery trading of lead credits was authorized in 1982.[27] To create lead credits, refiners had to produce gasoline that had a lower lead content than required by the standard. Banking of lead credits (for later use) was initiated in 1985 and was used extensively by firms.[28] Unlike many other programs, the lead trading program was scheduled to have a fixed life from the outset. The trading program was terminated at the end of 1987, when the lead phasedown had been accomplished.

Although the benefits of the trading program are difficult to measure directly, it is clear that the program was successful in meeting its environmental targets.[29] The level of trading between firms was high, far surpassing levels observed in other environmental markets. In 1985 over half of the refineries participated in trading with other firms.[30] The EPA estimated that savings resulting from the lead trading program were approximately $200 million annually.[31]

Trading in CFCs

The EPA has implemented a market in tradeable permits to help comply with the Montreal Protocol, an international agreement aimed at slowing the rate of stratospheric ozone depletion. The Montreal Protocol calls for reductions in the use of CFCs and halons, the primary chemical groups thought to lead to ozone depletion.[32] The market places limitations on both the production and consumption of CFCs by issuing allowances that limit these activities. If a firm wishes to produce a CFC, it must have an allowance.[33]

The Montreal Protocol recognizes the fact that different types of CFCs are likely to have different effects on ozone depletion. The treaty assigns weights to each CFC on the basis of its depletion potential. The allowances required for a particular type of CFC are calculated on the basis of the impact this substance is thought to have on ozone depletion.

Through mid-1991 there have been thirty-four participants in the market and eighty trades.[34] However, the efficiency of the market is difficult to determine, in part because no studies were conducted that estimated cost savings or the likely pattern of trading. The problem is compounded because the timetable for the phaseout of CFCs has been accelerated and a tax on CFCs has been introduced. Indeed, the tax may now be the binding (effective) instrument.[35] Despite these confounding factors, relatively low transaction costs associated with trading in the CFC market may suggest a somewhat cost-effective outcome.

Acid rain control under the Clean Air Act Amendments of 1990

A centerpiece of the Clean Air Act Amendments of 1990 is a tradeable permit system to regulate sulfur dioxide, the primary precursor of acid rain.[36] Title IV of the act reduces sulfur dioxide and nitrous oxide emissions by 10 million tons and 2 millions tons, respectively, from 1980 levels.[37] The first phase of sulfur dioxide emissions reductions is to be achieved by 1995, with a second phase of reductions to be accomplished by the year 2000. In Phase I, 111 electrical utilities are targeted with individual emissions limits. After 1 January 1995, these plants can emit sulfur dioxide in excess of limitations only if they qualify for extensions or substitutions, or obtain allowances for their total emissions.[38]

Essentially, these allowances are permits to emit designated quantities of sulfur dioxide during or after a specified year. Under Phase I, the EPA will annually allocate to all affected plants a specified number of allowances related to its capacity, plus bonus allowances, which are available under a variety of special provisions.[39] Cost-effectiveness is promoted by permitting legal-allowance holders to transfer their permits among one another.

Under Phase II of the program, beginning 1 January 2000, almost all electric power generating units will be brought within the system.[40] Certain exceptions are intended to compensate for potential restrictions on growth and unfair treatment of units that are already unusually clean. If trading permits represent the carrot of the system, its stick is a penalty of $2,000 per ton of emissions exceeding any year's allowances (and a requirement that such excesses be offset the following year).[41] It is essential that noncompliance be unattractive if the system is to achieve its objectives.[42]

It is too soon to assess the program, but preliminary indications are that trading among utilities will be active, particularly in the second phase of the program when all utilities are brought into the allowance program, the reduction target is increased to 10 million tons, and trading on a futures market is implemented.[43] Among the major unanswered questions is how state regulatory commissions will allow utilities to treat the benefits and costs of sales and purchases of allowances. How these financial impacts are allocated between ratepayers and shareholders, for example, can have an important effect on the level of trading, as well as on the degree of cost-effectiveness that is achieved.[44]

Learning from Experience

Marketable permits are rarely, if ever, introduced in their textbook form. Virtually all environmental regulatory systems using tradeable permits rely on the existing system of permits. This result should not be surprising, since these systems were not implemented in a vacuum. Rather, they were grafted onto regulatory systems in which permits and standards already played a dominant role.

Partly as a result of such hybrid approaches, the level of cost savings resulting from implementing marketable permits has varied widely but typically is far below their theoretical potential. The EPA's Emissions Trading Program has achieved only a small fraction of their potential cost savings. In contrast, the lead trading program enjoyed very high levels of trading activity, which suggests that the market was very efficient. The data on CFCs are more difficult to assess. Some trading has occurred, but it is unclear how much trading would be needed to reach the most cost-effective solution.

In most cases, marketable permit programs and command-and-control programs can affect environmental quality to roughly the same degree. In the case of lead trading and emissions trading, marketable permit programs have generally achieved similar environmental outcomes to the command-and-control programs they replaced. In the case of CFCs, there is no command-and-control benchmark for comparison; however, there is no reason to believe that the results of command-and-control regulations would have been significantly different from the market-based solution. Countries that agreed to phase out CFCs have generally complied with the spirit of the agreement, regardless of whether they chose to meet the phaseout using command-and-control or market-based approaches.

Although the impact of the acid rain allowance trading program on environmental quality is difficult to predict, it is unlikely that the targeted 10-million-ton reduction in sulfur oxides could have been achieved with a command-and-control approach. The political costs of an equivalent emissions reduction achieved through a command-and-control initiative of this magnitude would probably have been unacceptable. Either acid rain legislation would not have passed in 1990 or the emissions-reduction target would have been reduced.

In thinking about the environmental and economic characteristics of different regulatory approaches for environmental protection, it is important to take into account the political environment in which these approaches are implemented. Some of the design features of existing market-based approaches that affect economic performance are clearly dictated by politics.[45] An example is the bias toward scrubbing in the allowance trading market for the control of acid rain. At the same time, there is room within these political constraints for the design of more efficient markets. New environmental initiatives, which have not been subject to traditional forms of regulation, may afford greater opportunities for the implementation of market-based initiatives with fewer restrictions on trading dictated by political pressures. The control of greenhouse gases, of course, is an excellent example of a potential problem for which there is virtually no regulatory infrastructure in place.

TRADING IN GREENHOUSE PERMITS

A tradeable permit program for greenhouse gases would be a new application of the general approach that has been applied to lead permit trading among refiners, to transferable production permits for CFCs, and to sulfur dioxide trading for acid rain prevention. However, an international greenhouse permit trading program would not, by any means, entail a simple extension of the concept from these domestic programs to a global one. Concerns about proper design and implementation are well founded.[46] This section describes the fundamental properties of a system of international trading in greenhouse gas source and sink permits, reviews the potential attributes of such an approach, outlines some necessary conditions for a successful permit market, and highlights a number of major design issues.

AN OVERVIEW OF GREENHOUSE PERMIT TRADING

Economic-incentive policies in general, and emissions trading in particular, are well suited for the management of uniformly mixed air pollution problems, such as acid rain and global climate change, because these policy mechanisms allow for aggregate pollution reductions at minimum cost to society at large. With essentially uniformly mixed air pollutants, ultimate concern is on aggregate pollution levels, as opposed to specific emissions from individual sources.[47] It does not matter, for example, whether a reduction in carbon dioxide emission takes place in Thailand or the United States.

One potential application of tradeable permits in the greenhouse context is an international system of greenhouse gas emissions trading. An international tradeable permit system would essentially implement a regulatory program that sets overall limits on emissions of carbon dioxide or on combustion of fossil fuel or deforestation. Nations would be assigned a baseline that would establish the initial emissions levels from which reductions would be assessed.[48] Each country would have to meet its minimum standard, but could do so either by controlling emissions or by purchasing reduction credits from nations that exceeded their own standards.

After establishing responsibility among nations (as with the Montreal Protocol in the case of CFCs), the permits could be transferred among nations, thus ensuring that emissions-reduction goals are distributed in a cost-effective manner among participating nations.[49] Individual countries could thus achieve their respective control obligations through any means chosen. For example, the United States and other nations might choose to meet their control targets through some combination of carbon charges, domestic tradeable permits, or other incentive-based and conventional regulatory policies. In this way, an international carbon dioxide or greenhouse gas trading program could accommodate a variety of separate national implementation strategies. Such an international, government-to-government trading system raises a number of legitimate concerns, which we discuss later. Among these concerns are monitoring and enforcement problems and the likelihood that nations would not necessarily make cost-minimizing decisions about permit trading.

Tradeable permits could also be used as a domestic policy instrument to allocate the control burden among firms and individuals in the pursuit of a national goal for reducing greenhouse gases (presumably set by international agreement). In this case, the most likely trading system would not focus on emissions, but rather on the carbon content of fossil fuels. In a way analogous to the EPA's leaded gasoline phasedown, the trading currency would be units of carbon in coal, petroleum, and natural gas, whether these fuels are domestically produced or imported. Such a system is closely related to the charge system most frequently considered for greenhouse gas reduction, namely, a carbon tax. As in that case, it is conceivable that units of carbon bound for manufacturing use (that is, nonfuel uses) would be exempted from the system.

Midway between international (government-to-government) trading and domestic (firm-to-firm) trading is a spectrum of mixed approaches that would allow firms or individuals in one nation to trade with firms or individuals in other nations. Although this increased flexibility is desirable from some perspectives, it raises some special problems if it is carried out in the context of other active greenhouse policy instruments, such as domestic carbon or energy taxes.[50] Because of this, we focus on two prototypes—international carbon dioxide emissions trading and domestic carbon rights trading.

Depending on the type of system adopted, there are a number of potential advantages in the use of marketable permits to reduce greenhouse gas emissions.

- *Flexibility.* Businesses and individuals could have greater flexibility in choosing tactics and strategies for limiting greenhouse gas emissions. This flexibility could allow governments to focus on monitoring and enforcement rather than on writing detailed regulations that prescribe specific technologies for energy efficiency or pollution reductions.

- *Direct control of aggregate emissions levels.* Essentially, marketable permits place a cap on emissions levels. The number of permits issued determines the aggregate level, provided these permits are effectively enforced.

- *Cost-effectiveness in pollution control.* Markets provide positive incentives in the form of cost savings and profit for individuals and businesses to seek out the lowest cost methods of achieving emissions targets (if the trading parties are themselves cost minimizers).
- *Provision of mechanisms for trading among different greenhouse gases.* Allowing trading among different gases would enhance opportunities for cost savings. A key issue is whether such trades can be justified on scientific grounds.
- *Dynamic incentives for the development of low-polluting technologies and management strategies.* A major advantage of market-based approaches is that they provide incentives for the development of innovative approaches to emissions reductions that are largely absent from command-and-control regimes.
- *Establishment of a mechanism for directly addressing the equity concerns of developed and developing countries.* Policymakers can distribute permits in a way that promotes fairness, however they choose to define it.
- *Linkage of sources and sinks in a single, comprehensive strategy.* Theoretically, it would be desirable to link sources and sinks so that overall emissions limits could be achieved at the least cost. Some sinks, such as forests, pose formidable obstacles in measurement and enforcement.

Even a limited subset of these potential advantages of tradeable permit systems can be realized in practice only if very careful attention is given to a host of serious design and implementation issues. It is to such issues that we turn next.

Conditions for a Successful Permit Market

The full measure of potential cost savings offered by tradeable permits in greenhouse gases can be realized only if efficient markets develop. Four conditions are necessary for this to occur: (1) a sufficient degree of compliance must be achieved, (2) transaction costs must be low enough not to prevent efficient permit exchanges from taking place, (3) the market for permits must be competitive, and (4) the policy must be seen as one that will remain in place for a significant period of time.[51]

Monitoring and Enforcement: The Question of Compliance

For a tradeable permit (or any other) policy to be truly effective and to operate at least cost, firms or nations must comply with the policy's requirements. In the international trading context, this requirement means that nations must accurately report changes in greenhouse gas sources and sinks and must purchase the appropriate number of permits if their net emissions exceed their permitted level. The costs for an international body to monitor and enforce this system would be significant, but such compliance problems would arise with a number of alternative approaches as well. In the domestic-trading context, monitoring and enforcement problems and related costs are inextricably linked to the level of trading chosen. Trading in carbon-content rights for the three fossil fuels among producers and importers would likely involve much lower monitoring and enforcement costs than would emissions trading.

TRANSACTION COSTS

The potential cost savings associated with tradeable permit systems can be realized in practice only if trading involves sufficiently low transaction costs, including the costs of finding prospective buyers and sellers as well as the costs of obtaining any necessary approval for trades.[52] If nations or firms lack information on other countries or firms, identification would be costly; but in the presence of potentially high transaction costs, brokers would likely emerge to facilitate trading by linking potential buyers and sellers of permits.[53]

Regulatory constraints could lead to high transaction costs in an international tradeable permit market if governments were required to obtain approval from an international body for each and every transaction. Such regulatory constraints would likely be most significant where localized environmental impacts are important in order to ensure that hot spots of emissions do not occur; however, given the global commons nature of the impacts of greenhouse gases, these hot-spot effects are not an issue.[54]

Since transaction costs are partly a function of the number of potential traders in a relevant market, these costs (like those associated with monitoring and enforcement) will be closely linked to the chosen level of trading activity. In the case of domestic trading, this clearly argues in favor of carbon-input trading, as opposed to carbon dioxide emissions trading.[55]

COMPETITIVE MARKET CONDITIONS FOR PERMIT EXCHANGES

The degree of competition in the permit market will also affect the extent to which potential cost savings are likely to be realized.[56] Under perfectly competitive conditions, each nation or firm would decide whether to enter the permit market depending on the market price of permits versus its internal costs of controlling sources and sinks of greenhouse gases. However, a nation or firm that buys or sells a significant fraction of the total number of permits traded might be able to influence their price. If prices were manipulated by a particular firm or nation, then greenhouse gas reductions would not be achieved at minimum cost.[57]

Certainty in the Permit Market and the Willingness to Trade

Firms and nations cannot be expected to engage in trading if they believe that the policy is likely to change dramatically. Consequently, policies must be stable for a reasonable period of time. However, governments may have a great deal of difficulty in creating an international agreement that private parties believe will remain unchanged, which could have a significant adverse impact on parties' willingness to engage in cost-effective investments in reducing greenhouse gas emissions.

Even if a policy is viewed as stable by key participants, firms and nations can be expected to trade greenhouse gas permits only if the rights these permits bestow are clearly defined and only if there is little uncertainty regarding the legitimacy of transactions. One potential source of such uncertainty for permit buyers in the international-trading context is whether nations that sell permits have actually made the necessary net reductions in greenhouse gases. A possible solution is to place responsibility for permit legitimacy with sellers rather than with buyers. Permits could be registered with an appropriate international body with sole enforcement responsibility. This scenario returns us, however, to the question of enforcement. Since it is by no means clear what international body could credibly monitor and enforce a tradeable permit system (or any alternative approach), the true practicality of this and other instruments cannot be fully assessed at present.

Designing a Greenhouse Trading System

For the development of an effective and practical trading system, consideration should be given to a number of particularly important issues regarding policy design. Among these issues are (1) who should decide whether trading is allowed, (2) who should participate in trading, (3) at what level trading should take place, (4) whether there should be exclusive source programs or source and sink programs, (5) whether there should be carbon dioxide or multiple-gas trading, (6) what the aggregate target levels and initial allocation of control responsibility among nations should be, (7) how technology transfers to developing countries should be handled, (8) what approaches to issuing permits and to monitoring and enforcement should exist, (9) what temporal issues and permit banking possibilities should be considered, and (10) how alternative policy instruments should be adapted to changes in scientific understanding.

THE DECISION ON WHETHER TRADING IS ALLOWED

The decision to select a particular domestic regulatory approach, such as trading, should be left up to each country. Thus, an international agreement to limit greenhouse gases should allow nations to implement trading as a means of achieving their objectives. Moreover, if a country signs such an agreement, it should be responsible for demonstrating that it will meet the terms of the agreement using approaches permitted by the agreement. An international trading system should also be voluntary. Nations need not participate unless they so choose (as long as they comply with internationally mandated targets).

PARTICIPANTS IN TRADING

Negotiators will have to decide who should participate in trading. With regard to domestic trading, any individual, business, or public entity should be allowed to participate in programs, subject to constraints related to administrative feasibility. For example, obviously, it would be impractical to make individuals accountable for their carbon dioxide emissions. The question of how to draw the line to make the regulatory scheme manageable is an important one. Some have advocated starting off with a simple scheme, even if it does not encompass a large part of the problem.[58]

The problem of international trading is more subtle.[59] If international trading takes place among nations, there would be advantages of allowing firms and individuals within those nations to trade internationally. But depending on the nature of domestic greenhouse regulations, this allowance could raise serious problems of departures from cost-minimizing allocations of the control burden. In any event, limitations on trading may be necessary because of the potential for high administrative costs. On the other hand, it can be argued that national governments ought not be the primary agents for trading because they may not have the appropriate incentives or information needed to minimize costs. A large part of the decision of whether to allow various kinds of international trading will hinge on the differential ability and willingness of nations to enforce this kind of an agreement, a point that is addressed below.

Some have questioned whether developing countries should be permitted to participate in international trading because of fears that these countries, or individuals within these countries, might trade marketable permits to others to raise cash quickly without having taken adequate stock of long-term consequences. However, this problem may arise not because of a failure in these nations to take a long-term view, but rather because of the difficulty in these countries of implementing effective enforcement strategies, particularly in nations lacking stable political structures. The challenge is to develop international enforcement mechanisms that are credible, so that countries and individuals understand that not playing by the rules will entail real costs.

THE LEVEL OF TRADING

As mentioned earlier, there are a variety of points in the product cycle at which tradeable permits can be assigned to regulated parties. A system that merits consideration in the domestic context is a system of trading carbon rights in fossil fuels in which the rights are required both for the production of primary fuels at the mine mouth or wellhead and for importation. Such an approach would be similar to the lead rights trading program of the 1980s and is parallel to the type of charge system most frequently considered for carbon dioxide control, a carbon tax. If the permits were freely distributed, then the permit system would resemble a carbon tax system in which revenues were redistributed according to initial production and import levels.[60]

On the other hand, a system of international trading among governments of "control responsibilities" or targets could conceivably be linked to emissions, although the monitoring and enforcement problems are likely to be massive. In any event, it is safe to say that most attention ought to be focused on input and emissions trading, since in the case of this uniformly mixed global pollutant, ambient trading would be an unnecessary and costly complexity. The same can certainly be said of exposure and risk trading.

SINKS AND SOURCES

Should an international carbon dioxide trading program only consider changes in emissions of carbon dioxide or also consider changes in carbon dioxide sinks (such as expanding forests)? Since growing forests remove carbon from the atmosphere and their burning or destruction contributes to global carbon dioxide loadings, one question is whether and how an international agreement might help retard deforestation and promote reforestation. With a tradeable permit program for carbon dioxide, countries like Brazil and Indonesia might find it economically attractive, as well as environmentally sound, to retard the depletion of their forests or to implement reforestation programs in order to earn carbon dioxide credits, which their own industries could use or which they could sell to foreign governments.[61] Those countries in turn could use the revenues from the sale of such credits to finance programs to retard forest loss.[62] Depending on the initial distribution of carbon dioxide permits, which determine reduction responsibilities, an international trading program could contain an explicit mechanism for addressing issues of equity raised by developing countries.[63]

The inclusion of sinks, however, would entail many complications. First and foremost is the issue of the need to establish a relevant baseline. How many trees are out there now, and who should get the credits for these trees? Second, there is the issue of how to measure changes in greenhouse gas emissions associated with various sinks. It is not a simple matter to measure the carbon sequestered in trees and how it varies over time.[64] Moreover, should individuals get credit for planting trees in their backyards? Suffice it to note that sinks frequently pose formidable measurement problems and are often owned or managed by governments. While sinks can be included in a market-based approach in principle, caution is required before they are included on a large scale, at least in the short term.

CARBON DIOXIDE VERSUS MULTIPLE GREENHOUSE GAS TRADING

There has been considerable debate in the United States regarding whether to focus on carbon dioxide alone for a trading program or whether to include all greenhouse gases.[65] If there were trading in all greenhouse gases, should there be trading across gases as well? Trading across gases adds an additional layer of complexity because it requires the establishment of trading ratios.[66]

The advantage of the more comprehensive approach is the additional flexibility it introduces into the system, and hence the potential it creates for even greater cost-effectiveness.[67] On the other hand, such a system would increase administrative burdens and require greater scientific understanding of the relative impacts of the suite of greenhouse gases. One option is gradually to introduce other gases into the trading framework, contingent upon increased scientific knowledge about these gases.[68] Experience suggests that when there is significant profit potential and when it is clear that regulatory action will be taken, firms or nations may cooperate in the development of baselines, budgets, and appropriate certification methods.[69]

Given the current understanding of the causes and consequences of global climate change, and the technological limitations, a comprehensive market-based approach for greenhouse gas emissions is probably not appropriate, even in the United States. This is not to suggest that all gases should not be considered in an agreement, but that there are significant limitations to markets when monitoring and enforcement are particularly costly and when the science is highly uncertain.

AGGREGATE TARGET LEVELS AND INITIAL ALLOCATION OF CONTROL RESPONSIBILITY AMONG NATIONS

Any international greenhouse gas reduction policy presumes some agreed-upon aggregate goal for the management of greenhouse gas emissions into the atmosphere, which is translated into an allowable level of emissions over time. Initially, the goal can be framed as a fixed level of ambient greenhouse gas concentrations.[70] This level can be established as a reduction from a baseline, either historic or projected. Once established globally, however, these allowable emissions must be distributed to individual nations.

The most difficult problem associated with any international greenhouse gas control program will be negotiators achieving agreement on both the global emissions cap and the initial control obligations of individual nations. The trading program highlights this problem because it makes it explicit. Since the program would create a new environmental currency denominated in tons of carbon dioxide (or other gases), every nation will immediately know its reduction responsibilities.

A variety of alternative allocation mechanisms have been suggested, including allocations based on GNP, real GNP, total population, adult population, land area, and emissions.[71] There are numerous other possibilities. Each of these criteria will have adherents, largely those with larger allocations under that criterion.[72] Several criteria may need to be blended to create international consensus on emissions allocations.[73] For example, developing countries will have relatively little incentive to participate unless they see clear economic benefits from an agreement. At the same time, wealthy countries will want to ensure that their burdens are divided in ways that are perceived as equitable. Whatever the initial allocation, subsequent trading can lead to a cost-effective outcome.[74] This potential for pursuing distributional objectives while assuring cost-effectiveness is an important attribute of the tradeable permit approach.[75]

TECHNOLOGY TRANSFERS TO DEVELOPING COUNTRIES

A trading system could provide industry with economic incentives to develop and use more efficient energy technologies and to switch to non-fossil or less carbon-intensive fuels.[76] Internationally, an appropriately designed trading program could promote the transfer of energy-efficient technologies from highly industrialized to developing countries.[77] For example, the potential of a developed country to obtain credits in a developing country by investing in increased appliance efficiency could create an economic incentive on the part of firms in industrialized countries to transfer technology and, in effect, finance the transfer of that technology. A well-designed protocol that encourages such international trading of energy credits could promote least-cost energy efficiency investments (as well as renewable energy investments) on an international basis. As a general proposition, the tougher the carbon dioxide reduction goals that industrialized countries must meet, the more they will be inclined to look for opportunities in developing countries as a source of credits.

MONITORING AND ENFORCEMENT REQUIREMENTS

The nature and magnitude of monitoring and enforcement costs associated with a greenhouse gas tradeable permit system will depend on the level of trading (for example, emissions permits versus carbon rights) and on the character of participants in the program (that is, nations, firms, or individuals). In the domestic-trading context, there is little doubt that the monitoring and enforcement costs of a carbon-rights trading program would be significantly less than would be those associated with some sort of carbon dioxide emissions trading system.[78] Indeed, the overall administrative costs of a carbon-rights trading program should be no more than those of a system of carbon taxes.

In the context of international emissions permits, the authority to issue permits would presumably come from an international agreement on climate change. Some existing or new supranational body could, theoretically, be vested with the authority to issue permits. Nations could then develop regulatory approaches of their choosing to meet the limitations on greenhouse gases that are imposed by the permits. For such a system, even basic monitoring of compliance will be a formidable challenge. One only need take note of the widely varying estimates of Brazil's rate of deforestation to appreciate the magnitude of the problem.[79]

Clearly, there are significant trade-offs between monitoring ease and accuracy. For example, it would be theoretically desirable to allow full flexibility for nations to achieve their emissions targets (permit levels) through any means they might choose, including reduced fossil fuel combustion on the one hand and reforestation on the other. But this process would also necessitate an extremely expensive monitoring system *or* the adoption of some simplifying assumptions (regarding, given the above examples, the impact of given fuel uses on emissions and the relative impacts of various reforestation programs).

Two critical problems are likely to emerge in enforcement within the international emissions-trading context. First, enforcement will differ significantly across countries that sign an agreement. Second, countries that do not sign an agreement to reduce greenhouse gases will be able to free ride on those that do. Neither of these problems has simple solutions that are politically feasible in the near term.

One possible approach linking enforcement to international trading would be to restrict international trading to those nations that are deemed to be in compliance by some supranational group.[80] For example, if the supranational group found that Germany and the United States were both in compliance with their obligations, then trading would be allowed between the two nations. A problem with this approach could arise if countries change their level of effort in enforcing an agreement. If, for example, a country traded away permits while in compliance, but then subsequently went out of compliance with an international agreement, rules would need to be developed to define which country would be responsible for limiting its greenhouse gases to come back into compliance. While this problem is manageable in theory, it could quickly lead to a political quagmire. For example, the supranational authority could be asked to make difficult decisions about whether to allow developing countries, with limited resources for monitoring and enforcement, to engage in international trading.[81]

A somewhat more ambitious alternative would allow international trading based on allowances that do not trade on a one-for-one basis but that reflect their actual value (rather than the face value of the allowance). Thus, if Denmark were in compliance, but Brazil had greenhouse gas emissions that were 100 percent above its allowable levels, then Brazilian permits would be traded at a 2:1 ratio with Danish permits. Again, the supranational group would need to define the trading ratios between nations. This latter approach adds a level of complexity that may make the system very difficult to administer. Moreover, countries would probably be reluctant to cede this kind of authority, with its potential for large implicit wealth transfers, to an international body.

As technology improves for monitoring carbon dioxide and other greenhouse gases, it may be easier to reach agreements that would allow for international trading with modest transactions costs. At present, both technological constraints and political forces pose formidable obstacles to the emergence of a workable international emissions-trading regime.

TEMPORAL CONSIDERATIONS AND THE POSSIBILITIES OF PERMIT BANKING

The temporal component of any pollution problem can be important but is particularly so in the case of stock pollutants, which tend to accumulate in the environment at a rate that significantly exceeds their natural rate of decay. Accumulations of greenhouse gases are of this nature and thus raise a set of time-related issues. If the overall goal of some public policy were to limit the rate or degree of climate change, significant trade-offs would exist with regard to the timing of any proposed reductions in greenhouse gas emissions. Earlier reductions would have the effect of slowing the potential onset of climate change.

Within the context of a tradeable permit system, these temporal considerations can be addressed, to some degree, through provisions for (or restrictions on) banking, a mechanism that enables firms or nations to make early emissions reductions in exchange for the right to emit a comparable amount at some later date. This notion could be extended to sinks as well as sources. It could be advantageous to allow nations to engage in the banking of greenhouse gas allowances, since this practice would allow for intertemporally efficient market exchanges and would tend to delay the onset of global climate change.

On the other hand, the ability to hold permits over time raises concerns about possible strategic behavior in which nations or sources that receive large initial allocations may choose to hoard their permits in order to exercise market power. Regulated leasing of permits could be used to address these concerns, at least in principle.[82]

THE ADAPTABILITY OF POLICY INSTRUMENTS TO EVOLVING SCIENTIFIC UNDERSTANDING

A critical challenge in the design of greenhouse regulatory instruments is to make sure that they are capable of responding appropriately to the evolving scientific and economic understanding of global climate change and its causes and consequences. Marketable permits are somewhat flexible in this regard. The authority that issues permits can make clear the conditions under which they will remain valid. But placing too many contingencies on permits is dangerous. Firms may not find it in their interest to participate in such a market. Governments have a reputation for not being able to make credible commitments honoring the value inherent in tradeable permits. Indeed, in some cases, they have purposely discriminated against permits that have been traded.[83]

Nations may want to consider two strategies. The first is to use markets for greenhouse gases where the science is reasonably certain and the problem can be measured with a reasonable degree of precision. This strategy suggests that carbon dioxide may be the most promising candidate for the application of some kind of incentive-based approach.[84] A second strategy that nations could pursue is to agree to revisit the issue at fixed intervals in order to modify strategies with evolving scientific and economic understanding. This approach would provide firms and nations with some guarantee about the value of their allowances over a specified time. At the same time, it would provide nations with needed flexibility to adapt to the changing science.

Whether these and other design problems will overwhelm the potential advantages offered by greenhouse permit trading programs will be determined by the specifics of alternative instruments under consideration and by the skills of those negotiating the framework agreements.

THE CHOICES

Many of the current discussions regarding alternative mechanisms to address global climate change have focused on the potential use of carbon taxes.[85] Therefore, in this final part of the chapter, we compare charges and tradeable permits as practical mechanisms for addressing global climate change, examine some of their political implications, and offer some brief conclusions.

Comparing Tradeable Permits with Charge Systems

In many situations, economic-incentive policies can lead to lower total pollution control costs and can spur greater technological innovation than can conventional command-and-control approaches. However, which incentive-based instrument is most appropriate depends on a number of specific factors. We consider the broadest set of possible international and domestic applications.

1. *Both charges and permits impose costs on industry and consumers, but the costs associated with charges are more visible.*[86] Both charges and permits force firms to internalize the costs of their pollution. Practically speaking, this internalization of costs means that firms will experience financial outlays, either through expenditures on pollution controls or through cash payments (buying permits or paying charges). Charge systems tend to make these costs more visible to industry and to the public. This visibility may be problematic for political reasons, although in the long run it has the advantage of clearly signaling and educating the public about the costs and trade-offs associated with various levels of environmental control.[87]

2. *With permits, resource transfers are between private parties, whereas they are*

typically from a private party to the government with pollution charges.[88] Under permit trading, firms choosing to emit pollution beyond their initial permitted level must make payments to other firms that agree to control more than their initial share. With charges, payments for uncontrolled emissions flow to government. For those who believe that the private sector can utilize the resources more effectively, permits offer an advantage over changes. On the other hand, revenue collected from charges can be earmarked for environmental investments, deficit reduction, or reductions in distortionary taxes.

3. *In theory, permits fix the level of control, whereas charges fix the marginal costs of control.* Under a permit system, policymakers determine how much total pollution can occur (through the issuance of permits), but they do not and cannot set bounds on expenditures on pollution control. Such a strategy could be particularly appropriate for environmental problems that exhibit tight margins of error regarding emissions levels or in which the marginal costs of control do not increase dramatically with increasing regulatory stringency.[89] Charges, on the other hand, control the maximum amount that a firm may pay for each increment of emissions, but they do not dictate with certainty how much control will actually occur. Such a tactic may be more appropriate where the margin of error on damages is not tight but where the potential impacts on industry of overcontrol are especially great.[90] This result could occur, for example, when small increases in control costs lead to large swings in production and employment. Which case is closer to that of global climate control will be clarified only through future research.

4. *Short of additional governmental intervention, permits freeze the level of control while charges increase it over time in the presence of technological change.* With a permit system, technological improvement will normally result in lower control costs and falling permit prices rather than in declining emissions levels. Such technological change under a charge system, however, will lead to both lower total control costs and increased levels of control. As technological change pushes the costs of controlling emissions down, firms will choose to control more emissions and pay less taxes.[91]

5. *Permits adjust automatically for inflation, whereas charges do not.* Because the currency under a permit system is emissions rights, levels of emissions control are unaffected by price movements in the overall economy. This is not the case for pollution charges. General price inflation will have the effect of reducing taxes (which are expressed in

dollars per ton, for example) in real terms. Therefore, in an inflationary environment, firms will control less than if prices were constant.

6. *Permit systems may be more susceptible to strategic behavior.* In order for a permit system to work effectively, relatively competitive conditions must exist in the permit (and product) market. The degree of competition will help determine the amount of trading that occurs and the cost savings that will be realized. Should any one firm or nation control a significant share of the total number of permits, its activities may influence permit prices.[92] National governments or firms might attempt to manipulate permit prices to increase their positions in the permit market or in the final product market (for example, by withholding permits and forcing others to cut production or by keeping new entrants out).

7. *Transaction costs can be important; they depend, in part, on the number of traders in the market.* Transaction costs (such as the costs associated with the identification of willing buyers or sellers of permits, or the costs of tax collection) not only drive up the total costs of compliance of incentive-based mechanisms, but also affect the amount of trading that will occur in a permit system and the amount of pollution control that will be achieved with a charge system. Hence, the relative magnitude of transaction costs is another important determinant in the identification of the preferred mechanism. In most cases, a comparison of transaction costs will tend to favor a charge approach.[93]

The Political Economy of Charges and Permits

All economic instruments, including charges and tradeable permits, are considered by policymakers in an intensely political environment. This reality has several important implications for the nature of these instruments, as well as for the potential for reaching an international agreement on climate change.

1. *Which policy instruments are used to achieve goals can themselves affect the likelihood that an agreement will be reached.* As mentioned earlier, in the domestic context it is unlikely that a 10-million-ton sulfur dioxide reduction goal would have been adopted in the United States had tradeable permits (and the cost-effectiveness associated with them) not been part of the legislative package. In the international context, it should be noted that under certain conditions a tradeable permit system can have the effect of reducing the min-

imum number of countries necessary for a global agreement to be reached.[94]

Countries can affect negotiations by the stand they take on the application of regulatory instruments to achieve environmental goals. If, for example, the United States continues to insist that all signatories to an agreement limiting greenhouse gas emissions must use market-based approaches for achieving the desired targets, this approach could either reduce the probability of achieving consensus or reduce the number of countries willing to sign an agreement.[95]

2. *The enforcement of instruments is likely to vary dramatically across nations.* This statement is true for both charges and marketable permits, as well as for command-and-control approaches. Its truth results from the fact that nations are unlikely to grant significant authority to a supranational unit that would allow for consistent enforcement across countries.

3. *Any market-based approach that is implemented to control greenhouse gases, even within a given country, will vary dramatically from the textbook application of these concepts.* There are many reasons why market-based approaches will deviate from their ideal; an important one is politics. Past examples include special preferences for certain technologies in acid rain trading and special exemptions for taxes on CFCs. However, departure of actual instruments from a theoretical ideal is not just cause, on its own, for rejection of the approach.

4. *Any market-based approach that is implemented will have to acknowledge implicit claims on wealth associated with the current distribution of greenhouse gases.* Pollution control strategies that have used charges and permits share the feature that at least some of the wealth that inheres in these approaches remains with the affected parties. Thus, for example, many charge systems in Europe designed to limit pollution recycle revenues to the participants or earmark the revenue for specific tasks. Similarly, in the United States tradeable permits for protecting the environment are distributed on the basis of the historical pattern of emissions. While the precise nature of the distribution will be the subject of vigorous political discussions, countries and special interest groups (including environmental groups) will not accept an agreement that substantially shifts the distribution of wealth or political power. This resistance means that market-based approaches may be more controversial than command-and-control approaches, but it also means that market-based approaches can facilitate the formation of coalitions of support through the grandfathering of rights.

5. *A market-based approach for limiting greenhouse gas emissions is likely to have more stringent monitoring and enforcement requirements than would a command-and-control system.* For example, environmentalists bargained for the installation of continuous emissions monitors as a condition for allowing a tradeable allowance system for the reduction of sulfur dioxide emissions in the United States. A similar strategy is likely to be applied if market-based approaches are implemented for limiting greenhouse gases. One notable difference between the two control problems is that the technology for the accurate monitoring of many sources and sinks of greenhouse gases has not been developed.

Choosing Policy Instruments for Global Climate Change

This chapter focused on evaluating the use of tradeable permits for controlling greenhouse gas emissions. We compared tradeable permits with taxes and with command-and-control regulations, and on the basis of those comparisons, we can offer the following observations: First, international application of effective tradeable permits regimes is likely to be significantly more complicated than domestic applications. Second, given the current understanding of the causes and consequences of global climate change, and limitations on monitoring and enforcement, a comprehensive market-based approach for greenhouse gas emissions is probably not appropriate, even in the United States. Third, domestic application of carbon taxes or tradeable carbon rights for controlling carbon dioxide emissions in the United States is likely to be substantially more cost-effective than command-and-control approaches that achieve similar environmental results.

The best approach to limiting greenhouse gases will probably involve a mixture of instruments.[96] This mix will vary across countries depending on their ability to define baselines and enforce different control strategies. Whereas the United States, for example, might be capable of defining and enforcing a strategy that gives credit for carbon dioxide sequestration from forests, some developing countries might not have the administrative or technical resources.

Theoretically, an international system of tradeable greenhouse gas permits can simultaneously address the issues of cost-effectiveness and equity. As a global problem involving uniformly mixed pollutants, global warming is particularly well suited to an approach that controls carbon dioxide emissions (and perhaps other greenhouse gas emissions) at the aggregate level, while encouraging individual nations with the lowest costs of control to take on added responsibility. Through the initial allocation of permits, questions of fairness between industrialized and developing nations can be addressed directly, and technology transfer can thus be engendered. A key concern in implementing a greenhouse policy—whether it involves tradeable permits or not—will be to ensure that compliance is adequately monitored and enforced.

It is unlikely that scientists, economists, or others will be able to resolve any time soon the myriad uncertainties involved in our current understanding of the causes and consequences of global climate change, but the call for action from some quarters is unmistakable. If governments decide that action is indeed warranted, important policy questions will have to be addressed, possibly quite quickly.

Given the pervasive role of energy generated from fossil fuels in virtually all nations, policies designed to address global climate change could have profound effects on many aspects of our lives. Therefore, at both international and domestic levels, cost-effectiveness must be a central consideration in policy design to ensure that the economic well-being of millions of people around the world is not unduly compromised. A tradeable permit system offers one possible route to a cost-effective attainment of greenhouse gas reduction goals. The potential implementation problems associated with such systems, however, are by no means trivial. Those problems, combined with the lessons learned from the United States's experiences with tradeable permit systems, suggest that careful attention must be given to the design of any system for it to have a reasonable chance of success.

ACKNOWLEDGMENTS

Helpful suggestions on framing the general issues addressed in this chapter were offered by Daniel Dudek, Henry Lee, Bruce Stram, Miriam Avins, and Teresa Johnson. However, we alone are responsible for any remaining errors.

NOTES

1. On 9 May 1992, 143 nations voted at the Earth Summit meeting in Rio de Janeiro to adopt a treaty requiring signatories to limit emissions of greenhouse gases. See William K. Stevens, "143 Lands Adopt Treaty to Cut Emission of Gases," *New York Times*, 10 May 1992, 4.

2. In February of 1992, the United Nations Conference on Trade and Development released a study that proposed a system of tradeable permits to help mitigate climate change, similar to that examined in this chapter. See United Nations Conference on Trade and Development report, "Trading Entitlements to Control Carbon Emissions: A Practical Way to Combat Global Warming" (Geneva: UNCTAD, February 1992).
3. We do not attempt, however, to define a particular allocation of responsibility as equitable or fair. On this issue, see Richard S. Eckaus, "Laissez Faire, Collective Control, or Nationalization of the Global Commons," discussion paper, Center for Energy and Environmental Policy Research, Massachusetts Institute of Technology, 6 October 1992; and H. Peyton Young and Amanda Wolf, "Global Warming Negotiations: Does Fairness Matter?" *The Brookings Review* 10, no. 2 (spring 1992): 46–51.
4. Peter Bohm and Clifford S. Russell, "Comparative Analysis of Alternative Policy Instruments," in *Handbook of Natural Resource and Energy Economics*, vol. 1, eds. Allen V. Kneese and James L. Sweeney (Amsterdam: North-Holland, 1985), 395–460.
5. For a general discussion of instruments for environmental protection, see Robert W. Hahn and Robert N. Stavins, "Market-based Environmental Regulation: A New Era from an Old Idea?" *Ecology Law Quarterly* 18, no. 1 (1991): 1–42.
6. A good example is the control of sulfur dioxide emissions that contribute to acid rain in the United States. It is unlikely that the targeted 10 million tons of reduction would have been agreed to without the introduction of a market-based approach that could achieve the goal using fewer resources than would a command-and-control approach.
7. There are several instruments of importance to policymakers that do not fall conveniently within these two categories (incentive-based and command-and-control), including monitoring and enforcement techniques, use of the courts, and use of information. In designing a system, including one based on economic incentives, these mechanisms should not be overlooked as either complements or substitutes in system design.
8. Regulations usually do not explicitly specify the technology but rather establish standards on the basis of a particular technology.
9. In a survey of eight empirical studies of air pollution control, Tietenberg found that the ratio of the actual, aggregate costs of conventional command-and-control approaches to the aggregate costs of least-cost benchmarks ranged from 1.07 for sulfate emissions in the Los An-

geles area to 22.0 for hydrocarbon emissions at all domestic DuPont plants. See T. H. Tietenberg, *Emissions Trading: An Exercise in Reforming Pollution Policy* (Washington, DC: Resources for the Future, 1985).

10. Numerical examples of the variance of incremental costs of air pollution control are provided by Robert W. Crandall, "The Political Economy of Clean Air: Practical Constraints on White House Review," in *Environmental Policy under Reagan's Executive Order: The Role of Benefit-Cost Analysis*, ed. V. Kerry Smith (Chapel Hill: University of North Carolina Press, 1984), 205–225.
11. For recent theoretical examinations of the effects of alternative environmental policy instruments on the diffusion of new technologies, see Scott R. Milliman and Raymond Price, "Firm Incentives to Promote Technological Change in Pollution Control," *Journal of Environmental Economics and Management* 17 (1989): 247–265; and David A. Malueg, "Emission Credit Trading and the Incentive to Adopt New Pollution Abatement Technology," *Journal of Environmental Economics and Management* 5 (1989): 52–57. For an empirical investigation of these same effects, see Adam B. Jaffe and Robert N. Stavins, "Dynamic Incentives of Environmental Regulation: The Effects of Alternative Policy Instruments on Technology Diffusion," *Journal of Environmental Economics and Management*, forthcoming, Volume 29, No. 1, July 1995. For a discussion of the politics of standard setting and the adverse impacts that command-and-control regulations can have on innovation, see Matt Ridley, "How to Smother Innovation," *Wall Street Journal*, 9 June 1993, A12.
12. Each source's marginal costs of pollution control are the additional or incremental costs for that source to achieve an additional unit of pollution reduction. If these marginal costs of control are not equal across sources, then the same aggregate level of pollution control could be achieved at lower overall cost simply by reallocating the pollution control burden among sources, so that low-cost controllers controlled proportionately more and high-cost controllers controlled proportionately less. Additional savings could theoretically be achieved through such reallocations until marginal costs were identical for all sources.
13. Robert N. Stavins and Bradley W. Whitehead, "The Greening of America's Taxes: Pollution Charges and Environmental Protection" (Washington, DC: Report of Progressive Policy Institute, February 1992).
14. The monitoring burden for both charges and tradeable permits may exceed that required under command-and-control regulations for

political and legal reasons, as well as for technological ones. Environmentalists may require better monitoring approaches in return for allowing environmental agencies to experiment with incentive-based approaches. Moreover, because firms are being charged for their estimated pollution, laws and regulations may require higher levels of monitoring to ensure that charges are neither too high nor too low.

15. The political difficulty of establishing large charges can also be viewed as an advantage of charge systems. Charges tend to give highly visible signals to consumers (and thus to politicians) of the costs of environmental protection and thus encourage the public to consider not only the benefits, but also the costs of environmental protection. For an examination of the magnitude of carbon taxes that would be required to achieve various greenhouse goals, see the chapter by Jorgenson and Wilcoxen in this volume.
16. Robert Hahn and Roger Noll, "Designing a Market for Tradeable Permits," in *Reform of Environmental Regulation*, ed. Wesley Magat (Cambridge, MA: Ballinger, 1982), 119–146.
17. These systems are likely to be the simplest in terms of their monitoring burdens, but can lead to complexities of other kinds. For example, if the environmental concern is carbon dioxide emissions, but the point of control is the carbon content of fossil fuels, it can be desirable to exempt nonfuel uses of petroleum, natural gas, and coal from the system.
18. Exposure trading is discussed by James A. Roumasset and Kirk R. Smith, "Exposure Trading: An Approach to More Efficient Air Pollution Control," *Journal of Environmental Economics and Management* 18 (1990): 276–291. For an examination of risk trading, see Paul R. Portney, "Reforming Environmental Regulation: Three Modest Proposals," *Issues in Science and Technology* 4 (1988): 74–81.
19. In the case of localized air pollution, differences in source location and seasonal factors mean that not all emissions reductions are of equal value in terms of improving air quality, a problem that also applies to command-and-control approaches. But in the case of transboundary pollutants, such as sulfur dioxide as an acid rain precursor, this concern about hot spots is much less important. In the case of global commons problems, such as climate change due to greenhouse gas emissions, this concern is completely irrelevant.
20. For tradeable permit reductions for CFCs, see Robert W. Hahn and Albert M. McGartland, "The Political Economy of Instrument Choice: An Examination of the U.S. Role in Implementing the Montreal Protocol," *Northwestern University Law Review* 83 (1989):

592–611. For point-nonpoint source trading for water quality control, see Henry M. Peskin, "Nonpoint Pollution and National Responsibility," *Resources,* no. 83 (spring 1986): 10–11.

21. An evaluation of the EPA's Emissions Trading Program can be found in Tom Tietenberg, *Emissions Trading: An Exercise in Reforming Pollution Policy* (Washington, DC: Resources for the Future, 1985). For a broader assessment of the EPA's experiences with tradeable permit policies, see Robert W. Hahn, "Economic Prescriptions for Environmental Problems: How the Patient Followed the Doctor's Orders," *Journal of Economic Perspectives* 3 (1989): 95–114.
22. U.S. Environmental Protection Agency, *Emissions Trading Policy Statement,* 51 Fed. Reg. 43,814 (1986) (final policy statement).
23. Richard A. Liroff, *Reforming Air Pollution Regulations: The Toil and Trouble of EPA's Bubble* (Washington, DC: Conservation Foundation, 1986).
24. Daniel J. Dudek and John Palmisano, "Emissions Trading: Why Is This Thoroughbred Hobbled?" *Columbia Journal of Environmental Law* 13 (1988): 217–256.
25. Jeremy Main, "Here Comes the Big New Cleanup," *Fortune,* 21 November 1988, 102–118; and Carolyn Lochhead, "Credit Bartering in the Market for Air Pollution," *Insight,* 3 July 1989, 15–17.
26. Robert W. Hahn and Gordon L. Hester, "Where Did All the Markets Go? An Analysis of EPA's Emissions Trading Program," *Yale Journal of Regulation* 6 (1989): 109–153.
27. U.S. Environmental Protection Agency, *Regulation of Fuel and Fuel Additives,* at 38,078–90 (proposed rule), 49,322–24 (final rule).
28. In each year of the program, more than 60 percent of the lead added to gasoline was associated with traded lead credits. See Robert W. Hahn and Gordon L. Hester, "Marketable Permits: Lessons for Theory and Practice," *Ecology Law Quarterly* 16 (1989): 361–406.
29. The program did experience some relatively minor implementation difficulties related to the importation of leaded fuel. It is not clear that a comparable command-and-control approach would have done better in terms of environmental quality. See U.S. General Accounting Office, *Vehicle Emissions: EPA Program to Assist Leaded-Gasoline Producers Needs Prompt Improvement,* GAO/RCED-86-182 (Washington, DC: U.S. GAO, August 1986).
30. Hahn and Hester, "Marketable Permits."
31. U.S. Environmental Protection Agency, Office of Policy Analysis, *Costs and Benefits of Reducing Lead in Gasoline, Final Regulatory Impact Analysis.* Washington, DC: February 1985.

32. The Montreal Protocol calls for a 50-percent reduction in the production of CFCs from 1986 levels by 1998. In addition, the protocol freezes halon production and consumption at 1986 levels beginning in 1992.
33. The system was designed with allowances to limit both domestic production and consumption. See Hahn and McGartland, "Political Economy of Instrumental Choice."
34. Letter from Richard D. Feldman, U.S. Environmental Protection Agency, 7 January 1991. In addition, there have been a very small number of international trades. Such trading is limited by the Montreal Protocol.
35. As of 1992, no firms were producing CFCs up to their maximum allowable level and permits could not be banked (carried forward). As a result, there is an excess supply of permits. It is possible, however, that there would be an excess supply even if there were no tax and an effective price of zero for permits. This excess in supply is due to firms reacting to changes in regulations and new policy initiatives that call for a more rapid phaseout of CFCs and halons.
36. Clean Air Act Amendments of 1990, Public Law No. 101-549, 104 Statute 2399, 1990.
37. For a description of the legislation, see Brian L. Ferrall, "The Clean Air Act Amendments of 1990 and the Use of Market Forces to Control Sulfur Dioxide Emissions," *Harvard Journal on Legislation* 28 (1991): 235–252.
38. Under specified conditions, utilities that have installed coal scrubbers to reduce emissions can receive two-year extensions of the Phase I deadline plus additional allowances.
39. Utilities that install scrubbers receive bonus allowances if they clean up early. In addition, specified utilities in Ohio, Indiana, and Illinois will receive extra allowances during both phases of the program. All of these extra allowances are essentially tradeable (and bankable) compensation intended to benefit midwestern plants, which presently rely on high-sulfur coal.
40. In general, units with a capacity of 75 MW or more and that emit sulfur dioxide at a rate of 1.2 pounds per million Btu face limitations on total emissions that are related to their actual energy generation during the period 1985–1987.
41. Clean Air Act Amendments of 1990.
42. Daniel J. Dudek, statement made at *Acid Rain: Hearings on S. 1630 Before the Subcommittee on Environmental Protection of the Senate Committee on the Environment and Public Works*, 101st Congress, 1st Session, 1989.

43. For activity of trading among utilities, see, for example, Matthew L. Wald, "Utility Is Selling Right to Pollute," *New York Times*, 12 May 1992, D7; and Matthew L. Wald, "Electric Utility in Ohio to Buy Pollution Rights from Alcoa," *New York Times*, 1 August 1992, D1. For increase in the reduction target, see Dennis Wamstead, "EPRI: SO_2 Model Predicts Trading Market," *Environment Week*, 6 June 1991, 5. For trading on a futures market, see "Chicago Board of Trade to Create Smog Futures," *Washington Post* 17 July 1991, F1; and "Smog Futures to Be Traded," *New York Times*, 22 April 1992, D1.
44. See, for example, Paul L. Joskow, "Implementing the Tradeable Allowance System for Acid-Rain Control" (paper presented at the John F. Kennedy School of Government, Harvard University, 2 October 1991); Robert W. Hahn and Roger G. Noll, "Barriers to Implementing Tradeable Air Pollution Permits: Problems of Regulatory Interactions," *Yale Journal on Regulation* 1 (1983): 63–92; Douglas R. Bohi and Dallas Burtraw, "Utility Investment Behavior and the Emission Trading Market," discussion paper ENR91-04, Resources for the Future, Washington, DC, January 1991; and Robert W. Hahn, "Government Markets and the Theory of the *N*th Best," discussion paper 91–14, Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, December 1991.
45. See Robert W. Hahn and Roger G. Noll, "Environmental Markets in the Year 2000," *Journal of Risk and Uncertainty* 3 (1990): 351–367. For a discussion of some of the trade-offs that may be encountered in the implementation of market-based approaches for limiting greenhouse gas emissions, see Michael A. Toman and Stephen M. Gardiner, "The Limits of Economic Instruments for International Greenhouse Gas Control," discussion paper, Resources for the Future, Washington, DC, December 1991.
46. See, for example, Anne E. Smith, "Issues in Implementing Tradeable Allowances for Greenhouse Gas Emissions" (paper presented at the 84th annual meeting of the Air and Waste Management Association, Vancouver, British Columbia, 16–21 June 1991).
47. For practical policy purposes, acid rain precursors may be thought of as uniformly mixed within relevant regions (airsheds).
48. A comparison of an international system of greenhouse tradeable permits with alternative policy mechanisms is provided by Joshua M. Epstein and Raj Gupta, *Controlling the Greenhouse Effect: Five Global Regimes Compared* (Washington, DC: Brookings Institution, 1990).
49. Alan S. Manne and Richard G. Richels, "International Trade in

Carbon Emission Rights: A Decomposition Procedure," *American Economic Review Papers and Proceedings* 81 (1991): 135–139.

50. For example, suppose Holland imposes a carbon tax that is higher than the equilibrium price of carbon permits in an international trading regime. Then, marginal control costs for limiting carbon would vary across nations, and some of the expected cost savings from an economic incentive approach would not be realized. Vice President Gore has, in fact, suggested a similar approach for the United States. See Albert Gore, *Earth in the Balance: Ecology and the Human Spirit* (Boston: Houghton Mifflin, 1992).
51. This set of conditions for a successful tradeable permit market was originally developed in the context of newsprint recycling credits by Terry M. Dinan, "Implementation Issues for Marketable Permits: A Case Study of Newsprint," *Journal of Regulatory Economics* 4 (1992): 71–87.
52. Furthermore, in the presence of transaction costs, the initial allocation of permits can affect the amount of trading that will occur, the equilibrium allocation, and the aggregate costs of control. See Robert N. Stavins, "Transaction Costs and Tradeable Permits." *Journal of Environmental Economics and Management,* forthcoming, Vol. 29, No. 1, July 1995.
53. Brokers have been successful in lowering transaction costs in other tradeable permit markets, such as for lead and criteria air pollutants. See Dudek and Palmisano, "Emissions Trading."
54. On the other hand, carbon dioxide emissions are correlated with the emissions of other pollutants that can have localized effects, including sulfur dioxide.
55. Stavins in "Transaction Costs" provides an examination of the implications for public policy of transactions costs in tradeable permit markets in terms of choosing between command-and-control and market-based instruments, choosing between tradeable permits and pollution taxes, and designing tradeable permit systems.
56. Robert W. Hahn, "Market Power and Transferable Property Rights," *Quarterly Journal of Economics* 99 (Nov. 1984): 753–765.
57. Such manipulation is unlikely if there are a large number of buyers and sellers in the market.
58. See, for example, Daniel Dudek and Alice LeBlanc, "Offsetting New CO_2 Emissions: A First Rational Greenhouse Policy Step," *Contemporary Policy Issues* 8, no. 3 (1990): 29–42.
59. See, for example, Jonathan Green and Philippe Sands, "Establishing an International System for Trading Pollution Rights," *International Environmental Reporter,* 12 February 1992, 80–85.

60. Within the general notion of a carbon-rights system among producers, there also exist a number of potential levels of trading: (1) primary energy extractors and importers, (2) energy processors, and (3) energy distributors. See Anne E. Smith, Anders R. Gjerde, Lynn I. DeLain, and Ray R. Zhang, "CO_2 Trading Issues; vol. 2., Choosing the Market Level for Trading" (Washington, DC: Decision Focus Incorporated, May 1992).
61. Daniel J. Dudek and Alice LeBlanc, "Preserving Tropical Forests and Climate: The Role of Trees in Greenhouse Gas Emissions Trading" (New York: Environmental Defense Fund, February 1992).
62. Quantitatively defining the magnitude, size, and rates of the loss of sinks, such as forests, would be an enormous undertaking. Satellite monitoring is a critical tool. This effort must be made, however, whether or not the international trading of credits involving sinks is authorized, so long as carbon dioxide emissions from destruction or creation of such sinks is incorporated into a convention.
63. See, for example, Marlise Simons, "North-South Divide Is Marring Environment Talks," *New York Times,* 17 March 1992, A8.
64. R. A. Houghton, "A Blueprint for Monitoring the Emissions of Carbon Dioxide and Other Greenhouse Gases from Tropical Deforestation" (paper presented at the Woods Hole Research Center, Woods Hole, MA, 20 January 1992).
65. For further discussion of the arguments in favor of the multiple-gas approach, see Richard B. Stewart and Jonathan B. Wiener, "The Comprehensive Approach to Global Climate Policy: Issues of Design and Practicality," *Arizona Journal of International and Comparative Law* 9 (1992): 85–113.
66. Arguments against the multiple-gas approach are found in David G. Victor, "Limits of Market-based Strategies for Slowing Global Warming: The Case of Tradeable Permits," *Policy Sciences* 24 (1991): 199–222.
67. Alexander Cristofaro and Joel D. Scheraga, "Policy Implications of a Comprehensive Greenhouse Gas Budget," working paper, Office of Policy Analysis, Office of Policy, Planning, and Evaluation, U.S. EPA, Washington, DC, September 1990.
68. Easing more gases into the trading framework may be easier said than done, particularly if trading is allowed across pollutants. For example, methane being introduced after a decade of carbon dioxide trading could have major effects on participants in the carbon dioxide market, giving rise to political resistance if the addition of methane resulted in an effective devaluation of carbon dioxide permits.

69. A recent example of such cooperation is the toxicological testing of alternatives to CFCs that was funded by several major chemical firms.
70. While the initial goal can be stated in many forms, it is critical that it be sufficiently flexible to accommodate trading. For example, restricting the ambient concentrations of each greenhouse gas to a fixed level would place ultimate limits on trading among gases. On the other hand, a goal stated in terms of maximum allowable temperature change could be translated into a carbon dioxide equivalent if carbon dioxide is the numeraire gas.
71. Michael Grubb and James K. Sebenius, "Participation, Allocation, and Adaptability in International Tradeable Emission Permit Systems for Greenhouse Gas Control," in *Proceedings of OECD Workshop on Tradeable Emission Permits to Reduce Greenhouse Gases* (Paris: OECD, June 1991), and Geoffrey Bertram, "Tradeable Emission Permits and the Control of Greenhouse Gases," *The Journal of Development Studies* 28 (1992): 423–446.
72. For example, under an allocation system related to population levels, the big players in the market would likely be India and China, as permit sellers, and the United States and perhaps the former Soviet Union, as buyers. See Epstein and Gupta, *Controlling the Greenhouse Effect.*
73. For example, the Canadians proposed the use of population and GNP combined as allocation criteria when CFC reduction obligations were being considered in the development of the Montreal Protocol.
74. This statement is an abstraction from the potential consequences of significant transactions costs. See discussion above.
75. Most proposals for allocating control obligations among nations call for proportionately higher rates of reduction in emissions by industrialized countries (and, among the industrialized countries, by the United States) and for substantial reductions in the predicted rates of increase in carbon dioxide emissions by most developing countries. See, for example, Florentin Krause, *Energy Policy in the Greenhouse: From Warming Fate to Warming Limit—Benchmarks for a Global Climate Convention* (The Hague: Dutch Ministry of Housing, Physical Planning, and Environment and the European Environmental Bureau, 1989); Christopher Flavin, "Slowing Global Warming: A Worldwide Strategy," Worldwatch Paper 91 (Washington, DC: Worldwatch Institute, October 1989); and David Wirth and Daniel Lashof, "Beyond Vienna and Montreal—Multilateral Agreements on Greenhouse Gases," *Ambio* 19 (1990): 305–310.
76. The chapter by Norberg-Bohm and Hart in this volume discusses

the barriers to successful technology adoption in developing countries.

77. For further discussion, see James T. B. Tripp and Daniel J. Dudek, "Comments on the IPCC Working Group III Economic Measures Paper" (New York: Environmental Defense Fund, January 1990). For examinations of the international distributional implications of carbon dioxide controls, see Alan S. Manne and Richard G. Richels, "Global CO_2 Emission Reductions: The Impacts of Rising Energy Costs," *The Energy Journal* 12, no. 1 (1991): 87–107; and David Pearce and Edward Barbier, "The Greenhouse Effect: A View from Europe," *The Energy Journal* 12, no. 1 (1991): 147–160.
78. Scott Barrett, "Economic Instruments for Global Climate Change Policy," working paper, London Business School, November 1991.
79. Jose Goldemberg, "Brazil's Small Share of the Greenhouse," *New York Times*, 28 July 1990, A20.
80. This group would likely have limited authority, given the interest of countries in maintaining their sovereignty. The group could be patterned after the Montreal Protocol, which has designated an implementation committee consisting of six parties. This committee assesses the extent of compliance and works with countries to help bring them into compliance.
81. A variant on the preceding proposal would be to allow selected countries to trade internationally and allow the supranational authority to review special requests from other countries on a case-by-case basis. This alternative would be administratively cumbersome.
82. David Pearce, "Greenhouse Gas Agreements: Internationally Tradeable Greenhouse Gas Permits," working paper, Department of Economics, University College, London, March 1990.
83. Robert W. Hahn and Gordon L. Hester, "The Market for Bads: EPA's Experience with Emissions Trading," *Regulation* 3/4 (1987): 48–53.
84. See David Victor, "Limits of Market-based Strategies." The problem of defining which gases are appropriate for economic incentives is by no means straightforward. Consider the case of CFCs as they relate to climate change. CFCs were thought to have the greatest influence on climate change on a mass basis; however, CFCs are now considered to have a much lower impact on climate, and may even have a negligible one. Of course, CFCs may need to be limited because of their effect on stratospheric ozone, but this example illustrates the potential difficulties of defining control strategies when the science is uncertain.
85. See, for example, the chapter by Stram in this volume; Dale W. Jorgenson, Daniel T. Slesnick, and Peter J. Wilcoxen, "Carbon Taxes

and Economic Welfare," in *Brookings Papers: Microeconomics 1992* (Washington, DC: Brookings Institution), 393–454; U.S. Congressional Budget Office, *Carbon Charges as a Response to Global Warming: The Effects of Taxing Fossil Fuels*, Washington, DC, August 1990; David Pearce, "The Role of Carbon Taxes in Adjusting to Global Warming," *The Economic Journal* 101 (1991): 938–948; and Lawrence H. Goulder, "Effects of Carbon Taxes in an Economy with Prior Tax Distortions: An Intertemporal General Equilibrium Analysis," working paper, Stanford University, January 1993.

86. Compared with conventional command-and-control regulations, both charges and permits provide an explicit price signal about the marginal cost of limiting emissions.
87. The U.S. federal budget negotiations of 1990 provide at least indirect evidence of this point. The Bush administration proposed a 25 cent per gallon gasoline tax increase; Congress eventually enacted a 5 cent increase. The demise in 1993 of the Clinton administration's proposed Btu tax is a more recent example.
88. These distinctions between resource transfers assume that permits are distributed free of charge to firms, not auctioned by the government. In the latter case, permits and charges are quite similar in terms of these financial transfers. Moreover, it is possible to design a subsidy or charge scheme that is similar in distributional terms to a permit approach.
89. Reference here is to environmental problems with highly nonlinear dose-response functions, that is, threshold impacts.
90. Martin L. Weitzman, "Prices vs. Quantities," *Review of Economic Studies* 41 (1974): 477–491.
91. This change can be offset to some degree by expanded production that results from lower total operating costs.
92. Although there is no cutoff point, it is unlikely that firms or nations could engage in price-setting behavior if they controlled less than 10 percent of the market. See F. M. Scherer, *Industrial Market Structure and Economic Performance* (Chicago: Rand McNally, 1980). Ultimately, the question is whether other firms present credible threats of entry to the market, that is, whether the market is contestable. If so, it is less likely that anticompetitive behavior can thrive. See William J. Baumol, John Panzar, and Robert Willig, *Contestable Markets and the Theory of Industrial Structure* (New York: Harcourt Brace Jovanovich, 1982).
93. Stavins, "Transaction Costs."
94. Geoffrey Heal, "International Negotiations on Emission Control"

(paper presented at the National Bureau of Economic Research, Cambridge, MA, August 1991).

95. The likelihood of reaching an international environmental agreement will be affected by several factors. See James K. Sebenius, "Designing Negotiations toward a New Regime: The Case of Global Warming," *International Security* 15 (1991): 110–148; and Robert W. Hahn and Kenneth R. Richards, "The Internationalization of Environmental Regulation," *Harvard International Law Journal* 30 (1989): 421–446.

96. Rosina Bierbaum and Robert M. Friedman, "The Road to Reduced Carbon Emissions," *Issues in Science and Technology* 8 (1992): 58–65.