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Increasing Participation and Compliance in International Climate Change Agreements*

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Abstract. Scientific and economic consensus points to the need for a credible and cost-effective approach to address the threat of global climate change, but the Kyoto Protocol to the U.N. Framework Convention on Climate Change appears incapable of inducing significant participation and compliance. We assess the Protocol and alternative policy architectures, with particular attention to their respective abilities to induce participation and compliance. We find that those approaches that offer cost-effective mitigation are unlikely to induce significant participation and compliance, while those approaches that are likely to enjoy a reasonably high level of implementation by sovereign states are sorely lacking in terms of their anticipated cost effectiveness. The feasible set of policy architectures is thus limited to second-best alternatives.

Key words: compliance, cost effectiveness, global climate change, international agreements, participation

1. Introduction

A growing scientific and economic consensus points to the need for a credible approach to address the threat of global climate change. The Kyoto Protocol to the U.N. Framework Convention on Climate Change may or may not come into force, but serious questions have been raised regarding the Protocol's ability to induce sufficient participation and compliance to have more than trivial effects on the path of future climate change. Our purpose in this paper is to assess the Protocol and alternative policy architectures in regard to their abilities to induce participation and compliance.[1]

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When economists consider domestic environmental problems, they ordinarily put aside participation and compliance issues, because the existence of an effective government vested with effective coercive powers is assumed. In the international domain, however, full national sovereignty for individual nations means that free rider problems make it unlikely that adequate participation and compliance will be achieved. Free riding behavior can be expressed through non-participation or non-compliance, and so at a fundamental level this paper is concerned with how free riding can be deterred.

It might seem that if the problem of global climate change were sufficiently serious or perceived to be sufficiently serious, then countries would have incentives to reduce their emissions, and free riding would not arise. But free riding depends upon the structure of the underlying environmental problem. For climate change, each country can claim for itself only a small fraction of the global benefit of its mitigation efforts, and because marginal abatement costs are increasing, the incentive for countries to mitigate climate change on their own is greatly reduced. That the damages from climate change may increase at an increasing rate may only serve to enlarge the incentive to free ride (as others mitigate more, a country's incentive to mitigate at the margin falls). Indeed, theory suggests that for a collective action problem such as global climate change, free riding becomes more problematic the greater are the aggregate gains to cooperation (Barrett 2003). The only way to overcome the free rider problem is to restructure the underlying incentives. This should be a primary aim of a climate change treaty.

The Kyoto Protocol may be characterized by its four key architectural elements: ambitious, short-term emission reduction targets, but no long-term targets; full responsibility (targets) only for industrialized countries; flexibility provided through market-based mechanisms, such as tradeable permit systems; and an absence of effective instruments for promoting compliance and participation. Many of the proposed alternatives to Kyoto try to improve on the first three of these elements by incorporating: emission-reduction targets that are modest in the short-term, but increase in stringency over time; mechanisms such as growth targets intended to increase developing country participation over time; and market-based instruments. A few of the proposals also incorporate features intended to facilitate compliance and participation. Some of these are quite radical, dropping the setting of targets entirely, and in some cases eschewing the use of market-based instruments. These more radical alternatives address the problems of compliance and participation as a priority.

Proponents of the less radical alternatives correctly claim that *if they are implemented successfully* they can achieve climate goals at relatively low cost. The more radical proposals, by contrast, emphasize that successful implementation requires effective promotion of compliance and participation. There is, to be sure, a congruence between these objectives. Countries will be more inclined to participate and comply with a more cost-effective treaty. However, cost-effectiveness is neither a sufficient nor a necessary condition for achieving full compliance and participation. By contrast, cost-effectiveness does require full participation (a requirement of cost-effective implementation is that marginal mitigation costs be equalized across *all* countries).

This paper compares these various policy proposals, and discusses their relative merits in terms of these major criteria. We find that those proposals that are best in terms of cost-effectiveness (conditional on implementation) – primarily market-based instruments, such as tradeable permit regimes – are less likely to be effective in promoting compliance and participation. Other proposals – such as various kinds of domestic "policies and measures" – appear better at promoting compliance and participation, but are less likely to be cost-effective. None of the alternatives fully meets the challenge of offering a cost-effective international regime that will enjoy a reasonably high level of implementation by sovereign states. Both criteria are important: cost-effectiveness conditional on implementation; and probability of international implementation.

A global climate regime needs to pay attention to both dimensions. Up to now, the economic literature and actual negotiations have emphasized the criterion of cost-effectiveness. This may have been based on the belief or hope that compliance and participation could be addressed in a subsequent stage. We argue that these issues need rather to be addressed up front and alongside concerns for cost-effectiveness.

In Part 2 of the paper, we describe the fundamental characteristics of the Framework Convention on Climate Change, the Kyoto Protocol, and thirteen proposed alternative policy architectures. In Part 3, we consider available methods of increasing participation and compliance, and examine the implications for the Kyoto Protocol and for the proposed alternative policy frameworks. Part 4 summarizes our main conclusions.

2. Global Climate Treaty Architectures

Incentives for increasing participation and compliance in an international agreement on global climate change will be implemented only within the context of a specific treaty architecture. Therefore, in this part of the paper, we review the fundamental architecture of the Framework Convention on Climate Change and the Kyoto Protocol, and then review the fundamental characteristics of alternative international approaches to the climate change problem.

2.1. The Framework Convention on Climate Change and the Kyoto Protocol

In 1992, the Framework Convention on Climate Change (FCCC) established as its objective the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." As an interim step, the FCCC imposed a non-binding goal of reducing greenhouse gas emissions by industrialized countries (the so-called Annex I countries)[2] to their 1990 levels by the year 2000. Signed initially by 161 nations, the FCCC entered into force in January, 1994 after being ratified by 50 countries (including the United States). Today, the FCCC has 188 parties, more than any other international environmental agreement (Barrett 2003).

In December, 1997, 160 countries negotiated the Kyoto Protocol to the Framework Convention. Subsequent negotiations filled in many of the details of the Protocol, and the treaty was substantially completed by November 2001. The Protocol provides specific commitments for 38 industrialized (Annex B) countries for the 2008–2012 "commitment period."[3] These emissions targets are expressed relative to countries' emissions in the year 1990.[4] The relative commitments range from 8 percent below 1990 levels (for the European Union) to 10 percent *above* 1990 levels (in the case of Iceland). When one considers the growth in some economies since 1990, and the collapse in others, the range of implicit targets is even broader, with the United States facing a target of about 30 percent reduction below business-as-usual levels in the year 2012, and Russia and other economies in transition facing targets that would allow substantial increases in emissions *above* anticipated business-as-usual levels in 2012. Nations must comply with these targets *on average* over the five-year commitment period. Moreover, these targets apply to six classes of greenhouse gases: carbon dioxide (CO_2), methane, nitrous oxide, hydroflourocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

The Kyoto Protocol includes three flexibility mechanisms that can help countries achieve their commitments at lower costs: international emissions trading, joint implementation, and the Clean Development Mechanism (CDM). The international emissions trading mechanism allows Annex B countries to trade emissions allowances with one another, whereas the joint implementation mechanism allows these same countries to cooperate on projects and transfer emissions allowances on the basis of such projects. The CDM allows Annex B countries to finance projects in non-Annex B countries in exchange for credits towards meeting their own emission reduction commitments.

Unlike the underlying FCCC, the Kyoto Protocol stipulates that emissions commitments are legally binding. At the same time, however, Article 18 of the Kyoto Protocol prohibits adoption of a compliance mechanism entailing "binding consequences" unless adopted by means of an amendment. Thus, the Protocol demands substantial reductions in emissions by some countries, but denies parties the means for enforcing these obligations, except through amendment. A compliance mechanism was agreed in Bonn in July 2001: any industrialized country that fails to comply within the first commitment period must make up for this shortfall in the second commitment period with a 30 percent penalty.

As of July, 2003, the Kyoto Protocol had been ratified by 111 countries. To enter into force, it must be ratified by at least 55 countries, accounting for at least 55 percent of 1990 Annex I CO_2 emissions. As of July, 2003, 29 Annex I countries had ratified the Kyoto Protocol: the fifteen member states of the European Union, Bulgaria, Canada, the Czech Republic, Estonia, Hungary, Iceland, Japan, Latvia, New Zealand, Norway, Poland, Romania, Slovakia, and Switzerland. Together, these countries accounted for only 44.2 percent of Annex I emissions. Given non-participation by the United States, entry into force depends on ratification by Russia.

Though participation by this number of Annex I countries might seem to indicate success, it should be recalled that the decision by some Annex I countries to ratify was influenced by concessions given to these countries (including Japan and Russia) in Bonn and Marrakech. Giving these countries more (sink) allowances effectively relaxed the emissions constraints negotiated previously in Kyoto. Other modifications, such as the decision not to impose a quantitative limit on trading, also helped to promote participation by Annex I countries. However, these changes also reduced the environmental effectiveness of the treaty.[5]

2.2. Alternatives to the Kyoto Protocol

The Kyoto Protocol's architecture has been criticized on a variety of grounds, including: it imposes high costs and substantial burdens on some industrialized countries; it does not impose emission commitments on developing countries;[6] it provides ineffective incentives for participation; and it generates modest short-term climate benefits while failing to provide a long-term solution. In response to these and other perceived flaws in the agreement and in response to uncertainty regarding the agreement's future given the declared non-participation by the United States, a number of alternatives have been proposed. These proposals have been advanced in venues ranging from one-page editorials to book-length manuscripts.

Aldy, Orszag, and Stiglitz (2001) propose a hybrid international trading instrument that combines the sort of international trading mechanism found in the Kyoto Protocol with a safety-valve or price ceiling, which is implemented by an international agency making available additional permits at a fixed price.[7] Proceeds from the sale of additional permits would finance climate change research and aid developing countries' efforts to abate greenhouse gas emissions. Developing countries would be included in the short term via voluntary measures and in the longer term via mandatory commitments. This proposal does not represent a significant departure from the Kyoto framework.

Barrett (2003, 2001b) proposes a fundamentally different approach, emphasizing common incentives for climate-friendly technology research and development, rather than targets and time tables.[8] His approach includes an R&D protocol that would support collaborative research, and a standards protocol that would require common standards for technologies identified through the collaborative research efforts. Barrett maintains that the departure from emissions commitments and market-based instruments is the necessary cost of designing a participation- and compliance-compatible regime. His proposal also includes a protocol aimed at making some short term progress, but without the pretense that this can be achieved through international enforcement.

Benedick (2001) offers a somewhat similar proposal, which emphasizes (long-term) international standards and incentives for technology innovation and diffusion. However, he also recommends a renegotiation of the Kyoto targets, and a process in which participation in negotiations begins small and expands over time. His approach is to adopt a portfolio of policies, including a small carbon tax to fund new technology research, to move the international community toward a desirable technology strategy.

Bradford (2001) proposes the equivalent of an international emissions trading program but without a fixed cap on emissions. All nations, including developing countries, are allocated permits equivalent to their anticipated business-as-usual time path of emissions. Periodically, an international authority offers to purchase (and retire) emissions allowances. Distributional issues are handled through the financing of the international authority, with differential funding responsibilities being established on the basis of per capita income levels and other criteria, such as expected benefits from climate change mitigation.

Cooper (1998, 2001) moves considerably further away from the Kyoto framework: instead of multilateral negotiations over national emissions quotas, countries would negotiate regarding a set of common actions aimed at achieving global emissions targets. In particular, a harmonized carbon tax would be used by all participating nations – industrialized and developing alike – to tax their domestic carbon usage at a common rate, thereby achieving cost effectiveness.

Another significant departure from the "targets and time tables model" is provided by Hahn (1998), who proposes experimentation with multiple "case studies" of potential policy instruments to abate greenhouse gas emissions in the short term, including: coordinated measures; an emissions tax; tradeable emission permits among some set of industrialized nations; tradeable emission permits among industrialized nations with joint implementation for developing countries; and a hybrid system.

McKibbin and Wilcoxen (1997, 2000) recommend a largely price-based approach, with two domestic markets for tradeable permits – one for annual emissions and another for perpetuities ("endowments"). As in other proposals, governments would provide a safety-valve of permit sales at a fixed price (which can rise over time). Endowments would be made to both industrialized and developing countries, the latter well in excess of current or anticipated emissions to allow for economic growth. In this proposal, there is no international trading system.

Nordhaus (1998) combines the notion of harmonized carbon taxes with attention to the efficiency of the targets. This is done by setting the harmonized carbon tax at the efficient level through a dynamic benefit-cost analysis, where the benefits are determined through an international voting mechanism which is intended to reflect countries' true willingness-to-pay. As in other proposals, developing countries participate only when their per capita incomes reach particular threshold levels. Compliance is promoted through import duties which are levied on goods from non-participant countries, based on carbon content, with goods from poor countries exempted.[9]

Schelling (1997, 1998, 2002) proposes a climate "Marshall Plan," which focuses on mutually agreed actions by industrialized nations. International mechanisms in pursuit of targets and time tables (such as international permit trading) are dismissed, although domestic market-based instruments are recommended.

Schmalensee (1998) focuses on two dimensions of an international climate change agreement: the breadth of the coalition of countries that are meaningfully participating; and the depth of their commitment (stringency of targets). He argues that the most productive first step is to include as many countries as possible, but not require severe reductions. He terms this a broad and shallow approach, in contrast with the Kyoto Protocol, which he characterizes as being narrow and deep. Schmalensee's argument is that getting a large number of nations to make commitments now is the best strategy for building the depth and breadth necessary in the long term to address the problem in meaningful ways.

Stavins (2001) proposes a three-part policy architecture, which is consistent with the Framework Convention on Climate Change but departs from the Kyoto Protocol: (1) all countries participate, with an explicit mechanism providing for voluntary accession by developing countries, and a trigger, linked with per capita income, which would require developing countries to take on "growth targets," commitments that are a function of per capita income and other negotiated factors;[10] (2) aggregate short-term targets that are moderate yet rigid, and long-term targets – put in place now – that are much more ambitious (in order to induce needed technological change), but flexible to respond to learning; and (3) market-based instruments, including international permit trading, possibly with a safety-valve.

Stewart and Wiener (2001) focus on increasing developing country participation by four instruments: (1) a streamlined CDM; (2) voluntary participation in emissions trading without emissions quotas; (3) mechanisms for voluntary accession to the emissions quota system; and (4) automatic graduation to the quota system given particular per capita incomes having been reached. Stewart and Wiener (2001) specifically focus on the need to secure the participation of major developing countries like China and India by giving these countries "headroom" allowances.

Finally, Victor (2001) proposes an approach that in the short term is similar to the Kyoto Protocol, except that individual countries can sell unlimited numbers of allowances at a specified price (safety valve). In the short term, developing countries participate through the CDM, but in the long term, a graduation mechanism is proposed for developing countries as they reach particular incomes and then must adopt either quotas (as developed countries) or growth targets. Compliance, he argues, would be promoted through a buyer liability scheme.

2.3. Summary and Synthesis

Although there is considerable diversity among these alternatives to the Kyoto Protocol, a number of themes emerge (only some of which are shared by *all* of the proposals): use of relatively moderate short-term goals; provision for increased developing country participation over time; use of market-based mechanisms; cost constraints through hybrid instruments; and provision of incentives for participation and compliance.

First, many of the proposals reflect a general concern that the Kyoto commitments are "too little, too fast," that is, insufficient to do much about the climate change problem, but excessively ambitious (and hence costly) in the short term. Therefore, nearly all of the proposals feature commitments which are moderate in the short-term and become much more stringent in the long-term.

Second, many proposals maintain that developing countries must play a more significant role over time. Several proposals (Aldy, Orszag, and Stiglitz 2001; Schmalensee 1998; Stavins 2001; Stewart and Wiener 2001) would require developing countries to take on emission commitments in the near term. These proposals plus others (McKibbin and Wilcoxen 1997, 2000; Nordhaus 1998; Victor 2001) recommend some form of graduation: an income threshold above which nations must take on emission commitments. Other proposals include developing country participation in forms which do not involve emission commitments (Bradford 2001; Hahn 1998). Finally, the proposal by Barrett (2003, 2001b) would have developing countries participate in the financing of research and development activities, but with contributions reflecting their differentiated responsibilities and capabilities (perhaps based on the UN scale of assessments).

Third, a number of proposals provide positive incentives for developing country participation. Some would require that developing countries adopt emission ceilings but with "head room" so that these countries could become net exporters of emission allowances, providing the resources needed to finance their abatement (Aldy, Orszag, and Stiglitz 2001; Stewart and Weiner 2001). The proposal by Barrett (2001b, 2003) would have developing countries be bound by the technology standards incorporated in separate protocols, but the diffusion of these technologies in developing countries would be financed by industrialized countries, an element also of Benedick's (2001) proposal.

Fourth, nearly all of the proposals would allow, encourage, or require implementation through market-based instruments. While Cooper (1998, 2001) advocates harmonized carbon taxes, most proposals favor hybrid quota-tax schemes (Aldy, Orszag, and Stiglitz 2001; Hahn 1998; McKibbin and Wilcoxen 1997, 2000; Victor 2001) or tradable permit systems (Hahn 1998; Stavins 2001; Stewart and Wiener 2001). Bradford's (2001) proposal could potentially achieve a similar, cost-effective outcome by implementing a permit purchase scheme. Efficient implementation of all such instruments would allow countries to achieve their emissions commitments at lower cost, which would presumably increase the likelihood that they would comply with their commitments. It is precisely because of concerns about compliance/participation, however, that Barrett (2003, 2001b) departs from the conventional economists' prescription of market-based instruments, and advocates instead collaborative R&D combined with technology standards. Schelling's (1997, 1998) proposal also drops the pretense that targets and timetables can be enforced internationally, but his proposal may improve little on unilateralism.

Fifth, in response to concerns about the costs of complying with emissions commitments, many proposals recommend hybrid tax-quota or pure price regimes to set a cap on marginal costs (Aldy, Orszag, and Stiglitz 2001; Cooper 1998, 2001; McKibbin and Wilcoxen 1997, 2000; Stavins 2001; Victor 2001). Other proposals take different approaches to limiting the costs of climate policy (Barrett 2003, 2001b; Bradford 2001; Hahn 1998).

Sixth, although there is widespread recognition that the Kyoto Protocol does not provide effective incentives for participation and compliance, most proposals give relatively little, if any, explicit attention to this aspect of an international climate agreement, the chief exceptions being Barrett (2003, 2001b), Victor (2001), and Wiener (1999, 2001).[11] More broadly, advocates of policies to ensure low costs of attaining emissions commitments believe that such low costs will provide incentives for participation and compliance. Other authors (Aldy, Orszag, and Stiglitz 2001; Nordhaus 1998) argue that a treaty such as the Kyoto Protocol can, in principle, be enforced by means of trade restrictions. Cooper (2000), by contrast, rejects trade restrictions. Citing Chayes and Chayes (1995), he argues more broadly that sanctions are not needed and that transparency in governmental actions (monitoring) should provide sufficient incentive for compliance.[12]

Any pragmatic proposal addressing developing country participation must confront a difficult trade-off if the United States is to participate as well. If a proposal includes aggressive developing country commitments, the agreement may be expected to fail to elicit developing country participation, since nearly all developing countries believe that the industrialized world should take on binding emissions commitments first.[13] On the other hand, if a proposal recommends modest or no near-term emissions commitments by developing countries, the agreement may be expected to fail to gain political acceptance in the United States, as evidenced by the unanimous (95-0) passage of the Byrd~Hagel Resolution in the U.S. Senate (1997), which called for similar treatment of industrialized and developing countries in any international agreement on global climate change.[14] The notion of allowing short-term developing country participation *exclusively* through the CDM (Victor 2001) would likely garner little support from the United States, since such participation would fall well short of the criteria specified by the Byrd-Hagel Resolution.

3. Methods of Increasing Participation, Compliance, and Mitigation

An efficient (and, hence, cost effective) climate agreement would secure full participation by all countries, with each country mitigating its emissions to the point where its own marginal abatement costs were equal to the sum of marginal benefits globally, and with each country being made better off (at least no worse off) as compared with the alternative of no agreement. Achievement of the latter requirement may necessitate economic transfers – either explicit transfers in cash or in kind (technology transfers), or implicit transfers, facilitated by generous allowances of tradeable emission entitlements.

Equity considerations that go beyond the efficiency criterion may favor additional transfers. For example, it could be argued that the industrialized countries are largely responsible for the historic build-up of greenhouse gas concentrations, and so should not only pay for abatement by developing countries but should compensate these countries for the costs of adaptation as well as for damages that cannot be avoided. Concerns for fairness are not merely abstract notions. They are important for negotiations. People often refuse offers they perceive to be unfair, even when doing so comes at significant personal cost (Barrett 2003).

In principle, it should be possible to negotiate a treaty that is both efficient and fair. The problem comes in enforcing such an agreement, for nations have incentives not to participate and/or not to comply even when there is a collective gain to cooperation. Without transfers, and taking the behavior of other countries as given, each country can do better by mitigating only up to the point where its own marginal benefit equals its marginal cost. As long as global marginal benefits exceed each nation's own marginal benefits, all countries will either want to avoid participating or avoid full compliance if they do participate. If offered sufficient compensation, a developing country may be willing to participate, but the compensation that secures its participation is purchasing a public good, and each industrialized country may prefer that others pay this cost. Successful international cooperation must change these incentives.

3.1. The Relationship between Participation and Compliance

Participation and compliance have typically been analyzed separately,[15] although they are – in reality – joint problems. Customary international law requires that countries comply with treaties in which they participate, and most countries do comply with most treaties most of the time. But international law does not require that countries participate in international treaties. Hence, the easiest way for a country to avoid complying with a treaty is simply not to participate in the first place. This means that a first priority of international cooperation must be in deterring non-participation. If this can be done, then compliance can be secured (Barrett 1999). Non-participation is the biggest credible deviation that a single country can carry out. Deterring such a deviation requires sacrifices by others, and larger sacrifices are less credible because they are more self-damaging. Where monitoring or verification are difficult or impossible, compliance will be harder to enforce. For this reason, most agreements establish obligations that are easily monitored. Indeed, this is seen to be one of the advantages of a treaty focusing on actions (policies and measures) rather than outcomes (targets of emission levels).

3.2. The Relationship between Participation and Mitigation

Greater participation in an international climate change agreement can be obtained by reducing the cost of participation, such as through the use of cost-effective, market-based instruments or through limiting the degree of mitigation required by individual parties (nations). In the limit, a treaty can always secure universal participation by not requiring that any country make any sacrifice. The challenge is to induce countries to participate in an agreement requiring them to reduce their emissions substantially (while also ensuring that compliance is enforced).

This may not always be possible; it may be necessary to lower per-country mitigation in order to widen participation. There can be a tradeoff between the merits of a "broad but shallow" treaty and a "narrow but deep" one.[16] If marginal costs increase in the level of abatement – as they surely do for climate change mitigation – then a "broad but shallow" treaty will be preferable, because under such circumstances an expansion in the number of countries undertaking mitigating measures lowers total cost (holding constant the overall degree of mitigation).

This concern for broadening participation is reflected – to some degree – in the Kyoto Protocol. After the industrialized countries agreed in Berlin in 1995 to reduce their emissions without requiring reductions by developing countries, negotiations shifted toward flexible mechanisms, such as the Clean Development Mechanism (CDM), which aims to reduce differences in marginal abatement costs among countries, but does so indirectly by allowing industrialized countries to finance abatement projects in developing nations. In practice, the CDM is likely to be burdened by substantial transactions costs (Barrett 1998).

International trade may also favor the broadening of participation. As one group of countries reduces emissions, the costs of producing greenhouse-intensive goods and services within this group will rise relative to the costs of producing other goods and services. Comparative advantage in the manufacture of greenhouse-intensive goods will therefore shift towards non-participating countries. The increase in emissions by non-cooperating countries brought about by the reduction in emissions undertaken by cooperating countries is characterized as "emissions leakage." The conventional wisdom is that such leakage will be significant, but less than fully offsetting. It is possible, however, that global emissions may increase as a consequence of a set of countries mitigating their emissions, if production of greenhouse-intensive goods shifts to countries with higher emission-output ratios.[17] In the event that leakage is positive, it is likely that an expansion in participation would reduce leakage, making cooperation more potent. Leakage can be negated by the use of trade instruments, especially border tax adjustments, but these instruments may be difficult to incorporate in a climate agreement, and may reduce welfare overall.

3.3. Positive Incentives

Three alternative types of positive incentives for participation and compliance might be brought to bear in the context of the Kyoto Protocol and alternative approaches to addressing global climate change.

One form of positive incentive for participation and compliance is a side payment – a direct money transfer made by one party or set of parties to another. Under such arrangements, the countries that gain most from an agreement compensate those who would lose or gain least (in the absence of side payments).[18] The voluntary nature of international relations means that countries will only agree to exchange money for mitigation if they can gain from the transaction, though it cannot be guaranteed that a treaty will yield an actual Pareto improvement.[19] Side payments may reflect an underlying agreement about property rights (responsibilities), and/or they may play a strategic role (Barrett 2001a).

A second form of positive incentive is a link between cooperation on one issue and cooperation on another. Such issue linkage can ensure that all parties gain by participating or it can play a strategic role. A third form which positive incentives may take involves the allocation of emission entitlements. If the emissions of countries are limited by a treaty, if these limits imply different marginal costs of compliance, and if the treaty permits international trading in emission entitlements, then money will flow from parties with high marginal implementation costs to parties with low marginal costs. These flows act like side payments, the only significant difference being that they are not directly negotiated.

Given any total emission cap, trading promotes participation. Trading benefits the buyer, allowing it to save costs; and trading benefits the seller, allowing it to earn revenues. Compared with a treaty prohibiting trading, both types of parties are better off with a trading regime, and so will be more inclined to participate. Taking participation as given, however, the allocation of entitlements is a zero-sum game. If more entitlements are given to one country and fewer to another (with the total quantity unchanged), the former country gains and the latter loses. Though it is true that countries awarded a surplus of permits are more inclined to participate, it is also true that countries awarded a deficit gain less from participating. Giving one party more entitlements than required to secure its participation can thus be harmful to participation overall because of the effect on other parties. Thus, it has been argued that too much "hot air" was given to the economies of transition in the Kyoto Protocol.

Any negotiated outcome must be perceived as being fair to all parties, or else it is unlikely to be self-enforcing, but the concept of a "fair" agreement needs to take account of the incentives to participate. In the successful Montreal Protocol on Substances that Deplete the Ozone Layer, emission limits were set for *all* countries. For the industrialized nations, the agreed emissions limits were immediately binding. Developing countries, by contrast, were allowed a grace period during which their emissions could rise before they would be required to cut their emissions to the same level set for the industrialized countries. At the same time, the incremental costs of implementing the agreement were to be paid by the industrialized countries (Benedick 1998, Barrett 2003). The CDM mechanism in the Kyoto Protocol is only superficially similar.[20]

Of the proposed alternatives to Kyoto, almost all involve some transfer of resources from industrialized to developing countries, either by direct transfers (Barrett 2001b, 2003; Benedick 2001), by favorable allocations of emission entitlements (Bradford 2001; Stavins 2001), or by some combination of the two (Aldy, Orszag, and Stiglitz 2001; Hahn 1998; Stewart and Wiener 2001; Victor 2001). In other proposals (Nordhaus 1998; Schelling 1997, 1998), developing countries are treated differentially, but are not given a positive incentive to participate. Cooper's (1998, 2001) proposal is unique in requiring that developing countries impose the same carbon tax as industrialized countries (with a time-delay but with no compensation).

Designing a system of positive incentives on paper may be easy, but making such a system effective in changing behavior in practice is more difficult. Transfers, like allocations of tradeable emission allowances, are a zero sum game; in making one party better off, they make another worse off. Indeed, this is why side payments on their own are of limited help in sustaining real cooperation (Carraro and Siniscalco 1993). Positive incentives are needed where countries are highly asymmetric, but such incentives can sustain real cooperation only if they restructure the underlying incentive system. For example, the side payments in the Montreal Protocol changed that treaty from one aimed exclusively at encouraging countries to reduce their emissions to one which included encouraging industrialized countries to pay developing countries to reduce *their* emissions (Barrett 2001a). Contributions to the Multilateral Fund, which exceeded $1 billion, were an obligation, much the same as emission reductions.

Another lesson is that transfers should be limited. The Montreal Protocol's Multilateral Fund only compensates for agreed incremental costs; it does not transfer huge amounts of rents. The advantage of this is that in lowering the cost to the industrialized countries of reducing emissions in developing countries, more of the latter emissions are actually reduced. In this respect, proposals for direct transfers (that is, payments in exchange for specific actions) have an advantage, but care must be taken in designing such transfers. High transactions costs could reduce the advantage of direct transfers as compared with a decentralized trading system.

Finally, care must also be taken in implementing a system of direct transfers. Payments need to be linked to performance, and this requires institutional oversight. Victor, Raiustiala, and Skolnikoff (1998), upon reviewing the experience with implementation of international environmental commitments, found that such institutions typically work best when dedicated to the task of reviewing performance, supported by a network of existing institutions that together comprise a system for implementation review.

3.4. Negative Incentives

Potential negative incentives[21] include reciprocal measures, financial penalties, and trade restrictions. But before turning to specific types of negative incentives, it is helpful to highlight the fundamental difference between domestic contexts – where various types of negative incentives are frequently employed – and the domain of international cooperation. Domestic policies are enforced by national governments; indeed, it can be said that national governments exist and are given their unique powers of coercion so that they can supply public goods and correct for market failures. National sovereignty means that, by contrast, international agreements cannot be enforced by a world government. Such agreements must be enforced by their parties – the respective national governments.

The difference between the two contexts is well illustrated by comparing the Kyoto Protocol with Title IV of the U.S. Clean Air Act amendments of 1990, intended to reduce acid rain in the United States (and Canada) by 50 percent. Both regimes establish targets and timetables for emission reductions; both allow emissions trading; but in terms of enforcement, the two policies could not be more different. The Title IV penalty for excess emissions was set at $2,000 per ton, in contrast to marginal abatement costs on the order of $200 per ton (Schmalensee et al. 1998). Furthermore, it is a felony to violate Title IV; violators may be sent to prison. Hence, there is a significant incentive to comply, and – not surprisingly – compliance is virtually perfect (Stavins 1998). In contrast, the Kyoto Protocol explicitly prohibits compliance measures entailing "binding consequences."

Enforcement requires punishments (negative incentives), but can also be encouraged through positive incentives. It has sometimes been argued that positive incentives can suffice, but threats of punishment are inevitably required to achieve cooperation.[22]

Negative incentives must be credible, and must be seen to be credible, if they are to be effective; otherwise a threatened punishment is unlikely to influence behavior (Schelling 1960). Unfortunately, credibility is difficult to establish, because in many situations, countries that punish non-cooperating countries will harm themselves in the process. To be credible, countries that threaten to punish must be better off when they carry out the threat than when they do not, given the behavior of the deviant state.

To influence behavior, the threatened punishment must also be sufficiently severe. That is, the deviant state must be significantly worse off when it deviates and is punished than when it participates and complies. Making punishments both credible and severe is especially difficult because the more severe the punishment, the more harm it inflicts on the enforcing countries, making the punishment less credible.[23]

We should underscore what makes enforcement of a climate mitigation agreement so difficult. For trade agreements, enforcement is not a great problem because trade is a bilateral activity. The country harmed by a trade violation can reciprocate. Climate change mitigation, however, is a global public good. If a country fails to supply the good, another country can punish it, but in contrast to the trade situation, this enforcement has wider implications. First, enforcement by this country is itself a public good, and so is subject to under-provision for the usual reasons. Second, if the enforcement involves a reciprocal response (a reduction in mitigation), then other cooperating countries will also be harmed by the enforcement.

The first category of negative incentives we consider are reciprocal measures. In theory, reciprocity is at the heart of many potential incentives for participation in an international environmental agreement, since in the absence of centralized enforcement, what can deter participants from polluting is the prospect that others will pollute in retaliation. For such reciprocity to function, a number of conditions must be satisfied: there must be a limited number of parties; there must be a positive probability that they will meet again; cheating must be detected; and parties must be patient. The number of parties to an agreement is especially important for international cooperation (Barrett 1999), because the larger the number of cooperating countries, the less credible is the threat by them collectively to punish deviations. But climate change mitigation is a global public good, and cannot be segmented into a vast number of bilateral relations, as can a multilateral trade agreement.

A second category of negative incentives are financial penalties and self-punishment. The Kyoto negotiations held in 1997 deferred discussion of sanctions for non-compliance, and when the subject was eventually addressed in subsequent Conferences of the Parties, the focus was not on reciprocity, but on how non-complying countries might be required to make up for excess emissions in subsequent compliance periods. At the extended Sixth Conference of the Parties (COP-6), held in Bonn in July 2001, countries agreed to apply a penalty ratio for non-compliance of 1.3. This means that if an Annex I party were to emit, for example, 100 tons more than allowed in the first compliance period (2008–2012), then the party's emission cap for the next compliance period (possibly 2013–2017) would be reduced by 130 tons – 100 tons to offset the excess plus an additional 30 tons as a penalty for non-compliance.

This proposal may have been attractive to many countries, because it does not require sacrifices by other parties. However, it is precisely for this reason that the proposal can be expected to fail to affect behavior. Put differently, the enforcement provisions must themselves be enforced, and the Kyoto Protocol makes no allowance for this need. Three problems undermine this approach. First, the punishment is forever delayed. If a country fails to meet its obligations in the second control period, including the penalty for not complying in the first control period, it is punished by having to pay a penalty (to be determined by a future amendment) in the third control period, and so on. A punishment that is forever delayed cannot be expected to influence behavior. Second, the magnitude of the punishment depends not just on the agreed penalty rate, but on future emission limits. But a country must agree to its future emission limit; otherwise it will choose not to participate. Hence, if a country fails to comply in the first compliance period, it need only negotiate a relatively lax emission cap for the next compliance period.[24] Finally, the proposal ignores the reality that compliance and participation must be considered jointly. The easiest way of avoiding the penalties in the proposed scheme is simply not to participate in the treaty, either by not ratifying it or by withdrawing from it at a subsequent date.

Had the agreement required that non-complying countries pay financial penalties instead of emission penalties – as proposed earlier in the negotiation process – the effect would have been the same. The essential question is who would enforce the payment of financial penalties. Ultimately, enforcement requires that the other Kyoto Protocol parties take actions against non-complying countries, but such actions would be self-damaging and so may not be credible.

A third and final type of negative incentive for compliance is a trade restriction, promoted by Aldy, Orszag, and Stiglitz (2001), Nordhaus (1998), and others.[25] These can serve three purposes. They can dampen or even eliminate leakage; they can help shift production towards the cooperating countries; and they can promote greater participation in a treaty. For an example of the challenge that exists, suppose that the Kyoto Protocol were fully implemented and that emissions trading were perfect, so that marginal costs were identical among all of the treaty's parties. For simplicity, we can further assume that non-cooperating countries do nothing to reduce their emissions. To make the example concrete, let us assume that the Kyoto constraints imply a shadow price of $25 per ton of carbon (C), and that marginal abatement costs among non-parties are zero. Then leakage can be neutralized by means of a $25/ton C border tax adjustment (BTA). At the border of every cooperating country, the carbon emissions released in the manufacture of every traded good are calculated, irrespective of the point of production. All imports are subject to a $25/ton C tariff. All exports are subject to a $25/ton C export subsidy.

The result would be that leakage would be neutralized. Domestic producers in treaty countries would suffer no competitive disadvantage, either at home (where emissions of all traded goods would be taxed at the same rate, $25/ton C, irrespective of the point of production) or abroad (where emissions of all traded goods would be taxed at the same rate, $25/ton C within cooperating countries and $0/ton C elsewhere). The competitive playing field would be rendered level by the BTA.[26]

Though straightforward in principle, it would be virtually impossible in practice to calculate the carbon emitted in the manufacture and distribution of each and every good.[27] Indeed, although the Montreal Protocol anticipated the need to restrict trade in products made using but not containing CFCs, such restrictions were never imposed, mainly for reasons of feasibility. Moreover, although the World Trade Organization (WTO) has evolved in the direction of supporting environmental protection, even if at the cost of some disruption in trade, application of BTAs would pose a massive challenge to the trading system. They would apply not to a good directly but to the way in which the good was manufactured, violating a long-standing international principle and WTO rule. And if some members of the WTO were not parties to the climate agreement, the application of BTAs would also violate the WTO's non-discrimination principle.

These potential problems are exacerbated by the temptation to manipulate BTAs, either for reasons of improving the terms of trade or for enhancing climate mitigation (a higher BTA would shift production toward the cooperating countries, possibly creating a "negative" leakage rate, thus increasing the effectiveness of international cooperation). This motive might seem desirable to some, but if non-parties believe that climate mitigation is a poor investment for them or that the treaty employing BTAs was unfair to them, then the interests of these countries would be harmed by the application of trade restrictions, and it would be necessary to balance the gain to one set of countries against the loss to another.

In the case of the Montreal Protocol, the credible threat to restrict trade in CFCs and products containing CFCs between parties and non-parties was instrumental in sustaining cooperation (Benedick 1998; Barrett 2003). Trade has not actually been restricted, but the belief that trade would be restricted if countries failed to participate had the effect of promoting participation. What made this threat credible was not that trade restrictions were less self-damaging than reciprocity, but that great concern existed regarding leakage. To be credible, countries threatening to impose restrictions must be better off when they carry out their threats than when they do not, given that non-participation has occurred. If countries called upon to enforce participation believe that leakage would be severe – that in the absence of trade restrictions production would relocate to the non-participating countries – then they would gain by imposing trade restrictions (Barrett 2003). This effect increases as more countries participate. The greater is the rate of participation, the more credible is the threat to restrict trade. Trade restrictions can thus tip participation.

Can a similar approach be used in a climate treaty? The answer is not obvious. CFCs and products containing CFCs make up a very small portion of world trade. By contrast, the manufacture of virtually all traded goods results in the emission of greenhouse gases. Restricting trade in all goods and services is unlikely to be credible, and the damage such restrictions would do to the multilateral trade regime would likely offset any advantage trade restrictions might offer for climate mitigation.

The justification for using trade restrictions also depends on the perceived fairness of an international treaty. No country could gain from ozone depletion, and the countries that would gain the least from ozone protection – developing countries – were compensated for participating in the Montreal Protocol. This made the threat to impose restrictions appear to be fair. This explains why, in general, a combination of positive and negative incentives is required to sustain cooperation: positive incentives either ratchet up cooperation or legitimize the use of negative incentives; and negative incentives promote participation and compliance.

The Kyoto Protocol offers little in the way of negative incentives against non-participation. The minimum participation clause offers, at most, a very small incentive. If participation by an individual country would cause the Protocol to enter into force for others, then such a country might gain by participating. But this effect of the minimum-participation clause is likely to be extremely limited, since the Protocol can enter into force when emission restrictions are imposed on countries accounting for less than 20 percent of global emissions.

Most proposed alternatives do not address the enforcement problem. Exceptions include Aldy, Orszag, and Stiglitz (2001) and Nordhaus (1998), which recommend the application of trade restrictions to deter non-participation by industrialized countries. As we argue above, however, in the global climate change context trade restrictions are likely to be impractical or worse.

3.5. Strategic Incentives Provided by Treaty Mechanisms

In addition to explicit provisions for monitoring and enforcement, other elements of a global climate policy architecture can have important effects on participation and compliance. In the Kyoto Protocol, the fundamental instrument for effecting cooperative mitigation is the setting of targets and timetables. This approach imposes a considerable burden on monitoring and enforcement, a burden that may exceed capabilities. Is there another instrument that might perform better in this regard?

One alternative approach, proposed by Schelling (1998), would rely on countries pledging to adopt specific domestic policies or actions. Such pledges would be subject to international scrutiny, but *not* enforcement. Although this approach avoids the need for international enforcement, it may do little more than create a "tote-board" for international cooperation (Levy 1993). A similar role was played by the Framework Convention on Climate Change, through which parties pledged to stabilize their CO_2 emissions at 1990 levels by the year 2000. Very few countries did so, and those that did limit their emissions did so for reasons other than climate policy.

Another "policies and measures" approach would feature cooperative R&D efforts coupled with the setting of standards (Barrett 2001b, 2003). An example of a previous success with such a standard-setting approach is provided by the 1973 (and 1978) International Convention for the Prevention of Pollution from

Ships (commonly known as the MARPOL treaty, referring to maritime pollution), intended to limit emissions of oil from tankers. Prior international treaties had attempted to establish quantitative ceilings on emissions – much like the Kyoto Protocol – but such attempts either failed to enter into force or had no effect because of weak enforcement. The MARPOL treaty changed everything (Mitchell 1993). Since compliance with the quantitative ceilings could neither be monitored nor enforced, the treaty required only the adoption of a technology: the segregated ballast tank. Like most technology standards, this had the advantage of being relatively easy to monitor and hence enforce.

Parties to the MARPOL agreement had incentives to ban non-complying tankers from their ports. In addition, because shipping has network characteristics, the greater the number of countries that required the standard, the greater was the incentive for tanker operators to meet the standard. Failure to meet the standard meant being shut out of lucrative markets. The result was that as of early 2001, the treaty was ratified by 113 countries making up 94 percent of world tonnage.

A similar kind of positive feedback was created by the Montreal Protocol (Benedick 1998). This agreement opened up markets for new products and simultaneously shrank the market for ozone-destroying chemicals. Companies wanted to serve the new markets, but as they gained a share in these markets, they also wanted the old markets to be closed. Commercial incentives thus became aligned with the environmental goals of the treaty; in particular, they interacted with the treaty's trade restrictions and side payments. The trade restrictions dampened trade leakage effects, while increasing the incentives for participation for commercial reasons. Side payments also helped encourage developing countries to participate.

In theory, standards could be established in a climate treaty for the most important sources of greenhouse gas emissions. For some products, such as motor vehicles, the use of such standards would imply the imposition of trade restrictions that would be legal and relatively easy to apply.[28] For example, all vehicles sold in the United States today must meet emission standards which require the use of catalytic converters. Imports of vehicles not complying with the U.S. standards are prohibited, and this trade restriction is compatible with WTO rules.[29] A similar restriction could apply to new types of motor vehicles, as required by a new climate protocol.

The strategic advantage of such standards is that they can create a positive feedback. In the case of motor vehicles, for example, the greater the number of countries adopting a given standard, the greater would be the incentive for manufacturers to press for common international standards. Evidence of this effect comes from the fact that vehicle emission standards requiring the use of catalytic converters are becoming the global standard (Barrett 2003). A positive feedback for automobiles is aided by a number effects. Network externalities associated with refueling needs of alternative types of fuel in areas of frequent cross-border travel, such as the European Union, could lead to demand for common standards. Likewise, economies of scale in production mean that manufacturers are likely to resist significant differences among national standards. Finally, the burden of proof can weigh heavily on countries that have not yet adopted a standard.

Having highlighted the viability of the technology-standard approach in theory, we also wish to emphasize the limits of the MARPOL treaty analogy. Maritime oil pollution is obviously a vastly smaller problem than global climate change, and the costs of taking action in that realm were trivial compared with the costs of addressing the climate change threat. Also, a single technology could be specified in the case of oil tankers,[30] whereas cost-effective emissions reductions of CO_2 and the other greenhouse gases will require fundamental changes in technology throughout the global economy. Also, ports had a strong incentive to ban non-complying tankers because of risks of local spills, whereas the global commons nature of climate change eliminates that effect. And whereas some of the network effects do apply in the case of motor vehicles, the same would clearly not hold for power plants. Moreover, technology standards would be very attractive in the oil tanker case, even if it were an exclusively domestic problem, because the costs of monitoring emissions in that case are prohibitive. Monitoring requirements in the climate change context are severe, although not necessarily prohibitive.[31]

The oil tanker analogy, imperfect though it is, raises some interesting issues. For one thing, it is a reminder of the trade-offs that exist among the suite of potential environmental policy instruments. Whereas technology standards may dominate performance standards, including market-based instruments, in terms of related monitoring (and hence, enforcement) costs, these same technology standards are inferior to performance standards, particularly market-based ones, on both static and dynamic cost-effectiveness grounds. In static terms, it is well known that technology standards will not – in theory – and do not – in practice equate marginal abatement costs among sources; in other words, they tend not to minimize the costs of achieving an aggregate level of environmental protection. At the same time, however, market based policies that are actually adopted and implemented may diverge significantly from text book models (Hahn and Stavins 1992). For example, the carbon taxes adopted by several Nordic countries vary substantially by sector, mainly due to concerns about competitiveness. Similarly, the emissions trading program adopted by Denmark is backed up by a relatively small enforcement penalty, again because of concerns about competitiveness.

More important in the climate policy context, technology standards – even if a sufficient number of perfectly designed ones could be implemented for short-run cost-effectiveness – would not provide incentives for the invention, innovation, and diffusion of continuous improvements in technology. Indeed, the well-known irony is that technology standards tend to provide unintentional, perverse incentives that lock-in existing technologies and thus retard technological change. In other words, in stark contrast to the price signals provided by market-based instruments, technology standards are unlikely to be dynamically cost-effective. There may be ways to reduce this problem, but lock-in is more likely with technology standards than with market-based instruments.

Where does this leave us? Standards are likely to be significantly more costly than alternative approaches (if both types were fully implemented), in both the short-term and the long-term. But a well-designed standards approach is more likely to be successfully implemented than a targets-and-timetables approach, because of respective incentives for compliance and participation.[32] Hence, it is an empirical question whether the better international strategy is the one with "high payoff with low probability" or "low payoff with high probability." Creation of incentives for international cooperation is a problem of second best institutional design.

4. Conclusions

There is a large and rapidly growing literature on global climate economics and policy, and a considerable portion of that literature has focused on international approaches to addressing this global problem. We have examined the approach that is currently under active consideration by the world's policy community – the Kyoto Protocol to the U.N. Framework Convention on Climate Change – as well as alternative policy architectures. A number of deficiencies in the Protocol's approach have been identified by numerous observers, but one on which we have focused is its lack of incentives for participation and compliance. Are the alternatives any better?

Three elements that are common to most of the alternative architectures stand out: emission-reduction targets that are modest in the short-term, but increase in stringency; mechanisms such as growth targets intended to increase developing country participation over time; and the use of market-based instruments. The proponents of these architectures make the claim, correctly in our view, that *if they are implemented successfully* they can achieve climate goals at relatively low cost. This claim, however, may be said to beg the question that we have posed in this paper: how can participation and compliance in an international climate change agreement be increased? In other words, will these alternative architectures provide incentives that are likely to lead to reasonably high levels of participation and compliance – that is, to successful implementation?

To address this question, we have examined positive and negative incentives for participation and compliance, and asked whether various architectures include such incentives. On the positive side, we identified three generic incentives: explicit side payments among potential parties to an agreement; issue linkage; and the allocation of entitlements. Several proposals do call for direct transfers to bring developing countries into participation in an international agreement, although a more common feature is the use of an international tradeable permit system, which can provide implicit transfers. More broadly, market-based instruments, in general, can be thought of as providing positive incentives in the sense that they can reduce costs overall, and potentially for all parties. Growth targets for developing countries, linked with international tradeable permits, are a special case of this.

Providing positive incentives for participation and compliance is not difficult, but such provision is not sufficient to overcome the severe free-riding problems that plague efforts to address this global public goods problem. Negative incentives are also required. In a domestic context, the efficacy of such negative incentives is taken for granted because of the coercive power of states, but in the international context, the challenge is considerable. We identified three generic types of negative incentives: reciprocal measures; financial penalties; and trade restrictions.

Reciprocal measures are frequently employed in international trade relations, but trade is a bilateral exchange. The global climate policy context is one of a global public good which cannot be segmented effectively into a vast number of bilateral relations. In fact, this is the reason why the minimum participation clause in the Kyoto Protocol has such limited incentive effects. Financial penalties are a frequently employed device in domestic environmental regulations, but there is no international authority with the ability to impose credible penalties of sufficient magnitude. This leaves trade restrictions, which are included in at least two proposed policy architectures.

Trade restrictions can, in theory, promote greater participation in an international global climate regime, but they suffer from three major disadvantages. First, though straightforward in principle, it would be virtually impossible in practice to calculate a set of reasonable trade restrictions, since these would need to be linked with the greenhouse gases emitted in the manufacture and distribution of each and every good. Second, trade restrictions would not provide a credible threat. Virtually all traded goods result in greenhouse gas emissions (during their manufacture, if not their use), and restricting trade in all goods and services is simply not credible. Third and most important, the damage such restrictions would do to the multilateral trade regime would likely offset any advantage trade restrictions might offer in terms of participation in an international climate agreement.

The specifics of the global climate challenge thus reduce the likelihood of an effective pairing of conventional positive and negative incentives for participation and compliance within either the Kyoto Protocol or the alternative architectures which are likewise based on a targets and timetables approach. Although the common features of the alternative architectures – emission-reduction targets that begin modestly and become more stringent, inclusion of all countries, using mechanisms such as growth targets, and employment of market-based instruments, such as international tradeable permits – would, in theory, lead to a dynamically cost-effective approach *if successfully implemented* – our analysis suggests that the probability of sufficient participation and compliance (that is, successful implementation) is relatively low.

Other policy architectures, featuring domestic policies and measures, have been proposed. These would not be cost-effective relative to market-based instruments, but may promote greater participation and compliance. The options are not mutually exclusive, and the essential lesson is not that cost-effectiveness should be abandoned as a policy criterion, but that we need to move beyond the simplest policy proposals to ones which treat concerns for compliance and participation as more than an afterthought. National sovereignty demands that such concerns be part of the foundation for the design of multilateral institutions aimed at effecting global climate change mitigation.

If market-based instruments and other such cost-effective international policy regimes are unlikely to garner needed participation and compliance, then three alternatives remain, in principle. One alternative would be a powerful world government with coercive powers, so that national governments would be forced (by negative incentives) to participate and comply. Needless to say, such a solution is not likely to emerge (nor would it be desirable, for a host of other reasons). A second alternative would be "international volunteerism," whereby a change in national preferences would directly obviate free-riding tendencies. This also does not appear to be forthcoming. A third alternative is a regime of domestic policies and measures. This alternative is feasible and even likely. But, as noted in the introduction, the underlying structure of the climate problem means that countries will have little incentive to make significant emissions cuts unilaterally. Mitigation is a collective action problem of the first order. If emissions are to be cut substantially, the incentives to free ride must be changed. That is the central challenge for the design of a climate treaty.

Ultimately, both cost-effectiveness conditional on implementation, and probability of implementation are important. What seems clear at this juncture is that considerably more attention needs to be given – both by scholarly research and by international negotiations – to those aspects of international climate agreements that will affect the degrees of participation and compliance that can reasonably be expected to be forthcoming.

Notes

1. By "participation" we mean whether a country is a party to a treaty intending to mitigate emissions. By "compliance" we mean the degree to which a country that is a party to such a treaty implements the treaty's obligations.
2. These include the developed nations plus economies in transition.
3. The Kyoto Protocol designates these countries with emissions commitments as Annex B countries. With only a few exceptions, the set of countries with Annex B commitments is identical to the set of Annex I countries in the FCCC.
4. Transition economy countries were allowed to use a base year other than 1990 if their economic transition from central planning began prior to that date. Also, for all countries 1995 was employed as the base year of measuring changes in emissions of the synthetic greenhouse gases (hydroflourocarbons, perflourocarbons, and sulfur hexafluoride).
5. Kyoto established an emissions ceiling for Russia well below Russia's expected emission level – a difference sometimes referred to as "hot air." Without trading, the treaty does not limit Russian

emissions. With trading, Russia can sell its extra allowances without reducing its emissions. Trading thus allows buyers of Russian hot air not only to increase their emissions but to increase global emissions, and it is in this sense that the failure to restrict trading reduced the environmental effectiveness of the treaty. Hot air allowances made participation by Russia more attractive. But they also made the "tough" emission limits for other countries more acceptable.

6. It has been suggested that it is important for all countries to take on emission targets, because: (1) developing countries will account for more than half of global emissions by 2020; (2) developing countries provide the greatest opportunities now for relatively low-cost emissions reductions; and (3) if developing countries are not included, Annex B abatement will shift comparative advantage in the production of carbon-intensive goods and services outside of that coalition, and render developing economies *more* carbon-intensive than they otherwise would be.
7. The hybrid approach combining a tradable permit system with a "tax" (elastic supply of additional permits) has been examined by McKibbin and Wilcoxen (1997), Kopp, Morgenstern, and Pizer (1997), and Kopp, Morgenstern, Pizer, and Toman (1999), building on earlier work by Weitzman (1974) and Roberts and Spence (1976). A recent assessment is provided by Jacoby and Ellerman (2002).
8. For other commentaries on the potential for employing technological cooperation as a central architectural element, see: Buchner, Carraro, Cersosimo, and Marchiori (2002); Edmonds, Roop, and Scott (2001); Flannery (2001); and Jacoby (1998).
9. In a subsequent paper, Nordhaus (2002) provides a detailed comparison of price-based and quantity-based architectures, in which he strongly favors the former.
10. See, for example: Frankel (1999). In 1999, the Argentine government offered to take on an emissions commitment indexed to its economic growth. An analysis is provided by Lutter (2000).
11. Victor (2001) proposes to promote compliance through the use of a buyer liability scheme within an international tradeable permit system. However, this proposal does not address the participation problem.
12. The argument advanced by Chayes and Chayes (1995) is flawed in a number of respects. For critiques, see Downs, Rocke, and Barsoon (1996) and Barrett (1999, 2003).
13. A coalition of developing countries rebuffed New Zealand's call during the 1997 Kyoto Conference of the Parties for developing country commitments. The coalition has succeeded in keeping the topic off the agendas of subsequent Conferences of the Parties. While the case has been made that developing countries with emissions commitments could become net exporters of emissions allowances and thus enjoy gains from trade (Yellen 1998), this argument has generated little or no support in the developing world.
14. Senate Resolution 98 (June 12, 1997) states that the United States ought not be a signatory to any agreement under the Framework Convention on Climate Change which would "mandate new commitments to limit or reduce greenhouse gas emissions for the Annex I Parties, unless the protocol or other agreement also mandates new specific scheduled commitments to limit or reduce greenhouse gas emissions for Developing Country Parties within the same compliance period." The resolution refers to five developing countries by name: China, Mexico, India, Brazil, and South Korea. Subsequently, the Clinton Administration employed the phrase, "meaningful participation by key developing countries" (Eizenstadt 1998) in a deliberately loose interpretation of the Byrd-Hagel Resolution.
15. For example, Chayes and Chayes (1995) examined compliance but ignored participation. A critique by Downs, Rocke, and Barsoon (1996) did not distinguish between compliance and participation.
16. See our description, above, of Schmalensee's (1998) commentary on global climate treaty architecture.
17. In some cases, it is also conceivable that non-participants may increase their mitigation as the cooperating countries increase theirs (negative leakage).

18. Although such side payments are not common, they have been employed in some important cases. In the Rhine Chlorides agreement, the Netherlands, Germany, and Switzerland paid France to reduce chloride emissions at a potash mine; and in the Montreal Protocol, the industrialized countries paid for the "agreed incremental costs" of compliance by developing countries. For case studies of these two agreements, see, respectively, Bernauer (1996) and Benedick (1998). Both of these cases, and others, are also discussed in Barrett (2003).
19. Obviously, non-participants may either gain or lose from an agreement. Less obviously, even participants can lose. Though a country may be better off participating in a treaty, given the terms of the treaty and the decisions by other countries to participate or not, such a country may be even better off if the treaty did not exist.
20. Important differences exist. Developing countries are not subject to an emission ceiling in the Kyoto Protocol. Hence, there is a potential for CDM transactions to achieve emission reductions only on paper and for related transactions costs to be substantial. Kyoto also incorporates three funds to help developing countries. In contrast to the Montreal Protocol's Multilateral Fund, however, two of these climate change funds are voluntary. The third is mandatory, but it is to be spent on adaptation, not mitigation, and is financed by a tax on CDM projects.
21. Our use of the phrase, "negative incentive," does not include the simple reduction or removal of a positive incentive.
22. The need for punishments to sustain cooperation is one of the most basic insights to have emerged from the literature on repeated games; see Barrett (2003). Note, however, that not all problems requiring a treaty are cooperation problems. Some reflect a need to coordinate, and coordination does not necessarily pose a problem for enforcement. Later we consider how climate change mitigation might be transformed into a coordination problem.
23. Asymmetry can be important here. As noted by a referee, there can be a very large difference between discouraging non-participation by the United States and by Bhutan. It would be much more difficult to make a threatened punishment against the United States both severe and credible. But once the participation of the United States is secured, it is likely to be easier to entice other countries to participate. This, of course, is the source of much frustration for other countries, but it is also a reality that should be acknowledged.
24. The intention is that the second period ceiling should be agreed *before* the start of the first period, but there can be no assurance that countries will negotiate on this schedule, and as long as a country thinks it might find compliance difficult, it will insist on relatively weak emission ceilings for future control periods.
25. We consider only restrictions on goods related to the environmental problem. Chang (1995) also considers restrictions on trade in unrelated goods, an intervention he calls "pure trade sanctions."
26. Note, however, that capital flows may be affected, even with border tax adjustments. The full effect would depend on policy details, including any revenue recycling.
27. It is conceivable, however, that a set of BTAs could be developed by drawing on the average carbon content per dollar of value added at the three or four-digit SIC code level. Can cruder approximations work nearly as well? There is reason to believe that they would not. Sectoral differentiation – a common approach used by countries that impose carbon taxes – would raise costs and still fail to limit leakage appreciably (Hoel 1996; Oliveira-Martins, Burniaux, and Martin 1992).
28. Standards must conform to the Agreement on Technical Barriers to Trade, incorporated within the WTO.
29. A disputes panel has ruled against the Corporate Average Fuel Economy Standards, but this is only because these are applied to an entire fleet of automobiles.
30. Also, there is no distinction in the double-hulled tanker case, between adopting and using a technology, greatly reducing the monitoring and enforcement burden.

31. Existing satellite technology could be used to monitor the use of fossil fuels and even some emissions.
32. Buchner, Carraro, Cersosimo, and Marchiori (2002) find that an approach of combining environmental cooperation with technological cooperation would be better than a pure technology strategy.

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