11

An Economic Assessment of Policy Instruments for Combatting Climate Change

Lead Authors:
B.S. FISHER, S. BARRETT, P. BOHM, M. KURODA, J.K.E. MUBAZI,
A. SHAH, R.N. STAVINS

Contributors:
E. Haites, M. Hinchy, S. Thorpe

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CONTENTS

SUMMARY

A clear distinction needs to be drawn between the costs and benefits of actions taken to reduce the impacts of climate change and the costs and benefits of actions taken to reduce emissions. The first involves a consideration of adaptation policies such as developing new drought-resistant plant cultivars, whereas the second involves a consideration of policies designed to mitigate climate change. The final policy mix adopted by countries is likely to contain both adaptation and mitigation policies.

The world economy and individual national economies suffer from other distortions than those possibly leading to global climate change. Any of these may prevent economies from attaining efficient outcomes. In many cases, correcting for those other distortions would lead to actions that would also serve to reduce the expected damage from climate change. Plainly, such distortions should be corrected, and many governments are already taking steps to do so.

To effect a substantial reduction in net greenhouse gas emissions, such as would be required to stabilize atmospheric concentrations, requires policies expressly designed to mitigate global climate change. The associated policy instruments must be identified at two different levels: those that might be used by a coalition of countries and those that might be used by individual nations unilaterally or to achieve compliance with a multilateral agreement on greenhouse gas emission targets.

Governments may have different sets of criteria for assessing international as well as domestic greenhouse policy instruments. Among these criteria are efficiency or cost-effectiveness, effectiveness in achieving stated environmental targets, distributional (including intergenerational) equity, flexibility in the face of new knowledge, understandability to the general public, and consistency with national institutions and traditions. The choice of instruments may also partly reflect a desire on the part of governments to achieve other objectives such as meeting fiscal targets or influencing pollution levels indirectly related to greenhouse gas emissions. Governments may also be concerned about the effects of policy on competitiveness.

A coalition of nations may choose one or a mix of policy instruments, including tradable quotas, feasible forms of joint implementation, harmonized domestic carbon taxes, international carbon taxes, nontradable quotas, and various international standards. At both the international and national levels, market-based approaches are likely to be more cost-effective than other instruments.

At the international level, all the potentially efficient tax or quota solutions should be available to facilitate future negotiations. Under a harmonized carbon tax, incentives exist for countries to alter related policies to reduce the domestic implications of the tax (for example, by introducing offsetting production subsidies). This possibility could make harmonized carbon taxes less effective than tradable quotas in reducing emissions.

For a global treaty, a tradable quota system is the only potentially cost-effective arrangement where an agreed level of emissions is attained with certainty (subject to enforcement). The initial quota allocation could provide a means of compensation to countries – particularly developing countries – that would bear substantial costs in implementing international response measures. This attribute would provide the opportunity to encourage developing countries to participate actively in global action.

In principle, individual countries can choose from among a large set of available instruments, including carbon taxes, tradable permits, deposit refund systems, and subsidies, as well as technology standards, performance standards, product bans, direct government investment, and voluntary agreements. A choice of tradable quotas at the international level would provide maximum flexibility for instrument choice at the domestic level.

A tradable quota or permit system has the disadvantage of making the marginal cost of emission reductions uncertain, whereas a carbon tax has the disadvantage of leaving the level at which emissions will be controlled uncertain. The weight given to the importance of reducing these different types of uncertainty will be crucial in determining the final choice between competing market-based instruments. Regardless of the final mix of instruments adopted, there will remain a high degree of uncertainty about the physical effects of different levels of emissions.

The consequences of climate change policy will be determined by the choice of the mix of policy instruments, the design and implementation of those policies, and the institutional framework in which the policies must operate. For example, regulatory instruments are likely to have a different impact on innovation than market-based instruments. Furthermore, the welfare effects of a carbon tax or the government sale of tradable permits will depend on whether and how the associated revenues are recycled. In some countries monitoring and enforcement may be more difficult than in others, and such differences could have a direct impact on the effectiveness of some policy instruments.

11.1 Introduction

11.1.1 Guidelines from the FCCC

The aim in this chapter is to provide an economic assessment of possible policy instruments for managing greenhouse gas emissions under the Framework Convention on Climate Change (FCCC). The Framework Convention contains several key guidelines for policy implementation. First is the emphasis given to the need for developed countries to demonstrate that they are taking the leading role in policies to control greenhouse emissions. In essence, developed country signatories (as listed in Annex I of the Convention) have accepted the goal, but not necessarily the requirement, of stabilizing greenhouse gas emissions at 1990 levels by 2000 (Article 4.2). In ratifying the Convention, Annex I countries have effectively accepted a quantitative emission target, although the level of that target remains uncertain. Developing country signatories (non-Annex countries) are under no such obligation. Rather, the economic needs and special circumstances of developing countries (Articles 4.8 and 4.10), and of countries highly dependent on incomes from fossil fuels (Article 4.10), will be taken into account in determining specific commitments to control emissions.

To achieve greenhouse emission reductions, Annex I countries have the option to implement greenhouse policy measures jointly with other parties to the Convention (Article 4.2). This provision is consistent with another guiding principle in the Convention that stipulates that all greenhouse policy measures should be cost-effective – that is, that they should achieve policy goals at least cost (Article 3). Other key principles in Article 3 require the parties to promote sustainable development, to take precautionary measures to minimize the costs of greenhouse uncertainties and risks (noting that where there are risks of serious or irreversible damage, lack of scientific certainty should not be used to justify policy deferral), and to ensure that measures taken to combat climate change do not amount to unfair trade restrictions.

Prior to the development of the FCCC, the most closely related international conventions were the Vienna Convention for Protection of the Ozone Layer (concluded in 1985) and the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer (the text of which was revised in 1990 and again in 1992). The experience of the parties to the Montreal Protocol provides valuable information about the implementation of policy approaches within the FCCC.[1]

In this chapter, the factors affecting the policy mix for the control of greenhouse gas emissions are reviewed in the light of these guiding principles and the general international legal framework in which the Convention must operate.

11.1.2 The greenhouse policy problem

Two characteristics of the greenhouse problem are central to the design of policy responses. The first key feature is that it is a global problem. It is the total accumulation of greenhouse gases in the atmosphere that could cause global warming over the next century (IPCC 1990; 1992), regardless of the geographic source of emissions. In addition, there is a long time lag, up to fifty years, between emission reductions and their impact on atmospheric concentrations. Thus, the greenhouse problem is a pollution problem over space and time, and one in which increased absorption can reduce atmospheric concentrations of greenhouse gases as effectively as reduced emissions. Any benefits from controlling concentrations will depend on long-term global cooperation, and the costs of collective control will be incurred long before any potential benefits are realized.[2]

The second key feature of the greenhouse problem is that both the extent of any climate change and the nature of its effects are uncertain. This means that potential greenhouse policies must be assessed using a decision-making framework that explicitly incorporates risk, uncertainty, and the capacity to learn about evolving climatic and economic conditions around the world.

A basic principle in public policy (as for any financial decision) is to time the introduction of the policy to maximize the expected discounted value of the stream of net benefits from the initiative. In this context, there may be benefits from waiting to reduce uncertainties before implementing greenhouse policies.[3] The value of the information gained from waiting could allow greenhouse policy to be properly tailored to the most likely damage scenario in order to avoid excessive control costs (Peck and Teisberg, 1993; Leary and Scheraga, 1994; Richels and Edmonds, 1994). Conversely, there could be significant costs in waiting, if waiting makes excessive damage costs more likely (Chichilnisky and Heal, 1993) or results in the need for urgent action at some future time, with associated disproportionate adjustment costs.

Greenhouse policy assessment must therefore take into account the existence of opposing risks. Indeed, one important avenue for policy assessment is to examine the extent to which policy can be directed to reduce the costs of uncertainty and the costs of risk from natural damage caused by the enhanced greenhouse effect and from mitigation measures in response to climate change concerns. An immediate response to the greenhouse problem is to invest in research and development to reduce greenhouse uncertainties and subsequently to provide new information to decision makers.

An efficient greenhouse policy would ensure that the costs of greenhouse uncertainties, and of associated risks, and the costs of emission reductions and adaptation strategies are balanced, at the margin, with the benefits from avoiding damage from global warming. One implication of this efficiency criterion is that the optimal policy is the one that achieves a global greenhouse target at least cost in the face of risk, uncertainty, and the need for further knowledge about the causes and effects of climate change. However, regardless of the policy approach adopted, considerable physical uncertainty about both the effects and extent of climate change will remain.

11.2 Greenhouse Policy Instruments and Criteria for Policy Assessment

The variety of instruments available to policymakers to control greenhouse gas emissions is outlined here. Such instruments include conventional regulatory instruments, market-based instruments such as taxes, subsidies, and tradable quotas and permits, and other complementary policies. In this chapter the term "tradable quota" is used to describe internationally traded emission allowances. The term "permit" is more commonly used in the literature to describe domestic trading schemes, and that convention is adopted here. Existing global climate change research that has analyzed a broad range of policy instruments includes Mintzer (1988); US Congress, Office of Technology Assessment (1991); IPCC (1992); National Academy of Sciences (1992); and McCann and Moss (1993).

11.2.1 Domestic policy instruments

11.2.1.1 *Conventional regulatory instruments*

One way of controlling activities that both directly and indirectly lead to greenhouse gas emissions is to set standards and to regulate the activities of firms or individuals. By mandating standards, governments attempt to ban or alter the use of materials and equipment considered to be damaging. Standards are typically applied in areas such as buildings (energy efficiency, for example), fuel use by motor vehicles, energy efficiency of household appliances, and the content of fuels. Standards may be voluntary or mandatory. They may be fixed or set as targets, or "rolling standards" might be adopted (Grubb, 1991).

11.2.1.2 *Market-based instruments*

In using market-based instruments, governments attempt to alter price signals to ensure that emitters face direct-cost incentives to control emissions. The primary market-based instruments for greenhouse management are emission taxes and tradable emission permits.

11.2.1.2.1 Taxes and subsidies

Under an emission tax, those who produce emissions face a tax per unit of emissions.[4] All fossil fuels should be taxed at the same rate per unit of their long-term global warming potential. A tax on energy content measured in British thermal units, the so-called BTU tax, would not satisfy this criterion, as it relates to energy use per se rather than to any externalities associated with end products of combustion (see Poterba, 1993). A tax on the carbon content of fossil fuels, on the other hand, would approximate this criterion. Implementing such taxes at a uniform rate per tonne of carbon content of fossil fuels to curtail carbon emissions assumes that existing excises on energy products are levied at the optimal level based on minimizing the excess burden of taxation and internalization of environmental externalities. If such an assumption does not hold in practice, the design of carbon taxes becomes more complicated.

Subsidies might be offered for adopting particular technologies or practices. Such subsidies might be directed at fostering emission abatement or the creation of additional sinks by, for example, subsidizing tree planting.

A subsidy scheme could be linked to a tax scheme by applying the subsidy to reductions in emissions below a baseline and a tax on emissions above the baseline. The rate of subsidy would be applied per unit of emissions at the same rate as the emission tax. A tax/subsidy scheme would mean that firms would not pay a tax on every unit of emissions, but it would involve an additional administrative burden in setting the baseline for every firm.

11.2.1.2.2 Tradable permits

Under an emission-trading scheme, emitters are given permits to emit (the total allocation is the aggregate emission cap for the country) and have the option of buying or selling permits in the marketplace. Although there are important and often subtle differences between taxes and tradable permits, under some restrictive circumstances the outcome can be the same. Both may target full user-cost pricing of the atmosphere to dispose of net greenhouse gas emissions from human activity. When traded on a national market, permit prices are established that show the costs of marginal emissions, just as an emission tax does. The difference is that the tax is exogenous (in this case, set by the government) and its effects on emissions endogenous, whereas emissions are exogenously determined in the case of a permit system and, hence, permit prices are endogenous.

A tradable-permit system could be used in combination with either an international tradable-quota system or an international carbon tax. In the former case, the domestic permit system could either be integrated with an international quota system, where the permit-liable parties (say, a limited set of wholesale fossil fuel dealers) trade directly on the international quota market (see Grubb and Sebenius, 1991; Sandor *et al.*, 1994) or be run as a separate subsystem providing the national government with a net excess demand for (or supply of) emission quotas at the ruling international quota price. In the case where governments paid an international tax on carbon emissions, it would be up to each government to determine beforehand the volume of domestic permits available per period. Ideally, this volume should be such that the resulting permit price would be equal to the tax rate. If not, nationally as well as internationally, too little or too much abatement would take place.

11.2.1.3 *Other complementary policies*

A range of other complementary instruments exists that might be adopted to moderate greenhouse gas emissions or to promote adaptation to climate change. Education and provision of new information – by promoting research, for example – may be valuable in changing consumer behaviour with respect to energy consumption and the development and adoption of new technology. Family planning may play an indirect role in reducing total energy demand in the future, as might more general education directed specifically at women in developing countries. Modifications of trade policy and reductions in energy production and consumption subsidies (and other market distortions) may also have indirect consequences for greenhouse gas emissions. Changes in migration policies in some countries may allow more flexibility for developing countries to adapt to regional population pressures that may arise as a consequence of changes in the incidence of occurrences such as severe drought.

11.2.2 International policy instruments

The use of the available policy instruments will only lead to a cost-effective global outcome if certain conditions are met. First, unless individual countries undertake cost-effective domestic greenhouse policy measures that are compatible with the goal of global efficiency, the policy instruments adopted internationally will not lead to that goal. Each individual country is free to choose its own instrument or combination of instruments to meet its international obligations, but the choice of international instruments will, to some extent, dictate the choice of policy instruments at the domestic level. This is clearly so in the case of the harmonized carbon/energy tax proposed by the European Commission for member states of the European Union. Under this regime, every member of the Union would impose the same tax rate, although states would be free to decide for themselves what to do with the revenues from the tax. If nations themselves were taxed by an international agency, it would not necessarily follow that nations would choose to impose the same tax domestically. For example, they might instead choose to reduce emissions domestically by means of a tradable permit scheme. Similarly, in the case of a system of internationally tradable quotas, individual countries might choose to implement their obligations by means of a domestic tradable permit scheme or through a domestic emission tax.

Second, given that information is not perfect and that distortions already exist in both international and domestic markets, the actual market outcomes from the implementation of particular greenhouse policies will not necessarily be efficient. The importance of the policy environment is discussed in Section 11.3, and implementation issues surrounding the adoption of market-based instruments are outlined in Section 11.6.

11.2.2.1 Regulatory instruments

It is conceivable that uniform standards could be established among countries participating in an international emission reduction agreement. But it is likely to be difficult to achieve wide agreement about any large set of specific instruments of this type. For example, individual countries may adopt standards for housing insulation, but it is most unlikely that the same standards would be applicable in both temperate and tropical countries. Moreover, such an approach would limit the domestic policy choices of individual countries and, hence, their flexibility in adjusting their emissions under an international greenhouse gas reduction agreement. Another regulatory approach involves agreements by countries on fixed national emission levels (a "nontradable emission quota" system), much in the tradition of the European Union's Large Combustion Plants Directive, which specifies reductions in the emissions of sulphur dioxide and oxides of nitrogen from plants with a thermal rating of 50 MW or larger. Such an approach would mean that marginal emission abatement costs among participating countries would tend to be different and, hence, total abatement costs, globally speaking, would be unnecessarily high.

11.2.2.2 International taxes and harmonized domestic taxes

If countries agreed to apply the same level of domestic greenhouse or carbon taxes (harmonized domestic taxes), marginal abatement costs would tend to be equalized among countries. Such an agreement may have to include side payments from rich to poor countries if the latter are to be encouraged to participate.

An alternative type of international policy to reduce emissions could be an agreement to levy a uniform international tax on greenhouse or carbon emissions in each of the participating countries. The total international tax revenue would be shared among the participating countries according to rules established in the agreement.

If an international tax agreement did not cover all countries, world fossil fuel prices would decrease and fossil fuel use increase in nonparticipating countries (so-called carbon leakage). In addition, since carbon-intensive products would be less expensive in such countries, exports of them to the participating countries would likely rise. A policy instrument might then be introduced by the latter countries to control carbon leakage (see Section 11.6.5 for further discussion). For example, a carbon tariff might be imposed at a rate corresponding to the tax rate on imported products on the basis of their estimated carbon contents.

In the case of a domestic carbon tax imposed by international agreement, the national commitment to impose the tax will also vary because perspectives on global warming vary from one country to another. If a country has signed such an agreement under international pressure, that country could make the carbon tax ineffective by reducing existing energy taxes, by taxing substitutes for fossil fuels (for example, hydroelectricity), by providing subsidies to complements or products that are fossil-fuel-energy intensive, and by lax enforcement of the tax (see Hoel, 1993). Thus, by following a suitable strategy, a free ride becomes possible. A global carbon tax imposed by an international agency, on the other hand, would impinge on national sovereignty and would therefore be difficult to negotiate.

If global carbon taxes were levied as producer taxes instead of consumer taxes, tax revenue would be collected in fossil fuel producer countries instead of consumer countries and, hence, would shift the burden between the two types of countries (Whalley and Wigle, 1991). The distributional effects of a "producer cartel" solution may be unacceptable to a great many countries and, if used, could give rise to retaliatory trade policy measures. (Neither carbon producer taxes nor producer quota systems are further discussed in detail in this chapter.)

11.2.2.3 Tradable quotas

Another potentially cost-effective international solution would be one in which countries agree to an allocation of carbon emission quotas, perhaps reflecting an overall emission target. In a practical sense, signatories to the FCCC have implicitly accepted such a quantitative target. International quota trading (Sandor *et al.*, 1994) would establish a quota price – an implicit international tax rate – that would tend to equalize marginal abatement costs among countries. A carbon leakage problem similar to that mentioned above would arise to the extent that such an agreement was not global.

In the case of an international tradable quota scheme, participating countries could use whatever domestic policies they preferred in order to stay within their final quota entitlements once all quota trades were complete. For example, they might employ tradable permits, domestic taxes, or regulations. If a domestic carbon tax were used, the efficient tax rate for the coming period would be the (unknown) quota price level for that period.

11.2.2.4 *Other complementary policies*

Technology transfer from industrialized to developing countries potentially has a large part to play in reducing future emissions. One mechanism to facilitate such transfers is joint implementation, to the extent that it proves practically feasible. Joint implementation aims at minimizing the joint costs of emission reductions for a group of emitters. In the context of emitters who are committed to targets, it could lead to the development of a tradable quota scheme.

11.2.3 Criteria for policy assessment

In this chapter a range of criteria is used to assess policy instruments to manage the greenhouse problem. Two important criteria are economic efficiency and distributive justice. The efficiency objective or cost-benefit principle is to maximize the global net benefits from the use of resources. Both the global greenhouse emission target and the preferred policy instruments to achieve it are choice variables for satisfying this criterion. However, there is considerable uncertainty regarding the effects of unconstrained greenhouse gas emissions at this time. Hence, there is uncertainty regarding the benefit and cost functions, and as a consequence of this, there is considerable uncertainty regarding the optimal (economically efficient) level of control. One practical response is to employ a cost-effectiveness objective – that is, to minimize the costs of achieving a given global greenhouse emission target.

The cost-effectiveness of achieving a given but potentially time-varying target is a criterion that is employed in much of this chapter. Policies may differ in their ability to achieve an emission target under changing conditions. A policy that consistently "hits the target" (achieves environmental effectiveness) and remains cost-effective is desirable.

11.2.3.1 *The choice of policy instruments under uncertainty*

In the absence of uncertainty, emission taxes and quantity controls, such as a tradable quota system, are equivalent. Indeed, it would be neither harder nor easier to specify the appropriate tax than the appropriate quantity of quotas. This is because the same information is required to specify both. However, both the science and economics of climate change involve many uncertainties. It is not known precisely how the climate will change given different emission trajectories. Nor is the cost of following each of these trajectories known. It is therefore important to compare these different instruments under uncertainty.

Perhaps surprisingly, uncertainty with respect to the benefits of abatement on its own does not favour either instrument. If the marginal abatement cost curve is known, then choice of a tax will result in a known quantity of emissions and choice of a quantity of tradable quotas will result in a known quota price (under the usual assumptions). This means that the outcome in terms of both emissions and marginal cost can be determined as easily by one instrument as by the other. Although uncertainty about the benefits of abatement makes choosing the appropriate target difficult, one instrument works as well as the other once the target is chosen.

If the policy goal is to meet a particular emission target, then tradable quotas or an equivalent quantity-based instrument will be preferred, insofar as they can guarantee that the emission target is met. However, from the point of view of efficiency this instrument may not be best.

In an important paper, Weitzman (1974) showed that uncertainty with respect to the costs of abatement does affect the choice between these instruments if the goal of policy is to maximize the net benefits of abatement. A substantial literature in the context of environmental policy followed, including major works by Adar and Griffin (1976), Yohe (1977), and Watson and Ridker (1984). Where there is uncertainty about abatement costs, use of tradable quotas will guarantee that emissions do not exceed the quantity of quotas allocated (assuming full compliance), irrespective of the costs of doing so. Conversely, an emission tax would guarantee that marginal abatement costs did not exceed the magnitude of the tax, no matter how large or small was the resulting level of emissions. What Weitzman shows is that, if the marginal benefit and marginal cost curves are linear, the two instruments will be equivalent only if the slopes of these curves are equal (in absolute value terms). If the marginal cost curve is steeper than the marginal benefit curve, emission taxes will result in a more efficient outcome. Conversely, if the slope of the marginal cost curve is less than the slope of the marginal benefit curve, then tradable quotas would be preferred.

The available evidence indicates that marginal abatement costs will be steep once abatement becomes substantial (see, for example, Nordhaus, 1991b), although this curve may flatten out considerably if a "backstop technology" becomes available. By contrast, little is known about how marginal abatement benefits vary with the level of abatement. There is, however, some concern that a threshold may exist in the damages associated with greenhouse gas concentrations (which depend, in turn, on emissions and the rate of sequestration). Hence, there are arguments that can be made in favour of both instruments.

Although benefit uncertainty on its own has no effect on the identity of the optimal (efficient) control instrument, in the presence of simultaneous uncertainty in both marginal benefits and marginal costs and with some statistical dependence between them, the usual Weitzman result can be reversed, depending on the magnitudes of benefit and cost uncertainty and the degree and sign of the correlation between them (Stavins, 1996). A positive correlation will always tend to favour a quantity instrument and a negative correlation will tend to favour a price instrument.

However, these two instruments are not mutually exclusive, and it turns out that a mixed system can be preferable to either of the pure instrument options (see Roberts and Spence, 1976). Under a mixed system, a certain quantity of quotas may be made available. In addition, both a tax and a subsidy are imposed, with the tax being higher than the subsidy. If costs turn out to be higher than expected, polluters may pay the tax instead of purchasing more costly quotas. The tax thus serves to cap marginal abatement costs. If, on the other hand, costs turn out to be lower than expected, polluters can reduce their emissions even further in order to obtain the subsidy. The mixed system performs better than either pure system under cost uncertainty because the mixed system effectively has two instruments at its disposal.

A nonlinear emission tax can do better still. Under such a tax the marginal tax rate varies with the quantity of emissions. The tax schedule should approximate the marginal benefit curve. If the marginal benefit curve were known with certainty, then obviously a marginal tax schedule identical to the marginal benefit curve would ensure a fully efficient outcome, irrespective of the uncertainties regarding abatement costs. The marginal benefit curve is not known in the case of climate change. However, enough may be known to specify two or three steps in the curve.

For the remainder of this chapter, it will be assumed that a given ceiling on emissions has been identified as a target, and that governments seek to minimize the costs of meeting this target. The main concern here is thus with cost-effectiveness rather than efficiency as such. This assumption is made partly for analytical convenience (only pure tax and tradable quota systems are considered in detail) and partly because so much of the policy debate about global climate change has focussed on the appropriate emission targets. Indeed, the Framework Convention on Climate Change refers explicitly to such targets.

11.2.3.2 Other considerations

As a practical matter it is also important to distinguish static from dynamic cost-effectiveness. Static efficiency refers to a short-term operating environment in which technology options and aggregate primary resource availabilities are fixed; dynamic efficiency pertains to a long-term operating environment in which technology options and primary resource availabilities change. A policy that is cost-effective in the short run may not be cost-effective in the long run.

In addition to the application of the global least-cost principle to policies for emission control, the other main criterion for policy assessment is the objective of distributive justice. This requires that the total net benefits (costs) generated by the policy should be "equitably" shared.

Central to the analysis of the performance of any greenhouse policy is the recognition that the real-world operating environment involves major sources of greenhouse uncertainty and associated risk regarding future economic and ecological conditions. Decision makers will face the costs of uncertainty and risk from making incorrect decisions. But it is possible to reduce these costs by ensuring that policy is flexible and reversible in response to new information about the most cost-effective future strategy. The ability to modify policy settings and introduce new policies without generating major costs of adjustment are key criteria for greenhouse management.

Potential net benefits from a policy initiative must also take into account the administrative costs of the programme. Whether an efficiency criterion (maximizing net benefits) or a cost-effectiveness criterion (minimizing aggregate costs) is being employed, it is essential that the full measure of costs include both implementation costs (typically borne by governments) and transaction costs (typically borne by the private sector).

Costs need to be measured correctly. A taxonomy of the costs of environmental regulation, beginning with the most obvious and moving towards the least direct, is provided in Table 11.1.[5] First, many policymakers, and much of the general public, would identify the on-budget costs to government of administering (monitoring and enforcing) environmental laws and regulations as *the* cost of environmental regulation. However, most analysts would identify the capital and operating expenditures associated with regulatory compliance as the fundamental part of the overall costs of regulation, although a substantial share of compliance costs for some environmental regulations fall on government rather than private firms – one

Table 11.1. *A Taxonomy of costs of environmental regulation*

Government Administration of Environmental Statutes and Regulations
Monitoring enforcement
Private Sector Compliance Expenditures
Capital
Operating
Other Direct Costs
Legal and other transactional
Shifted management focus
Disrupted production
Negative Costs
Natural resource inputs
Worker health
Innovation stimulation
General Equilibrium Effects
Product substitution
Discouraged investment
Retarded innovation
Transition Costs
Unemployment
Obsolete capital
Social Impacts
Loss of middle-class jobs
Economic security impacts

Source: Jaffe *et al.* (1995).

example being regulations for contaminants in drinking water. Additional direct costs include legal and other transaction costs, the effects of refocussed management attention, and the possibility of disrupted production.

Next, the potential "negative costs" (in other words, non-environmental benefits) of environmental regulation, including the productivity impacts of a cleaner environment and the potential effects of regulation on innovation, should also be considered. General equilibrium effects associated with product substitution, discouraged investment,[6] and retarded innovation constitute another important layer of costs, as do the transition costs of real-world economies responding over time to regulatory changes. Finally, there are potential social impacts, such as those on jobs and economic security, that are given substantial weight in political forums.[7]

This discussion of some of the special difficulties of assessing the cost-effectiveness of alternative policy instruments should not be taken to mean that this single criterion is of exclusive or paramount importance. On the contrary, individual nations will inevitably choose their own criteria to distinguish between competing policy instruments. The specific criteria chosen will always be a function of the individual socioeconomic and cultural context, but in many cases the following set of criteria will be among those considered:

(a) probability that the environmental goal will be achieved
(b) efficiency or cost-effectiveness
(c) dynamic incentives for innovation and the diffusion of improved technologies
(d) flexibility and adaptability to exogenous changes in technology, resource use, and consumer tastes
(e) distributional equity
(f) feasibility in terms of political implementation and administration.

Finally, in assessing policy options in this chapter both the spatial and temporal aspects of emission coverage are considered. The general design features of economic instruments are categorized by the coverage of net greenhouse gas emissions, the scope and level of participation, and the point of application. For example, an emission control objective could involve imposing a target on all or a subset of all human sources and sinks and all or a subset of all greenhouse gases. In addition, the scope of a policy instrument could involve all or a subset of countries. The level of participation in a scheme refers to the economic unit responsible for meeting a target. Options range from the level of the country to that of individuals or companies. The point of application of the policy simply refers to the point in the production or consumption chain of a good or service at which greenhouse gas emissions are to be counted or proxied.

11.2.4 Coverage of greenhouse gases

11.2.4.1 The need for comprehensive targets

Should an initial international programme include all greenhouse gases or focus on CO_2 alone? This question has received considerable debate in the literature (see, for example, Cristofaro and Scheraga, 1990; Victor, 1991; Stewart and Wiener, 1992). 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. However, the sources and sinks of methane and nitrous oxide emissions are as yet poorly understood. Currently, important anthropogenic sources of emissions of methane appear to include domesticated ruminant animals, rice cultivation, landfills, and mining. For nitrous oxide, they appear to include legume crops and nitrogen fertilizers (Howden and Munro 1994; Pearce and Warford 1993). Clearly, countries with a comparative advantage in agricultural industries could be significantly affected by either the exclusion or use of a multiple gas scheme. Although CO_2 is the main source of past and present greenhouse concerns, methane and nitrous oxide are also significant in radiative forcing.

By including all the major greenhouse gases (sources and sinks) in setting global and any national greenhouse management targets, policymakers would avoid throwing away valuable knowledge (Schmalensee, 1993). Given a set of weights relating the radiative forcing potential of each greenhouse gas to a common base (say CO_2), a multiple gas market policy would only need to involve one quota market or one emission tax scheme and one permit market or domestic tax scheme as well as one control obligation for each country. At this stage, however, these weights are uncertain and may vary with both environmental and economic conditions (Hoel and Isaksen, 1993).

If the administrative burden is deemed to be too great initially for the incorporation of net emissions of greenhouse gases other than CO_2 in an international greenhouse management programme, the programme still needs to be flexible enough for this to be done when implementation costs fall. Indeed, it could provide incentives to generate such an outcome. Care must be taken not to worsen problems for future greenhouse management. The international target must therefore be comprehensive, as must targets for countries within a coalition that adopts any international market-based policy regime.

11.2.4.2 Initial coverage of CO_2 sources and sinks

The coverage issue in the case of CO_2 has been widely discussed (see, for example, UNCTAD, 1992; OECD, 1992a, b). One major question relates to whether consideration should be limited only to changes in emissions of CO_2, or whether it should also include changes in CO_2 sinks, such as expanding forests? Another concerns whether and how an international agreement might help retard deforestation and promote reforestation (Dudek and LeBlanc, 1992). Deforestation could be treated as equivalent to emissions, whereas afforestation activities could be a source of emission abatement credits. A good deal of care is needed in establishing the accounting methodology to ensure that the net effects of land clearing and revegetation with alternative species are measured and that domestic consumption and exports of wood products are separated.

Whether one is considering net CO_2 emissions from fossil fuel burning or net deforestation, it is helpful and, in some policy contexts, even necessary to have a baseline level for net emissions in the absence of any policy change, which can be used to assess the effectiveness of the greenhouse policy in place. This baseline has yet to be determined for the forestry sectors of the world's economies, and cost-effective monitoring techniques have not yet been proven. One of the major difficulties is that many trees exist outside forests, and measuring their contribution to carbon sequestration with remote sensing devices is extremely difficult. A further and more pervasive issue is associated with specifying *ex ante* a "status quo" timepath, against which "improvements" can be measured.

The coverage of the scheme may have a major impact on the incentive of different countries to participate. With an international market programme for CO_2, 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 programmes. Under an international tradable quota regime, CO_2 emission credits would amount to a valuable export commodity from the seller's viewpoint and would be an equally valuable import from the viewpoint of the buyer (a country that would otherwise have a CO_2 emission deficit). Under an international CO_2 emission tax, net emissions would also be treated symmetrically.

Currently, there are significant difficulties in measuring the carbon stored in trees and how it varies over time (Houghton, 1992). Hollinger *et al.* (1994) have made some progress toward a standardized carbon accounting system for a single-species plantation forest established on previously cleared agricultural land in New Zealand. Use of this accounting system within an international system of tradable emission credits has been explored by both MacLaren *et al.* (1993) and the Tasman Institute (1994). Current estimates of the costs of carbon sequestration through tree planting vary widely (ranging from US$1 to US$50 per short ton of carbon abated). These differences reflect the opportunity costs of alternative land uses (Stavins, 1995b) as well as the effects of uncertainty (see Sedjo, 1994, and the references cited there). However, estimates at the low end of the range refer to developing countries and, aside from the limitation of uncertainty, appear promising in terms of shifting any long-term need for high-cost carbon-free backstops further into the future. According to current estimates, such backstops become economic when the marginal cost of emissions is around US$250 per ton of carbon (Manne and Richels, 1991).

Satellite imagery is a critical tool in monitoring forestry systems. Given the potential stimulus of global net CO_2 emission trading, it could be tailored to ensure that coverage is complete and backed by verification (OECD, 1992b). Further, such a price stimulus for reduced deforestation (and increased afforestation) could yield complementary gains in terms of sustainable land management practices and global gains in biodiversity values. Indeed, the global nature of biodiversity values has prompted one suggestion for an international tradable quota system in global forestry management (see Sedjo 1994).

Hence, an important option value would be preserved by including in any international agreement to control CO_2 sources a provision for all parties to review the adoption of sinks at fixed points in time. However, it would be important to ensure that the integrity of the existing policy regime be preserved as new sinks were included.

11.3 The Domestic Policy Context

From the basic theorems of welfare economics it can be deduced that if an economy is perfectly competitive, if there is a full set of markets, and if information is perfect, then the resulting equilibrium (if it exists) is efficient in the sense that no one could be made better off without making someone else worse off (Pareto efficiency). The real world does not satisfy these conditions. There exist many externalities, of which climate change is only one. Competition is not perfect, nor in many cases is information, and markets are not complete. What is more, even if all the conditions of perfect competition were satisfied, the resulting Pareto-efficient outcome might not accord with society's view of a distribution of resources that is equitable or "fair." If certain other conditions hold, then an alternative, feasible, Pareto-efficient allocation could be sustained as a competitive equilibrium with appropriate lump-sum taxes and transfers, and so the objectives of efficiency and equity need not necessarily clash. But lump-sum taxes and transfers are typically infeasible, and, as a consequence, distorting taxes and transfers are employed virtually everywhere.[8]

The above observations about distortions are important because many analyses of climate change policy assume that the externality of climate change is the only distortion that exists. In fact, climate change policy must be considered in the context of real economies, already rife with distortions. A market economy can function effectively only if governments define property rights and provide for the enforcement of contracts. In some countries, even these basic requirements are not met. The extent to which governments can provide these basic requirements and correct market failures will in part determine GNP. (The importance of GNP, and other economic and social factors, in determining future emissions is highlighted in Chapter 8.)

It is also necessary to take into account any distortions introduced by governments. In some cases, government interventions can undermine net national income and cause environmental damage (see Binswanger, 1989). Another important determinant of future emissions, as discussed in Chapters 3 and 8, is population. Here, too, both market and government failures play a role. For example, high rates of fertility have been linked to the absence of effective capital markets, which makes it difficult or impossible for people to obtain social security (see Dasgupta 1993).

One purpose of this section is to draw attention to the importance of the domestic policy context in evaluating climate change policy proposals. The merits of any given proposal depend on this context. Equally, changes in the context have implications for emissions. Sometimes these two different observations are confused, and another purpose here is to clarify the distinction between them. Obviously, the types of policies that might warrant discussion here are many. However, the discussion is restricted to a few areas that seem particularly important and on which some research has already been done.

11.3.1 Preexisting market distortions

11.3.1.1 *Energy subsidies*

The emissions abated by a climate change policy will depend not only on the policy itself but also on whether the consumption of energy is subsidized and the magnitude of such subsidies. It is the combination of the climate change policy and these subsidies (and indeed other policies) that will determine relative prices and hence the incentives to adopt substitutes for carbon-intensive fuels.

In some regions such subsidies are significant (Larsen and Shah, 1995). Using border prices as a benchmark, Larsen and Shah (1992) calculated that primary fossil fuel subsidies worldwide are equivalent to a negative carbon tax of US$40 a ton. Larsen and Shah (1995) estimate that global CO_2 emissions would be reduced by between 4 and 5% if all energy subsidies were removed.[9] At the same time, eliminating such subsidies would increase real incomes by improving efficiency. The reason is that the subsidies distort prices; users pay less for fossil fuels than it actually costs to supply them.

An OECD study using its GREEN model arrives at a similar result. The OECD estimates that the removal of energy subsidies would reduce global emissions by 18% compared with the level that would otherwise be attained by 2050 (Burniaux *et al.*, 1992a). Elimination of subsidies could increase global real incomes by 0.7% annually, and real incomes in non-OECD countries could rise by 1.6% annually.

Fossil fuels may also receive indirect subsidies from electricity generation. Electricity is typically subsidized in both developed and developing countries. In the U.S., for example, government regulation frequently restricts electricity prices from privately owned utilities to a level equal to long-run average costs, which are often below marginal costs. Power is sold by the federal government at approximately 25% below even these levels, because of interest and tax subsidies (DCEIA 1992). In developing countries, electricity prices declined in real terms by 25% during the 1980s, and by 1988 were at an average level just over half as large as the average level in OECD countries, even though long-run marginal costs in real terms were higher in developing countries (Schramm, 1992). In 80% of developing countries, electricity prices are, on average, 30% below long-run marginal costs (World Bank 1990, 1992). Such distortions lead to excessive expenditure on new capacity, failure to generate sufficient internal funds to maintain or expand service, excessive energy consumption, and excessive environmental impacts from power generation.

11.3.1.2 *The "local" environmental benefits of climate change policy*

So far, the effect that the removal of energy subsidies can have on income, as conventionally measured by GNP, has been stressed. But the effects are likely to be felt more widely. One consequence of actions to reduce CO_2 emissions will be a reduction in other pollution. For example, Bye *et al.*, (1989) estimate that a policy that reduced CO_2 emissions in Norway by 20% would have the incidental effect of reducing SO_2 emissions by 21% and NO_x emissions by 14%. Larsen and Shah (1994) calculate that for Pakistan, for example, a carbon tax could be justified on the basis of the benefits of reductions in local pollutants alone, despite the fact that Pakistan already has high energy-related taxes.

11.3.1.3 *Information and energy conservation*

There has long been concern that apparently cost-effective energy conservation technologies were being adopted and diffused only very gradually and that market penetration rates for such technologies were not as high as engineering-based models predicted. This may be due partly to imperfect capital markets. Another possible reason may be the failure of the market to supply appropriate and credible information about these technologies (Hassett and Metcalf, 1992; Jaffe and Stavins, 1994a).

Empirical work dating back to Hausman (1979) shows that purchases of energy-saving technologies often reflect high rates of discount (see Treadwell *et al.*, 1994).[10] In other words, purchasers of such technologies may insist on earning a higher rate of return on this investment than on alternative investments. In an econometric analysis, Hassett and Metcalf (1992) show that future uncertainty regarding energy prices, due to past volatility in those prices, can attribute a large option value to waiting before investing in energy-conserving capital. On the other hand it could be argued that uncertainty about future energy prices creates an incentive to invest in energy-efficient equipment to minimize the share of energy costs in total costs. This would reduce risk exposure if energy prices were more uncertain than other input prices.

One means of avoiding this dilemma is for the company manufacturing the technology to offer a warranty on the product's performance. But there is a problem in that the performance of the good may depend on how it is used by the consumer, as well as on its intrinsic qualities (the moral hazard problem). A full warranty would therefore create an incentive for the consumer to misuse the good. Another problem is that there may be a tendency for the users most likely to purchase a more expensive good with a full warranty also to be those most likely to misuse the good (the adverse selection problem). For both these reasons, warranties may not be able to convey the information that would benefit both consumers and the firms manufacturing the technology.

Empirical evidence in the United States (Horowitz and Haeri, 1990; Sutherland, 1991) indicates that when information on energy efficiency is widely available, the real estate market functions efficiently – consumers show a willingness to pay more for houses with energy-saving features, all else being equal. However, Jaffe and Stavins (1994a, c) demonstrate that information problems can directly inhibit the diffusion of energy-efficient technologies in new housing. They also show that decisions on such investments depend on expectations about the future. If the price of such technologies is expected to fall, or the availability of information about the performance of such technologies is expected to increase, then consumers may delay making such purchases. Though individually rational, such behaviour can lead to less investment than is socially desirable, depending on whether true market failures are involved (Jaffe and Stavins, 1994b). This creates a potential role for public policy. The provision of home energy ratings is an example of such a policy designed to encourage the purchase of more efficient homes.

A number of projects designed to convey information to rural people exist in developing countries. One such project is the Mount Elgon Conservation and Development Project in Uganda, which is designed to provide new information to local people to enhance the cost-effective use of local fuel resources and minimize damage to forest reserves (Ugandan Ministry of Finance and Economic Planning, 1993).

A more general approach to the provision of information could be to use "eco-labelling." In this way, final consumers could be informed of the total contribution to greenhouse gas emissions as a result of the production of particular consumer durables or other items.

11.3.1.4 Transport

A large and growing fraction of CO_2 emissions arises from transport fuel use. Full social (user cost) pricing can promote greater efficiency in transport while reducing these emissions substantially. Most countries tax gasoline (petrol) to finance highways and other public automotive transport services. However, some countries do not collect enough from drivers to pay the full social costs of automotive travel (Repetto *et al.*, 1992).

Appropriately designed road user charges should also reflect the peak-period costs of using congested road capacity (Cameron, 1994). Congestion costs, in the form of time delays, accidents, excess fuel costs, and pollution, are an increasingly serious urban problem in developed and developing countries. In the U.S., the cost of time delays alone has been estimated to be $50 billion a year (Repetto *et al.*, 1992). User charges set at an appropriate level could lead to a change in the allocation of resources to the transport task and, coincidentally, might also lead to a reduction in greenhouse gas emissions, assuming that such charges could be collected cost-effectively.

11.3.1.5 Agriculture and forestry

Distortions in agriculture and forestry are common. As already noted, government subsidies and tax policies have encouraged deforestation in the Amazon (see Binswanger, 1989; Mahar, 1988). But the distortions in agriculture go further than this. The external environmental costs of wood harvesting, including loss of soil cover and fertility, are substantial (Newcombe, 1989), and yet user charges for rights to harvest timber on public lands typically do not even cover the replacement costs of the wood. In many countries, land must be cleared to gain land rights (Pearce and Warford, 1993). In sub-Saharan Africa, farmers and nomads carry extra cattle as an insurance against droughts and as an asset. Herd size may also be taken as a measure of status. Herds are therefore larger than they would be if capital and insurance markets were fully developed (Dasgupta and Göran-Mäler, 1994).

Underpricing of water in agriculture leads to inefficiency in water use, excessive expenditure on irrigation, and a variety of local environmental and social costs, including soil waterlogging and salinization and the degradation of riverine and estuarine environments. Irrigation charges in a sample of six developing countries covered only 1-23% of storage and conveyance costs during the 1980s. Charges for federally supplied irrigation water in the U.S. cover only 5-20% of these costs (Repetto 1986). These charges fail to reflect the marginal opportunity cost of water in alternative urban and industrial uses, which is typically an order of magnitude higher than its value in agriculture. When irrigation water is underpriced, farmers grow more rice than they otherwise would. These practices increase methane emissions (Ranganathan *et al.*, 1994). Proper pricing for water could well generate global benefits as well as significant domestic gains.

11.3.1.6 Policies affecting adaptation

The net adverse effects of climate change will depend not only on the extent of climate change, but also on the extent to which economies successfully adapt to any change. Some existing policies may mitigate against adaptation or increase the vulnerability of some sectors of the economy to climate change. For example, subsidized drought or flood insurance may encourage investment in high-risk areas and reduce incentives for self-reliance. Similarly, some agricultural support policies might discourage farmers from shifting to enterprises and production systems better suited to an altered climate.

11.3.2 Revenue recycling

The abatement achieved by a carbon tax, and the effect of the tax on an economy, will depend on what is done with the tax revenue. Likewise, a tradable permit scheme can raise the same government revenue as a carbon tax if the government auctions the permits. The impact of such a scheme on the economy will again depend on what is done with the revenue. The direct impact on government revenue of the two policies can be made equivalent across a variety of cases. No direct impact on government revenue would occur if permits were grandfathered (that is, allocated on the basis of some historical record) or tax revenue redistributed to emitters. Intermediate cases would be represented by partial grandfathering or partial redistribution of revenue to emitters. Thus, in principle, the same revenue recycling issues apply regardless of whether a tax or tradable permit scheme is used (Bohm, 1995a), although taxes have been studied in more detail in the literature.

There is widespread agreement that revenue recycling can significantly lower the costs of a carbon tax (Koopmans *et al.*, 1992; Shackleton *et al.*, 1992; Goulder, 1992, 1993, 1995; Bovenberg and de Mooij, 1994; European Commission, 1994; Jorgenson and Wilcoxen, 1994). Some researchers have suggested further that all the abatement costs associated with a carbon tax can be eliminated through revenue recycling in the form of cuts in income taxes or taxes on payrolls. However, at least in the case of cuts in income taxes, research by Goulder (1992, 1993, 1995) and related theoretical work by Bovenberg and de Mooij (1994) reject this stronger claim. Their work indicates that the recycling of revenues through income tax cuts only partly offsets the total general equilibrium abatement costs implied by a carbon tax (also see Chapters 8 and 9 of this report).

None of the above research denies the possibility that raising revenue from a carbon tax or a permit scheme may increase national income when combined with reductions in a burdensome existing tax. However, such a result is an argument for reform of the taxation system rather than for the introduction of a carbon tax or permit scheme (Bohm, 1995a). It may be that some tax other than a carbon tax could result in a greater efficiency gain in raising public revenue. If there are efficiency arguments for a carbon tax or tradable permit scheme and reform of the tax system, then both changes should be introduced.

11.3.3 The broader context for climate change policies

11.3.3.1 "No-regrets" policies

Policies or policy reforms that improve the efficiency of an economy while also reducing greenhouse gas emissions have sometimes been described as "no-regrets" policies because they offer sufficient benefits in other contexts that their adoption could not be regretted even if climate change were later shown not to be detrimental (also see Chapters 8 and 9).

The reduction of virtually any distortion is to be encouraged, provided equity concerns can be safeguarded. Policy reforms that help in this regard are therefore also to be welcomed, whatever the consequences for climate change. If greenhouse gas emissions are reduced as well, then extra potential gains exist. But even where this is not so, the removal of distortions can lead to greater economic welfare. In general, such policies should not be linked directly to climate change policy. However, their significance for climate change policy needs to be recognized, and the prospects of "double dividends" from carbon taxes or tradable permit systems can give the extra political impetus needed to reduce existing distortions. These policies will influence both the "business-as-usual" emission scenario and the effectiveness of any climate change policy.

Although there may be political advantages (particularly in terms of providing impetus for reform) in linking so-called no-regrets policies to climate change policy, such linkage may serve to confuse the policy debate. For example, the observation that a carbon tax (or auctioned tradable permits) may increase national income when combined with a tax reform is really an observation that the structure of taxation could be improved. A carbon tax is not the only device available for improving public finance, and indeed it may not be the best device available; it is possible that a different tax could raise revenue more efficiently than a carbon tax. What this means is that the merits of a carbon tax will depend on whether the tax is evaluated taking all other existing policies as given, or whether it is instead evaluated against the background of a (second-best) efficient tax regime. Put differently, estimates of the full consequences of a carbon tax must take account of how the revenues are to be employed.

It is not obvious, however, how a carbon tax should be evaluated. If the tax is evaluated against the background of a (second-best) efficient tax regime, and yet the actual tax regime is different, then the evaluation could lead to inappropriate public policy. A better approach would be to demonstrate how the performance of a carbon tax (reflecting both the emissions and level of economic activity associated with the tax) depends on the policy context, including the regime for raising public revenue and the presence of distortions in energy pricing.

11.3.3.2 Adaptation policies

It is important to draw a clear distinction between the costs and benefits of actions taken to reduce the impacts of climate change and the costs and benefits of actions taken to reduce emissions. The first reduces the potential damage caused by climate change directly, whereas the second has the effect of reducing emissions of greenhouse gases now, which, in turn, will have an impact on future climate. Examples of adaptation include such actions as increasing irrigation water availability in regions where the climate has become drier, improving refrigeration to offset the effects of a warmer climate, and relocating economic activities away from the coast where sea levels have risen. Measuring the cost of adaptation is somewhat problematic, given that both ecosystems and economic systems are changing all the time and will to some extent adapt autonomously to climate change.

The term "adaptation" may be confusing because actions falling into this category can be counted as a cost of climate change. To see why adaptation can yield a net benefit, consider the problem of estimating the costs of climate change. An estimate might be based on the assumption that there will be no adaptation – that is, if sea level rises by say 50 cm, then all shoreline property less than 50 cm above sea level will be lost. Alternatively, it might be assumed that there will be some adaptation – that dikes might be built, for example. The latter response is indeed a cost of climate change: It would not need to be taken in the absence of climate change. However, the response may reduce the damage associated with climate change. If the reduction in such damage exceeds the costs of adapting, then adaptation should be undertaken (Fankhauser, 1993).

Unlike the case of abatement of greenhouse gases, adaptation typically involves private goods. If the climate were to become drier, a demand would be created for drought-resistant crop varieties, and the firms that developed these would be rewarded by the market. If climate were to become more variable, then individuals would seek to insure themselves against such changes. Such responses belong in the realm of the private sector. However, even when dealing with strictly private goods, there may be a role for the state. Dasgupta (1993), for example, argues that some assistance should be given to the assetless in developing countries who are not able to command sufficient purchasing power to convert their potential labour power into actual labour power. Such assistance, perhaps in the form of agrarian reform, not only redistributes income but results in an increase in the rate of growth of aggregate incomes. Although such policies are already needed in some countries, the need for them may be increased in the event of climate change.

However, the principal role for government in the context of adaptation is in supplying public goods. Public infrastructure projects such as building dikes or funding resettlement programs are cases in point, as is the funding of public research and development of carbon-free technologies where there would otherwise be strong free-riding incentives. Furthermore, if there are risks of increased environmental hazards (drought, flood, fire, famine, pests) then greater hazard insurance is an appropriate defensive action. Another type of "insurance" could be purchased by increasing public research expenditure (for example, increasing efforts in plant breeding in order to develop plant cultivars better adapted to new climatic conditions).

Any adaptation policies should be designed in concert with mitigation policies. Both types of policies are aimed at minimizing the expected damage from climate change. Adaptation will be undertaken up to the point where the damage avoided by an incremental increase in adaptation equals the associated incremental cost. Abatement will be undertaken up to the point where the reduction in damage effected by an incremental unit of abatement equals the incremental cost. However, the two types of policies are not entirely equivalent. First, the benefits of adaptation are likely to be felt much more quickly than the benefits of mitigation, and, second, some types of adaptation policies will not be subject to the same problems of free riding (see Section 11.6.5) as abatement. For example, if a country defends its shoreline by building seawalls, its own population, in most cases, will receive all the benefits. This is not true of unilateral abatement.

Recent climate research indicates that local changes in climate may depend not only on global phenomena such as the increase in atmospheric concentrations of greenhouse gases but also on local phenomena such as emissions of sulphates. It might be argued that sulphate emissions should be reduced to prevent damage from acid rain, and that policy on sulphate emissions should not be linked to global climate change policy. However, where local climate can be influenced by local policy, it seems that such linkages may nevertheless be made, not least because local climate modifications may be less costly and may not suffer from free-riding problems. To date, research has not considered the economic and policy implications of local climate modification (but see Section 11.4.2).

11.4 Regulations, Voluntary Agreements, and other Nonmarket-Based Instruments

The conventional approach to environmental policy in many countries has employed policy instruments in the form of uniform standards (based on technology or performance) and direct government expenditures on projects that are designed to improve the environment (Baumol and Oates, 1979; OECD, 1989; Hahn and Stavins, 1991). Like market-based incentives, the first of these strategies requires that polluters undertake pollution abatement activities; under the second strategy the government itself expends resources on environmental quality. Both these strategies figure prominently in current and proposed policy measures to address global climate change.[11] For the reasons already mentioned in Section 11.2.2.1, the discussion of regulations is confined to their application in a domestic policy context.

11.4.1 Uniform technology and performance standards

Uniform regulatory standards (often described as "command-and-control" regulations) can be loosely categorized as either *technology-based* or *performance-based,* although the distinction between these two categories of instruments is often unclear. Technology-based (or design) standards typically require the use of specified equipment, processes, or procedures. In the context of climate change policy, technology-based standards could require that particular types of energy-efficient motors, combustion processes, or landfill gas collection technologies be utilized by firms.

Performance-based standards are more flexible than technology-based standards, specifying allowable levels of pollutant emissions or polluting activities, but leaving the specific methods of achieving those levels to the regulated entities. Examples of performance standards for greenhouse gas abatement include minimum levels of energy efficiency for appliances, maximum allowable levels of carbon dioxide emissions from combustion, and maximum levels of methane emissions from landfills.

Uniform standards can also take the form of outright bans of certain products or processes, such as aerosol sprays containing ozone-depleting substances. Although bans may appear to be the strictest form of regulation, they may actually be a relatively cost-effective policy instrument if low-cost substitutes for targeted products are available. Moreover, bans or other more proactive design standards may make economies of scale in the production of substitutes materialize faster than if market mechanisms are used by themselves (Bohm and Russell, 1985).

Although uniform technology and performance standards may be effective in achieving established environmental goals and standards, they typically lead to economically inefficient outcomes in which firms use unduly expensive means to control pollution (Tietenberg, 1985; Hahn, 1989; Hahn and Stavins, 1991). Because the costs of controlling pollution vary greatly among and even within firms, any given aggregate pollution control level can be met at minimum aggregate control cost only if pollution sources are controlled at the same *marginal cost,* as opposed to the same *emission level.* Indeed, depending on the age and location of emission sources and available technologies, the cost of controlling a unit of a given pollutant may vary by a factor of 100 or more across a range of sources (Crandall, 1984). Nonetheless, because performance standards give economic agents additional flexibility to make choices based on economic criteria, performance-based standards will generally be more cost-effective than technology-based standards. On the other hand, if there is essentially only a single means of achieving a particular performance standard, a technology-based standard may save on information and administration costs.

In theory, the government could achieve a cost-effective allocation of pollution control responsibility among different sources if it assigned source-specific control levels that equated the marginal costs of control across these sources. This approach would, however, require detailed information on the pollution control cost functions of individual firms and sources – data that governments usually lack and could obtain only at great cost, if at all. Although they are not typically designed to address the cost-effectiveness issue, source-specific or firm-specific permit programmes are one approach traditionally taken to adjust regulatory standards to individual circumstances. If pollutants exhibit highly localized effects, such an approach may have distinct advantages over a tax or a more general permit system. Global climate change is not, however, a localized problem; a unit of greenhouse gas emission will have roughly the same impact regardless of where it is emitted.

Even if governments were able to use conventional technology and uniform performance standards to achieve a cost-effective allocation of pollution control at present, such standards would not necessarily provide continuous *dynamic* incentives for the development, adoption, and diffusion of environmentally and economically superior control technologies in the future (Bohm and Russell, 1985; Jaffe and Stavins, 1995).

All forms of intervention have the potential for inducing or forcing some amount of technological change because, by their very nature, they induce or require firms to do things they would not otherwise do. Performance and technology standards can be explicitly designed to be "technology forcing," mandating performance levels that are not currently viewed as technologically feasible or mandating technologies that are not fully developed (Jochem and Gruber, 1990). The problem with this approach, however, is that while regulators can assume that *some* amount of improvement over existing technology will always be feasible, it is impossible to know just how much. Standards must either be made unambitious or else run the risk of being ultimately unachievable, leading to political and economic disruption (Freeman and Haveman, 1971). Another difficulty with a regulatory approach to environmental protection is that the regulatory agency may, over time, develop such a close working relationship with the regulated industry that it relaxes its enforcement standards in the interests of the industry itself. This phenomenon is sometimes referred to as "regulatory capture."

Once a performance standard has been satisfied, there is little benefit to the individual firm from developing and/or adopting even cleaner technology. In addition, regulated firms may fear that if they do develop a cleaner technology, the performance standard will be tightened. Technology standards are even worse than performance standards in inhibiting innovation, since, by their very nature, they constrain the technological choices available, and may thereby remove all incentives to develop new technologies that are environmentally beneficial (Magat, 1979). For example, when vehicle emissions standards requiring the use of catalytic converters were adopted by the European Union,[12] incentives to develop lean-burn engines were reduced. This disincentive occurred because the technologies are presently incompatible, at least in the sense that a lean-burn engine cannot be fitted with a three-way catalytic converter.[13] Lean-burn technology (with two-way converters) capable of meeting Japanese and European standards is now available. However, this technology does not meet present U.S. emission standards or the stricter standards expected to emerge in the near future.[14] However, lean-burn remains an important and developing approach. Not only does it have the potential advantage of reducing CO_2 emissions significantly,[15] but it also offers the prospect of reducing other emissions more effectively over the lifetime of the automobile.[16]

Under some circumstances, however, a performance standard may provide greater incentives for technological adoption than a marketable permit system (Malueg 1990). There are better and worse ways of establishing performance standards. To take an example, the Corporate Average Fuel Economy (CAFE) standards in the U.S. are applied to the fleet *average* of every manufacturer and importer. CAFE may thus be binding on a manufacturer that sells many larger cars as well as some small cars, but not on a manufacturer that sells only small cars. The problem here is that the former manufacturer may sell small cars that are more energy-efficient than the latter manufacturer. In other words, the innovation and manufacture of more efficient automobiles may not be rewarded by these standards. If CAFE differentiated the standards according to the market segment of each vehicle (sub-compact, compact, mid-size, etc.), then firms that sold vehicles that were more efficient for their class than required by the standard would be rewarded by not having to pay the penalty for which the manufacturers of less efficient cars were liable. Better still, if manufacturers were allowed to trade in energy efficiency credits, then even the manufacturer of the most efficient cars would have a continuous incentive to develop even more energy-efficient cars. Finally, a tax on gasoline (petrol) would not only provide incentives for the manufacture of more fuel-efficient cars, but would also provide incentives for vehicle owners to reduce their fuel consumption.

As with virtually all policy instruments, the administration of uniform standards typically includes programmes for compliance monitoring and enforcement. Although technology-based standards may seem to be the least cost-effective of the policy instruments, if monitoring costs are high in some particular circumstances they may have an advantage because they are relatively easy to monitor and enforce. An inspector can simply check whether a particular piece of equipment has been installed, rather than continuously monitor information on emission levels. Performance standards, in general, and pollution charges and marketable permits for non-CO_2 greenhouse gas emissions all require more detailed monitoring systems. These can suffer from the following problems (Beavis and Walker, 1983):

(a) Once emissions leave the source they are usually lost to measurement.

(b) Emissions may be random, rather than fixed values, and may vary depending on equipment breakdowns, shifts in product mix and input quality, or changes in production levels.

(c) Monitoring instruments may be imprecise.
(d) Unless monitoring is continuous, polluters may adjust emissions up or down according to the likelihood of inspection.[17]

11.4.2 *Government investment*

Direct government expenditures also play a major role in both current and prospective environmental programmes in many countries. As Baumol and Oates (1975) have noted, such government activities include projects to

(a) prevent, mitigate, or adapt to changes in environmental quality
(b) disseminate information
(c) conduct research
(d) educate specialists and the general public

Government purchasing policies may also be used in some instances to attempt to achieve secondary goals such as influencing environmental quality. Many environmental ends that could be achieved through incentive-based policy instruments or uniform standards can also be met directly through government-funded projects or programmes.

The two primary economic rationales for the inclusion of direct government investment in an effective overall government policy are the public good character of many environmental services and the possibility of economies of scale. Public goods arguments for direct government expenditure to disseminate information, conduct research, and sponsor education programmes are common in debates about much public policy. The potential role for government research and information provision regarding renewable energy and energy-efficient technologies is particularly prominent in the climate change context (Jaffe and Stavins, 1995). Proposed methods for addressing climate change through climatic engineering or "geoengineering" options are also likely to require direct government involvement, but at this stage far more research needs to be conducted before such options can be contemplated. For details of some suggested approaches see Nordhaus (1991a), National Academy of Sciences (1992), and Clinton and Gore (1993).

Government or institutional investment at the international level also has a part to play in mitigating climate change. For example, the Global Environment Fund's portfolio on renewable energy includes support for promising backstop technologies such as gasification of wood and crop residue coupled with advanced gas turbines in Brazil and anaerobic digestion of organic residues from agriculture and urban households in India and Pakistan (World Bank, 1993).

11.4.3 *Voluntary agreements*

Beyond mandatory policy instruments, voluntary agreements can also play an important role in an overall greenhouse gas reduction strategy. The threat of mandatory government intervention may be enough to encourage voluntary agreements. Forward-looking firms may undertake some steps in controlling greenhouse gas emissions if they fear more costly mandatory controls in the absence of voluntary reductions. This could explain why voluntary agreements have arisen in some cases in domestic energy management.[18] The vast majority of greenhouse gas reductions from the actions announced or expanded through, for example, the U.S. *Climate Change Action Plan* (Clinton and Gore, 1993) come from voluntary initiatives aimed at increasing the energy efficiency of the industrial, commercial, residential, and transport sectors.

11.4.4 *Demand-side management*

Demand-side management may be defined as any activity by an electric utility to influence customer use of electricity in ways that will produce desired changes in the utility's load shape.[19] Demand-side management programmes may affect the quality of service. For example, a lighting retrofit may improve lighting levels as well as reduce electricity consumption, or electricity supply to water heaters may be interrupted during periods of system peak demand. There is an extensive literature on demand-side management (EPRI, 1984, 1991; Katz, 1992; Kahn, 1992; Hirst, 1993; Gellings and Chamberlin, 1993).

Demand-side management programmes may enable a utility to reduce or defer capital expenditures. Regulators evaluate the economic costs and benefits of demand-side management programmes from the perspective of society, all customers, participants, nonparticipants, and utility costs.[20] One criterion applied to these programmes is the Rate Impact Measure (RIM) test, which measures the ability of a programme to reduce costs more than revenues. Programmes that pass the RIM test lead to lower rates immediately and are attractive to nonparticipants. Most regulators, however, focus on the Total Resource Cost (TRC) test, which measures the aggregate benefit to all customers. A programme that passes the TRC test but fails the RIM test (and most fall into this category) raises rates in the short run but reduces them from what they otherwise would have been in the long run.[21]

Literature on the effects of demand-side management programmes on greenhouse gas emissions is sparse. It is too simplistic to assume, however, that demand-side management programmes that reduce aggregate demand for electricity automatically lead to lower emissions of greenhouse gases. For example, peak period demand that would be supplied by hydraulic or natural gas units could be shifted to periods where it is supplied by coal-fired units, resulting in a net increase in emissions (Faruqui and Haites, 1991; Haites, 1993). Nevertheless, demand-side management programmes are generally expected to reduce greenhouse gas emissions. Indeed, some argue that such programmes can be regarded as disguised environmental impact taxes (Sioshansi, 1992).

Evaluations indicate that many demand-side management programmes can be made more cost-effective. There is disagreement in the literature about whether well-designed and delivered demand-side management programmes yield net benefits (Nadel, 1990) or not (Joskow and Marron, 1993). Changes to the electric utility structure in the U.S. have led a number of utilities to scale back their demand-side management efforts. The prospect of a competitive generation market creates pressure to reduce costs and defers plans for capacity additions, thereby reducing the economic justification for demand-side management programmes aimed at reducing aggregate demand for electricity. Demand-side management programmes aimed at smoothing demand for electricity continue to be attractive.

11.4.5 Distributional impacts

Any greenhouse policy will have distributional effects on firms and households. Regulations impose quantity limits on the use of particular inputs or outputs in production and consumption activities. The direct cost of regulation is the reduction in profits and consumer welfare due to the regulatory constraint on choice. The distribution of this cost is often hidden, but that does not make it unimportant. For example, poorer households tend to own appliances that are cheaper to purchase but more costly to run. That is, poorer households tend to make appliance purchasing decisions reflecting higher effective individual discount rates (Hausman, 1979). A regulation that required all households to purchase more efficient appliances would thus disproportionately affect the poor, even though by outward appearances it might seem not to. To the extent that regulation is not a least-cost option to control greenhouse emissions, the excess burden it implies must also be distributed. However, with quantity limits – whether in the form of conventional regulations or tradable permit systems – individual emitters do not face an environmental cost for emissions that are less than the limit. This is in contrast with the distributional consequences of a system that taxes all emissions.

Although the initial incidence of a greenhouse regulation will fall on greenhouse-intensive energy users, the final incidence will depend on the ability of firms to pass the costs of the regulation to others through higher prices for goods and services, and these distributive impacts are likely to differ over time. For example, over the the long run the application of increasingly strict greenhouse pollution controls to newer cars might be regressive (i.e., with costs falling disproportionately on the poor), as low-income earners face substantial increases in used car costs; in the short run, though, low-income earners might gain a relatively larger capital reward on selling their cars (Tietenberg, 1992). Where the costs of regulation are regressive, compensatory transfers may be used, funded from a specific tax or general government finances, or the regulation might be modified, exempting some individuals from the regulatory net.

To date, most applied economics research on potential greenhouse policy responses has concentrated on analyzing the overall costs and incidence of market-based instruments. Multicountry and national studies on the economic impacts of regulatory measures are needed. Researchers may need to give more emphasis to incorporating real world conditions in these models, such as uncertainty and asymmetric information in energy markets. This would allow for any differences in the informational role of price and quantity controls (as well as policy mixes) in determining the size and distribution of greenhouse control costs.

11.5 Market-Based Policy Instruments

Because of the considerable potential costs of meeting greenhouse gas emission targets, one of the central issues for parties to the Framework Convention is the identification of least-cost measures, that is, policies that minimize the costs of achieving a given greenhouse gas emission target. In this section attention is focussed on emission taxes and tradable quotas and permits, the two core market-based instruments that directly target least-cost measures to meet greenhouse gas emission targets. Mention is also made of joint implementation, an instrument that can facilitate technology transfer and is equivalent to bilateral "trading" in emissions.

There is an extensive literature on the principles underlying the use of market-based policy instruments for greenhouse management (for example, Bohm and Russell, 1985; Baumol and Oates, 1988; Stavins, 1988; OECD, 1989, 1993; Tietenberg, 1990; Epstein and Gupta, 1990; Dornbush and Poterba, 1991; Stavins, 1991; Bureau of Industry Economics, 1992; Cropper and Oates, 1992; IIASA, 1992a, b; Pillet *et al.*, 1993; Hahn and Stavins, 1995). For a summary and assessment of the cost and environmental effectiveness of emission taxes and tradable quotas in national applications see Howe (1994).

In a perfectly competitive marketplace, under an emission tax or tradable quota scheme, emitters would reduce emissions up to the point where the marginal cost of control equals the emission tax rate or the equilibrium price of an emission quota. Both instruments would promote dynamic efficiency (cost minimization over the long term, when factors of production are variable and technological change may be stimulated), as each provides a continuous incentive for research and development in emission abatement technologies to avoid the tax or quota purchases. Under competitive markets and certainty, an emission tax is identical to a tradable emission quota scheme in which quota rights are auctioned and revenues are redistributed in the same way (Rajah and Smith, 1993).

11.5.1 Domestic carbon taxes

With market-based policies, there can be incentives to reduce greenhouse emissions through the development and use of new technologies and by making changes to existing production and consumption practices. The aim in using an emission tax (a tax per unit of emissions) is to minimize the total economic costs of achieving a given emission target. In principle, both static and dynamic efficiency gains can be fostered under an emission tax. These gains arise where emitters have different opportunities for emission control (have different marginal abatement cost curves) both in the short run, when factors of production and technological opportunities are largely fixed, and in the long run, when they vary endogenously.

Most research has focussed on the carbon content of primary fossil fuels consumed as the most practicable base for a tax on greenhouse emissions (Pearce, 1991; Boero *et al.*, 1991; Jorgenson and Wilcoxen, 1992; Repetto *et al.*, 1992; Dower and Zimmerman, 1992; OECD, 1992a, 1993; Jones and Tobler, 1993; Pillet *et al.*, 1993; Boyd *et al.*, 1994). A carbon tax is not, however, a perfect proxy for a tax on CO_2 emissions. For example, a carbon tax on fossil fuels provides an incentive to reduce the use of carbon-based fuels, but not to reduce CO_2 emissions by such means as capture (fixation) and disposal of the emissions at source (on carbon removal, see Section 11.5.1.1). There may also be, due to leakage or incomplete combustion, emissions of other carbon compounds that differ from CO_2 in their greenhouse effects (notably methane). In addition, to be consistent, accounting would need to apply to domestic emissions resulting from the processing of fuels from one energy form to another (as in electricity generation).

There is a variety of points in the "product cycle" for fossil fuels, from production to end use, at which a carbon tax could be applied. End use is obviously the point at which emissions occur, but monitoring points covered under the policy would be fewest, and hence implementation costs lowest, if carbon contents were measured and policy applied at the wholesale level.

A carbon tax is a more efficient instrument for reducing energy sector CO_2 emissions than taxes levied on some other basis, such as energy content of fuels or the value of energy products (*ad valorem* energy tax). For example, model simulations of the U.S. economy indicate that an energy tax could be between 20 and 40% more costly, and an *ad valorem* tax two to three times more costly, than a carbon tax for equivalent reductions in emissions (Scheraga and Leary, 1992; Jorgenson and Wilcoxen, 1992). This is because an energy tax raises the price of all forms of energy, whether or not they contribute to CO_2 emissions, and would make it more costly to substitute lower-emitting or nonemitting energy sources for high-emitting energy sources. As a corollary, a combined carbon/energy tax would be less efficient and more costly than a pure carbon tax, due to its energy tax component.

11.5.1.1 Related instruments: Deposit refund systems for carbon removal

As already mentioned carbon can be removed from the atmosphere by enhancing natural sinks. It could also be removed by technical means if cost-effective technologies can be developed. One policy instrument that might be considered to provide an incentive to undertake such carbon removal is a deposit refund scheme. A deposit refund system can take one of several forms. One variant combines a tax (deposit) on a commodity with a subsidy for the socially least-cost disposal option (a refund). Another uses mandated deposits, which require private sellers of a commodity to add to the price a deposit that will be refunded under certain conditions. Yet another uses a performance bond, which requires an agent engaging in specified production activities to avoid certain negative consequences of these activities. For surveys of current uses of deposit refund systems and descriptions of potential new areas of application, see Bohm (1981); Hahn (1988); Russell (1988); Stavins (1988); OECD (1989); Anderson *et al.*, (1990); Hahn and Stavins (1991); Sigman (1991); Stavins (1991); and U.S. Environmental Protection Agency (1991).[22]

For a deposit refund system to be a feasible means of encouraging carbon fixation, there must exist alternative actions that decision makers can take to avoid creating the environmental externality in question. This could be a choice between controlling emissions at source and "end-of-pipe" emissions removal.

Currently, potential emitters of CO_2 – purchasers of fossil fuels for combustion, for example – do not have the option of choosing to remove the carbon from emissions.[23] On the other hand, new techniques for carbon removal may eventually become economically feasible. (In 1993, for example, Japan's Ministry of Trade and Industry launched a project on CO_2 fixation – see MITI, 1993.)[24] When and if this option becomes available, incentives will exist to choose carbon removal when this is less expensive than reducing fossil fuel combustion through improvements in energy generation or use efficiency. This would open up the possibility of applying the deposit refund concept to CO_2 emission reduction. It could, for example, provide a mechanism for the inclusion of sinks, such as the development of new forests and other changes in land management, in a market-based permit or tax system.

This suggests that it is important, in the meantime, to maintain appropriate incentives for research and development of technologies that can eventually provide cost-effective options for carbon removal. The appropriate incentive will exist if future carbon removal is known to be subsidized at a level equal to the (tax, tradable quota price, or shadow) cost of carbon emissions.[25]

Thus, it may be possible to introduce clauses into a future climate change protocol that would validate subtractions of carbon removal from emissions. This would, in effect, be equivalent to creating an international deposit refund system – a tax/subsidy scheme – where nations would be credited for certified carbon removal (estimated carbon emissions avoided) by equally large additions to their emission quotas. These quotas would be measured by the carbon content of fossil fuel use, equal to production plus imports minus exports. Moreover, if fossil fuel use is taxed domestically (directly or indirectly through a tradable permit system), and carbon removal is subsidized (credited by a refund of the deposit, equal to the tax), the resulting policy package will be an international deposit refund system.[26]

Other greenhouse gases, such as CFCs, that could be recovered when servicing cooling equipment such as refrigerators or air conditioners, could be made subject to a system with general deposits (taxes) on CFCs and a refund when and if CFCs are recovered, provided that the transaction costs of such a system are not prohibitively high (Stavins, 1988; Miller and Mintzer, 1986). Obviously, if CFCs are successfully phased out in the near future, the role of policy instruments such as deposit refund systems to control CFC emissions will be very limited. Still, the problem of CFCs remaining in discarded cooling equipment, perhaps for some twenty years after their use in new production had been phased out, may be significant enough to justify the use of a CFC deposit refund system (Bohm, 1981, 1990). Note, however, that for products that contain CFCs and that have already been purchased by final users, the deposit refund system will be one with zero deposits and a positive subsidy. In other words, it will collapse into a pure subsidy system. Then, one of the advantages of deposit refund systems, that ordinary taxes are not required for financing the refund/subsidy incentive, would no longer hold.

11.5.2 Tradable permits

A powerful theoretical feature of a perfectly competitive tradable domestic permit scheme is that, no matter what the initial permit allocation, equilibrium permit prices will be the same and the final allocation after domestic trade will be the one that minimizes the cost of reducing emissions. Firms will want to buy permits if abatement costs exceed the permit price and sell permits in the opposite case. In this way, trade will continue until all firms reach a position of indifference between buying and selling permits – that is, between marginal abatement and additional fossil fuel use. When this state is reached, an *ex post* allocation of permits that minimizes the costs of reducing emissions has also been reached.[27]

An international tradable quota scheme could coexist with domestic permit schemes within each country, or particular countries might choose to meet their emission targets by some other means, such as taxes or regulatory systems. In the case of a domestic tradable permit scheme, a national government would issue emission permits (perhaps time-limited) to wholesale dealers in fossil fuels or producers and importers of fossil fuels and allow them to trade on a domestic permit market. The government could also allow permit holders to trade directly on an existing international market. Alternatively, to the extent that both international quota and domestic permit markets existed for a particular country, the government could trade on the international market and set a definite or preliminary domestic limit on the volume of domestic permits for some period ahead.

A government could choose one of two main ways to distribute permits to individual firms. In the first case, firms would be given shares of the total permit volume based on some historical record ("grandfathering") such as their recent fossil fuel sales. The second alternative would be for the government to auction permits. Some combination of these two approaches might also be feasible.

The two approaches differ primarily in two respects. First, grandfathering implies a "transfer" of wealth, equal to the value of the permits, to existing firms, whereas, when permits are auctioned by government, this wealth is transferred to the government. The government would then collect revenue similar to that from a domestic tax producing the same volume of emissions. As with tax receipts, auction revenues could be used to reduce preexisting distorting taxes as outlined in Section 11.3. Second, since grandfathering improves the wealth of incumbent firms and, given uncertainty, may keep them in business longer than otherwise, this allocation approach may reduce the rate of entry of new firms and slow technological change (Bohm, 1994b).

To date most tradable permit systems have made use of eternal permits. However, there are several reasons for preferring a system of time-limited permits in the case of climate change applications. First, to the extent that permits may be initially grandfathered, the negative effects mentioned above would be mitigated – after emitters were given sufficient time to adjust, subsequent allocations of permits could be made by auction. Second, potential future policy changes about emission targets in response to new information, for example, could cause significant problems for permit price formation if eternal permits were used. An alternative approach would be for the government to retain ownership of the permits and lease them to firms for a fixed period.[28]

Allowing permits to be banked, that is, allowing permits for emissions during a given period (e.g., a year) to be used at a later date, is important for both the efficiency and political acceptability of a tradable permit scheme. Without a banking option permit-liable firms would be confronted with greater end-of-period permit price uncertainty.

Stavins (1995a) considers a market for emission permits in which costs are associated with the exchange of permits, and he models several alternative types of transaction cost functions. He finds that transaction costs reduce trading levels and increase abatement costs and, most important, that in some cases, equilibrium permit allocations and hence aggregate control costs are sensitive to initial permit distributions. Thus, in the presence of transaction costs, the initial distribution of permits can matter in terms of efficiency, as well as in terms of equity.

By contrast with international tradable quota systems, which have so far been applied on a small scale only (for example, under the Montreal Protocol for the international CFC production quota trade and for the CFC consumption quota trade within the European Union), there is considerable experience with the use of tradable permit schemes within countries (see OECD, 1992b; UNCTAD, 1992). In most of these applications, permits have been allocated by grandfathering. Many of these applications have been designed to deal with local air pollution problems, and, as a consequence, the permit markets have often been relatively small and far from perfect. This contrasts with the case of a tradable carbon permit system, which would be nationwide. The contrast would be even starker for an international scheme involving many governments and possibly large firms as well.

11.5.3 International carbon taxes

International action would be required to meet a global emission target. One possibility is that a carbon tax could be imposed on nation states themselves by an international agency. In this case, the agreement would specify not only tax rate(s) but also a formula for reallocating the revenues from the tax. Cost-effectiveness would demand that the tax rate be uniform across all countries (assuming full participation), but the reallocation of revenues would not have a direct bearing on cost-effectiveness. As an alternative, the agreement could stipulate that all countries should levy the same domestic carbon tax, so-called harmonized domestic carbon taxes. In both cases, the tax rate that achieved the coalition's emissions target could only be struck through trial and error. The tax rate would also need to be adjusted over time as economic conditions change and as more scientific information becomes available.

Uniform tax rates are required for reasons of cost-effectiveness. But the resulting distribution of costs may not conform to principles of equity and justice. For this reason, transfers of resources may be required. In principle, the two versions of an international tax agreement could involve the same actual financial transfers, although the transfer principles may differ. Under the harmonized tax system, the agreement could involve fixed lump-sum payments from rich to poor countries, whereas under the first-mentioned international tax system, the agreement could specify what shares of the total international tax revenues would go to each participating country (Hoel, 1993). (In a tradable quota system, the financial transfers could again, in principle, be the same, but would then be represented by sales of time-limited quotas by poor countries and quota purchases by rich countries.)

11.5.4 Tradable quotas

Under an international tradable emission quota scheme, all coalition countries would be allocated a quota for emissions (for whatever emission is being controlled). A quota could define either a right to repeated emissions (for example, one tonne of carbon per year over the indefinite future) or a right to emit a given volume once only. Thus a quota system could comprise either "eternal" quotas of the first type or a series of "noneternal" quotas (for example, quotas for five-year periods) or some combination of both. In the case of either type of quota, emission rights could be "banked." In other words, any unused right to emit during a given year could be kept and used at a later time.

In each period, countries would be free to buy and sell quotas on an international exchange (on the spot or forward market) in order that neither buyer nor seller need be identified. Time-limiting the quotas would probably be necessary not only to account for uncertainty about the extent of the enhanced greenhouse problem but also to give credibility to the system. More specifically, it would be necessary to avoid a situation where a government sold quotas, that is, part of the nation's wealth, to an extent that would not be honoured by future governments in the country. Time-limited quotas would also reduce the risk of large countries gaining market power on the quota trade market or the need for measures (such as limits to quota holdings) to ensure that such market imperfections were avoided (Bohm 1995b).

An efficient international tradable quota system presupposes a market organization for quota trade (see Sandor *et al.*, 1994). In the case of a system for the control of emissions of CO_2, quotas would have to be denominated according to the carbon content of the fossil fuel used. If quotas were to be established for the full range of greenhouse gases, it would be necessary to weight gases according to their estimated (and agreed) global warming potential. For any such scheme to be effective in controlling emissions, it is clear that there must be a reasonable probability of detecting and penalizing those responsible for unauthorized emissions. This, however, does not distinguish a tradable quota system from any other international agreement on emission reductions. In what follows, the focus is on quota systems for carbon emissions only.

Negotiations on initial quota allocation are likely to be facilitated by reference to some criteria such as GNP, real GNP, total population, adult population, land area, "basic needs" (defined by industry structure and/or local climate), dependence on fossil fuel production, and others (for an overview, see UNCTAD, 1992; also see Grubb and Sebenius, 1991; Bertram, 1992; Bohm and Larsen, 1993; Hinchy *et al.*, 1993). There are numerous other possibilities (see Chapter 3). Evaluation of proposed rules would need to take account of their international trade repercussions.

Each of the criteria will have adherents, largely those with larger allocations under that criterion.[29] Several criteria may need to be blended to create international consensus on emission allocations.[30] For example, it is clear that the developing countries have relatively little incentive to participate unless they see clear economic benefits from an agreement. At the same time, the wealthy countries will want to make sure their burdens are divided in ways that are perceived as equitable. Whatever the initial allocation, subsequent trading can lead to a cost-effective outcome.[31] This potential for pursuing distributional objectives while assuring cost-effectiveness is an important attribute of the tradable quota approach.[32]

Compared to an international tax agreement, where the effect on emissions is uncertain but related lump sum transfer payments are known, the tradable quota system has a known effect on emissions but quota prices are uncertain and, hence, the distributional effects through quota trade are also uncertain. (This is true for fully global agreements; if only a limited set of countries is involved, carbon leakage must be taken into account in both cases.) This means that the benefits of known effects on emissions in a tradable quota system must be bought at the price of some distributional uncertainty. Thus, if a decision is taken that a poor country should be offered some minimum compensation, then initial quota allocations to that country would have to be increased as compared with the case under certainty. Alternatively, the agreement would have to include some co-insurance system.

Countries allocated quotas surplus to their emission requirements would be able to use the revenue from the sale of these surplus quotas to increase their imports relative to their exports (Chichilnisky *et al.*, 1993). Countries allocated quotas less than their requirements would have to reduce imports relative to exports to pay for additional quotas. In this way a tradable quota scheme would tend to reallocate world production. The allocation of tax revenue from an international carbon tax scheme would have similar effects.

Providing large initial quotas to poor countries for compensatory reasons implies that they would be selling quotas primarily to rich countries. Since quota permit prices represent an implicit or explicit tax on all participating countries, the terms of trade within the coalition for countries with the same carbon intensities in production would remain unaffected. Giving some tariff or other protection from competition from nonparticipating countries, when the agreement does not involve all countries, means that industrialization in poor countries would not have been made more difficult, relatively speaking, aside from the inevitable consequences of reduced global fossil fuel use. In addition, reducing fossil fuel use would emerge as a potentially important "export industry" for the poor countries. From a distributional point of view, the end result would be that poor countries would be perhaps fully compensated, whereas rich countries would have to pay, first, for their own emission reductions as called for by the quota price and, second, for carbon reductions imported through quota purchases from abroad.

11.5.5 Joint implementation

Joint implementation, provided for by Article 4.2 (a) of the FCCC, involves cooperation between two countries, with one funding emission reduction in the other to help the first meet its reduction commitments.[33] Pilot joint implementation projects are now being undertaken by a number of countries. Although many of these involve intergovernmental agreements, the private sector may also be involved directly. The U.S. Initiative on Joint Implementation, for example, involves private sector proposals being approved by an interagency panel.

The potential economic merits and demerits of joint implementation proposals have been widely discussed (Hanisch, 1991; Hanisch *et al.*, 1992; Hanisch *et al.*, 1993; Anderson, 1993; Barrett, 1995; Jones, 1993; Johnson, 1993; Parikh, 1994a, b; Reddy, 1993; Bohm, 1994a; Loske and Oberthür, 1994; Jepma, 1995). In essence, there are three potential roles for joint implementation: (a) as the first step toward establishing an international tradable quota system for greenhouse management among parties that have made a firm commitment to limit their emissions; (b) as a cost-effective option for developed countries to fund emission reduction projects in developing countries that have made no such commitments; and (c) as an activity for exploring when it is cost-effective to bring new emission sources or sinks into an existing international greenhouse management scheme.

A system of joint implementation trades in carbon reduction projects could develop automatically into an international tradable carbon quota system for countries that have carbon targets (Bohm, 1994a). Where aggregate targets exist, the joint level of aggregate carbon emissions reported is a sufficient monitoring statistic for the actual aggregate abatement levels undertaken by each country under a joint carbon reduction policy. Cost incentives are such that emission reductions below the target in one country, when less costly than in another country, would be purchased by, and credited to, the latter. In particular, when several countries are committed to carbon target trading in this fashion, the incremental costs of emission reductions will tend to be equalized across economies. As a result, an international tradable quota scheme could be established once countries commit to binding targets, which would in effect then become their tradable quotas.

The literature on joint implementation has focussed mainly on low-cost emission reduction projects in developing countries. Bohm (1994a) also considers the case of joint implementation between developed and developing countries, where the former commit to binding targets but the latter do not. In the absence of binding targets in developing countries it would be difficult to determine the net emission reduction effects due to a specific joint implementation project, since nationwide indirect and direct effects on emissions must be counted (see Tietenberg and Victor, 1994). The net emission reduction effects of low-cost abatement projects are particularly uncertain, since such projects may be close to being profitable and, hence, may be carried out by the market itself in the near future. In addition to these systematic risks, there are incentives to misrepresent the effectiveness of projects. Parties to a joint implementation project may exaggerate the project's nationwide net emission reduction effects. A clearinghouse version of joint implementation trades between developed and developing countries would eliminate these incentives on the part of the buyer countries. The role of the clearinghouse would be to screen and aggregate all projects from potential sellers before they are offered as anonymous carbon credits to buyers at a market clearing price.

Another potential role for joint implementation is as a complementary exploratory tool for gathering information to expand an existing international regime that initially involves only international carbon trading resulting from fossil fuel emissions. Participating nations could agree to revisit the coverage issue at fixed intervals, modifying strategies to accord with the underlying science and economics of climate change. Successful joint implementation programmes are those that provide the necessary information to incorporate a truly cost-effective new emission source or sink into an international market-based policy. However, this application of joint implementation raises problems of estimating project emission baselines similar to those mentioned in the preceding case, and hence difficulties in ascertaining the nationwide net emission reduction effects of individual noncarbon projects. Current and future joint implementation demonstration projects could provide additional insight into these estimation problems, provided there were sufficient incentives for developed countries to finance them.

The potential driving force behind joint implementation is that both buyer and seller countries, developed as well as developing, would benefit from this particular trade as they do from other forms of voluntary transactions. However, monitoring is a problem in using joint implementation as an instrument for significant cost-effective operations, except for the limited case where parties to the FCCC have committed themselves to emission targets, primarily for carbon emissions. This type of joint implementation amounts to an international tradable quota system, the cost-effectiveness of which is determined by the number of countries that have made such commitments and want to engage in operations under such a system.

11.5.6 Distributional impacts of market-based measures

The literature on industrialized countries typically portrays carbon taxes and other market-based instruments such as

Table 11.2. *A Summary of empirical evidence on the redistributive impact of economic instruments*

Instrument	Author	Country	Model	Results
Carbon tax	Bull, Hassett, & Metcalf (1993)	U.S.	Computable dynamic general equilibrium model; spending behaviour may adjust	Tax burden is nearly proportional with respect to lifetime income
Carbon tax	DeWitt, Dowlatabadi, & Kopp (1991)	U.S.	Partial equilibrium model; spending behaviour may adjust; expenditure data; no recycling of tax revenues	Distributional impact is regressive and varies across regions
Carbon tax	Jorgenson, Slesnick, & Wilcoxen (1992)	U.S.	Computable general equilibrium model; three stages; intertemporal optimization for household consumption	Carbon tax is either mildly progressive or regressive depending on the welfare function used
Carbon tax	Poterba (1991)	U.S.	Partial equilibrium model; expenditure and income data	Carbon tax is regressive, but the impact is smaller if expenditure data are used
Carbon tax	Schillo, Giannarelli, Kelly, Swanson, & Wilcoxen (1992)	U.S.	DECO aggregate macroeconomic model; expenditure data	Depending on the compensation system adopted, the carbon tax is regressive to neutral
Carbon tax	Schillo, Giannarelli, Kelly, Swanson, & Wilcoxen (1992)	U.S.	Urban Institute's TRIM2 microsimulation model; two compensation systems	Carbon tax is regressive with respect to pretax income in both scenarios, but it becomes regressive to neutral relative to posttax income
Carbon tax	Pearson (1992)	Europe	Partial equilibrium model; spending behaviour may/may not adjust (2 models); Eurostat data	Both models indicate that tax on domestic fuels is regressive, while tax on motor fuels is mildly progressive
Carbon tax	Pearson & Smith (1991)	Europe	IFS model of consumer expenditures; compensation system; spending behaviour may adjust	Ireland and UK show a regressive impact. For other countries, the burden is weakly related to income
Carbon tax	Shah & Larsen (1992)	Pakistan	Partial equilibrium model; income and expenditure data; three scenarios	Carbon tax incidence is either proportional or progressive in a developing country context
Carbon tax	Hamilton & Cameron (1994)	Canada	CGE model and simulation model of household expenditure	Tax burden is moderately regressive with the greatest effect on low-income married couples
BTU tax	Bull, Hassett, & Metcalf (1993)	U.S.	Computable dynamic general equilibrium model; spending behaviour may adjust	Tax burden is nearly proportional with respect to lifetime income
Gasoline tax	Greening, Schipper, & Jeng (1993)	U.S.	Partial equilibrium model; expenditure data	Gasoline tax affects negatively mainly older married couples with dependent children. Income distributional results not reported
Gasoline tax	Krupnick, Walls, & Hood (1993)	U.S.	Partial equilibrium econometric model; limited adjusting behaviour	Gasoline taxes are regressive, much more than previous studies since income data are used
Gasoline tax	Poterba (1990)	U.S.	Partial equilibrium model; expenditure data	Gasoline tax is broadly regressive if the lowest income class is ignored; this class devotes a smaller share of its budget to gasoline than the lower-middle income class
Tax on GHG emissions	International Energy Agency (1993)	Europe	Partial equilibrium model; expenditure data	Regressive effect on households if no compensatory measures with respect to domestic heating; less clear result for motor fuels
Tax on direct fuel expenditure	Smith (1992a, b)	Europe	Partial equilibrium model; expenditure data; spending behaviour may/may not adjust; two compensatory systems	Carbon tax is regressive, but if spending behaviour adjusts its impact is smaller; only lump-sum transfers make the impact progressive
Tax on industrial energy use	Smith (1992b)	UK	Input/output tables plus consumer spending simulation program	Modest effect of changes in prices on consumer spending, but negative especially for low-income households

Source: Larsen and Shah (1995).

Table 11.3. *Carbon tax incidence in developing countries*

Institutional considerations	Implications for tax shifting	Tax incidence with respect to: Income	Expenditure	Lifetime income
a. Foreign ownership and control	Borne by foreign treasury through foreign tax credits	Nil	Nil	Nil
b. Full market power	Full forward shifting (100% on final consumption)	Regressive (pro-rich)	Less regressive	Less regressive
Perfectly inelastic demand or perfectly elastic supply				
c. Price controls and legal pass-forward of the tax disallowed	Zero forward shifting (100% on capital income)	Progressive (pro-poor)	Progressive	Progressive
Completely inelastic supply	Reduced rents	Progressive	Progressive	Progressive
Import quotas and rationed foreign exchange	No effect on prices (100% on capital income)	Progressive	Progressive	Progressive
d. An intermediate case of (a) and (b) above	Partial forward shifting (31% to capital income, 69% to final consumption)	Proportional	Progressive	Progressive

Source: Shah and Larsen (1992).

emission taxes and gasoline or BTU taxes as regressive because outlays on fossil fuel consumption as a proportion of current annual personal income tend to fall as incomes rise. But recent studies (see Table 11.2) using U.S. and European data show that carbon taxes are considerably less regressive relative to lifetime income or annual consumption expenditures than to annual income (see Poterba, 1991, 1993; Jorgenson *et al.*, 1992; Smith, 1992a, b).

Jorgenson *et al.* (1992) provide the most detailed assessment to date for the U.S. They decompose the simulated equity and efficiency impacts of a carbon tax, using an explicit national social welfare function. In this decomposition, the negative efficiency effect dominates when the carbon tax revenue is rebated as a lump sum, and the much smaller equity effect is either mildly progressive or regressive, depending on assumptions regarding the nation's aversion to income inequality and the measure of progressivity used.

There is evidence that the same holds true for the rest of the world, although for quite a different reason. In developing countries, institutional factors play an important role (see Shah and Larsen, 1992). In the developing world, progressivity, or at least low regressivity, could be fostered by three mechanisms. First, a significant tax burden could be passed on to foreign treasuries, producers, and consumers where there is a significant degree of foreign direct investment from countries where investors are allowed foreign tax credits against domestic liabilities. Second, price controls could be applied to limit the ability of producers to pass the tax on to consumers in terms of higher prices. Finally, combined with binding import quotas or rationed foreign exchange, a tax could reduce the excess profits made by the privileged class.

The existence of factors such as market power are likely to lead to regressivity. In this situation, producers could increase product prices in order to pass on a carbon tax to consumers. As it turns out, in most developing countries, there is some combination of the above elements, creating a situation where taxes can be only partially shifted to consumers. This means that a carbon tax would be either progressive or much less regressive than often suggested (see Table 11.3). Further, it is likely to be regressive only for the lowest income groups, which could be protected through direct subsidies or alternative measures. In addition, the overall tax structure could be made even less regressive by using a carbon tax to reduce other more regressive taxes.

In principle, if a policy is introduced in order to achieve a particular outcome and it is found to be regressive, then the theoretically appropriate policy instrument to deal with the equity issue is a lump sum transfer to the affected parties. This rests on the assumption that there are no nongreenhouse market distortions. If such distortions exist, then nonlump-sum transfers can improve welfare (Jorgenson *et al.*, 1992). As Schillo *et al.* (1992) explain, if carbon tax revenue is used to reduce labour taxes, or a blend of labour and capital taxes, then simulated household welfare improves as the adverse efficiency effect is reversed by the rebate, but at the cost of reducing the equality of wealth. A capital rebate is shown to neutralize the efficiency effect but has uneven distributional effects.

11.6 Policy Implementation Issues

In assessing any of the wide range of instruments as potential devices for addressing global climate change, it is imperative to give due consideration to the implementation issues that can so severely affect real-world outcomes. Such issues need to be considered in the design of practical policies, whether at the national, multinational, or global level.

In the case of tradable permit systems, as applied to local air pollution problems in the U.S., the claims made for their cost-effectiveness have in some cases exceeded what can reasonably be anticipated. Tietenberg (1980) assimilated the results from ten analyses of the costs of air pollution control, and, in a frequently cited table, indicated the ratio of cost of actual regulatory programmes to least-cost benchmarks. Unfortunately, the resulting ratios (which ranged from 22.0 to 1.1) have sometimes been taken by others to be directly indicative of the potential gains from adopting specific ("cost-effective") mechanisms such as tradable emission permits. A more realistic and appropriate comparison would be one between actual regulatory policies and either actual trading programmes or *reasonably constrained* theoretical permit programmes (Hahn and Stavins, 1992).

A number of factors can adversely affect the performance of tradable permit systems: concentration in the permit market (Hahn, 1984; Misiolek and Elder, 1989); concentration in the output market (Malueg, 1990); transaction costs (Stavins, 1995a); nonprofit-maximizing behaviour, such as sales or staff maximization (Tschirhart, 1984); the preexisting regulatory environment (Bohi and Burtraw, 1992); and the degree of monitoring and enforcement (Keeler, 1991). In the case of taxes, research on implementation issues has focussed on administrative costs (Polinsky and Shavell, 1982), monitoring (Russell, 1990), and enforcement (Harford, 1978; Russell *et al.*, 1986).

In the following sections a review is undertaken of what is known about some prominent issues regarding the implementation of (carbon) taxes and/or tradable permit systems. Where appropriate, reference is also made to regulatory systems. It is important to note that most of the research on tradable permit schemes is based on experience in the U.S., where such schemes were superimposed on regulatory policies. These schemes typically involve a limited number of participants and eternal permits allocated by grandfathering. To control carbon emissions, however, tradable permit schemes might operate where there was no former regulation. They would also involve a larger number of participants, and permits might be time-limited and allocated by auction. Thus, experience in the U.S. may not generalize to such schemes with rather different characteristics.

11.6.1 The "currency" of regulation

Because of the monitoring and enforcement burden associated with regulating actual carbon dioxide emissions, the most practical "currency" for a tax or tradable permit system would presumably be the carbon content of fossil fuels. Given the proportional relationship between carbon content and CO_2 emissions and the present lack of practical means of sequestering these stack gases, this is a highly appropriate approach. Monitoring could rely partly on self-reporting, supplemented by international access to national fossil fuel inventories. Under an international carbon tax or tradable permit scheme, implementation costs may be least where incentives to comply are self-enforcing. An effective enforcement system makes ultimate sanctions credible, so that penalties would rarely need to be imposed. However, in many countries even monitoring fossil fuel consumption is not a trivial problem.[34]

11.6.2 Market power

There are two components to the market power problem for tradable permit systems (Bureau of Industry Economics, 1992). The first is the potential for some economic agents to influence the permit price. The second is the potential for some economic agents to use permits to exercise market power in the output market for the product that "generates" emissions. Market power in the permit market is sufficient but not necessary for market power in the output market (BIE, 1992). Malueg (1990) argues that market power in the output market may reduce economic welfare under a tradable permit scheme even if tradable permits are fully cost-effective.

The degree of competition in the tradable permit market will affect the extent to which potential control cost savings are likely to be realized. Hahn (1984) considers the case of a monopsonist (a price-setting buyer) who forces down the real permit price below the competitive level. This behaviour is not cost-effective, since the monopsonist buys too few permits (spends too much on abatement) whereas the competitive agents will buy too many (thus spending too little on abatement). Misiolek and Elder (1989) consider the converse case of a monopolist (a price-setting seller) who forces up the real permit price above the competitive level. That is, the monopolist spends too little on abatement whereas competitive agents spend too much. To the extent that market power derives from the initial allocation of permits, one solution may be to limit the number of permits held by any player (Tietenberg, 1985). This may be achieved by widening the market to many players, using a variety of means, including limiting the temporal duration of permits.

An emission tax designed to make emitters face the full costs of production will tend to result in a cost-effective allocation of the control burden, provided that emitters are all price takers (that is, small relative to the size of the market). But this outcome does not necessarily occur where emitters have some degree of monopoly power in emission-intensive output markets (Buchanan, 1969). In principle, a monopolist in an output market for an emission-intensive commodity will tend to reduce output below the competitive level in order to raise its profits. Hence, the welfare gains from reduced emissions must more than offset the losses from the monopolist's reduced output for an emission tax to be worthwhile (Cropper and Oates, 1992). Which effect dominates is an empirical issue.[35] For example, Oates and Strassman (1984) find that monopoly power in the output market is unlikely to be a key concern in their study of U.S. industries.

In the case of a scheme to reduce global emissions, there typically will be many more participants than under the schemes operating in the U.S. This would reduce the problem of market power. In an international scheme, firms that are large domestic emitters may be required to hold permits as a means of broadening the market. If market power poses a problem in domestic schemes, government intervention may be required, or a tax scheme may be a preferable option.

The issue of market power warrants further consideration in the context of either tax or permit schemes. Whether or not OPEC is involved in a scheme, the potential oligopolistic response of oil producers could interfere with the effectiveness of attempts to control global emissions (Sinclair, 1992).

11.6.3 Transaction costs

Transaction costs are potentially important in the performance of tradable permit markets (Baumol and Oates, 1988; Tripp and Dudek, 1989; Hahn and Hester, 1989a). Stavins (1995a) identifies three potential sources of transaction costs in tradable permit markets:

(a) search and information
(b) bargaining and decision
(c) monitoring and enforcement

The magnitude of these transaction costs will depend on the structure of the market and the extent to which individual transactions require regulatory approval. If a full market is developed, a market price for permits will be known, and this price will convey all the information parties need in order to decide whether to trade. One party would not need to search for another to trade with, and the terms of trade would not need to be negotiated. Even where such a full market does not develop, innovations may serve to keep transaction costs low. For example, where there are search and information costs, brokers may provide information about pollution control options and potential trading partners in order to exploit potential gains from trade. The third source of transaction costs – monitoring and enforcement – can be significant, but these costs are typically borne by the responsible government authority and not by trading partners and, hence, do not fall within the notion of transaction costs incurred by firms as defined here.

There is abundant anecdotal evidence indicating the prevalence of significant transaction costs in some U.S. trading programmes involving mainly local pollution. Atkinson and Tietenberg (1991) survey six empirical studies that found trading levels – and hence cost savings – in permit markets to be lower than anticipated by theoretical models. Liroff (1989) suggests that this experience with permit systems "demonstrates the need for . . . recognition of the administrative and related transaction costs associated with transfer systems."[36] For example, under the U.S. Environmental Protection Agency's emission trading programme for "criteria air pollutants," there is no ready means for buyers and sellers to identify one another, and as a result buyers frequently pay substantial fees to consultants who assist in the search for available permits (Hahn, 1989). At the other extreme, the high level of trading that took place under the programme of lead rights trading among refineries as part of the U.S. EPA's leaded gasoline phasedown has been attributed to the programme's minimal administrative requirements and the fact that the potential trading partners (refineries) were already experienced at striking deals with one another (Hahn and Hester, 1989a). Hence, transaction costs were kept to a minimum and there was little need for intermediaries.

Another source of indirect evidence of the prevalence of transaction costs in permit markets comes from the well-known bias in actual trading toward "internal trading" within firms, as opposed to "external trading" among firms. It has been hypothesized that the crucial difference favouring the internal trades and discouraging the external trades is the existence of significant transaction costs that arise when the trades are between one firm and another (Hahn and Hester 1989b). The existence of commercial brokers charging significant fees to facilitate transactions lends further credence to this suggestion.

However, although this U.S. experience provides valuable data for the assessment of trading regimes, it must be borne in mind that it is not necessarily relevant to a policy for reducing greenhouse gas emissions. Most of the U.S. programmes have concerned local pollution problems where the market for trading was very thin and where substantial regulatory oversight was required to ensure that the associated environmental objectives were met. Furthermore, it has partly been concerns about future regulatory uncertainty that have discouraged intercompany trading. The lesson from this experience is not that trading involves large transaction costs but that trading regimes should be designed partly with the aim of keeping transaction costs low.

The effects of transaction costs should be ameliorated in markets with relatively large numbers of potential trading sources or where formal international or domestic trading exchanges have been established. As the pool of potential trading partners increases, it should be easier for sources to identify potential trading partners, even in the absence of formal exchanges, thereby lowering transaction costs. A larger number of firms can also mean more frequent transactions, as a result of which more information is generated and uncertainty is reduced.

Economists have tended to give greater emphasis to the symmetry between tradable permits and pollution charges than to their differences, although the two approaches are not symmetrical under conditions of uncertainty (Weitzman, 1974), in the presence of transaction costs (Stavins, 1995a), or under a number of other conditions (Stavins and Whitehead, 1992). Analyses that have compared taxes and permits have assumed zero transaction costs. Systems of pollution taxes can also involve substantial administrative costs, both fixed (per firm) and variable (Polinsky and Shavell, 1982).

11.6.4 Free riding and emission leakage problems

Can a unilateral policy by one country alone or by a group of cooperating countries prove effective in abating global greenhouse gas emissions? This is an important question, for it is total emissions, and not individual country emissions by themselves, that determine global concentrations of greenhouse gases, and yet some countries seem more willing than others to adopt abatement policies.[37] The answer depends on how the other ("noncooperating") countries respond to the unilateral policies adopted by the "cooperating" countries. These responses in turn reflect two phenomena: "leakage" and "free riding."

As Barrett (1994a) explains, free riding and leakage can undermine any international greenhouse management initiatives, whether they be market-based or rely on regulatory measures. Free riding arises when countries that benefit from global abatement do not contribute towards its provision. Leakage arises when abatement by the cooperating countries alters relative world prices (including shadow prices) in a way that leads noncooperating countries to increase their emissions. Leakage thus undermines the competitiveness of cooperating countries as well as the environmental effectiveness of their efforts.

11.6.4.1 *Policies to reduce free riding*

As long as participation in an international greenhouse management policy is voluntary, countries will have incentives to free ride, sharing in the benefits from such a policy without sharing in the costs. Even if there were no leakage, free riding would result in abatement being less than would be globally optimal, in the sense that the benefit of a small increase in global abatement would exceed the associated cost. This issue has been examined in a number of studies, including Barrett (1992a), Hoel (1992), and Parson and Zeckhauser (1992). None of the existing empirical models has been used to estimate the magnitude of potential free riding, although some insights into the gains from full cooperation are provided by Barrett (1992a, b, c), Bohm and Larsen (1993), Hinchy *et al.* (1994a, b), and Hoel (1992).

As Hoel (1992), Carraro and Siniscalco (1993), and Barrett (1994b) have shown, a stable coalition of cooperating countries may exist in spite of free-rider incentives. The size of this coalition will depend on the ability of the cooperating countries to punish countries that might withdraw from the coalition and to reward countries that might accede to it. However, to be effective, such punishments and rewards must be both substantial and credible, and these requirements often clash. As a result, the size of the stable coalition may be quite small. In fact, these analyses do not consider international trade, and where there is trade, free riding will be exacerbated by leakage. On the other hand, trade may also provide a vehicle for deterring free riding.

For example, Barrett (1994a) explains how the threat of a complete ban on trade in carbon-based fuels and products between cooperating and noncooperating countries could work to support full participation in a greenhouse management scheme. The key to this agreement, as with the Montreal Protocol on Substances that Deplete the Ozone Layer, is that the threatened trade ban would come into effect once a threshold level of countries agreed to participate in the scheme. However, the threshold is determined so that all countries would gain from participation once it is reached. In other words, it is not necessary that trade be restricted, but rather that the threat to impose trade restrictions be credible.

An actual ban on trade introduces a distortion in the global economy and is in this sense undesirable. However, free riding is itself a distortion, and if trade restrictions reduce free riding, they may be beneficial overall. The implication for climate change policy is that trade restrictions should not necessarily be prohibited. Whether, and under what circumstances they should be allowed is a different matter and one requiring additional research.

Finally, Heal (1992) argues that the free-riding problem can be exaggerated. He notes that in repeated games it is more likely that players will cooperate than in one-shot games. There may be reinforcing effects that strengthen the chances of forming a stable coalition. An example would be countries sharing in the costs of developing abatement technology. Since developing countries may benefit from abatement technology created in developed countries, this may increase their incentive to abate.

11.6.4.2 *The severity of emission leakage*

There are two main channels through which emission leakage may be transmitted. First, the implementation of a carbon abatement policy by a coalition of cooperating countries would shift comparative advantage in carbon-intensive goods towards noncooperating countries. As a result, production of such goods, and emissions, would rise outside the coalition. Second, the unilateral policy would have the effect of lowering world demand for carbon-intensive fuels, and thereby reduce the world price for such fuels traded in international markets. As a result (and ignoring income effects), demand for such fuels, and emissions, are likely to rise outside the coalition. It should be emphasized that these two responses by noncooperating countries do not result from any deliberate policy to increase emissions, but rather result from the absence of a policy to reduce emissions.

Barrett (1994a) surveys several global simulation studies that provide positive leakage estimates, including GREEN, 12RT, Global 2100, and the Whalley-Wigle model. The leakage rate is defined as the increase in emissions by noncooperating countries divided by the reduction in emissions by cooperating countries. The evidence of positive emission leakage varies widely and is strongly dependent on the model used. For example, positive leakage rates are low in GREEN (Oliveira-Martins *et al.*, 1992) and high in the Whalley-Wigle model (Pezzey, 1992).

In particular, Pezzey estimates that a 20% reduction in carbon emissions within the European Union alone (relative to a baseline trend) would be associated with a leakage rate of 80%. In other words, for every 10 tonnes of carbon abated by the EU, global emissions would fall by only 2 tonnes. Pezzey also calculates that a 20% reduction in OECD emissions would be associated with a leakage rate of 70%. These leakage rates suggest that unilateral policy would be largely ineffective. On the other hand, Oliveira-Martins *et al.* (1992) estimate much lower leakage rates for policies aimed at stabilizing carbon emissions at their 1990 levels. They estimate leakage rates for a unilateral EU policy of 11.9% in 1995 and 2.2% in 2050, and for a unilateral OECD policy of 3.5% in 1995 and 1.4% in 2050. These leakage rates suggest that leakage does not render unilateral policy ineffective. These rates are more in accord with those reported by Hanslow *et al.* (1995), who estimate that a policy-induced 20% reduction in CO_2 in Annex I countries would be associated with a leakage rate of 3.8%.

One reason for the difference in these leakage estimates is that emission leakage is greater where a country's fossil fuel-intensive products and fossil fuels have close substitutes.

Trade flows in GREEN (Oliveira-Martins *et al.*, 1992) are based on the Armington assumption that goods produced from different countries are imperfect substitutes (implying an exporter has some degree of market power). By contrast, in the Whalley-Wigle model goods from different countries are assumed to be perfect substitutes, thus making trade flows more sensitive to relative price changes. In MEGABARE, the model reported in Hanslow *et al.* (1995), imported goods from different sources are imperfect substitutes. Hinchy and Hanslow (1995) report an extension to that model where, in its dynamic version, capital is internationally mobile. As would be expected, the reported emission leakage rates from the dynamic version of MEGABARE are higher than for the comparative static version of the model and lie about halfway between those reported from GREEN and those from the Whalley-Wigle model.

As already noted, other studies estimate leakage rates somewhere between these two sets of estimates. Oliveira-Martins *et al.* (1992) estimate negative leakage rates for some regions in some years, and Horton *et al.*, (1992) argue that leakage may exceed 100% in some cases. Currently, there is no consensus among economists about the magnitude of leakage. More research is needed, and it would be particularly helpful if leakage rates were calculated for identical simulations employing a consistent set of assumptions, as has already been done in estimating the costs of climate change policies (see Dean and Hoeller, 1992). What can be said now is that leakage is a potentially serious problem for unilateral policies.

The above studies ignore a possible third channel for leakage transmission. Under certain assumptions, noncooperating countries will abate their emissions up to the point where their own national marginal benefit of abatement equals their own marginal cost of abatement (see Barrett, 1994b). In the extreme, this optimization rule will mean that noncooperating countries will not abate their emissions at all. However, more generally, this rule implies that noncooperating countries will abate their emissions by less than they would if they cooperated. Where noncooperating countries do undertake positive unilateral abatement, and where the marginal benefit of abatement to noncooperating countries decreases with the level of global abatement, an increase in abatement by cooperating countries will create an incentive for noncooperating countries to reduce their abatement. Hence, leakage may occur even in the absence of trade.

11.6.4.3 *Policies to reduce leakage*

What can be done to reduce emission leakage? What is currently known stems from the basic general equilibrium model of trade so commonly used. As background, take the somewhat simpler case of the international incidence of a global carbon tax. Most of the results from greenhouse modelling studies to date are based on the simplifying assumption that the global cost-effectiveness of a common carbon tax (or tradable quota system) does not depend on the distribution of incomes between or within countries; that is, only relative prices matter for this cost-effectiveness result. (This is not to say that the international distribution of the impacts from these policies does not depend critically on what is done with tax revenues or initial quota allocations.)

Hence, as is consistent with basic trade theory, a uniform global production tax (quota) on greenhouse emissions is equivalent to a uniform global consumption tax (quota) on these emissions. Both minimize the cost to global economic welfare of achieving a given global emission target where there is perfect foresight. However, there are terms-of-trade gains to net fossil fuel exporters under a production tax, and terms-of-trade losses to importers. Under a consumption tax, the converse holds true. That is, fossil fuel exporters are worse off under a consumption tax on emissions, whereas net importers are better off. Precisely such results are illustrated in the Whalley-Wigle model (Dean and Hoeller, 1992).

What happens in this standard framework when coalition membership is less than global? This issue has been examined by Markusen (1975), Krutilla (1991), Bohm (1993), Hoel (1994, 1995), and Barrett (1994a). Treating the coalition as a single entity and the rest of the world as another single entity suggests that, if the coalition is a net importer of carbon-intensive products in the absence of the carbon tax, then a tariff should be imposed on its imports to reduce emission leakage through the terms of trade. If the coalition is a net exporter of these products in the absence of a carbon tax, then it should subsidize its exports. This response minimizes the coalition cost of meeting the greenhouse constraint. Precisely the same argument holds for leakage through trade in carbon-based fossil fuels. In addition, instead of using an import tariff (export subsidy) the equivalent production subsidy (tax) and consumption tax (subsidy) could be applied in the coalition. Hoel (1995) shows that if an optimal tariff (subsidy) or its equivalent can be employed, then the carbon tax should be uniform across all sectors in all coalition countries, but, if not, then differential tax rates and exemptions may be required.

Although border tax adjustments may theoretically be appropriate for reducing leakage, their application poses a number of practical problems. How are the emissions associated with the manufacture of a particular product to be determined? The Montreal Protocol includes a provision for restricting trade in products made using ozone-depleting substances, such as electronics components that are made using CFCs as a solvent. However, this provision has not been implemented, and the Protocol Secretariat was advised in 1993 that to do so would not be feasible (Van Slooten, 1994). To implement the provision would require either sophisticated equipment capable of detecting trace residues of CFCs or certification of the manufacturing facilities of industries in countries that are not parties to the agreement. In the case of global climate change, similar adjustments would be even harder to implement, as virtually all production results in some greenhouse gas emissions.

Furthermore, the appropriate border tax adjustments may not be compatible with current multilateral trading rules. World Trade Organization (WTO) rules allow for border tax adjustments where the taxed or controlled inputs are physically incorporated in the final product. However, in the case of greenhouse gases, the concern is typically with the carbon emitted in the process of manufacturing a good. A GATT dispute panel has ruled (in the Superfund case) that adjustments may be allowed when the use of inputs can be inferred by assuming that the product was manufactured using the "predominant production method." However, a similar approach would not be appropriate in the case of climate change, not least because production methods vary so widely. The recently completed Uruguay Round allows energy taxes to be remitted on exports of manufactured goods, although there is some question about the generality of this provision and whether it could be extended to include imports. Plainly, the rules for applying border tax adjustments need to be clarified.

In summary, all the results from basic trade theory hold in analyzing emission leakage from a carbon tax or quota (see, for example, Woodland, 1982; Vousden, 1990). However, as with a customs union, determining the optimal tariff (subsidy) to reduce positive emission leakage from the carbon tax will be a complicated calculation, given the extensive but differential use of carbon-based fuels in all economies and the differential ability of some countries to exercise market power. Trade compliance with WTO rules will also need to be considered. In addition, further research on the leakage problem is warranted to consider strategic interactions between greenhouse policies in coalition and noncoalition countries.

11.6.5 Compliance

Free-rider deterrence is concerned with securing broad participation in an agreement, and leakage reduction is concerned with making abatement by cooperating countries more effective. A related concern is compliance, or the incentives that countries have to fulfil their pledges under an international agreement. Some international agreements contain explicit compliance measures such as trade sanctions. However, it is more usual for agreements to seek alternative means for securing compliance (see Chayes and Chayes, 1993).

Indeed, it is a fundamental norm of international law that treaties are to be obeyed, and as a rule countries do not negotiate, sign, and ratify agreements with the intention that they will not comply fully with all relevant provisions. Hence, compliance is not so great a problem as it is sometimes taken to be. More difficult are the problems of negotiating an agreement that requires real sacrifices by the parties and of getting countries to sign the agreement in the first place.

Where compliance is a problem, the reasons are usually innocent. For example, four years after the Montreal Protocol was signed, only about half the parties to the agreement had complied fully with the reporting requirements of the treaty. This was not because these countries hoped to get away with noncompliance, but rather because they did not have the resources and technical know-how needed to carry out their obligations. On the other hand, compliance with certain oil pollution treaties once proved more worrying because noncompliance was linked to the difficulty of monitoring and verifying the amount of oil discharged by tankers at sea. However, once an equipment standard was established requiring all new tankers to have separate ballast tanks, monitoring became easy and problems of noncompliance subsided. Indeed, monitoring of international agreements may be the more important problem (U.S. General Accounting Office, 1992). The lessons seem to be that treaties should be designed to facilitate easy monitoring, and that they should also ensure that all parties have the means to comply with the requirements of the agreements, given the will to do so.

11.6.6 Information issues, the role of brokers, and risk management

Policy instruments should be designed to provide needed information. In the case of tradable permit systems, there are three ways this can be done:

(a) Government can take actions that directly reduce regulatory uncertainty.
(b) Barriers to private brokerage services can be reduced.
(c) Allowance can be made for the development of futures markets.

In the first case, at a minimum, government authorities can avoid creating regulatory barriers (such as requirements for government preapproval of trades) that drive up transaction costs and discourage trading.

Private provision of brokerage services can also play an important role in information provision. Thus, although commercial brokers can certainly be recipients of transaction costs, their activities reduce transaction costs below what they would otherwise be (Stavins, 1995a). Intermediaries, in general, can contribute to social welfare by helping parties economize on transaction costs. Brokers can play the role of consultants, adding value by understanding the regulatory process and by maintaining information about prospective suppliers and demanders of permits. Under the more conventional function of bringing together buyers and sellers ("brokering deals" by matching buy orders and sell orders), these firms both absorb and reduce transaction costs. Finally, brokers may assume risk by buying, holding, and selling permits.

An important merit of an international tradable quota system (compared with an emission tax scheme) is that it can be used as a risk management tool to reduce the costs of greenhouse risks. Some simple examples of the risk management potential of a quota scheme are given below. In these examples, quotas themselves are used as the hedging instrument. If a sophisticated market were to develop, "derivatives" of quotas, such as options and forward and futures contracts, might be used to perform these risk management functions more efficiently. However, in the first instance, the logic of the risk management potential of quotas can be brought out most simply by taking quotas as the instrument.

In the first example, the use of quotas to reduce risks will be considered for investments that have the potential to reduce emissions. Such investments include research and development into new abatement technologies and the transfer of abatement technology across countries. These investments may either succeed or fail and, hence, the return to the investment is uncertain. The key to the risk-reducing role of quotas is that the quota price will be negatively correlated with the success of the investment.

Suppose that quotas (or permits) of some finite duration are widely traded. When a new investment with emission reducing potential is announced, the price of quotas will tend to fall. This is because there is some probability that the investment will succeed and it will be expected that there will be less need for quotas in the future, resulting in reduced demand. If the investment actually fails, this reduced demand will not eventuate and the price of quotas will rise. On the other hand, if the investment succeeds it will not be the probability but the certain success that will influence demand. Quota prices will fall.

Investors can use this negative correlation between the price of quotas and the success of the project to reduce the variability of their returns. If quotas are bought at the start of the project and it fails, investors will be able to sell their quotas above the purchase price. Such a profit will help to offset their losses on the project. If the project succeeds, investors will suffer a loss on their quota sales. However, by narrowing the gap in expected profits between a successful and unsuccessful outcome, quota operations will reduce the risks for investors (see Epstein and Gupta, 1990, for a numerical example). Risk-averse investors will be willing to trade higher average profits for more certain profits. The availability of quotas as a risk management tool increases the probability that the investment will be undertaken.

In the second example, the use of quotas (or permits) to manage the temporal nature of risk is emphasized. Investments in some activities such as coal-fired power stations have a long payback period and generate emissions. If emissions are taxed, future tax levels may have a critical bearing on the return on the investment. There may be sufficient uncertainty about future tax levels to deter some risk-averse investors from the project. However, under a quota scheme, if there are quotas of sufficient duration, the costs of future emissions to investors can be known with certainty. However, in a scheme dominated by long-lived quotas, there would be inflexibility in adapting emissions to changing information on desirable emission levels. A number of ways to reduce this problem have been proposed.[38]

As mentioned above, a forward or futures market could provide a more effective risk management tool than the direct use of a quota market in the simple examples described. A forward market for quotas could develop if there were a sufficient number of hedgers and speculators, and none of them had excessive influence over price signals. The latter requirement could be met by a rule fixing the maximum share of total net emission entitlements held by any one country. By reducing the costs of risk and uncertainty, time-limited quotas would tend to reduce any nation's incentive to pursue strategic behaviour (such as quota hoarding) and could also reduce validity forecasting problems.

Once the parties to the agreement know the basis on which quotas will be allocated over time, a futures market could develop. Provided contracts are standardized, one of the main differences between the forward contracts market described in the previous paragraph and a futures market is that the latter offers greater liquidity if contracts can be settled by the monetary equivalent of quota transactions, as opposed to the delivery of the quota itself. As a consequence, more transactions are likely in the futures market and this should lead to greater information flows, reducing uncertainty and risk and transaction costs. As a consequence, spikes in the quota price would tend to be rapidly smoothed out as market players took up speculative and hedging positions.

A major factor favouring a tradable quota scheme, therefore, is that a forward and/or futures market based on (net) emission quota contracts would provide a way of efficiently reducing the elements of uncertainty and risk in greenhouse costs. This would reduce the costs of control and stimulate investment in the research, development, and use of least-cost mechanisms for net emission control. For example, suppose a country invests in a risky technology transfer project as part of a strategy to meet its national greenhouse target. It can hedge against the risk of project failure by buying futures. Any profit on the futures market transaction can partly compensate for any rise in the spot price if it needs to buy quotas.

In the U.S. an auction system for forward sales of emission quotas is provided for in the 1990 amendment to the Clean Air Act for controlling domestic sulphur dioxide (SO_2) emissions from fossil fuel fired power plants. As Howe (1994) notes, the amended legislation requires total SO_2 emissions from the U.S. electricity power sector to be around 50% below the 1980 level by the year 2000. After January 1, 1995, each of the 111 power plants directly affected in the first phase of measures must hold tradable quotas covering its total annual emissions target (its quota allocation), capped at about 50% of the 1980 level. Currently, allowances may be traded to any party or credited ("banked") for future use. In the second phase, beginning January 1, 2000, most electric power utilities will be brought within the system. In addition to receiving an annual target allowance, quotas for excess emissions may be bought directly from other plants or through auctions held by the Chicago Board of Trade for the United States Environmental Protection Agency.

The temporal component of any pollution problem can be important, but this 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, then 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 tradable 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 emission 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 banking of greenhouse gas allowances, since this would allow for intertemporally efficient market exchanges and could tend to delay the onset of global climate change.

11.6.7 Implementation issues for economies in transition

Nations with economies in transition from centrally planned to market-based systems are likely to exhibit certain characteristics relevant to the choice, design, and implementation of greenhouse policy instruments. A small but rapidly growing literature has begun to investigate issues of particular concern for implementation of environmental policy in transition economies, including matters such as the adaptation of existing environmental tax systems to changing conditions (OECD, 1994; Semeniene and Kundrotas, 1994; Markandya, 1994), historical, institutional, and fiscal factors (Zylicz, 1994a, b), the use of economic instruments to raise revenue for highly constrained government budgets (Zylicz, 1994c, OECD, 1994), the environmental impacts and cost-effectiveness of instruments for air pollution control in specific regions (London Economics, 1993; Csermely, Kaderjak, and Lehoczki, 1994; Dudek, Kulczynski, and Zylicz, 1993), and environmental liability (Bell and Kolaja, 1993).

High rates of economic growth and price inflation could affect the attractiveness of alternative policy instruments over time, due, for example, to the rapid inflation of relative permit prices or the erosion of unit-based taxes (Stavins and Whitehead, 1992). Situations in which a large portion of the economy is state-owned or the private sector is in its infancy suggest the need to validate the usual assumption that emission sources (firms and individuals) are cost-minimizers and that markets are relatively complete (Stavins and Zylicz, 1994). Enterprises may be protected from bankruptcy, facing only "soft budget constraints," or they may have the ability to avoid environmental requirements through negotiation (OECD, 1994).

Concentration of product or emission permit markets due to inherited industry mixes and possible barriers to entry (for example, imperfect capital markets) may also impede the efficient operation of a tradable permit system (Hahn, 1984). Significant structural adjustment, including privatization, shifts in industrial sector shares in the economy, and disruptions in international trading relationships could also affect the stability and predictability of greenhouse gas emissions resulting from alternative policy instruments. Effective taxes may, for example, increase bankruptcies in a period of severe economic problems (OECD, 1994). Even after privatization, many enterprises may be unable to respond efficiently to policy because they lack information on technological options for pollution control and their cost-effectiveness (OECD, 1994).

Other noneconomic characteristics of transition economies may also be relevant to the implementation of policy instruments to manage greenhouse gas emissions. Problems may arise from the legal and administrative constraints inherited from central planning, making monitoring and enforcement difficult. A relatively undeveloped sense of corporate responsibility, a lack of public awareness of environmental issues, and a lack of pressure from nongovernment organizations could further impede effective implementation. Government personnel may lack the necessary administrative skills, due to a shortage of economic, financial, and accounting skills and an inability on the part of government agencies to offer competitive salaries (OECD, 1994). Finally, high *ex ante* levels of pollution, high levels of desired reduction, and a concentrated pattern of pollution exposure may present environmental conditions that are more extreme than in many advanced industrialized countries, but they may also provide abundant opportunities for low-cost abatement.

11.7 Comparative Assessment of Greenhouse Policy Instruments

In this section an attempt is made to outline the issues that need to be considered in determining any greenhouse policy mix. Countries differ in their institutional structures, their resource endowments, and their levels of industrialization. Differences in economic and technical capacities among countries offer the potential for emission abatement cost saving under a harmonized international greenhouse management scheme but, at the same time, add complexities in terms of reaching final agreement about appropriate policy approaches and burden sharing.

Economic instruments are considered by policy makers in a political environment. This has several important implications for the nature of the instruments finally adopted, as well as for the potential for reaching an international agreement on climate change.

First, to some extent the choice of instrument will be dictated by existing institutional infrastructure and experience. For example, market-based instruments are likely to be seen as less appropriate in an economy with a high level of central planning than in one with a long history of free enterprise.

Second, the ability to enforce the different instruments is likely to vary across nations. In addition, nations are unlikely to grant significant authority to a supranational body that would allow for consistent enforcement across countries.

Third, to the extent that domestic policy is affected, the choice of policy instruments at the international level could affect the likelihood that an agreement will be reached.[39] For example, some countries may be unwilling to accept an agreement involving the use of international taxes or harmonized domestic taxes. On the other hand, as pointed out earlier, a tradable quota scheme leaves open the choice of domestic instruments.

Fourth, any approach that is implemented to control greenhouse gases may vary from the textbook application of these concepts. There are many reasons why both market-based and regulatory approaches deviate from their ideal. Departure of actual instruments from their theoretical ideal, however, is not sufficient cause for rejection of an approach.

Fifth, the adoption of any international instruments will have some impact on the distribution of wealth between countries, as will domestic instruments on the distribution of wealth within them. Negotiations about distributional issues are likely to be crucial in determining the final policy mix that is chosen. In the case of domestic taxes and tradable permits, some of the government revenue may be returned to the affected parties. Thus, for example, many charging systems in

Europe are designed to limit pollution recycle revenues to the participants or earmark the revenue for specific tasks. Similarly, in the U.S., tradable permits for protecting the environment are distributed according to the historical pattern of emissions (grandfathering). Although the precise nature of the distribution will be the subject of vigorous political discussions, countries and special interest groups (including environmental groups) are unlikely to accept an agreement that substantially shifts the distribution of wealth or political power. Since all instruments probably will have to, and also can, be connected with compensatory measures – side payments or specific quota/permit allocations – no difference between them would arise in this regard. For example, an international tax or tradable quota scheme might be designed in such a way as to encourage developing countries to join a coalition in order that they benefit from international transfers of income.

Sixth, governments are likely to attach more stringent monitoring and enforcement requirements to a market-based approach for limiting noncarbon greenhouse gas emissions than to a regulatory system. For example, environmentalists bargained successfully for the installation of continuous emission monitors as a condition for allowing a tradable allowance system for reducing SO_2 emissions in the U.S. A similar strategy is likely to be applied if market-based approaches are implemented for limiting noncarbon greenhouse gases or for controlling carbon sequestration. One notable difference between the two control problems is that technology for accurately monitoring many sources and sinks of greenhouse gases has not yet been developed.

And finally, there are several reasons why politicians have traditionally taken a regulatory approach, rather than an economic incentive-based approach to environmental policy (Bohm and Russell, 1985; Hahn and Stavins, 1991). First, industry tends to favour direct regulation over incentive mechanisms because (a) if a tax instrument is used, the polluter must pay fees in addition to controlling costs, although the acceptance of this approach will be influenced by any revenue recycling, as mentioned above; and (b) firms may have greater influence over the specifics of uniform standards. Second, the effects of quantity regulation are likely to be perceived to be more certain than pollution charges, whose effect will depend on abatement cost functions, which are typically unknown. Third, economic efficiency arguments often rely on a relatively sophisticated understanding of market operation and price effects which seem indirect when compared with regulation of the polluting activity. Finally, in many countries, economists play a minor role in the development of environmental policy, compared with the number of decision makers with backgrounds in law, natural science, or engineering.

11.7.1 Comparing regulatory systems and market-based instruments

Regulatory policies may be defined as those where the authorities determine the level of permissible emissions from an emission source. Market-based policies may be defined as those where firms are free to determine their level of emissions but must pay some penalty (such as a tax or the purchase of an emission permit) determined by the authorities for their level of emissions. To minimize the total costs of abatement, the level of abatement at each source needs to be chosen to equalize the marginal costs of abatement for given output and input prices. If the authorities had complete information about the marginal costs of abatement at each source, regulatory policies could be determined to minimize the total costs of abatement. Given that the authorities will not have such complete information and typically cannot acquire it at a reasonable cost, regulatory approaches tend not to be cost minimizing.

On the other hand, it is necessary to consider the public as well as the private costs of control (Stavins, 1995a). In other words, the total costs to be minimized by a truly cost-effective environmental policy instrument include both the costs of abatement (typically borne by private industry and including transaction costs) and the costs of administration (typically borne by government in the form of monitoring and enforcement costs). When monitoring and enforcement needs are particularly burdensome, performance-based standards in general may not be cost-effective. On the other hand, certain forms of technology standards, which are typically relatively high-cost in terms of abatement, can involve only minimal needs for adequate monitoring and enforcement. Finally, in addition to such concerns about static or allocative cost-effectiveness, it is important to consider the relative effects of alternative policy instruments on the invention, innovation, and diffusion of new technologies. That is, in the long term, it is the dynamic efficiency properties of environmental policy instruments that are likely to be most important.

In the international context, monitoring and enforcement requirements would hardly differ with respect to fossil fuel use, since fossil fuel output plus imports minus exports would have to be reported for each participating country under all systems.

Tradable permits (for emissions during a given time period) and taxes are the two major domestic market-based policies. With tradable permits a national permit exchange would develop among permit-liable fossil fuel producers and importers (or wholesale dealers in fossil fuels) after the initial allocation of permits through recurring government permit auctions or (temporary) grandfathering. In this connection transaction costs would arise. Under a tax scheme administrative costs would be incurred in payment and collection of the tax. The issue of how the costs of violation detection and enforcement would differ between policies has not been studied, and there does not appear to be any empirical evidence that could be applied to the study of these questions.

There have been a number of empirical studies that suggest significant potential cost savings from the adoption of truly cost-effective instruments instead of regulatory approaches (Tietenberg, 1985), although most of these studies have contrasted actual regulatory instrument costs with a theoretical cost-minimizing alternative rather than an actual market-based policy instrument (Hahn and Stavins, 1992). In the final analysis, governments are likely to choose a portfolio of instruments including both some regulatory and some market-based approaches.

In economies without well-developed market systems, there may be net efficiency gains from applying regulatory approaches over a wider range of emission sources. On the other hand, the adoption of a market-based approach may speed the development of the market system. Net efficiency gains may favour the development of market-based systems at an earlier date than otherwise would be the case.

At the international level, there is little scope for using direct regulation of emissions over and above nontradable emission quotas. Such a quota system would clearly entail extra costs to the extent that marginal abatement costs differ among countries. Cost-effective candidates for an international agreement are tradable quotas and international or harmonized domestic carbon taxes.

11.7.2 Comparing domestic tradable permits and domestic tax systems

Both taxes and tradable permits impose costs on industry and consumers.[40] In effect, they force firms to internalize the costs of their pollution. Practically speaking, this means that firms will experience financial outlays, either through expenditures on pollution controls or through cash payments (buying permits or paying taxes). Taxes and permit prices (especially when permits are auctioned by the government) tend to make these costs more visible to industry and the public. This may be problematic for political reasons, although in the long run it may have the advantage of clearly signalling and educating the public about the costs and tradeoffs associated with various levels of environmental control.

In principle, there need be no difference between domestic carbon taxes and tradable carbon permits from a distributional point of view. Moreover, the tax recycling and "double dividend" benefits associated with carbon taxes can exist to the same extent for a permit system. Tradable permits may be grandfathered, in the short run, to (partly) compensate existing firms that may not have been sufficiently forewarned about the new policy. This choice corresponds to a tax scheme where, in a period of transition, all carbon tax revenues are redistributed to the firms that would have received free permits under a permit scheme. Alternatively, or after a period of transition is over, no compensation at all would be paid. This would amount to a tax system where the government kept the tax revenue (and used it for unrelated purposes) or a permit scheme where all permits were auctioned and the government retained the sales revenue. Partial matching versions of each type of scheme might also be imagined.

The difficulty of controlling emission levels through taxes could be a distinct disadvantage in terms of an international agreement. Taxes would have to be varied frequently, given the inadequate information base of the authorities, to determine the appropriate tax level and the need for adjustments in response to changes in the level of economic activity and changes in relative and absolute price levels. The need for frequent changes in tax levels would add to business uncertainty and to the practical difficulty in a political sense of implementing such a policy.

Tradable permit systems may be more susceptible to "strategic" behaviour than tax systems. In order for a tradable 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 control a significant share of the total number of permits, its activities may influence permit prices. Firms might attempt to manipulate permit prices to improve their positions in the permit market (say, by withholding permits and forcing others to cut production or keeping new entrants out). These risks would be reduced by (a) using time-limited permits – that is, permits for emissions for a period of, say, five years, which could be compatible with a corresponding international tradable quota scheme;[41] and (b) government auctioning of permits.[42]

Tradable permits have some advantage over taxes when time and uncertainty are introduced into the analysis. A tradable permit scheme can be designed to reduce uncertainty about the future in a number of ways. One approach would be to issue permits with different durations (Bertram, 1992) or for a set of future (for example, five-year) periods. Firms undertaking emission-intensive investments with long payback periods would be able to reduce uncertainty about future costs by buying permits for the desired number of periods. The development of a forward or futures market for permits (that could be coupled with permits of different duration) would provide an even better mechanism to spread the risks associated with uncertainty about future emission policy. Firms undertaking research and development into technologies to reduce emissions would be able to hedge the risks associated with the payoff from such technologies through operations in the futures market (Epstein and Gupta, 1990). Similarly, firms investing in emission-intensive activities would be able to hedge against the risks of future policy changes through the operations of futures markets.

To summarize, permits are more effective than taxes in achieving given emission targets. The difficulty of controlling emissions through taxes could be a disadvantage. The frequent changes in taxes that may be required would add to business uncertainty. Permits may be more susceptible to strategic manipulation than taxes, but this problem can be reduced, as explained above. Permits appear to have a distinct advantage in creating the basis for a futures market that could enable a more efficient spreading of the risks of future policy uncertainty.

11.7.3 Comparing international tradable quotas and tax systems

As outlined above, economic incentive policies can lead in many situations to lower total pollution control costs and spur greater technological innovation than conventional regulatory approaches. Which incentive-based instrument is most effective, however, will depend on a number of specific factors. The broadest set of possible international applications is considered below.

A system of harmonized domestic carbon taxes would involve an agreement about compensatory international financial transfers as well as the precarbon tax net tax rates on fossil fuels. These taxes would represent (at least) what amounts to an estimate of the domestic environmental effects of fossil fuel combustion. Internationally acceptable estimates of these basic tax levels, which would tend to differ between countries, would be difficult to establish. Moreover, no design seems feasible and generally acceptable where participants are not allowed to undertake policies on their own which indirectly affect fossil fuel use, such as levying a tax on substitutes for carbon and subsidizing complements to carbon (Hoel, 1993). Thus, there are significant risks that a tax harmonization agreement would either never be adopted or fail after implementation.

A system of international taxes, where all participating countries were liable to pay a given carbon tax, could include an agreement on how tax receipts would be shared among the participants. Under such a system countries might retain all or part of the taxes raised domestically, and some participants (low-income countries) might receive a transfer (Hoel, 1993). Each country would have a good knowledge of the amount of tax revenue likely to be raised internally. However, less information would be available about other countries' tax revenues and, hence, there would be uncertainty about the size of the net transfers to and from each country.

A tradable quota scheme leaves each participant to decide what domestic policy to use. Such a scheme does not require any ongoing side payments. Here, the initial allocation of quota entitlements among countries reflects distributional considerations. A disadvantage of a tradable quota scheme is that the (endogenous) future prices in international quota trade are unknown when an agreement on the quota allocation is reached. Hence, the exact distributional implications cannot be known beforehand. This is the price paid for the main advantage of such a scheme, namely that the resulting global emissions will be known with certainty for a global agreement and, net of carbon leakage, for a nonglobal agreement.

Thus, the choice between a tax and a quota regime remains ambiguous. As Yohe (1992) points out, nations facing different circumstances could favour different control strategies. For example, if a case can be made that the marginal social cost of climate change is relatively flat in industrial countries because of their comparative advantage in applying technology to adapting to change, then such countries might favour a tax instrument. On the other hand, developing countries that are likely to face much steeper marginal social cost schedules because of their lower capacity to adapt may favour a system of tradable quotas (perhaps regardless of the initial quota allocation).

Endnotes

1. For a comprehensive legal review of the Convention, see Bodansky (1993).

2. However, it is worth noting that there may be side benefits (in health-related factors, for example) as a consequence of any reductions in pollution arising from reductions in greenhouse gas emissions.

3. For a general review of the literature on investment under uncertainty, see Pindyck (1991). See also Chapter 10 of this report.

4. Strictly speaking, the term emission "charge" or "fee" would be more appropriate because this is a payment for a right to emit. However, the term emission "tax" is adopted here because the term "carbon tax" is so widely used in the literature.

5. For a very useful breakdown and analysis of the full costs of environmental regulations, see Schmalensee (1994). Conceptually, the cost of an environmental regulation is equal to "the change in consumer and producer surpluses associated with the regulations and with any price and/or income changes that may result" (Cropper and Oates, 1992).

6. For example, if a firm chooses to close a plant because of a new regulation (rather than installing expensive control equipment), this would be counted as zero cost in typical compliance cost estimates.

7. For a fuller explanation of these different categories of environmental protection costs, see Jaffe *et al.* (1995).

8. Although lump sum taxes and transfers are typically infeasible in a single economy, market-based instruments such as a tradable quota scheme or a carbon tax can be designed to achieve transfers of goods and services between countries to implement the equity criteria listed in Section 11.2.3.

9. They estimate that a carbon tax of US$60-70 per tonne of carbon would be required in OECD countries to achieve an equivalent reduction in global emissions.

10. For a comprehensive coverage of discount and social time preference rates, see Chapter 4 of this report.

11. In the case of the United States, for example, see U.S. Environmental Protection Agency (1989); National Academy of Sciences (1992); Clinton and Gore (1993).

12. This is no longer the case even in Europe, which now has performance-based standards as in the U.S. and Japan.

13. These technologies remain incompatible because of the stringent requirements for NO_x control.

14. Currently there are lean-burn Japanese-made vehicles that can meet present Japanese standards and that are also available on the European market (H. Watson, Melbourne University, personal communication). The lower temperatures obtainable in lean-burn combustion reduce NO_x production but result in less complete combustion of hydrocarbons, forcing a continued reliance on at least two-way catalytic converters. These vehicles therefore also incorporate two-way catalysts (which control hydrocarbons and carbon monoxide), with NO_x control being left to careful engine management and exhaust gas recirculation.

15. Lean-burn engines are potentially more fuel-efficient, since by definition they use less fuel in the air/fuel mix. A 10% improvement in fuel efficiency has been reported for Toyota's lean-burn control system with two-way converter (Watson 1994). Such an improvement in fuel efficiency would have to be offset against other effects of lean-burn technology, such as lower temperatures of operation and less smooth running in the absence of more sophisticated engine-control systems. Any disincentive to the technological development of lean-burn engines is of particular concern in the context of reducing carbon dioxide emissions from conventionally fuelled cars, since vehicle-based "engineering" advances in this respect depend essentially on improving fuel efficiencies.

16. Lean-burn technologies also have the potential to reduce toxic emissions more effectively over the lifetime of the automobile; because they are a more durable technology than currently available catalytic converters, which are constructed with an expected lifetime equal to that of the U.S. car (60,000 miles or 100,000 km). However, many cars have lifetimes well in excess of this – for example, the Australian experience is 240,000 km. The resulting number of older cars with malfunctioning converters is a concern, since even a relatively small number of them may be major sources of toxic emissions.

17. For discussions of relevant enforcement issues see, for example Harford (1978), Shibata and Winrich (1983), Polinsky and Shavell (1979).

18. See, for example, the experience of the Netherlands cited in Lenstra and Bonney (1994).

19. Natural gas and water utilities also implement demand-side management programmes, but they have been most common in electric utilities because the cost of meeting peak demand is highest in the case of electricity.

20. These are the co-called California Standard Practice tests (see EPRI, 1991). The tests have been criticized on the grounds that they provide an incomplete cost-benefit analysis (Herman, 1994).

21. Electric transmission and distribution systems are regarded as natural monopolies. Historically, generation technology has exhibited economies of scale, which have produced declining marginal costs. Utilities tended to integrate generation and transmission, and to a lesser extent distribution, to realize the economies of scale with minimal risk. To enable the utility to recover its full costs, rates were based on average costs, which are higher than marginal costs. Marginal costs vary with the demand for electricity and, during peak periods, exceed the average cost. Demand-side management programmes that shift demand from peak periods to lower-cost periods reduce costs with little loss of revenue. Such programmes can reduce current demand and still pass the RIM test. Load growth creates a need to add capacity. This affects future rates regardless of whether the marginal costs of the new capacity are higher or lower than those of existing capacity. Demand-side management programmes that lower load growth defer the need to add capacity and so reduce costs. Since the demand-side management costs are incurred earlier than the expenditures for new capacity, they lead to an initial increase in rates. However, assuming all the estimates to be accurate, the rates should ultimately decrease.

22. A related instrument is the tradable absorption/abatement obligation. See Read (1994).

23. It is precisely for this reason that a carbon tax (with relatively low monitoring costs) is feasible. In contrast, a true CO_2 emission tax would obviously be extremely costly to monitor and enforce. (Compare this with the case of sulphur dioxide (SO_2). Controlling SO_2 emissions by means of a sulphur content tax on coal would be problematic, since it would fail to provide incentives for flue gas desulphurization (scrubbing), even when this would be the cost-effective route to reducing SO_2 emissions.)

24. For a further discussion of decarbonization of fuels and flue gases, see Chapter 19 of the IPCC Working Group II Second Assessment Report.

25. An option of this kind was used to some extent in the Montreal Protocol (Article 1.5). For an analysis of the cost-effective attributes of the Protocol, see Bohm (1990).

26. In addition, uses of fossil fuels for purposes other than combustion, for example, as chemical feedstocks, could be subjected to similar deposit refund treatment to "keep the prices right." Likewise, products such as lubrication oil could be subjected to the carbon tax whereas waste lubrication oil would be entitled to a tax refund if returned for oil recovery or disposal other than by incineration (Bohm, 1981).

27. In a static model that has fixed prices and neglects the public goods aspect of abatement, transfers have purely distributional effects. However, this is not the case where economies are growing and production technology differs across countries (in the sense that different quantities of capital and emissions are required to produce a given output of consumption or capital goods). In this case, transfers make it possible to raise the growth rate of an economy above the maximum determined by its original productive capacity. This is illustrated by Hinchy and Hanslow (1994), using an *n*-country generalization of a model developed by Tahvonen and Kuuluvainen (1993).

28. When permits are leased from government or when time-limited permits are auctioned by government, the revenue implications of permit schemes approach those of taxes. Theoretical analysis indicates that this is not true in the case where eternal permits are auctioned by government (Bohm, 1994b).

29. 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 U.S. and perhaps the former Soviet Union, as buyers. (See Epstein and Gupta, 1990.)

30. For example, the Canadians proposed using population and GNP combined as allocation criteria when CFC reduction obligations were being considered in the development of the Montreal Protocol.

31. This assumption excludes the potential consequences of significant transaction costs.

32. For a general discussion, see Bohm (1992). "Appropriate" initial allocations can serve as an effective device to draw countries – particularly, developing countries – into an international agreement. On this, see Barrett (1992c) and Hinchy *et al.* (1994a, b). Most proposals for allocating control obligations among nations call for proportionately higher rates of reduction in emissions by the industrialized countries (and, among the industrialized countries, by the U.S.) and substantial reductions in the predicted rates of increase in CO_2 emissions by most developing countries. See, for example, Krause (1989), Flavin (1989), and Wirth and Lashof (1990).

33. For a comprehensive review of the legal and practical aspects of joint implementation, see Kuik *et al.* (1994).

34. Monitoring and enforcement are discussed in detail by Tietenberg and Victor (1994).

35. Although there is no cutoff point, it is unlikely that firms or nations could engage in price-setting behaviour if they controlled less than 10% of the market (see Scherer, 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 behaviour can thrive (see Baumol *et al.*, 1982).

36. Alternative explanations of low observed trading levels have also been advanced. These include lumpy investment in pollution-control technology; concentration in permit or product markets; the sequential and bilateral nature of the trading process (in the context of a nonuniformly mixed pollutant) leading to some initial trades that then preclude better trades from being carried out subsequently (Atkinson and Tietenberg, 1991); and the regulatory environment. Some of these "alternative explanations" of low trading levels can be viewed as special cases of transaction costs, broadly defined.

37. This problem may exist within groups of countries as well as more generally. For a discussion of issues surrounding the attempted introduction of a harmonized carbon tax in the European Union and a possible alternative policy, see Bergesen *et al.* (1994).

38. One proposal is to limit quotas to, say, ten years, with one year overlapping for banking and for practical "end-of-period" reasons (see Bertram, 1992; OECD, 1992b). In particular, one-tenth of quotas could expire each year and could be replaced by a new issue according to a procedure that could be modified, say, every five years. This would reduce the costs of uncertainty by providing flexibility to adapt to new information, including the entry of new sources and sinks into the system. It also establishes a market in forward contracts to reduce the costs of greenhouse risks. Quotas of different duration would coexist in the market to cover both short- and long-term risks, and the quota price would reflect the costs of risk.

39. The likelihood of reaching an international environmental agreement will be affected by several factors. See Sebenius (1991).

40. Compared to conventional regulations, both taxes and permits provide an explicit price signal about the marginal cost of limiting emissions.

41. Granting permits for moving periods of, say, five years, instead of issuing eternal permits, would reduce the possibility of hoarding by a monopolist who could "forever" expose future buyers to leasing permits at monopoly prices.

42. Auctioning could be used to help avoid a situation that may arise under grandfathering in which one large firm is allocated a significantly large share of permits. However, it could be argued that grandfathering would provide an asset that could be sold by a firm wishing to leave an industry and would thus facilitate adjustment.

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