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ADDRESSING COST:
THE POLITICAL ECONOMY OF CLIMATE CHANGE

JOSEPH E. ALDY

RICHARD BARON

LAURENCE TUBIANA

This paper is one of six in the Beyond Kyoto series examining core challenges in mobilizing an effective international response to global climate change. The Pew Center welcomes comments on the working drafts of the papers through September 1, 2003. Please forward comments to beyondkyoto@pewclimate.org.

I. INTRODUCTION

Greenhouse gas emissions occur as a by-product of virtually every type of economic activity, from driving a car to using a computer, operating a steel mill, or growing rice. Any effort to mitigate greenhouse gas emissions (GHG) will require investments in new technology and probably changes in behavior – in short, modifications to economic activity that will entail costs for society. These costs could be quite substantial for some activities and could vary significantly across countries. Strictly from an economic vantage point, then, it is important that any international strategy against climate change include measures to manage cost. But perhaps more importantly, effective strategies to address cost are key to securing the broadest possible participation in a climate agreement, and to ensuring that parties ultimately fulfill their commitments. Successfully addressing cost, in other words, is essential to achieving the goal of climate protection.

Since the start of international climate negotiations more than a decade ago, cost concerns have figured prominently. To promote compliance at least cost, the 1992 UN Framework Convention on Climate Change allowed for joint implementation among industrialized countries to meet their voluntary emissions goal of returning emissions to 1990 levels by 2000.[1] Cost minimization is also an overriding consideration in the very architecture of the subsequent Kyoto Protocol. Its market-based mechanisms – international emissions trading, joint implementation (JI), and the Clean Development Mechanism (CDM) – are designed to promote cost-effective mitigation among developed countries and investment in low-cost mitigation projects in developing and transition economy countries.[2] In negotiations over Kyoto's implementation rules, further cost concessions were granted to some parties through credit for GHGs sequestered through forestry and other sinks activities. Even so, the United States has flatly rejected the Protocol, and Australia has declared it will not ratify at this time, both citing cost as their principal concern.

Cost concerns will become even more critical in the next stage of climate diplomacy. Whether through a single, global framework, or through parallel regimes, any effort to deepen and broaden emission commitments will present larger cost issues than those encountered thus far. Effectively addressing those issues is key to advancing the international climate effort.

This paper examines the critical cost considerations that present themselves in international climate negotiations. Section II discusses two overarching issues key to understanding cost in the climate context: timing and uncertainty. Section III explores three critical dimensions of cost: aggregate cost, relative or distributional cost, and cost certainty. Section IV then applies those dimensions in an evaluation of various international policy options for managing cost. Section V summarizes the options and how well they address the three cost dimensions. The paper concludes with an assessment of the implications of cost for the viability and stability of a long-term climate change agreement.

II. OVERARCHING ISSUES

Broadly speaking, economics looks at cost through two different, interdependent lenses: efficiency and cost-effectiveness.

An activity is efficient in economic terms if in the long run the costs to society are justified by the resulting benefits. In the climate context, efficiency pertains most directly to the choice of a long-term goal – for instance, the level at which GHG concentrations in the atmosphere are to be stabilized – and the emissions path to achieve it. An efficient climate change policy would ideally result in the last unit of investment in climate protection, or marginal cost, yielding an identical unit of avoided climate damage, or marginal benefit. As long as the benefit of incremental investment exceeds the cost, it should be undertaken. At the point when the marginal benefit of an additional unit of investment falls below the marginal cost, it is more efficient to reallocate investment resources from climate protection to other socially beneficial purposes.

An activity is cost-effective if its goal is achieved at the lowest possible cost. In the climate context, the focus is ensuring the greatest possible GHG mitigation for every dollar or yuan invested. A cost-effective climate policy would ideally result in each greenhouse gas emitter investing the same amount for the last ton of emissions abatement it is required to undertake. If a policy requires two power plants to reduce emissions by an identical amount – even though the marginal cost is $10 per ton for one, and $100 per ton for the other – it is not cost-effective: the total cost is more than necessary to achieve the desired GHG reduction. It is important to recognize that cost-effective implementation is a prerequisite for a policy to be efficient. Yet even if a chosen goal cannot be fully justified on efficiency grounds it makes economic sense to achieve it as cost-effectively as possible.

While these core economic principles may be reasonably straightforward, their application is not. Calculating the efficiency or cost-effectiveness of a given climate strategy is complicated by a host of factors. Two of the most critical are timing and uncertainty.

TIMING

While environmental policies usually entail up-front costs (such as investment in a scrubber) to deliver benefits spread out over the future (such as reduced ambient particulate matter), few environmental risks exhibit such a stark divergence in the timing of costs and benefits as climate change. Greenhouse gas emissions can reside in the atmosphere for decades (e.g., methane), centuries (e.g., carbon dioxide), and even millennia (e.g., perfluorocarbons). These long atmospheric residence times imply that today's emissions may impact the global climate for hundreds of years. While past and current anthropogenic emissions currently influence the global climate, the more substantial impacts from an environmental and economic perspective will occur much later in this century and beyond (IPCC 2001). To effectively address the risks of climate change then requires efforts to abate emissions in the near term that will deliver benefits in the long term. The substantial lag time between costs and benefits complicates the political economy of developing an appropriate response to the challenge of climate change: policymakers do not like to impose costs on their publics if the benefits are so distant and uncertain.

In weighing potential investments, consumers and businesses ordinarily apply a discount rate to compare present and future costs and benefits. The discount rate assigns a reduced, or discounted, present-day value to a cost or benefit that will not be realized until some time in the future. For example, a return of $100 anticipated in 10 years is worth about $50 today if a discount rate of 7 percent is used. Climate change, however, presents much longer time horizons than typically encountered. With potential benefits from avoided climate change decades to centuries away and mitigation costs potentially starting soon, the efficiency calculation turns heavily on how the former are expressed in today's value. Benefits accruing 100 years from now will be worth 45 times more in present value terms with a 3 percent discount rate in lieu of a 7 percent discount rate. Yet there is no consensus on how to discount the far-distant future.[3]

Whatever emissions target is chosen, timing is critical to determining its cost. A priori, reducing emissions 10 percent from current levels by the end of the decade is necessarily more costly than doing so by 2020. The first scenario imposes a significant departure from the current trend: the early retirement of physical capital that could be operated for another decade. The second approach provides firms with more opportunities to make mitigation investments consistent with the turnover of their capital stock, resulting in a lower-cost adjustment. It also gives time for the development of more effective and lower-cost abatement technologies. However, the cost savings will be achieved only if the delayed target is firm enough to send a credible signal to investors, firms, and consumers. If pushing the commitment out by a decade implies postponing action *altogether*, this additional lead-time could instead mean higher cost as GHG-intensive technologies and behaviors become more deeply embedded and therefore more costly to change (Hourcade 1993, Grubb 1997). No matter how distant the goal, near-term action is needed to promote the development of technologies to achieve it most cost-effectively (Hourcade and Shukla 2001).

UNCERTAINTY

A second, and related, issue that complicates the choice of global climate change policy is uncertainty. There are significant limits to our understanding of both the physical and social phenomena at play – from climate processes and their localized impacts to future trends in economic and population growth. These uncertainties confound any assessment of the benefits and costs – i.e. the efficiency – of any climate strategy. Economic models rely heavily on assumptions – some simple, others quite sophisticated – to overcome key uncertainties. While helpful in comparing the relative cost of alternative policies and in characterizing the critical elements of a low-cost policy, modeling thus far is able to provide only crude estimates of the potential costs and benefits of climate action.

The ultimate goal of climate action – in other words, the anticipated *benefit* – is to avoid the deleterious impacts of climate change. Yet any projection of impacts rests on projections of atmospheric GHG concentrations, which in turn rest on projections of emission trajectories. There are significant uncertainties at each stage. Long-term emission forecasts reflect uncertainties over population growth, economic output, energy endowments and their prices, technological change, and land use activities – not to mention geopolitical changes. An effort by the Intergovernmental Panel on Climate Change (IPCC) to project long-term emission trends yielded six illustrative scenarios based on different story lines, with global carbon dioxide emissions in 2100 varying by a factor of six and concentration levels varying by a factor of two or more.[4]

For a given atmospheric concentration of greenhouse gases, substantial uncertainty remains about the magnitudes, variability, and geography of impacts such as temperature changes, precipitation patterns, sea level rise, disease incidence, etc. For the range of projected concentrations, projections of global average temperature increase by 2100 range from 1.4 to 5.8°C (IPCC 2001), and this global averaging masks additional variability in temperatures at regional and local scales. Substantial challenges also plague assessments of low-probability, large-impact events such as the collapse of the

Gulf Stream or the melting of the West Antarctic ice sheet. Even if these biophysical impacts could be accurately forecast, assigning economic values to them is by no means straightforward. Estimating the present value of non-market goods and services such as endangered species habitat, watershed protection, or reducing mortality risk involves substantial uncertainty. Extending these valuations hundreds of years into the future introduces yet more layers of uncertainty.[5]

Projecting the *cost* of climate action likewise entails substantial ambiguity. Uncertainties over future emission trends are important because the level of effort required to meet a given target must be measured from a presumed baseline of "business as usual" emissions growth. There are significant uncertainties as well over the likely social and economic responses to a given GHG mitigation policy. For instance, the costs will depend in large part on how easily consumers and producers can substitute away from carbon-intensive activities towards carbon-lean ones.[6] The more flexible and responsive firms and consumers are, the lower the costs. The rates of technological change and diffusion are also critical, and also hard to predict. Most models treat technological change as exogenous – assigning a price to GHG emissions stimulates the deployment of lower-carbon technologies, but not additional innovation – although in reality higher costs will almost certainly drive investment toward new technology. The models also are not adept at portraying different types of policy approaches. The models typically project cost impacts by assigning a price to greenhouse gas emissions – in effect, modeling every policy as if it were an efficient emissions tax or efficient emissions trading program.

These layers of uncertainty, and the widely varying assumptions used to overcome them, are reflected in the wide range of cost estimates in the economic modeling literature. For example, 13 models participating in the Stanford Energy Modeling Forum estimated the marginal cost of GHG reductions under the Kyoto Protocol – the cost of removing the last ton to achieve the Protocol's goal – from less than $20 to more than $200 per ton of carbon (Weyant and Hill 1999).[7]

Uncertainty over potential climate damage and the cost of mitigating it is all the more critical to the degree that they are irreversible: once elevated, atmospheric GHG concentrations will remain so for centuries if not millennia; and once expended, resources invested in mitigation are largely irrecoverable and no longer available for other private or social priorities (Fisher 2000).

On the cost side, uncertainty coupled with irreversibility tends to favor a less ambitious environmental objective. Firms would prefer to delay investment and gain new information that can allow for a better-informed decision in the future (Dixit and Pindyck 1994). From this perspective, there is value to postponing the investment and maintaining as much flexibility as possible about the appropriate type of investment until some of the uncertainty about costs can be resolved (Pindyck 2000).

From the perspective of climate damages, however, uncertainty coupled with irreversibility favors a stronger environmental objective (Arrow and Fisher 1974). If new information shows that the risks to the climate are not as serious as now believed, easing or removing emission limitations remains an option. If, on the other hand, new information shows the risks are greater, but little or no abatement action has been taken, society may have foreclosed the option of stabilizing GHG concentrations at the optimal level (Chichilinsky and Heal 1993). The potential for climate change damages to increase at an accelerating rate – faster than the rate of warming – reinforces the case for acting sooner (Webster 2002). Rather than a rationale for inaction, uncertainty is in this sense a powerful argument to begin acting now to avoid an irreversible change in global climate.[8]

III. THREE KEY DIMENSIONS OF COST

Three critical dimensions of cost confront negotiators as they attempt to forge an effective international response to climate change. They must, of course, consider the cost implications of a potential commitment for their country's economy as a whole. In fact, much of the economic analysis of climate change policy has taken a macro-economic perspective with results expressed in terms of losses or gains in gross domestic product (GDP) for countries or regions.[9] This *aggregate* measure of cost, however, is only of limited value without some measure of the distribution of cost – or possibly gain[10] – both between and within countries. The *relative* cost for various actors is therefore another essential dimension of the cost issue. Finally, the willingness of a country to take on a commitment depends in part on the how confidently it can anticipate the resulting costs. We refer to this third dimension as cost certainty.

For any given level of commitment, how a country chooses to meet it will have significant bearing on cost. This paper, however, focuses primarily on the international architecture and how its design opens or constrains the choices available to parties. The attractiveness of an international agreement will hinge in part on its capacity to alleviate – or, at least, not exacerbate – concerns about these three critical dimensions: aggregate cost, relative cost, and cost certainty.

AGGREGATE COST

The overall cost of GHG mitigation hinges largely on the stringency of the goal – which, as we have seen, is a function of both its magnitude and its timing – and the cost-effectiveness of the measures chosen to meet it. At the country level, the projected cost is most often analyzed and expressed as a reduction in GDP, or the country's ability to generate value added through various activities. While the change in GDP may be the most accessible aggregate cost concept within the policy arena, it is important to recognize that it does not fully reflect the economic welfare losses of a climate change mitigation policy. Other measures of the reduction in welfare, such as household consumption or employment, by illustrating potential losses more concretely, can strongly influence perceptions of cost and, in turn, the political viability of alternative approaches.

The cost of mitigation arises as companies and individuals undertake actions they would not have had they not been subject to a constraint on their emissions. Whether through a tax, an emissions quota, or regulatory action, the choices of technologies and behaviors that depart from "business-as-usual" are viewed as more costly. Either because less is spent on more productive activities or more is spent for the same economic outcome, reducing emissions entails reduction in value added and losses in GDP. These are the basic assumptions of computable general equilibrium models that have looked into the economic effects of various emission targets.[11]

The nature of the climate challenge suggests that aggregate cost is best minimized by allowing flexibility as to *where*, *when*, and *what* type of mitigation action is taken. Greenhouse gas emissions fully mix in the atmosphere, so a ton of carbon dioxide abated in Boston yields the same benefit to the climate as a ton abated in Berlin or Beijing. To minimize costs, abatement should occur where it is cheapest. Since changes in the climate reflect greenhouse gas concentrations (the long-term accumulation of emissions), the exact timing of emissions abatement does not matter. The climate is not sensitive to annual variations in greenhouse gas emissions, so some flexibility in the timing of emissions abatement can result in lower costs with no adverse climate impact.[12] Several gases contribute significantly to warming – carbon dioxide, methane, nitrous oxide, perfluorocarbons, hydrofluorocarbons, and sulfur hexafluoride – arguing for a policy that provides incentive to focus on those whose reduction yields the greatest climate bang for the buck.[13] In addition, a ton of CO_2 sequestered yields the same climate benefit as abating a ton of CO_2 emissions so a cost-minimizing policy should include sequestration as well as abatement measures.

The international architecture of the Kyoto Protocol provides all three elements of flexibility: its trading mechanisms exploit *where* flexibility; the five-year commitment period and the possibility to bank reductions for use in the future reflect *when* flexibility; and the so-called basket approach (covering six gases, not only CO_2) and inclusion of carbon sinks address *what* flexibility.

In theory at least, these three forms of flexibility should lower the cost of meeting any given emissions objectives by ensuring that no economic agent or sector spends more than necessary to abate emissions. In economic terms, the marginal cost of reduction is then equal for all sources, and kept to a minimum, as sources seek to abate emissions at lowest possible cost and are encouraged to compete to provide least-cost solutions.

RELATIVE COST

In assessing the political acceptability of a climate agreement, aggregate cost may ultimately be less critical for some parties than relative cost – the distribution of costs both among and within countries. While the issue of relative cost is often portrayed as one of countries' competitiveness , it operates principally at the sectoral level. It arises when a sector competing in the international marketplace faces climate-related costs different from those of its competitors in other countries. Even if a country's aggregate cost or the impact on national competitiveness overall is minimal, the concentration of cost in discrete sectors concerned about competitive disadvantage can be a powerful domestic obstacle to an international climate commitment.

The potential competitiveness impact of a climate policy is a function of two factors: the total amount of reductions being asked from sources, and their marginal cost schedule to achieve these reductions. The first is a function of the country's total abatement commitment and of the allocation of effort among domestic sources. The second is a function of available technology but also of domestic and international policy, as some policy options allow participants to equalize marginal costs of mitigation.

Relative cost issues arise across different international dimensions. First, there are concerns among parties to an agreement with mitigation commitments – for instance, those developed countries ratifying the Kyoto Protocol. Even if two countries have comparable commitments, variations in their underlying economic and energy structures and implementation strategies may yield significant differences in relative energy price increases and, thus, the relative cost of compliance. A second set of competitiveness concerns arises between those parties to an agreement that have mitigation commitments and those that do not – in the case of Kyoto, between developed and developing countries. A third set of issues may arise between parties and non-parties – for instance, between the developed countries participating in Kyoto and the United States, which has not taken on a comparable commitment.

Relative cost differences influence not only the political viability of a climate agreement, but also its environmental effectiveness. This is usually illustrated by the notion of emissions leakage: emission reductions in one place are partly offset by emission increases elsewhere that otherwise would not have taken place. As an illustration, the implementation of GHG reductions would likely increase the cost of using energy. Some energy-intensive industries may attempt to avoid this increase by relocating plants or shifting production to countries with lower costs.[14]

Another type of emissions leakage can result from impacts on world energy prices. Countries that adopt mitigation measures would reduce their consumption of fossil fuels in response to higher domestic energy prices. The reduced demand would depress world energy prices, especially in internationally traded fuels such as crude oil and to a lesser extent coal.[15] This could adversely affect the terms of trade of major crude oil exporters, such as members of OPEC, although they could take measures to maintain their export revenues.[16] Countries without emission commitments could benefit from the lower energy prices and increase their petroleum consumption and emissions, again undermining the efforts of those countries with commitments. By reducing the environmental effectiveness of an agreement, the competitiveness and leakage concerns may reduce incentives to participate and comply with mitigation commitments. Estimates of leakage under Kyoto (assuming U.S. participation) ranged from 5 to 20 percent.[17,18]

Finally, the distribution of costs *within* a country can significantly influence its willingness to participate in an international policy regime. Fossil fuel energy producers, energy-intensive industries, consumers, and workers in these industries are likely to bear a larger share of the burden of an emissions mitigation policy. In contrast, suppliers of energy-efficient and renewable energy technology or forestry and agricultural firms that engage in carbon sequestration may benefit from such a policy. The effectiveness of these various actors in influencing a country's climate change policy can determine in part the position that country takes to international negotiations, how it may advocate for various means of implementation to improve the lot of its domestic constituents, and its willingness to accept and participate in a final agreement.

The design of an international agreement can ease or exacerbate each of these facets of relative cost. It would be a fallacy, however, to assume that there exists an approach that would preserve the current status of international competitiveness in carbon-exposed industry. The changes required to effectively address climate change are too far-reaching, and involve substantial differences in impacts on the owners or various types of fossil fuel resources (Pershing 2000). However well an international agreement can minimize differences in relative costs across countries, it may ultimately fall to domestic policy to redistribute the burden domestically in order to allay competitiveness concerns.

COST CERTAINTY

Another critical cost dimension influencing a country's willingness to accept and meet a climate commitment is the predictability – or certainty – of the costs it entails. A regime that provides greater certainty may promote stronger participation and compliance.

In entering into a climate agreement, national governments must secure the support of their constituents based on an expectation of the resulting costs and domestic policy implications. If realized costs vastly exceed expected costs, the probability of non-compliance would increase. Even the existence of an international emissions trading regime may not help if unexpected excess demand results in allowance price spikes causing either unacceptably high compliance costs or triggering non-compliance.[19] Further, some countries may use this as a rationale to opt out of the agreement. A climate policy resulting in realized costs well in excess of expected costs may also undermine the credibility of the international policy regime and the prospects for stronger commitments and broader participation in subsequent rounds.

Certainty is also critical to the firms that in the end must deliver on a government's commitment. Businesses have a well-known aversion to regulatory uncertainty: new regulations (including environmental rules) can affect the profitability or sometimes the viability of industrial activities. Greater cost certainty can facilitate better investment strategies, allowing firms to adjust their behavior over time to mitigate the costs of the policy change. For example, an unexpected 25 percent increase in the price of energy in 2010 would have a much more negative impact on firms and the economy than the same price increase anticipated ten years in advance. The former case may resemble an oil price shock while the latter allows time to reduce the energy intensity of the economy in response to the expected price change.

Firms have no substantial interest in the aggregate cost of climate change policy, unless it requires responses in macroeconomic policies (e.g., monetary policy). Their interest is primarily in the direct costs they will face. A policy that provides greater certainty about marginal cost may therefore address the firms' concern even if it reduces uncertainty over their total cost only marginally if at all. Still, such a policy can help overcome political opposition to a climate agreement and increase the probability that a country will comply with it. Moreover, increased cost certainty may enable a country to take on a more ambitious commitment than it otherwise could, facilitating a stronger agreement and greater net climate benefits.[20]

IV. SHAPING THE LONG-TERM CLIMATE REGIME

A number of international policy options have been proposed that offer different solutions to concerns about costs. This section assesses how several of the more prominent proposals would perform vis-à-vis the three dimensions of cost described above. They include international emissions trading, a safety valve, indexed targets, sectoral targets, non-binding targets, and two non-quota based approaches – harmonized taxes and technology standards. Some of these policy options can complement each other, such as international emissions trading and the safety valve and a suite of developing country commitments that may include indexed targets, sectoral targets, and even forms of non-binding targets.

INTERNATIONAL EMISSIONS TRADING

Governments can promote cost-effective achievement of a given level of GHG mitigation through policies that ensure that all emissions sources face the same marginal cost of reduction. If one source faces higher marginal costs than a second, the latter could abate additional emissions while the former abates less and the same environmental outcome could be achieved at lower total cost. The same holds across countries. While both an emissions tax and a tradable emissions allowance program can result in this equalization of marginal costs across sources and countries, the international negotiations have given preference to the latter, based on legally binding emissions targets. This is the approach taken by the Kyoto Protocol. The main advantage of emissions trading over taxation is that it also allows a negotiation over the distribution of cost, via the setting of country targets.

An abundant literature supports the cost-minimization advantage of international greenhouse gas emissions trading.[21] While economic models offer a rather large range of marginal cost estimates for implementing the Kyoto Protocol, they support the robust conclusion that trading can reduce overall costs (Weyant and Hill 1999). In the case of Kyoto, cost reduction hinges partly on the availability of excess allowances in countries in transition (especially Russia and Ukraine) but the main factor is the efficiency gain achieved by not requiring countries to meet their obligations exclusively through domestic measures. A country with a high marginal cost of abatement has a direct interest in paying a country with a lower cost to make the necessary reductions.[22]

These remain, nevertheless, theoretical results based on macro-economic models, assuming efficient domestic policies that relay the price signal provided by the international emissions trading system. These models assume that all sources in all countries with emissions commitments effectively participate in a perfectly efficient international emissions trading regime.[23] In practice, however, while some governments may choose to allocate some of their emissions commitments to large industrial sources and allow them to trade on that basis (i.e., as currently envisioned in the European Union), they may regulate emissions from other sources and sectors of the economy through alternative approaches. Some governments may implement "upstream" trading regimes (where the introduction of carbon into the economy is subject to an aggregate quota, and these upstream firms, such as coal mine operators and crude oil suppliers, would trade among themselves) in order to address all emissions from all sectors – and attempt to come closest to the ideal reflected in economic models. Still other governments may decide to implement domestic emissions mitigation policies that involve no devolution of emissions allowances and no direct role for their private sector in an international emissions market. In contrast to the economic models, the international market may be characterized by transactions among large industrial sources and governments of those countries with commitments.

Without perfect foresight and the capacity to change policies rapidly, governments may find themselves short of emissions allowances at the end of a commitment period. They would then have to consider buying allowances on the international market at any price – a far cry from the standard economic modeling of GHG emissions trading regimes. Governments also may not possess good information about the marginal cost of achieving reductions in activities that are not directly linked to the trading regime. The notion that they would take action up to the point where the cost reaches the price of internationally traded allowances does not stand the test of even simplified market experiments.[24] There may also be barriers to international transactions, or biases introduced by different regulatory regimes – domestic commitment periods of different durations, different penalty levels, limited access to the international regime, etc.[25] Despite these limitations, it is widely agreed that emissions trading is among the most effective means of minimizing the aggregate cost of GHG reduction.

Emissions trading also helps address relative cost. By ensuring that all sources have access to the same least-cost potential to comply with their objectives, emissions trading reduces the competitive differentials that may exist when sources in different countries face various marginal costs of abatement. This also reduces leakage by lowering incentives to relocate. In addition, a domestic trading system linked to the international system can help address relative costs within a country. A government could auction emission allowances and use some of the proceeds to finance transition assistance for workers in energy-production and energy-intensive industries who may lose their jobs under the climate change mitigation policy. A government also could return some of the auction proceeds to adversely impacted industries and leave them no worse off. Alternatively, a free allocation of some or all allowances would compensate sources for the negative effects of an emissions constraint, as shown by various economic analyses.[26]

International emissions trading can reduce some of the uncertainty about costs. A well-functioning international emissions market can help absorb country-level spikes in emission, e.g. weather related, and limit their impact on compliance costs. Instead of undertaking costly domestic abatement to offset the effects of the weather, a country could purchase allowances from other countries at a more reasonable cost. The likelihood that trading does reduce cost uncertainty depends on how the institution evolves over the next decade and countries' participation decisions. If emissions trading does not lead to a liquid and efficient market, it may not offer many cost-saving opportunities or insurance against unexpectedly high domestic abatement costs. The role of countries likely to be large buyers or sellers of emissions allowances will influence the expected price of allowances in the international market. How they implement reductions domestically – with or without domestic emissions trading – will influence how reliable and competitive the international market will be.

QUANTITATIVE TARGETS WITH SAFETY VALVE

The approach to emissions commitments in the Framework Convention and the Kyoto Protocol focuses on quantitative targets reflecting historic greenhouse gas emissions. A variant that may offer greater cost certainty would maintain quantitative targets but incorporate a "safety valve" mechanism to insure against unexpectedly high costs. While the quantitative targets would determine countries' emissions allocations, countries would have the option to go to an established central authority and buy additional emissions allowances at a predetermined price.[27] This option would effectively put a ceiling on the price of nationally or internationally traded allowances and thus provide an upper limit on the *marginal* cost of compliance.

Some may view – or characterize – the safety valve as an indirect way to impose a harmonized emissions tax.[28] If the price is set low, it would likely be binding and effectively convert the system of quantitative emissions commitments to a tax-based emissions regime. If the price is set "too low" – i.e., below the forecast cost of the quantity target (and not as an insurance mechanism) – it could provide less incentive for the near-term R&D investment necessary to produce lower-cost abatement technologies than a system of fixed quantitative targets. With less price-induced innovation, the long-run cost of abating greenhouse gas emissions could then be higher with a safety valve than with the same set of targets.[29]

If, however, the objective is to guard against unexpectedly high mitigation costs (as opposed to the marginal cost that negotiators expect when reaching agreement on commitments), then the safety valve should be designed to function as an insurance mechanism: the price should be set above the forecast marginal cost of complying with a policy's quantitative emissions commitments. For the purposes of this discussion, we will focus on the safety valve as an insurance mechanism.[30]

Theoretically at least, the safety valve would have no impact on forecast aggregate cost. If countries do not expect to rely on the safety valve, then incorporating this mechanism in the international policy framework would not affect their forecasted cost estimate. Ex post, the safety valve would only reduce aggregate costs relative to a policy without a safety valve if the costs of abatement were unexpectedly high. The safety valve provides greater, but not absolute certainty with respect to aggregate cost. Countries would know the maximum they would pay for each ton above target, but not exactly how many tons they would need to offset at that price.

The primary tradeoff for greater certainty about the marginal abatement cost is greater *uncertainty* about the environmental outcome. Countries are free to exceed their emission commitments provided they are willing to pay the agreed price. However, the insurance provided by the safety valve may increase the willingness of countries to take commitments and the likelihood of compliance, and hence actually increase the certainty of achieving at least some environmental benefits.

INDEXED TARGETS

Both the Framework Convention and the Kyoto Protocol employ absolute targets aiming to reduce emissions from a base year by a given percentage. An indexed emissions target, by contrast, does not fix the quantity commitment at the time of the negotiations. Instead, it adjusts the quantity commitment based on measures of economic performance or other potentially relevant indicators. For example, Argentina proposed a commitment indexed to the square root of its GDP: a 10 percent increase of its GDP would add roughly 5 percent to its emissions goal. The United States has set a voluntary goal of reducing its ratio of greenhouse gas emissions to GDP to 151 million metric tons per million dollars by 2012 (from the 2001 ratio of 183).[31]

Indexing can address the uncertainty about absolute quantity targets that has raised concerns on both environmental and development grounds. Some developing countries argued that they could not adopt emissions commitments, even targets that allowed emissions growth beyond current levels, because of the difficulty in forecasting emissions and concerns that an absolute target could constrain economic development. This risk that an absolute quantity target could be excessively stringent and entail too high an aggregate cost could be addressed by indexing the target to economic growth. If a country grew faster than expected, then the indexing formula would increase the total quantity allowed under that country's commitment. However, since a GDP-based formula includes only one factor influencing the effective stringency of an emissions commitment, it does not eliminate cost variability nor provide certainty on the marginal cost of compliance.[32] For example, it does not offer insurance against weather-related shocks, energy price shocks, or changes in the expected rate of technological innovation and diffusion (except through their indirect effects on GDP).

Indexing can address another risk raised by setting absolute emissions objectives years in advance, the creation of so-called "hot air" – a quantity commitment in excess of a country's emissions even in the absence of any emissions abatement efforts. With an indexing approach, if a country grows much slower than expected, the total quantity allowed under that country's commitment would be reduced, thereby reducing or eliminating the prospect of a commitment becoming a hot air target. An indexing approach could be designed to effectively eliminate the possibility that a country would bear exorbitant mitigation costs as well as the possibility that it would not bear any mitigation costs.

Integrating such an approach with international emissions trading may encounter some challenges. For instance, a country may find it easier to allocate emissions allowances from an absolute, Kyoto-type quantitative target to industrial sources and allow them to engage in international emissions trading than to do so based on an indexed emissions target in which the number of tons, and thus number of allowances, are not known with certainty in advance of the commitment period. One approach would be to index the emissions commitment to economic growth between the date of negotiating the international agreement and the year before the commitment period begins, instead of through the entire commitment period. The quantitative emissions target would then be a fixed, absolute quantity at the start of the commitment period, just like the Kyoto-type targets. This would address the risk of committing to an absolute, quantitative objective that could be significantly influenced by a small change in economic growth over the time between the negotiations and the commitment period. This may reduce some of the benefits of indexing, but does provide an absolute quantity at the beginning of the commitment period in lieu of one determined at the end of the commitment period after the economic data have been compiled.

In designing an indexing approach, two principles are important. First, the indexing criteria should not create perverse incentives. For example, the preceding year's greenhouse gas emissions are a good predictor of next year's emissions, but including the previous year's emissions in a formula for an emissions target may create the incentive to increase the emissions intensity of the economy during the time leading up to the commitment period. Second, the indexing formula cannot be too complicated. The international climate change negotiations are already very technical, and complex formulas relating a country's emissions commitment to various predictors of emissions may be too difficult for the world's policy-makers to effectively negotiate. The U.S. and Argentine indexing approaches simply use economic growth as the indexing measure.

The form of the indexing approach can also influence the level of effort it ultimately entails. A more sophisticated form may allow for the effective emissions abatement effort to increase with GDP. If a country experiences faster than expected economic growth, and is thus wealthier, it would have to undertake more emissions abatement effort than if it grew more slowly than expected, and was less wealthy. The Argentine proposal, by allowing greenhouse gas emissions to grow with only the square root of GDP (instead of linearly in GDP), takes this form. In contrast, the Bush Administration target – a simple linear function, or ratio – would require more emissions abatement if the economy grows slower than under current forecast and less emissions abatement if the economy grows faster than under current forecast. For example, if the U.S. economy grows at 3.4 percent over the 2002-2012 period instead of 3.0 percent (the central economic forecast used in developing the climate change policy), the required emissions abatement effort would be reduced by nearly half.[33] In designing an indexing form, consideration of how greenhouse gas emissions change with economic output is necessary to ensure against policies that actually increase costs when the economy grows slower than expected.

SECTORAL TARGETS

Policymakers may consider an array of options for developing country emissions commitments more consistent with their capacity and resources than economy-wide quantitative targets like those established in the Kyoto Protocol. One approach would allow for commitments that focus on specific sectors or greenhouse gases instead of the entire economy and all six types of gases. First, few developing countries have the capacity to adequately monitor all greenhouse gases from all activities. Second, some activities and industries within a country may be responsible for a large fraction of that country's emissions and may be more amenable to emissions mitigation in the near term. For example, the power generation sector could be regulated more easily than other sectors in many developing countries. Instead of waiting for these countries to develop the capacity and regulatory infrastructure to allow them to take on economy-wide emissions commitments, they could adopt a power sector commitment.

The issues associated with the aggregate costs of a sectoral target are essentially the same as those in taking on an economy-wide commitment.[34] The magnitude of the costs will depend on the timing and stringency of the sectoral target. Such an approach does raise several questions about relative costs. It may reduce competitiveness concerns with respect to the affected sector – if it were in competition with other countries on the international market. Firms in developed countries with emissions commitments competing with those in industries covered by a sectoral target may appreciate the policy's impact in leveling the playing field. It would also reduce sector-specific leakage from countries with economy-wide targets to those countries with the sectoral target. Such a policy option could result in giving a competitive advantage to those activities outside of the sector with the target, and may result in emissions leakage, if substitutes to the products of the capped activity were to be available and to generate GHG emissions.[35] The net effect on emissions leakage will depend on the positive impact a sectoral target has in reducing leakage from countries with economy-wide commitments and the negative impact on inter-sectoral emissions leakage within the country. Sectoral commitments do not specifically promote cost certainty, but such an approach could be integrated with a safety valve.

A sectoral target could allow a country to engage in international emissions trading, at least based on the activities in the covered sector. Participating in trading could provide a potential source of financing for emissions abatement and technology improvements.[36] Such an approach could also be integrated in a Clean Development Mechanism framework, with a modification for a sector-wide (in lieu of a project-specific) baseline.

NO-LOSE TARGETS

Some developing countries may prefer a policy approach that completely eliminates the downside risk of mitigating emissions. Non-binding – or "no-lose" – targets coupled with international emissions trading may allow developing countries to experiment with emissions mitigation efforts.[37] First, an agreement on a country's business as usual emissions forecast must be made for the commitment period.[38] Then the country can consider implementing various emissions mitigation policies. At the end of the commitment period, the country's actual emissions are compared to its forecast baseline. Successful emissions mitigation would allow (but not obligate) the country to sell allowances representing the difference between the baseline and actual emissions to countries with binding emissions commitments. The opportunity to gain revenues from participating in international emissions trading would create the incentive for the country to abate emissions below its otherwise non-binding target.

The aggregate costs for such a policy would obviously be negligible if not negative. A country that implements such a policy would incur cost to abate emissions, but would only do so if the international emissions market price exceeded the domestic cost, hence generating a net gain. The country would not need to acquire allowances if its emissions exceeded projections. The approach is in fact similar to the Clean Development Mechanism: projects are only submitted if they achieve reductions and have something to sell.[39] If such a policy increased the number of countries participating in international climate efforts, it would reduce the aggregate costs to countries with binding targets that buy and finance emissions abatement in these developing countries. Promoting emissions mitigation in these developing countries could also reduce the incentive for emissions leakage. By eliminating the downside risk of a commitment, non-binding targets obviously provided certainty that the net costs of participating in climate policy should not exceed zero.

A variant of this approach could encompass both developed and developing countries.[40] Instead of agreeing to quantitative targets, countries would agree on their business as usual emissions forecasts for a commitment period and financing for a central authority. This central authority would then solicit bids for emissions abatement from countries. Once countries demonstrate that they have delivered the actual emissions abatement, the central authority would then pay the agreed bid price. This would have the same economic properties as a trading regime; in this case, the central authority would be the allowance buyer and all countries would be sellers. The commitments could be differentiated in terms of countries' obligations to finance the central authority, not unlike funding for the United Nations. It is not clear, however, what would make this a better option than a Kyoto-type approach where countries can design and implement their own mitigation policy without resorting to an international intermediary to finance them.

EMISSIONS TAXES

In contrast to the preceding discussion of policy options based on quantitative emissions commitments, a harmonized emissions tax would set a common world price for emitting greenhouse gases.[41] While emissions targets provide for certainty about the quantity of emissions, an emissions tax provides certainty about the cost of emitting another ton of greenhouse gases. By equating the marginal cost of emissions across all countries, an emissions tax can result in least-cost emissions abatement comparable to what would occur in theory under an emissions trading regime. An emissions tax can thus minimize aggregate costs, and provide certainty on marginal cost, but at the price of uncertainty in emissions abatement and without a possibility to negotiate over the distribution of cost across countries.

Some proponents of emissions taxes note that they can allow governments to substitute taxing a "bad" (e.g., pollution) for current taxes on "goods" (e.g., labor). This shift in taxation away from valuable factors of production could increase economic output and offset some of the costs of the climate change policy. The sizable revenues can also finance programs to alleviate the distributive impacts of climate policy, such as transition assistance for workers who lose their jobs, subsidies for low-income households to afford more expensive heat and electricity, etc. Note that in a domestic context, governments can employ a comparable approach under emissions targets by auctioning emissions allowances and using the auction proceeds in a similar fashion.

While emissions taxes appear to have favorable characteristics on the three key cost dimensions and could improve the means of government financing, the approach suffers from several drawbacks. First, emissions taxes clearly trade off emissions certainty for cost certainty. This trade-off appears sensible on economic grounds – research indicates that by reducing the uncertainty in costs, the net expected benefits of a price-based climate policy would exceed those of a quantity-based policy

(Pizer 2002**).** Second, governments could effectively circumvent the effect of an emissions tax by reducing other taxes affecting energy-related activities. For example, a government could reduce existing gasoline and diesel taxes in response to a carbon tax. This fiscal cushioning would undermine the environmental effectiveness of a climate policy without triggering non-compliance penalties (Wiener 1999a). Third, a harmonized emissions tax may not gain the acceptance of the developing world, just as quantitative targets in the Kyoto negotiations did not appeal to these countries. In fact, many of these developing countries continue to provide subsidies for the consumption of carbon-based energy[42] and may not be inclined to bear the costs of a greenhouse gas emissions tax, even if by effectively reducing energy subsidies it improves their economies' performances. Without the participation of these countries, competitiveness and leakage concerns between countries with taxes and those without could arise.

Finally, an emissions tax makes the costs of climate policy more transparent than a quantitative approach. Even if the impact on consumers' electricity bills, heating bills, and gasoline expenses is the same as under a tradable allowances program, a tax may be politically less palatable because it highlights the cost, presenting an easier target for opponents of climate action. This transparency also further complicates measures to promote an equitable distribution of the emissions abatement burden. Under quantitative targets, higher-income countries may induce lower-income countries to participate by granting them less stringent commitments (more emissions allowances). Under an emissions tax, these countries may need to make overt financial transfers to induce participation, which may not be as politically acceptable as granting extra emissions allowances.

TECHNOLOGY STANDARDS

The preceding sections have focused on the two primary means of achieving emissions abatement at least cost – quantitative targets with emissions trading and emissions taxes. An alternative approach could focus on an international agreement to finance climate-friendly R&D and mandate such technologies once they become commercially available.[43] Such a technology development effort would likely aim to deliver the breakthroughs necessary to significantly abate greenhouse gas emissions in the medium to long term, but with little of the near-term incentive for technology investment that might be provided by quantitative targets or emissions taxes.

A global technology standards agreement would not likely compare well with alternative policies in terms of aggregate, relative, or predictable costs. Policymakers and economists have learned through experience with domestic environmental policies that one size does not fit all. Imposing technology standards, perhaps tailored to specific industries, would not result in cost-minimizing emissions abatement because the technology would be very expensive for some firms and less expensive for others. An international negotiating body cannot implement technology standards in a manner that equates marginal costs among all affected firms. Allowing diplomats to select technologies – instead of the private sector operating under a clear market signal – may result in the choice of an unnecessarily expensive suite of technologies, raising aggregate cost. Further, the process of setting standards may risk regulatory capture – policy-makers with the mandate to design standards become strongly influenced by interest groups – resulting in greater disparities in abatement effort across industries (and countries), exacerbating the relative costs of the policy. Finally, a technology and standards agreement does not provide any certainty about the costs of climate policy.

While technology standards do not compare well with emissions trading and emissions taxes in terms of efficiency and cost-effectiveness, some have argued that they could address a fundamental problem in international environmental negotiations: securing participation and promoting compliance (see Barrett 2003). The voluntary nature of international negotiations effectively requires self-policing, even if some agreements call for "binding commitments." The Framework Convention and the Kyoto Protocol, like virtually every other international agreement, allow parties to withdraw from the agreement without explicit penalty. Promoting an international climate policy that can entice participation and achieve compliance requires an implementation that is consistent with the interests of all the negotiating parties – a much higher standard than necessary in the domestic context in which legal coercion can secure participation and compliance (Wiener 1999b). The Kyoto Protocol clearly suffers on these grounds given its inability to secure participation by the world's largest emitter, despite its cost-effective design. Whether these participation and compliance problems are fatal to *any* quantitative emissions commitments and whether a technology standards approach can effectively circumvent these problems are essentially empirical questions that merit additional research.

V. SYNTHESIZING THE OPTIONS

Each of the options described above has different implications for the three critical cost dimensions that present themselves in climate negotiations: aggregate cost, relative cost, and cost certainty.

Regarding aggregate costs, an efficient international emissions trading system appears the most effective means of minimizing cost in any regime based on quantitative emissions targets. Emissions taxes could result in low aggregate costs, but it would be difficult to monitor their effective implementation at the national level – governments would have many ways to mitigate the impact of the emissions tax (by cutting energy taxes), which would yield higher emissions. Several forms of quantitative commitments can limit or eliminate aggregate costs – such as sectoral targets and no-lose commitments – and may serve as useful incentives for developing country participation. The safety valve and indexed commitments may take advantage of emissions trading and guard against unexpectedly high aggregate costs. A technology standards approach would result in higher aggregate costs than targets-and-trading or emissions taxes.

Regarding relative costs, an effective international emissions trading system again could help eliminate the differences in marginal cost across countries. In the ideal outcome – all countries adopting emissions commitments and participating in trading, with one global emissions allowance price – no incentive for industry to relocate would effectively exist. Less than full global participation, variations in domestic implementation, and possible trading frictions may be a more realistic outcome for some time. In contrast with a regime based on emissions trading, technology standards would likely result in substantial variations in costs across industries and across countries.[44] Emissions taxes could achieve comparable outcomes to a system of quantitative emissions targets with trading with respect to marginal cost, so long as fiscal cushioning is not pursued. While international regime design may have a significant bearing on relative cost, in the end the choice of *domestic* measures may be just as critical in minimizing competitiveness impacts.

Regarding cost certainty, the standard Kyoto-type target provides very little certainty. In contrast, modifications to quantitative targets such as the safety valve or indexed targets could reduce the uncertainty in marginal cost. The safety valve, functioning basically as an insurance mechanism to quantitative targets with trading, would eliminate marginal cost uncertainty at some threshold – along the same line, an emissions tax would provide full certainty on the marginal cost of compliance. The indexed targets would limit uncertainty, at least that associated with economic growth and other potential measures used to index the commitment. No-lose targets eliminate the downside risk of an emissions commitment, but such an approach obviously can only be pursued by a subset of countries. There would otherwise be no buyers of emissions allowances to provide the incentive for countries to abate their emissions below their forecast no-lose objective. In all of these cases, increasing certainty about costs presents a trade-off to policymakers: it reduces the certainty about the environmental objective.

It is important to note that these policy options are not mutually exclusive. They can, in fact, complement each other in an international regime, and coordination among them can help further address cost concerns. For instance, different categories of countries could take on different types of commitments, with higher-income countries adopting Kyoto-style quantitative targets and lower-income countries first adopting some form of sectoral and/or no-lose targets. Coupled with a system of international emissions trading, this suite of policies could allow for lower aggregate costs for a given level of emissions abatement than the current approach under the Kyoto Protocol focused almost exclusively on the industrialized countries. Another example could involve industrialized countries adopting indexed emissions commitments and some developing countries again taking on no-lose commitments. At the end of the commitment period, the developing countries with excess emissions credits could sell these to industrialized countries so they could comply with their indexed commitments, although this ex post trading may complicate the development and evolution of an efficient trading mechanism.

VI. CONCLUSIONS

Many factors influence the viability of an international climate agreement – not only its political acceptability in the first instance, but also its stability over the long term. Acceptability will hinge heavily on questions of fairness: whether countries feel the agreement provides for an equitable sharing of burdens and benefits.[45] Developing countries will carefully assess whether a proposed agreement is compatible with their development priorities and, particularly for those most vulnerable to climate impacts, whether it addresses their adaptation needs. In the long run, an agreement will prove viable only if it provides sufficient pressure or incentive for parties to in fact fulfill their commitments. To be effective, a climate agreement must in other words promote both participation and compliance. And how well it manages cost is more than a strictly economic concern; it is critical to achieving both.

There is, in fact, a two-way interaction between cost and participation. Clearly approaches that minimize, or provide greater certainty over, cost can help draw more countries into an agreement or even foster more ambitious commitments. As different approaches may best suit the circumstances of different countries, this suggests a flexible architecture that accommodates multiple types of commitments. Broader participation can, in turn, ease the cost of meeting a collective climate target. Compatibility with an international emissions trading system would ensure that each country minimizes its aggregate compliance cost. Competitiveness impacts and emissions leakage would also be reduced.

With more countries participating in trading, emissions allowance prices would be subject to less uncertainty and variability. It is important that the current fragmentation of climate policy approaches does not become permanent: the cost of GHG mitigation in various regions could diverge to the point where reconciling regimes become unfeasible. This would hinder a broad based emissions trading mechanism in the future, lead to higher costs, and deter more ambitious abatement goals.

Action on climate change by necessity entails decision-making in the face of uncertainty. Our limited understanding of both physical and social systems allows only a crude approximation of either the costs or the benefits of any climate strategy. In the absence of better data, economics can offer guidance on the most cost-effective ways to reduce greenhouse gas emissions. Experience has demonstrated the value of market-based approaches in minimizing the cost of achieving a given environmental goal. While taxes or trading might appear equally effective in strictly economic terms, the international community has shown a strong preference for trading, which is likely to remain central to any future multilateral climate strategy. The implementation of Kyoto will provide crucial lessons on the real-world performance of this mechanism.

More difficult is the question of efficiency – deciding the right balance between costs and benefits. The uncertainties over both are too great to allow a reliable economic rendering even with the most sophisticated modeling. The balancing must, in the end, be a political calculation. It is premised in part on the perceived need: how much action do we think is necessary? But it rests also on willingness to pay: how much action do we think we can afford? In searching for the appropriate balance, countries will seek to narrow the range of uncertainty. One approach is to favor certainty on the environmental outcome, for instance through a fixed target that delivers a given emission reduction. This raises the question of whether the target can be reasonably attained. Another approach is to favor certainty on cost, for instance through a safety valve. While the affordability of the commitment may be more apparent, the environmental outcome is less certain. As the ultimate goal is reducing GHG concentrations in the atmosphere, however, flexibility on the near-term emissions target may be deemed acceptable, particularly if the assurance of affordability allows a more ambitious goal.

Cost is an economic term. But in the political arena, particularly when the data are so uncertain, what may matter most is not cost in the true economic sense, but rather how cost is presented and perceived. The safety valve that some may promote as "insurance," for instance, may be derided by others as an unbearable "tax" and yet by others as an "escape clause." The latter argument was used by non-governmental organizations to lobby against this option at the Sixth Conference of the Parties in The Hague.

Experience with emerging climate policies, particularly the international and domestic emissions trading systems and the full suite of domestic policies now taking shape, will provide stronger insight into the best ways to manage the costs of mitigating climate change. The lessons learned may help replace competing perceptions with a clearer consensus on the best approaches, allowing a more effective and durable international response to the challenge of climate change.

ENDNOTES

[1] Article 4.2(a).

[2] While economic modeling and the successful U.S. experience with sulfur dioxide trading supported the view that GHG trading would be critical to making Kyoto's emission targets affordable, the usefulness of this tool was not universally recognized during the Kyoto negotiations. However, even reluctant parties, such as the European Union, have since embraced the concept of emissions trading as evident in the effort to implement an EU-wide trading program to reduce emissions from industrial sources.

[3] See Weitzman 2001, Newell and Pizer 2001, and Philibert 2003.

[4] Nakicenovic et al. 2000.

[5] Refer to Nordhaus and Boyer 2000 for a recent attempt to monetize the costs of global climate change.

[6] See Jorgenson et al 2000.

[7] These estimates assume full participation of all countries listed in Annex B of the Kyoto Protocol in the trading regime, including the United States.

[8] Aldy, Joseph E., Peter R. Orszag, and Joseph E. Stiglitz. 2001. Climate Change: An Agenda for Global Collective Action. Paper presented at Pew Center for Global Climate Change Workshop on the Timing of Climate Change Policies, Washington, DC, October 2001. http://www.pewclimate.org/media/stiglitz.pdf.

[9] Weyant and Hill 1999; Hourcade and Shukla 2001

[10] See Hourcade and Shukla et al. 2001 for a discussion of negative cost potentials.

[11] ABARE, 1995, 1997; Richels et al., 1996, Weyant and Hill 1999.

[12] This may not hold true over very long periods of time, if damages from climate change were a function of the rate of change in global concentrations; Grubb et al. (1995) argue that this would call for more reductions early. Wigley, Richels, and Edmonds (1996) argue that fewer reductions now would not endanger our capacity to control the world's climate, provided that accelerated reductions occur in the future. The GHG absorption capacity of the climate system would allow more overall emissions and therefore a lesser constraint, if more emissions were released early. A critique of this approach on economic grounds was provided by Grubb (1997).

[13] Expanding the coverage from energy-related CO_2 to CH_4 and N_2O, including emissions from agriculture lowers the GDP cost for Annex I countries by some 30 percent (OECD, 2000). Reilly et al. (2003) arrive at a similar result for the United States, when all gases six gases are taken into account instead of carbon dioxide only, if the US were to meet its objective under Kyoto through purely domestic measures.

[14] However, empirical evidence indicates that multinational companies often use an identical technology irrespective of country location implying that new plants will probably have an efficiency far above the average level in the host country. (Jaffe et al., 1995). This is likely to reduce the potential for GHG leakage.

[15] Natural gas, however, could benefit from a GHG advantage against coal, especially in power generation. Depending on the stringency of the GHG constraint, this could result in a net increase for natural gas for some time.

[16] The effect on major oil exporters will depend on how they respond collectively in terms of production and further exploration. Note that in response to depressed world petroleum demand after the Asian financial crisis in 1998 and 1999 (when crude oil prices fell to nearly $10 per barrel), OPEC effectively increased the size of the cartel by engaging in informal production agreements with non-OPEC members, such as Mexico. This effort, coupled with increases in demand, supported a tripling the price of crude oil in less than a year. Research by OPEC Secretariat staff shows that such an approach could maintain OPEC crude export revenues at forecast levels under the implementation of the Kyoto Protocol (Ghanem et al 1999).

[17] Hourcade and Shukla, 2001.

[18] In contrast to this literature on leakage, some recent research has shown the potential for positive technology spillovers to reduce greenhouse gas emissions in countries without emissions commitments. Grubb et al. (2002) evaluated the Kyoto Protocol and found that, by accounting for technology spillovers to non-Annex I countries, global emissions may grow more slowly.

[19] Refer to Harrison (2003) for a review of the RECLAIM trading program during the 2000 California electricity crisis when nitrogen oxide permit prices increased more than tenfold and aggregate emissions exceeded the regulatory cap.

[20] IEA, 2002.a.

[21] Hourcade and Shukla 2001; IEA, 2001; Edmonds, Scott et al., 1999; Weyant and Hill, 1999; Richels et al., 1996.

[22] However skillful the negotiators are in agreeing to emission goals, it is unlikely that countries' commitments will ever result in equal marginal costs across countries and therefore make international emissions trading redundant. In addition, if this had been negotiators primary objective, they would of course had chosen the tax approach, as this provides full certainty about the marginal cost of reduction.

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[23] See IEA, 2001 for further discussion on this issue. Although eco-taxes and tradable permits have a role to play in curbing GHG emissions and are already used in a number of countries, a range of activities are covered by other policy instruments of a regulatory or fiscal nature (IEA 2002.b).

[24] A simulation conducted by the IEA for governments of Annex I Parties showed that the theoretical efficiency gains may not be met as governments and market participants would face uncertainty about future allowance prices, about overall market size – it takes about two years to finalise a country's GHG inventory, and would be subject to policy inertia – once negotiated and launched, domestic policies are unlikely to be reconsidered on the ground of variations in the international price of allowances (IEA, 2001).

[25] See Hahn and Stavins, 1999 for a discussion of these problems integrating international emissions trading with domestic policy regimes.

[26] See Bovenberg and Goulder 2000; Burtraw et al. 2003; Goulder 2001; and Kopp et al. 1999.

[27] See Kopp et al., 2000. This concept has received substantial attention from economists for three decades. See IEA, 2002.a for a summary of this debate, starting with the paper by Weitzman (1974) comparing price (i.e. tax) and quantity (i.e. tradable permits) instruments for pollution control under uncertainty.

[28] With the caveat that countries, not their sources, would be subject to this "tax." How they implement it domestically is entirely up to them. They may well levy a tax on all fossil fuel uses to finance the purchase of the emissions over and above their target, e.g. a tax on 1,000 MtCO2 to pay for 25 $MtCO_2$: the price signal on energy users would be much lower than the safety valve.

[29] Conversely, an overly stringent target without a safety valve will result in too high a price, causing too much investment in climate-related R&D and diverting resources from investments with potentially greater social benefit.

[30] The economics of a safety valve as a backdoor implementation of an emissions tax can be inferred from the discussion of an emissions tax later in this section.

[31] The Argentine proposal reflects an evaluation of a number of emissions forecasts reflecting different assumptions about economic growth, the structure of the energy sector, and agricultural sector (especially livestock) emissions. Argentina's analysis indicated that its emissions would not likely grow in a linear fashion with economic growth, but instead would grow slower with economic growth, and that this would become more pronounced at higher rates of economic growth. For details on the Argentine proposal, refer to the Argentina National Communication, First Revision at http://unfccc.int/resource/docs/natc/argnc1e.pdf.

For details on the Bush Administration proposal, refer to http://www.whitehouse.gov/news/releases/2002/02/climatechange.html. For more information on indexing, refer to Lutter 2000 and Baumert et al 1999.

[32] Pizer, 2003 illustrates the variability in GHG intensity and questions how well these types of commitments would mitigate cost uncertainty.

[33] See Aldy, 2003 for details on this analysis. Note that whether the emissions abatement necessary to comply with a linear indexed commitment decreases with faster economic growth would depend on the composition of that country's economic growth.

[34] In addition, a sector-based commitment offers no guarantee that the cheapest potential for reductions is being exploited in the country that commits to this approach. The possibility, however, to sell allowances on the basis of such commitment may offset this loss in economic efficiency.

[35] IEA 2002.a.

[36] Interestingly, the EU emissions trading directive may create a precedent of sectoral targets for countries otherwise without commitments under the Protocol. A range of industrial activities of Cyprus and Malta, two accession countries, fall under the jurisdiction of the trading directive and should be given absolute cap to allow trading with other industrial companies in the rest of the EU.

[37] Philibert 2000.

[38] The no-lose target could also be set at some level below its forecast business as usual, e.g. to ensure that potential no-regret options are undertaken before a country achieves the no-lose target, and only starts selling tons when cost is incurred to achieve reductions.

[39] See IEA 2002a, for further details on this option.

[40] See Bradford, 2002.

[41] Refer to Cooper 1998 and Nordhaus 2002.

[42] IEA 1999.

[43] Refer to Barrett 2001, 2003 and Benedick 2001.
[44] For example, an obligation to adopt a capture and storage technology for fossil-based generation would entail a higher cost for a country whose generation is mostly based on coal than for a country where hydro and nuclear account for a large share of supply.
[45] Ashton, John and X. Wang. 2003. "Equity and Climate: In Principle and Practice." (working draft), Pew Center on Global Climate Change, Arlington, VA.

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