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Policy Instruments for Climate Change: How Can National Governments Address a Global Problem?

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Abstract

There continues to be great debate about the desirability of taking actions to limit carbon dioxide (CO_2) and other greenhouse gas emissions, but it is important to consider policy instruments that can be employed to meet targets that may eventually be forthcoming. The theoretical advantages of market-based instruments, such as carbon taxes and systems of tradable carbon rights, are striking. In the U.S. domestic context, grandfathered tradable permits will probably be the preferred approach (if any) in the short run, although revenue-neutral carbon taxes will hold greater promise in the long run. In the international context, a system of international tradable permits could provide important advantages over alternative approaches, but it is difficult to imagine what existing international institution could administer such a system. Hence, despite the great theoretical advantages of market-based approaches to addressing global climate change, neither domestic political barriers nor international institutional impediments to implementing these and other instruments should be underestimated.

Key Words: global climate change, policy instruments, political and institutional barriers

JEL Classification Nos.: Q25, Q28, Q4

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1. INTRODUCTION

Concerns about global climate change due to the greenhouse effect have led policy makers from many countries to consider ways of limiting emissions of greenhouse gases, particularly carbon dioxide (CO_2) emissions associated with the generation of energy from fossil fuels.[1] Although there continues to be great debate about the desirability of taking actions to limit CO_2 and other greenhouse gas emissions, it is important to consider policy instruments that can be employed to meet targets that may eventually be forthcoming.[2] In a recent essay, Schmalensee convincingly argues that "the creation of durable institutions and frameworks seems both logically prior to and more important than choice of a particular policy program that will almost surely be viewed as too strong or too weak within a decade" (1996, p. 8). My primary purpose in this paper is to explore frameworks and instruments that can be adopted by individual nations and multilaterally to achieve goals that may be specified by future "policy programs." This exploration strongly reaffirms the importance of institutional dimensions of the global climate change problem.

I begin -- in part 2 of the paper -- by considering some criteria for assessing policy instruments and describing the major alternative instruments available. In parts 3 and 4, respectively, I review conventional regulatory and market-based instruments. In part 5, I focus on implementation issues; in part 6, I provide a comparative assessment of instruments; and in part 7, I offer some conclusions.

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[1] Since pre-industrial times, CO_2 has been the most important anthropogenic source of radiative forcing (the so-called "greenhouse effect"), accounting for about 60 percent of the forcing. Anthropogenic emissions of methane and nitrous oxide account for 15 percent and 5 percent, respectively. Other, less important greenhouse gases include tropospheric ozone (whose chemical precursors include nitrogen oxides, non-methane hydrocarbons, and carbon monoxide), halocarbons (including HCFC's and HFC's), and sulfate aerosols (Houghton, Fiho, Callander, Harris, Kattenberg, and Maskell 1996).

[2] In May, 1992, at the "Earth Summit" in Rio de Janeiro, 143 nations agreed to adopt the Framework Convention on Climate Change. For a comprehensive review of the Convention, see: Bodansky (1993). In July, 1996, Undersecretary of State for Global Affairs, Timothy E. Wirth, stated at United Nations sponsored talks in Geneva that the Clinton Administration was committed to seeking binding international limits on greenhouse gas emissions (Cushman 1996).

2. THE MENU OF POLICY INSTRUMENTS

Two distinct categories of policy instruments need to be considered to address global climate change. First, there are fundamentally domestic policy instruments, intended to enable individual nations to achieve their specific targets or goals. Second, there are international (bilateral, multilateral, or global) instruments that can be employed jointly by groups of nations.

By necessity, I investigate both domestic and international instruments, but it should be acknowledged at the outset that although there is abundant precedent for national environmental policy actions, there is much less experience with successful environmental initiatives at the international level. The "exceptions that may prove the rule" include the successful agreements for stratospheric ozone and the somewhat less successful international whaling agreements. In the case of global climate change, the challenges are significantly greater than either of those experiences might suggest.

It is most reasonable to anticipate that stringent climate change policies will be adopted by individual nations only to the degree that those nations perceive that positive net benefits -- including international transfers -- will be forthcoming (Carraro and Siniscalco 1993; Heal 1994). The general point has been made in the starkest terms by Nordhaus and Yang: "It is single nations, not the United Nations, that determine energy and environmental policy, so any grand design to slow global warming must be translated into national measures" (1996, p. 742). On the other hand, there is little doubt that successful policies to address this truly global environmental problem will require the adoption of international agreements. Hence, it is necessary to consider both domestic and international policy instruments.

2.1 Criteria for Instrument Choice

From an economic perspective, the first candidate criterion for instrument assessment should probably be relative efficiency, that is, the degree to which instruments are capable of maximizing net benefits.[3] But the efficiency criterion can be problematic, because it requires not only knowledge of the costs of abatement, but also knowledge of the benefits of abatement. And the latter requires both an understanding of the physical consequences of climate change and the economic valuation of those consequences. This information burden is overwhelming in many circumstances, as it surely is at present in the global climate context; and so frequently the less ambitious criterion of cost effectiveness has been used, that is, seeking a policy instrument that achieves a given target or goal (which may or may not represent the efficient level of control) at minimum aggregate cost of abatement.[4]

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[3] The "efficient" level of abatement is that level where the difference between (social) benefits and (social) costs is maximized. If the benefit and cost functions are shaped as they are typically believed to be, then this efficient level occurs at the (single) point where marginal benefits equal marginal costs (Baumol and Oates 1988).

[4] The "cost-effective" allocation of the pollution-control burden among sources is that allocation for which all sources are controlling at the same marginal abatement cost (Baumol and Oates 1988).

In either case, whether an efficiency or cost-effectiveness criterion is employed, it is of course important that costs be measured correctly. This is easier said than done, since the full costs of environmental regulation involve a number of disparate elements (Table 1).[5] Many policy makers and much of the general public would identify the on-budget costs to government of administering environmental laws and regulations as *the* cost of environmental regulation. Most analysts, however, would identify the direct capital and operating expenditure associated with regulatory compliance as the fundamental element of the overall cost of regulation.[6] Additional direct costs include legal and other transaction costs, the effects of refocussed management attention, and disrupted production. "Negative costs" (in other words, non-environmental benefits) of environmental regulation, including the productivity impacts of a cleaner environment and the potential effects on innovations of regulation should, in theory, also be considered. General equilibrium effects associated with product substitution, discouraged investment, 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, some social impacts are given substantial weight in political forums, including those on jobs and economic security.[7] Thus, correctly assessing cost effectiveness is by no means a trivial task.

Other criteria can also be very important in comparing policy instruments. Individual nations will inevitably choose their own sets of criteria (explicitly or implicitly) to distinguish among alternative policy instruments. Although these chosen criteria will be functions of individual socioeconomic and cultural contexts, in many cases the following will likely be among those considered: probability that the environmental goal will be achieved; efficiency or cost-effectiveness; dynamic incentives for innovation and the diffusion of improved technologies; flexibility and adaptability to exogenous changes in technology, resource use,

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[5] For a useful decomposition and analysis of the full costs of environmental regulation, see: Schmalensee (1994). Conceptually, the cost of an environmental regulation is equal to the change in consumer and producer surpluses due directly to the regulation and due to any price or income changes that also result from the regulation (Cropper and Oates 1992).

[6] These direct costs are typically borne by the private sector, although a substantial share of compliance costs for a minority of environmental regulations fall on government rather than on private firms, one example being the regulation of contaminants in drinking water under the U.S. Safe Drinking Water Act.

[7] For a fuller explanation of these different categories of the costs of environmental protection, see: Jaffe, Peterson, Portney, and Stavins (1995).

Table 1. 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, Peterson, Portney and Stavins (1995)

Table 2. Taxonomy of Policy Instruments For Global Climate Change

DOMESTIC INSTRUMENTS

A. Command-and Control and Voluntary Instruments

- Energy efficiency standards
- Product prohibitions
- Voluntary agreements

B. Market-Based Instruments

1. Charges, Fees, and Taxes
   - Carbon taxes
   - BTU taxes on fossil fuels; other energy taxes
2. Tradable Rights
   - Tradable carbon rights
   - Tradable "emission reduction" credits

INTERNATIONAL INSTRUMENTS

A. Command-and Control Instruments

- Uniform energy efficiency standards
- Fixed national emission limits

B. Market-Based Instruments

1. Charges, Fees, and Taxes
   - Harmonized domestic taxes
   - Uniform international tax
2. Tradable Rights
   - International tradable permits
   - Joint implementation

and consumer tastes; distributional equity[8]; and feasibility in terms of political implementation and administration. Several of these criteria -- including efficiency, cost effectiveness, dynamic effects on technological change, distributional equity, and political feasibility -- are particularly important in the climate change context.

2.2 Domestic Policy Instruments

The most frequently employed approach in virtually all countries of the world for addressing a variety of environmental problems has been to set standards and directly regulate the activities of firms and individuals: so-called command-and-control instruments (Table 2). Conceivably, such approaches could be employed in the greenhouse context as well. By mandating standards, governments could ban or attempt to alter the use of materials and equipment considered to be damaging. For example, standards could be applied to buildings (energy efficiency), fuel use by motor vehicles, energy efficiency of household durables, and the content of fuels.

In contrast, *market-based instruments* have recently been employed by governments to alter price signals to ensure that polluters face direct cost incentives to control emissions. The primary market-based instruments to be considered for greenhouse management are taxes and tradable permits. Under a true emissions tax, a charge is imposed per unit of pollutant discharge.[9] A closely related application would be a tax on the carbon content of fossil fuels. As an alternative, under an emission trading scheme, sources receive permits to emit, and can then buy and sell these permits among one another.[10] Because these market-based instruments have the effect of inducing decision-making units (typically firms) to choose control levels at which their marginal abatement costs are the same, overall pollution abatement costs will, in theory, be minimized.[11] That is, market-based instruments can, in principle, be cost effective.

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[8] It is widely recognized that issues of distributional equity--both among nations and intertemporally--are central concerns affecting the identification of the time path of appropriate aggregate levels of greenhouse policy action and the appropriate distribution of that burden among the nations of the world. In particular, because of the significant coal resources of China and India combined with their relatively high rates of economic and population growth, it is frequently suggested that massive resource transfers from the industrialized countries to some developing nations will be a necessary ingredient for a successful global greenhouse agreement. Hence, in the present context, the use of a distributional equity criterion essentially means that we need to ask to what degree can alternative policy instruments facilitate such transfers. We address this, below, in the case of "international instruments." The evidence from existing institutional experience is not promising (Keohane and Levy 1996).

[9] The development of the notion of a corrective tax on pollution is generally credited to Pigou (1920).

[10] The initial proposal for a system of tradable permits to control pollution was by Dales (1968), and first formalized by Montgomery (1972), although much of the literature can be traced back to Coase (1960).

[11] Because the costs of controlling pollution vary greatly among and within firms, any given aggregate pollution control level can be met at minimum aggregate control cost only if pollution sources control 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 a 100 or more among sources (Crandall 1984). Such cost heterogeneity is characteristic of: carbon

2.3 International Policy Instruments

Climate change is truly a global commons problem. The location of emissions of greenhouse gases has no effect on the global distribution of damages, and so free-riding problems plague unilateral or multilateral "solutions." Further, nations will not benefit proportionately from greenhouse-gas abatement policies. In fact, some countries -- such as Canada and Russia -- might experience no benefits from control, since they actually stand to gain from global climate change (due to the effects of increased temperatures and precipitation on agricultural production). Thus, for some countries, costs of control may exceed benefits. This means that to be successful an international (voluntary) agreement needs to include a mechanism for transferring gains to countries that would otherwise not benefit from joining an agreement. This is a central challenge for any international policy instrument that is to allocate responsibility among nations.

It is at least conceivable that standards could be employed that are uniform among countries participating in an international emissions reduction agreement. It would be difficult, however, to achieve wide agreement about any large set of specific instruments, because such approaches would place severe limits on individual countries' domestic policy choices. An alternative regulatory approach would involve countries agreeing on fixed national emission levels. But marginal abatement costs would then vary greatly among participating countries, and so total global abatement costs would be much greater than necessary.

Instead, some degree of aggregate cost effectiveness could be achieved if market-based instruments were employed internationally. Four possibilities stand out. First, if countries agreed to apply the same level of domestic greenhouse taxes (*harmonized domestic taxes*), marginal abatement costs would tend to be equalized among countries. Second, a *uniform international tax* on greenhouse emissions could be employed, with the total tax revenue being allocated among participating countries according to some set of rules.

A third potentially cost-effective approach would be a system of *international tradable permits*, in particular, a system of tradable carbon rights, the total allocation of which would reflect the overall emissions target. International permit trade would establish a market price -- an implicit international tax rate -- which would equate marginal abatement costs among countries, leading -- in theory -- to a cost-effective solution. Within the context of such an international tradable permit scheme, participating countries could then use whatever domestic policy instruments they chose to achieve their permit-determined targets. They might employ domestic tradable permits, domestic taxes, or conventional regulations.[12]

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abatement linked with fuel switching and energy-efficiency enhancement; and carbon sequestration linked with changes in land use.

[12] As I discuss later, with a domestic tax there is uncertainty regarding the quantity of emissions reductions that will be induced. Given this caveat, any of a variety of price or quantity instruments can be used domestically if a tradable permit system is used to allocate targets internationally.

A fourth market-based instrument, closely related to the concept of international tradable permits, is *joint implementation*, essentially bilateral trading arranged on an ad hoc basis. This policy mechanism, which we also consider below, has received considerable attention from policy makers and others in the past few years.

With any of these international instruments, it is imperative to keep an important caveat in mind: there is no world government -- or other institution -- that appears to be immediately capable of administering, monitoring, and enforcing truly international instruments (Schmalensee 1996). We return to that critical issue later.

3. REGULATIONS, VOLUNTARY AGREEMENTS, AND OTHER NON-MARKET-BASED INSTRUMENTS

The conventional approach to environmental policy in virtually all countries has employed policy instruments in the form of uniform standards or voluntary programs to improve the environment (Baumol and Oates 1988; OECD 1989; Hahn and Stavins 1991). Both approaches are prominent in current and proposed policy measures to address global climate change.[13]

3.1 Uniform Technology and Performance Standards

Conventional regulatory standards (often described as "command-and-control" regulations) can loosely be categorized as either *technology-based* or *performance-based*, although the distinction is often not clear. Technology-based (or design) standards typically require the use of specified equipment, processes, or procedures. In the context of climate change policy, these could be requirements 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 up to regulated entities. Examples of uniform performance standards for greenhouse gas abatement include maximum allowable levels of carbon dioxide emissions from combustion or maximum levels of methane emissions from landfills. Uniform standards can also take the form of outright bans of certain products or processes, such as the banning of aerosol sprays containing ozone-depleting substances.[14]

Although uniform technology and performance standards can be effective in achieving established environmental goals and standards, they tend to lead to non-cost-effective outcomes in which firms use unduly expensive means to control pollution (Tietenberg 1985;

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

[14] Although prohibitions may be the least flexible form of regulation, if low-cost substitutes for targeted products are available, bans can turn out to be a relatively cost-effective policy instrument.

Hahn 1989; Hahn and Stavins 1991). Nonetheless, because performance standards give economic agents flexibility to make choices based partly 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 conserve on information and administration costs.

In theory, the government could achieve a cost-effective allocation of pollution control responsibility among sources if it assigned source-specific control levels that equated marginal costs of control. But this approach would require information about the pollution control cost functions of individual firms and sources -- information that governments usually lack and could obtain only at great cost, if at all.[15]

Even if the government were able to use conventional technology or uniform performance standards to achieve a (statically) cost-effective allocation of pollution control at present, such standards would not provide *dynamic* incentives for the development, adoption and diffusion of environmentally and economically superior control technologies (Bohm and Russell 1985; Jaffe and Stavins 1995; and Newell, Jaffe, and Stavins 1996).[16] Once a performance standard has been satisfied, there is little benefit to an individual firm from developing and/or adopting cleaner technology. In addition, regulated firms may fear that if they adopt a superior 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).[17] Finally, although technology-based standards may seem to be the least cost-effective of policy instruments, if monitoring costs with alternative instruments are sufficiently high, they can be relatively attractive.[18]

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[15] Source-specific or firm-specific permit programs are one approach traditionally taken to adjust regulatory standards to individual circumstances. If pollutants exhibit highly localized effects, such an approach can have distinct advantages over a tax or permit system, but global climate change is obviously *not* a localized problem.

[16] Performance and technology standards can be 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). But while regulators can typically 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 run the risk of being unachievable (Freeman and Haveman 1971).

[17] Under some circumstances, however, a performance standard may provide greater incentives for technological adoption than a market-based system (Malueg 1990).

[18] For discussions of relevant enforcement issues see, for example: Harford (1978); Shibata and Winrich (1983); Polinsky and Shavell (1979).

3.2 Voluntary Agreements

In addition to mandatory policy instruments, voluntary agreements can play significant roles within greenhouse gas reduction strategies, and the threat of mandatory government intervention may sometimes be enough to encourage voluntary agreements. Firms may undertake some steps in controlling greenhouse gas emissions if they fear more costly mandatory controls in the absence of these voluntary reductions. This may help explain why voluntary agreements have already arisen. The vast majority of planned greenhouse gas reductions from the actions announced or expanded through the U.S. *Climate Change Action Plan* (Clinton and Gore 1993) were associated with voluntary initiatives aimed at increasing energy efficiency.[19]

4. MARKET-BASED POLICY INSTRUMENTS

Because of the great potential costs of meeting greenhouse gas emission targets (Weyant 1993), considerable attention has been given to the possible use of market-based instruments, which can be cost effective, provide dynamic incentives for technological change, and address concerns about distributional equity.[20] At the greatest level of abstraction, in a perfectly competitive market place, under an emissions tax or tradable permit scheme, emitters would reduce emissions up to the point where the marginal cost of control equals the emissions tax rate or the equilibrium price of an emissions permit. Both instruments would promote dynamic efficiency, as each provides a continuous incentive for adoption of better abatement technologies. We consider five market-based instruments. Two are in the domestic context: carbon taxes and tradable carbon rights. And three are international: carbon taxes, tradable permits, and joint implementation.

4.1 Domestic Carbon Taxes

A carbon tax is not a perfect proxy for a tax on CO_2 emissions, because 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 chemical fixation (scrubbing) and disposal. Since feasible means of the latter are severely limited (Jepma, Asaduzzaman, Mintzer, Maya, and Al-Moneef 1996), however, this is not a significant defect of a carbon tax. Hence, the carbon content of primary fossil fuels would be the most practicable base for a CO_2 tax system.[21] In addition, one form of atmospheric carbon *removal* is quite feasible technologically: carbon sequestration through

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[19] Significantly, it is now recognized that this diverse set of voluntary programs will fail to enable the United States to meet its announced targets.

[20] There is an extensive literature on the principles underlying the use of market-based policy instruments for greenhouse management. See, for example: Bohm and Russell (1985); Baumol and Oates (1988); Stavins (1988); OECD (1989, 1993); Tietenberg (1990); Epstein and Gupta (1990); Nordhaus (1991, 1993); Dornbush and Poterba (1991); Stavins (1991); Cropper and Oates (1992); and Hahn and Stavins (1995).

[21] For further commentary on the appropriate base of a CO_2 tax, see: Pearce (1991); Jorgenson and Wilcoxen (1992); Repetto, Dower, Jenkins, and Geoghegan (1992); OECD (1992a, 1992b, 1993); and Boyd, Krutilla and Viscusi (1994).

forestation and retarded deforestation. Since this approach may be competitive (on a marginal cost basis) with emissions abatement in some countries, at least at low levels of aggregate abatement (Richards, Moulton, and Birdsey 1993; Callaway and McCarl 1996; Stavins 1996b), policy instruments that will provide appropriate incentives for adoption of a cost-effective portfolio of both emissions reductions and sequestration increases are desirable. Carbon taxes could hence be combined with sequestration tax credits.[22]

There is a significant number of points in the "product cycle" of fossil fuels at which a carbon tax could conceivably be applied, ranging from primary fuel extraction to product and service end use. Energy generation from fossil fuels is obviously the point at which emissions occur, but there would be far fewer monitoring points and hence lower implementation costs if carbon contents were measured and policy applied to wholesale use. 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. Indeed, simulations indicate that an energy (BTU) tax could be between 20 and 40 percent more costly, and an *ad valorem* tax two to three times more costly, than a carbon tax for equivalent reductions in emissions (Jorgenson and Wilcoxen 1992; Scheraga and Leary 1992).

The abatement achieved by a carbon tax and the tax's effect on the economy will depend partly on what is done with the tax revenue. There is widespread agreement that revenue recycling (that is, using revenues to lower other taxes) can significantly lower the costs of a carbon tax (Jorgenson and Wilcoxen 1994; Goulder 1995). Some researchers have suggested, further, that all of the abatement costs associated with a carbon tax can be eliminated through revenue recycling in the form of cuts in taxes on labor (Repetto, Dower, Jenkins, and Geoghegan 1992). There is an emerging consensus, however, that rejects this stronger claim (Bovenberg and de Mooij 1994; Bovenberg and Goulder 1996). Indeed, carbon and other energy-related taxes can exacerbate distortions associated with remaining taxes on investment or labor.

4.2 Domestic Tradable Permits

An important attribute, in theory, of a domestic tradable permit scheme is that, no matter what the initial permit allocation, the final allocation after trading will be the one that minimizes the cost of reducing emissions.[23] Firms will want to buy permits if their abatement costs exceed the permit price, and sell permits in the opposite case. In this way, trade will continue until all firms are indifferent between buying and selling permits, that is, between

[22] For economic efficiency reasons, these sequestration tax credits might take the form of a combination of taxes on deforestation and tax credits or subsidies for forestation (land-use changes). On this, see: Stavins (1996b).

[23] As we discuss later, transaction costs reduce trading levels and increase abatement costs; and, in some cases, equilibrium permit allocations and hence aggregate control costs will be sensitive to initial permit distributions. Thus, in the presence of transaction costs, the initial distribution of permits can matter in terms of efficiency, not only in terms of equity (Stavins 1995).

marginal abatement and additional fossil fuel use. When this state is reached, marginal abatement costs are equated, and an *ex post* allocation of permits that minimizes the costs of reducing emissions is achieved.

The most reasonable basis for a domestic tradable permit system to control CO_2 emissions would be parallel to the carbon tax system already discussed, that is, a system of tradable carbon rights, not unlike the tradable lead rights used in the United States in the 1980's to phase down the lead content of gasoline. A national government could issue permits to wholesale dealers in fossil fuels or producers and importers of fossil fuels, and allow them to trade in a national permit market.[24] Also, as with carbon tax/credit programs, tradable permit programs could -- in theory -- be designed to give appropriate credit to carbon sequestration through forestation.[25]

A government might choose one of two ways to distribute permits to individual firms. First, firms can be given shares of the total permit volume, based on some historical record ("grandfathering"), such as recent fossil fuel sales. Second, the government can auction permits. Combinations of these two approaches are also possible. Grandfathering involves a transfer of wealth, equal to the value of the permits, to existing firms, whereas, with an auction, this wealth is transferred to the government. In fact, the government would -- in theory -- collect revenue identical to that from a domestic tax producing the same volume of emissions abatement.

As with tax receipts, auction revenues could be used to reduce pre-existing distortionary taxes. In principle, the same issues apply, regardless of whether a tax or tradable permit scheme is used (Bohm 1994b). Like pollution taxes, tradable permits raise the costs of produced goods relative to labor, and thereby introduce efficiency costs in labor markets (Goulder, Parry, and Burtraw 1996). This is the case for both grandfathered and auctioned permits. Some of these costs, however, can be offset when permits are auctioned and revenues are used to reduce pre-existing distortionary taxes. When costs are offset by using revenues in this way, the government takes the rents generated by the permit program and --instead of leaving those rents in private hands -- devotes them to reducing distortionary taxes (Fullerton and Metcalf 1996).

To date most tradable permit systems have made use of perpetuities, but there are several reasons for considering a system of time-limited permits in the case of climate change. First, if permits are initially grandfathered, then time-limited permits can reduce the anti-

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[24] The government could also allow permit holders to trade directly on an existing international market. Alternatively, to the extent that both international permit 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.

[25] An interesting attribute of a tradable permit system -- whether domestic or international -- is that the market prices of permits that emerge can provide exceptionally useful feedback to policy makers, since these market prices will reflect the underlying marginal abatement/sequestration cost functions of sources (Yohe 1996).

competitive effects of entry barriers. Second, potential future changes of emissions targets, in response to new information, can be facilitated with time-limited permits. The government can retain ownership of permits, leasing them to firms for fixed periods.[26] Allowing permits to be banked, that is, allowing permits for emissions during a given period to be used at a later date, is important for both the efficiency and political acceptability of tradable permit schemes.

In contrast with other market-based environmental policy instruments, there has been considerable experience with the use of tradable permit schemes, particularly in the United States.[27] Beginning in the 1970s, the U.S. Environmental Protection Agency (EPA) offered states the option of employing variants of tradable permits for the control of localized, criteria air pollutants (Hahn 1989). More significantly, tradable-permit systems were used in the 1980s to accomplish the phasedown of lead in gasoline (Kerr and Maré 1995) and to facilitate the phasedown of ozone-depleting chloroflourocarbons (Lee 1996); and in the 1990s to cut nationwide sulfur dioxide (SO_2) emissions by 50 percent by the year 2005 (U.S. Environmental Protection Agency 1996), to achieve ambient ozone reductions in the northeast, and to implement stricter local air pollution controls in the Los Angeles metropolitan region.

4.3 International Carbon Taxes

Because international action will essentially be required to meet any significant global emissions target, it is necessary to consider international policy instruments that can be employed by groups of nations (or globally). One possibility is a carbon tax imposed on nation states by an international agency. The supporting agreement would have to specify both tax rates and a formula for allocating the tax revenues. Cost-effectiveness would demand that the tax rate be uniform across all countries (assuming full participation); and reallocation of revenues need not hamper cost effectiveness. It is unclear, however, what international agency could actually impose and enforce such a tax, and so as an alternative to an international carbon tax, we can consider a set of harmonized domestic carbon taxes. In this case, an agreement would stipulate that all countries should levy the same domestic carbon taxes. In either case, some experimentation could be required to set the tax rate to achieve the coalition's emissions target. The tax rate would also need to be adjusted over time as economic conditions change.

The uniformity of tax rates is necessary for cost-effectiveness. But the resulting distribution of costs may certainly not conform to principles of distributional equity, and so there may be calls for significant resource transfers. Under a harmonized tax system, an

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[26] When permits are leased by the government or when time-limited permits are auctioned by the government, the revenue implications of permit schemes approach those of taxes. This is not the case where eternal permits are auctioned by government (Bohm 1994b).

[27] This is not to suggest that taxes have never been utilized in the context of environmental policies. The Superfund program, for example, is financed primarily through a tax on petroleum and chemical feedstocks; and since 1990, the United States has levied a tax on (stratospheric) ozone-depleting chemicals (Hoerner 1996). For a comprehensive review of "environmental taxes " (broadly defined), see: Barthold 1994.

agreement could include fixed lump-sum payments from rich to poor countries, and under an international tax system, an agreement could specify shares of the total international tax revenues that go to participating countries (Hoel 1993).

4.4 International Tradable Permits

Under an international tradable permit scheme, all coalition countries would be allocated permits for "net emissions," that is, emissions minus sequestration. A permit could define a right to a perpetuity or a right to emit a given volume over some time period. In each period, countries would be free to buy and sell permits on an international exchange. Limiting the temporal duration of permits could help lend credibility to the system by rendering less likely situations where governments sell permits (part of a nation's wealth) to a degree that would not be honored by future governments in those same countries. Time-limited permits could also reduce the risk of large countries gaining market power on the permit market.

Negotiations on initial permit allocations are likely to involve criteria such as gross national product (GNP), real GNP, population, land area, and dependence on fossil fuel production.[28] All criteria will have adherents, essentially those with larger allocations under those criteria,[29] and several criteria may therefore need to be blended to create international consensus on emission allocations.[30] Whatever the initial allocation, subsequent trading can lead to a cost-effective outcome, if transaction costs are not significant. This potential for pursuing distributional objectives while assuring cost-effectiveness is an important attribute of the tradable permit approach.

Countries allocated permits greater than their emission requirements could use revenue from the sale of permits to increase their imports relative to their exports (Chichilnisky, Heal and Starrett 1993), while countries allocated permits less than their requirements would have to reduce imports relative to exports. In this way, a tradable permit 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 permits to poor countries (for reasons of distributional equity) implies that they would be selling permits primarily to rich countries. Since 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. From a distributional point of view, poor countries would receive compensation, whereas rich

[28] For an overview, see: UNCTAD 1992; Grubb and Sebenius 1991; Bertram 1992; and Bohm and Larsen 1994.

[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 United States 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 chloro-flourocarbon (CFC) reduction obligations were being considered in the development of the Montreal Protocol.

countries would have to pay, first, for their own emission reductions as called for by the permit price and, second, for permit purchases from abroad.

Inevitably, the institutional question of who would monitor and enforce such an international program seems paramount. Here it is useful to decompose the "monitoring and enforcement problem" among coalition countries into three separate issues: monitoring; enforcing violations at the margin; and maintaining an enforcing coalition.[31] First, the monitoring problem is really quite similar for different policy instruments, and, it may not even be necessary to monitor. This is because an international tradable permit system -- and some other instruments -- could be based on *ex ante* demonstration of likely compliance, rather than *ex post* validation (Victor and Salt 1995; Schmalensee 1996), an approach that has been used successfully in the past in international economic agreements, if not environmental ones. This is not to suggest that compliance problems are trivial; only that they are not necessarily insoluble.

Thus, monitoring, *per se*, need not be a great obstacle, but this leaves the enforcement problem. Here, the tradable permit mechanism itself can help address the challenge, since permits can initially be allocated to favor low-cost abaters, i.e. permit sellers. Such an allocation can reduce the probability of marginal violations, because it makes sellers vulnerable to enforcement actions by the (enforcing) coalition of countries (Keohane and Nye 1977). On the other hand, under such an initial allocation (of permits to low-cost controllers, which may largely be developing countries), the incentives for the high-cost controllers (the buyers, most likely the industrialized countries) to maintain the enforcing coalition (the original agreement) are reduced. In the past, this factor has contributed to the collapse of international agreements (Lien and Bates 1987).

[31] I am grateful to Bob Keohane for having pointed out the importance of this decomposition.

4.5 Joint Implementation

Joint implementation (JI), provided for in the Framework Convention on Climate Change, involves cooperation between two countries, with one funding emission reduction in the other to help the first meet its reduction commitments.[32] Joint implementation projects are already being undertaken by a number of countries.[33] While many of these involve intergovernmental agreements, the private sector can be involved directly. The U.S. Initiative on Joint Implementation provides for private-sector proposals, to be approved by a government panel.[34]

The potential economic merits and demerits of joint implementation have been widely discussed.[35] Joint implementation has been promoted as potentially serving three related purposes: (a) a first step toward establishing an international tradable permit system; (b) a cost-effective option for industrialized countries to finance emission reductions in developing countries; and (c) an activity to identify when it is cost effective to bring new emissions sources or sinks into an existing international greenhouse management scheme.

Joint implementation also raises many concerns. When applications are between developed and developing countries, where only the former commit to binding targets and the latter do not, it will be difficult to determine the emission-reduction effects of a specific joint implementation project (Tietenberg and Victor 1994). The effects of low-cost abatement projects are particularly difficult to estimate, because such projects may be nearly profitable in the absence of the JI arrangement, and hence may be carried out without any policy intervention. In general, bilateral JI efforts are hampered by significant transaction costs and poorly defined property rights (Richards 1996).[36] Further, there are significant incentives for parties to a joint implementation project to exaggerate a project's net emission reduction effects. Lastly, a system of JI agreements -- on its own -- would inevitably be inefficient, since countries would ignore benefits to third-party nations. In other words, the free-rider problem could not be overcome.

In the United States, although the Climate Action Plan includes an Initiative on Joint Implementation, there has been relatively little action. This is principally because there has

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[32] For a comprehensive review of the legal and practical aspects of joint implementation see: Kuik, Peters and Schrijver (1994).

[33] JI has taken on a significant "life of its own," including the creation of a number of institutions that have been developed purely for the purpose of furthering JI projects. See various issues of the periodical, *Joint Implementation Quarterly*, now in its second year of publication (in the Netherlands).

[34] For a recent summary of joint implementation projects, see: Zollinger and Dower 1996.

[35] See, for example: Barrett 1994b; Bohm 1994a; Loske and Oberthür 1994; Jepma 1995.

[36] This also suggests that current efforts to better define property rights and reduce transaction costs in joint implementation programs are well placed (Schmalensee 1996).

been no binding emissions cap on domestic sources and thus no credit incentive in place (Yanulis 1996).

5. IMPLEMENTATION ISSUES

In order to assess alternative instruments for global climate change, it is important to consider implementation issues, since these can severely affect real world outcomes. In the case of market-based instruments, 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 programs 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 market-based instruments. A more realistic and appropriate comparison would be between actual regulatory policies and either actual market-based programs or *reasonably constrained* theoretical programs (Hahn and Stavins 1992).

Several factors can adversely affect the performance of market-based systems: concentration in the permit market (Hahn 1984; Misolek and Elder 1989); concentration in the output market (Malueg 1990); transaction costs (Stavins 1995); non-profit-maximizing behavior, such as sales or staff maximization (Tschirhart 1984); the pre-existing regulatory environment (Bohi and Burtraw 1992); the degree of monitoring (Russell 1990) and enforcement (Keeler 1991; Russell, Harrington, and Vaughan 1986); and administrative costs (Polinsky and Shavell 1982).

In the following sections, I review some of the most prominent issues regarding the implementation of carbon taxes and tradable permit systems.

5.1 The Effects of Uncertainty on the Choice of Policy Instrument

In the absence of uncertainty, price instruments, such as emission taxes, and quantity controls, such as tradable permit systems, are -- to a large degree -- equivalent in terms of their ability to achieve the efficient level of control. But climate change involves many uncertainties. It is not known precisely how the climate will change given different emission trajectories, and the costs of abating emissions and the economic benefits of doing so are known only imperfectly. Hence, it is necessary to compare alternative instruments under conditions of uncertainty.

Perhaps surprisingly, uncertainty with respect to the benefits of abatement does not affect the choice between a price and a quantity instrument. If the marginal abatement cost function is known, then any target level of emissions will be achieved as easily by either instrument. While uncertainty about the benefits of abatement will make choosing the efficient target very difficult, one instrument will work as well as the other in achieving the chosen target. Hence, the deadweight losses associated with having chosen an inefficient target will be the same with either type of instrument.

In contrast with such instrument symmetry in the presence of benefit uncertainty, the difference between price and quantity instruments can be significant in the presence of uncertainty about the costs of abatement (Weitzman 1974).[37] If the marginal benefit and marginal cost functions are linear, the two instruments will be equally efficient only if their slopes are identical (in absolute value). If the marginal cost function is steeper than the marginal benefit function, emission taxes will result in a more efficient outcome. Conversely, if the slope of the marginal cost function is less than the slope of the marginal benefit function, then tradable permits would be preferred.[38]

In the case of global climate change, the available evidence indicates that marginal abatement costs will be relatively flat over some range, then steep beyond some abatement level (Nordhaus 1991). Little is known about how marginal benefits will vary with the level of abatement. There is, however, concern that at some level a threshold may exist in the damages associated with greenhouse gas concentrations. Hence, the effects of uncertainty on optimal (efficient) greenhouse instrument choice will vary, depending critically on the level of national and global targets.

5.2 The Currency of Regulation

Due to the monitoring and enforcement costs associated with regulating carbon dioxide emissions, the most reasonable "currency" for a tax or tradable permit system is likely to be the carbon content of fossil fuels. Given the proportional relationship between carbon content and CO_2 emissions and the lack of practical means of sequestering these stack gases, this seems to be the right approach. Monitoring could rely mainly on self-reporting, supplemented by international access to fossil fuel inventories. Under an international carbon tax or tradable permit scheme, a system of credible sanctions would presumably be required to make any enforcement system effective. There is little doubt, as I emphasize below, that in the international domain satisfactory solutions to these monitoring and enforcement problems will be preconditions for the successful implementation of any policy instrument, be it market-based or otherwise. Looked at this way, the central challenge is to understand how a credible and effective system of monitoring and enforcement can be established (at reasonable cost) in the absence of a centralized authority (Keohane 1996).

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[37] A substantial literature in the context of environmental policy has followed, including major works by Adar and Griffin (1976), Yohe (1977), and Watson and Ridker (1984). In theory, if a non-linear tax (equal to expected marginal damages at each level of emissions or concentration) is feasible, then a tax (price) instrument dominates a quantity instrument (Roberts and Spence 1976; Kaplow and Shavell 1996).

[38] Although benefit uncertainty on its own has no effect on the identity of the efficient 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 1996a). A positive correlation will always tend to favor a quantity instrument, and a negative correlation will tend to favor a price instrument.

5.3 Market Power

Tradable permit systems raise two potential market power problems: the potential for some economic agents to influence permit price (Hahn 1984); and the potential for some economic agents to use permits to exercise market power in the output (product) market (Malueg 1990). Thus, the extent of competition in a tradable permit market will affect the degree to which potential control cost savings are realized. A monopsonist may force the permit price below the competitive level; or a monopolist may force the permit price above the competitive level (Misolek and Elder 1989). To the extent that market power derives from the initial allocation of permits, one solution is to limit the share of permits held by any one participant (Tietenberg 1985). One way to do this may be to adopt temporally limited permits.

Emissions taxes can also be problematic when emitters have monopoly power (Buchanan 1969). In principle, a monopolist in an output market for an emissions-intensive commodity would tend to reduce output below the competitive level in order to raise its profits. Hence, welfare gains from reduced emissions must more than offset welfare losses from reduced output for an emissions tax to be worthwhile (Cropper and Oates 1992). Which effect dominates is an empirical issue.[39]

5.4 Transaction Costs

Transaction costs can affect the performance of tradable permit markets. Three possible sources of transaction costs in tradable permit markets can be identified (Stavins 1995): search and information; bargaining and decision; and monitoring and enforcement.[40]

There is abundant anecdotal evidence indicating the prevalence of significant transaction costs in some trading programs. Atkinson and Tietenberg (1991) surveyed six empirical studies that found trading levels -- and hence cost savings -- in permit markets to be lower than anticipated by theoretical models. Liroff (1989, p.2) suggests that this experience with permit systems "demonstrates the need for ... recognition of the administrative and related transaction costs associated with transfer systems." For example, under the U.S. EPA's emissions trading program for "criteria air pollutants", there is no ready means for buyers and sellers to identify one another, and -- as a result -- buyers have frequently paid substantial fees to consultants to assist in the search for available permits (Hahn 1989). At the other extreme, the high level of trading that took place under the program of lead rights trading among refineries as part of EPA's leaded gasoline phasedown in the 1980's has been attributed to the

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[39] Although there is no cutoff point, it is unlikely that firms or nations could engage in price-setting behavior if they controlled less than 10 per cent of the market (Scherer 1980). Ultimately, the question is whether other firms present credible threats of entry to the market — that is, whether the market is "contestable" (Baumol, Panzar and Willig 1982).

[40] The third source of transactions 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 conventional notion of transaction costs incurred by firms.

program'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 1989). Hence, transaction costs were kept to a minimum and there was little need for intermediaries (Kerr and Maré 1995). Likewise, the apparent success of the new SO_2 allowance trading program for acid rain control can partly be attributed to the program's very low transaction costs (Montero, Ellerman, and Schmalensee 1996). The obvious lesson from these experiences for global climate policy is simply that trading regimes should be designed partly with the aim of keeping transactions costs low.

5.5 Free-Riding and Emissions 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? The answer depends on how the other (non-cooperating) countries respond to the policies adopted by the cooperating countries. These responses in turn reflect two phenomena -- free riding and leakage -- that can undermine any international greenhouse management initiatives, whether they are market-based or conventional (Barrett 1994a). Free riding arises when countries that benefit from global abatement do not contribute toward its provision; and leakage arises when abatement by cooperating countries alters world relative prices in ways that lead non-cooperating countries to increase their emissions.

As long as participation in an international greenhouse policy is voluntary, countries will have incentives to free ride, leading to a level of aggregate abatement less than what is globally optimal.[41] The threat of a ban on trade between cooperating and non-cooperating countries in carbon-based fuels and products could work to support full participation in a greenhouse management scheme (Barrett 1994a). Of course, a ban on trade introduces distortions in the global economy; on the other hand, free riding is itself a distortion, and if trade restrictions reduce free-riding, they may yield positive net benefits. This issue, like so many others, is an empirical question.

There are two main channels through which emissions leakage may be transmitted. First, a carbon abatement policy by cooperating countries may shift comparative advantage in carbon-intensive goods toward non-cooperating countries, and so production of such goods, and emissions, may rise outside the coalition. Second, a unilateral policy may lower world demand for carbon-intensive fuels, and thereby reduce the world price for such fuels traded in

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[41] This issue has been examined in a number of studies, including: Barrett (1992a, 1992b, 1992c); Bohm and Larson (1993); Hoel (1992); and Parson and Zeckhauser (1995). In spite of free-rider incentives, a stable coalition of cooperating countries may exist, however (Hoel 1992; Carraro and Siniscalco 1993), its size depending on the ability of cooperating countries to punish countries that would withdraw.

international markets. As a result, demands for such fuels (and emissions) can rise outside of the coalition.[42]

What can be done to reduce emissions leakage? If the coalition is a net importer (exporter) of carbon-intensive products in the absence of a carbon tax, then a tariff (subsidy) imposed on these net imports (exports) can reduce emissions leakage through the terms of trade. But the tariff (subsidy) would have to be set proportionately to the carbon-intensity of *every* product, a clearly impractical approach. Further, whether the welfare losses (distortions) caused by the tariffs would be greater or less than the welfare losses reduced by cutting emissions leakage remains an open, empirical question. Finally, such border tax adjustments pose a number of other problems, not the least of which is possible conflict with existing multilateral trading rules.[43]

In general, free-riding and emissions leakage problems are reminders of the importance of compliance issues and expanding membership in the active coalition in any international agreement, whether political, economic, or environmental. More broadly, this is yet another example of the centrality of institutional issues in the global climate policy domain, a point to which I return below.

6. COMPARATIVE ASSESSMENT OF GREENHOUSE POLICY INSTRUMENTS

This section begins with a comparison of conventional regulations and market-based systems for addressing global climate change. We find that market-based systems are particularly well adapted to the problems that climate change presents, but this raises two further questions. How do domestic tradable permit systems compare with domestic tax systems? And how do international tradable permit systems compare with international tax systems?

6.1 Comparing Regulatory Systems and Market-Based Instruments

Even the most optimistic estimates indicate that the costs of addressing the threat of global climate change will be exceptionally great (Weyant 1993). Hence, the relative cost effectiveness of alternative policy instruments is of central importance. If governments had

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[42] There is a third possible channel for leakage transmission. Under certain conditions, non-cooperating countries will abate their emissions up to the point where their own marginal benefit of abatement equals their own marginal cost of abatement (Barrett 1994b). Non-cooperating countries will abate their emissions by less than they would if they cooperated. Where non-cooperating countries undertake positive unilateral abatement, and where the marginal benefit of abatement to non-cooperating countries decreases with the level of global abatement, an increase in abatement by cooperating countries will create an incentive for non-cooperating countries to reduce their abatement. Hence, leakage may occur even in the absence of trade.

[43] World Trade Organization (WTO) rules allow for border tax adjustments where the taxed or controlled inputs are physically-incorporated in the final product, but in the case of greenhouse gases, the concern is with the carbon emitted in the process of manufacturing. The 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.

complete information about the marginal costs of abatement at each and every source, conventional regulatory policies could be employed to minimize total abatement costs. But since governments do not have such information and can acquire it only at great cost, if at all, regulatory approaches will, in general, not be cost effective. In contrast, market-based policy instruments -- such as charges and tradable permits -- will, in theory, be cost effective.

Despite the fairly clear abatement-cost advantages of market-based instruments, we should not lose sight of the fact that it is necessary to consider the public as well as the private costs of control. That is, the total costs minimized by a truly cost-effective environmental policy instrument should 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 -- whether market-based or command-and-control -- may not be cost effective. 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 among major instruments, since fossil-fuel output plus imports minus exports would have to be reported for each participating country under any system. In terms of dynamic efficiency -- as well as static cost effectiveness -- the advantages of market-based instruments are striking. Additionally, taxes and, to some degree, auctioned permits, will make the costs of climate-change protection more visible to private industry and thereby to the general public. This may be strategically problematic in the short term for political reasons, but in the long term, it has the advantage of clearly signaling and educating the public about the real tradeoffs associated with various levels of greenhouse control.

6.2 Comparing Domestic Tradable Permits and Domestic Taxes

If market-based instruments are indeed preferable in the domestic context on cost-effectiveness grounds, then it becomes necessary to compare charge systems with tradable permit instruments. In principle, with no uncertainty, there need be no fundamental difference between domestic carbon taxes and tradable carbon permits from an aggregate cost-effectiveness or distributional point of view. Auctioned permits are virtually identical in those regards to a proportional tax; and grandfathered permits are identical to a tax linked with particular lump-sum refunds to regulated firms. This symmetry between taxes and permits begins to break down, however, in the presence of uncertainty, transaction costs, and other market imperfections, and when political feasibility is seriously considered. In particular, the lack of control over emission levels with taxes could be a distinct disadvantage in the context of an international agreement. Taxes would have to be varied because of inadequate information to determine the appropriate tax level. Furthermore, adjustments would be required in response to changes in economic activity and relative price levels. Finally, although permit systems are more compatible with quantity-based targets, they may be more susceptible than tax systems to strategic behavior, but -- as indicated above -- tradable permit schemes can be designed to reduce these effects.

The final choice will likely depend upon political factors. And, here, the political system in the United States, at least, has revealed its strong preferences for quantity instruments in their grandfathered form (Hahn and Stavins 1991). But, as indicated previously, these instruments distribute scarcity rents to the private sector and hence exacerbate pre-existing distortions in the economy. Ironically, it is precisely because of this rent distribution that grandfathered permits have found political favor. Thus, the preferred domestic greenhouse instrument in the United States in the short run may be grandfathered tradable permits, and in the long run, revenue-neutral carbon taxes.

6.3 Comparing International Tradable Permits and International Tax Systems

In the international context, the likely superiority of market-based systems is clear. Which incentive-based instrument is most effective, however, will depend on a number of factors.

A system of harmonized domestic carbon taxes would require an agreement about compensatory international financial transfers, as well as the pre-carbon-tax net tax rates on fossil fuels. Internationally acceptable estimates of these basic tax levels would be difficult to establish, at best. Moreover, no design seems feasible and generally acceptable where participants are not allowed to undertake policies on their own which affect fossil fuel use, such as levying a tax on substitutes to carbon and subsidizing complements to carbon. Thus, there is some likelihood that a tax harmonization agreement would either fail to 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. Although each country would know the amount of tax revenue likely to be raised internally, less information would be available about other countries' tax revenues. Hence, there would be uncertainty about the size of net transfers among countries. Most important, it is difficult to imagine what existing international institution could impose and enforce such as system.

Some of these same institutional barriers would face an international tradable permit scheme, but such an approach -- if implemented -- could leave each participating country to decide what domestic policy to use,[44] and such a scheme would not require any ongoing side

[44] Strictly speaking, only domestic quantity instruments could guarantee that some quantity goal would be met. The point is that a system of international tradable permits gives individual nations more leeway in choosing domestic instruments than does an international tax system.

payments. Instead, the initial allocation of permits among countries would reflect distributional considerations. On the other hand, endogenous future prices in international permit trade would be unknown at the time an agreement on the allocation was reached. Hence, the distributional implications could not be fully known beforehand. This is the price paid for the key advantage of such a scheme, namely that global emissions will be known in advance for a global agreement, and, net of carbon leakage, for a non-global agreement. Thus, the weight of evidence would appear to favor -- in the long term -- a permit scheme over a charge system at the international level.[45] In the short term, however, political problems -- in particular, the lack of an adequate institutional structure -- would appear to render it highly unlikely that a global permit trading program will be adopted by the community of nations.[46]

7. CONCLUSIONS

There are a wide variety of factors that nations will need to consider to identify their optimal (and feasible) portfolios of greenhouse policy instruments. Countries differ dramatically in their institutional structures, their resource endowments, and their levels of industrialization; and their policy makers will inevitably consider alternative instruments in intensely political environments.

The choice of policy instruments at the international level could affect the likelihood that an agreement will be reached, because the adoption of any such instruments will affect the distribution of wealth among countries. Hence, debates and negotiations about distributional issues are likely to be central to the determination of the final portfolio of policies.

On the domestic level, even the most cost-effective greenhouse policy instrument will be desirable only if the national target it seeks to achieve is part of an accepted set of international mandates. By virtue of the fact that unilateral action will inevitably be highly inefficient, a necessary precondition for any domestic program is the existence of an effective international agreement, if not indeed a set of international greenhouse policy instruments. This returns us to the international context, where we are faced with the awesome task of identifying (or, more likely, creating) an institutional framework for achieving agreement among nations and for credibly administering any program.[47]

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[45] For a review of legal issues pertaining to the implementation of an international greenhouse gas trading system, see: Stewart, Wiener, and Sands 1996.

[46] This is not to deny that significant elements within the Clinton Administration in the United States are firmly committed to developing an international emissions trading or joint implementation system that is "credible, efficient, transparent, and verifiable" (Hambley 1996).

[47] Further, the international domain inescapably links considerations of cost-effective instruments with the difficult question of the desirable degree of greenhouse action, a question that is ignored at the risk of "designing fast trains to the wrong station."

7.1 A "Broad, Then Deep" Time-Path for Goals, Institutions, and Policy Instruments

As I emphasized at the outset, it is generally acknowledged that tremendous uncertainty characterizes both the future damages of greenhouse warming and the costs of avoiding or adapting to such warming. Because much of this uncertainty may be resolved gradually over time, it is important to consider alternative *time-paths* of public policies, which might feature "insurance policies" in earlier years and more aggressive abatement policies in later years. Furthermore, since the creation of a satisfactory institutional framework is a precondition for the successful implementation of any international policy instrument (and, as argued above, for the enactment of a serious domestic program), it is also important to consider *time-paths* for developing *institutions* that can implement such policies.

There are compelling arguments for beginning with broad-based (if not global) agreements that require only low-cost measures to achieve moderate goals with relatively unsophisticated instruments. As appropriate institutions develop and as more is learned about the benefits and costs of addressing climate change, there might be an evolution toward more ambitious goals, requiring higher-cost measures, achieved (cost-effectively) with more sophisticated policy instruments. This is the "broad, then deep" policy architecture that Schmalensee (1996) and -- by implication -- Schelling (1992) have proposed.

This "broad, then deep" strategy is similar to the approach frequently taken to address other kinds of international problems. For example, if one were to seek the eventual peaceful coexistence of Israelis and Palestinians, a reasonable first step might simply be to bring the parties together; in this case, bringing all of the relevant interest groups into a single room would be a "broad, but shallow" first step. As institutions develop, more ambitious targets might be adopted, but still ones that would be relatively low-cost to achieve, such as more efficient and equitable allocation of scarce water supplies or support for movement of tourists. Only later, after the relevant parties were more comfortable working with one another and credible implementing institutions had come into being, would truly ambitious goals (such as the location of settlements and ultimate authority of governments) be adopted that -- by necessity -- require (politically) high-cost strategies and potentially complex implementing instruments.

So too, in the case of global climate change, reasonable first steps should involve the broad participation of many nations (presumably including, at the very least, the OECD countries, China, Russia, and India) in low-cost agreements, which could later be made more ambitious (and costly), as appropriate. The default alternative appears to be to begin with narrow participation by a limited set of countries (most likely, some subset of the OECD) in a relatively ambitious agreement that involves considerable costs and hence requires fairly sophisticated policy instruments. Examples of this approach include some proposals for ambitious harmonized taxes and JI programs among European nations.[48]

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[48] For a review of such proposals, see: Fisher, Barrett, Bohm, Kuroda, Mubazi, Shah, and Stavins (1996). At the July, 1996 climate change meeting in Geneva, Switzerland, the United States initially proposed a completely open

Potentially severe free-rider and emissions-leakage problems, together with other implementation concerns discussed above, are among the reasons why a default "deep, then broad" strategy would have a low probability of success. Emissions leakage induced by a bilateral or narrowly multilateral greenhouse agreement means that the very existence of an effective multilateral agreement can make the formulation of a global agreement more difficult. This is because such an initial greenhouse agreement would cause non-participant countries to increase their economic specialization in carbon-intensive production, and thus to be even more resistant than previously to joining any future agreements.[49]

Furthermore, the severe enforcement problems that characterize the global climate policy realm suggest another advantage of the "broad, then deep" approach. Successful collaborative agreements -- in the absence of some kind of low-cost, effective enforcement regimes -- require substantial degrees of mutual confidence, which is typically fostered through increased interaction over time (Keohane 1986; Ostrom 1990; Putnam 1995).

7.2 Positive Political Economy: Political Barriers to Better Policy Instruments

Turning from normative to positive considerations, we may reflect on the fact that despite thirty years of normative arguments from economists, the U.S. political system has typically taken a command-and-control regulatory approach, rather than an economic incentive-based approach, to environmental problems (Hahn and Stavins 1991). Why has this been the case? First, in terms of the demand for environmental regulation by interest groups, private industry clearly prefers command-and-control standards to auctioned permits and taxes. Standards produce rents, while auctioned permits and taxes require firms to pay not only abatement costs to reduce pollution to a specified level, but also costs of polluting up to that level. Environmental interest groups also tend to prefer command-and-control instruments, for philosophical, strategic, and technical reasons.

In terms of the supply of environmental regulatory options, command-and-control standards are also typically preferred by legislators: their training and experience makes them more comfortable with a direct standards approach; standards tend to hide the costs of pollution control while emphasizing the benefits; and standards offer greater opportunities for symbolic politics (Keohane, Revesz, and Stavins 1996). These factors have led to twenty-five years of resistance to market-based policy instruments in the United States and to the predominance of command-and-control regulation. There is no reason to think that these factors will be any less important in affecting the domestic choice of policy instruments for global climate change.

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regime on joint implementation and emissions trading, but the Chinese and Indian delegations objected. The result was that the proposal was revised to include only Annex I countries, a list from the Framework Convention on Climate Change that consists essentially of the OECD countries plus the former Soviet Union (Curtis 1996).

[49] On this, see: Schmalensee (1996).

7.3 Concluding Comments

This suggests that despite the great theoretical advantages of market-based approaches to addressing global climate change, in terms of static cost effectiveness, dynamic efficiency, and distributional equity, the domestic political barriers to this set of policy instruments should not be underestimated; nor should the severe institutional challenges that characterize the international domain. The ultimate test of any greenhouse policy instrument -- whether domestic or international -- will be whether it is scientifically effective, economically rational, and politically feasible.

Where does this leave us in terms of an agenda for future research, at least within the social sciences? First of all, economics, as a discipline, can continue to play a central role by helping formulate and address questions about appropriate greenhouse targets and cost-effective and equitable instruments to achieve those targets. But if some of the greatest barriers to progress in dealing with the threat of global climate change are political hurdles domestically and institutional challenges internationally, we should be modest -- to say the least -- about the likelihood of analytical dominance by economics. The profession is simply less well suited to address political and institutional dimensions of the climate change problem, both because of the nature of the analytical tools of economics and because of professional incentives within the discipline that tend to work against institutional research, particularly when it is of a qualitative nature. Instead, this is an area where economists can learn from their colleagues in political science and law. Over the past several decades, legal scholarship and political science have been significantly influenced by economics. Now, global climate change policy -- with its centrally important political and institutional features -- presents an opportunity for that favor to be repaid.

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