policy

Beyond Kyoto

Advancing the **international effort** against **climate change**

Joseph E. Aldy
John Ashton
Richard Baron
Daniel Bodansky
Steve Charnovitz
Elliot Diringer
Thomas C. Heller
Jonathan Pershing
P.R. Shukla
Laurence Tubiana
Fernando Tudela
Xueman Wang

PEW CENTER ON Global CLIMATE CHANGE

Contents

Addressing cost

The political economy of climate change

Joseph E. Aldy, Richard Baron, and Laurence Tubiana

I. Introduction

Addressing cost—and the perception of cost—is a central issue in fashioning an effective international response to climate change. 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 (GHG) emissions will require investments in new technology and probably changes in behavior—in short, modifications to economic activity that entail costs to society. These costs could be substantial for some activities and could vary significantly across countries. Strictly from an economic vantage point, it is important that any international strategy against climate change include measures to manage cost. Perhaps more importantly, though, addressing cost concerns is 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.

The question of cost is only partly an economic one. Even if economists were able to accurately forecast the full costs and benefits of climate action, their calculations would be received differently from individual to individual and from country to country. Some may consider cost considerations paramount while others will assign them a lower priority. The same costs, then, are perceived differently, and the willingness to bear costs is ultimately more a matter of politics than economics. The scope for differing perceptions is all the greater when the economic realities are themselves highly uncertain, as is the case with climate change. Widely divergent estimates of the potential costs and benefits leave those with a stake in the debate freer to characterize costs as best suits their interests. These characterizations, more than the underlying economics, may determine the ultimate policy outcome. A cost-conscious climate strategy, then, may need to concern itself as much with the perception of cost as the reality.

Cost concerns have figured prominently since the start of international climate negotiations more than a decade ago. 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 goal of returning emissions to 1990 levels by 2000.[1] Cost minimization is integral to 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 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. Yet despite these efforts to manage or minimize costs, the United States has flatly rejected the Protocol, and Australia has declared it will not ratify at this time, both citing cost as a 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 mitigation commitments will present larger cost issues than those encountered thus far. For developed countries, stronger commitments will push efforts past "no-regrets" measures like improved energy efficiency and force deeper shifts in capital investment. Developing countries, if they are to take on commitments, must be assured that they are compatible with their broader economic and development strategies. Effectively addressing these challenges is key to advancing the international climate effort. Even a well-designed and functioning international framework can go only so far in meeting countries' cost concerns; the economic impact of a mitigation commitment will depend also on the domestic measures chosen to implement it. These domestic choices, however, are beyond the scope of this paper. Similarly, while a full accounting of climate economics would include the costs of adapting to climate change impacts and the potential local benefits brought about by GHG mitigation, these two sets of issues are not explored here in depth. The focus of this paper, rather, is how mitigation cost concerns present themselves in climate negotiations and how they can best be addressed in the design of international climate measures.

Section II of the paper 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 mitigation costs. 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, euro, yen, or yuan invested. A cost-effective climate policy would ideally result in each GHG 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

The long-term nature of climate change confounds both the economic and political calculus of how best to address it. While environmental policies usually entail up-front costs (such as investment in emission control technology) 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 (CH_4); centuries, e.g., carbon dioxide (CO_2); and even millennia, e.g., perfluorocarbons (PFCs). 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 will occur much later in this century and beyond.[3] To effectively address the risks of climate change, then, requires emission abatement efforts in the near term that will deliver benefits in the long term. The substantial lag time between costs and benefits poses a political dilemma: 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.

With potential benefits from avoided climate change decades to centuries away, the efficiency calculation turns heavily on how they 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 among economists or policymakers on how to discount the far-distant future.[4]

Timing also strongly influences the cost of meeting whatever emissions target is chosen. A priori, reducing emissions 10 percent from current levels by the end of the decade is more costly than undertaking the same amount of abatement 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. Society's ability to control GHG emissions at a reasonable cost in the future depends heavily on the path chosen in the short run.[5] No matter how distant the goal, near-term action is needed to promote the development of technologies to achieve it most cost-effectively.[6]

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. However, while helpful in comparing the relative cost of alternative policies and in identifying cost-effective policies, 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 regarding population growth, economic output, energy endowments and energy 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 CO_2 emissions in 2100 varying by a factor of six and concentration levels varying by a factor of two.[7]

For any given atmospheric concentration of GHGs, there is substantial uncertainty as well about the magnitudes, variability, and geography of impacts such as changes in temperature and precipitation, 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 degrees Celsius,[8] and this 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—if only because future generations cannot express preferences at present.[9]

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.[10] 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 (they assume that 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. They typically project cost impacts by assigning a price to GHG emissions—in effect, modeling every policy as if it were an efficient emissions tax or 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.[11]

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.[12] 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.[13] 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.[14]

From the perspective of climate damages, however, uncertainty coupled with irreversibility favors a stronger environmental objective.[15] 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.[16] The potential for climate change damages to increase at an accelerating rate—faster than the rate of warming—reinforces the case for acting sooner.[17] Rather than a rationale for inaction, uncertainty is in this sense a powerful argument to begin acting now to avoid an irreversible change in the global climate.[18]

III. Three Key Dimensions of Cost

Three critical dimensions of cost confront nations as they attempt to negotiate an effective international response to climate change. Each nation, of course, must consider the cost implications of a potential commitment for its 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.[19] This *aggregate* measure of cost, however, is only of limited value without some measure of the distribution of cost—or possibly gain[20]—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*. Each of these dimensions rests on economic realities but how they affect decision making is heavily shaped by perceptions.

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. As noted earlier, 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.

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 timing—and the cost-effectiveness of the measures chosen to meet it. At the global and country level, the projected cost is most often analyzed and expressed as a reduction in GDP, or the economy's ability to generate value added through various activities. For example, the IPCC estimates that a goal of stabilizing atmospheric GHG concentrations at 450 parts per million would reduce global GDP 1-4 percent from the forecast business-as-usual level in 2050.[21] (Global GDP is projected to be 4 to 9 times higher in 2050 than in 1990.[22]) 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 welfare effects 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. On the other hand, such estimates generally omit the positive side-benefits of climate policy such as reduced local pollution.[23] These may play a role in building public support for GHG mitigation.

The cost of mitigation arises when companies and individuals undertake actions they would not have otherwise taken 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.[24]

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 CO_2 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 GHG 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 GHG emissions, so some flexibility in the timing of emissions abatement can result in lower costs with no adverse climate impact.[25] Several gases contribute significantly to warming—CO_2, CH_4, nitrous oxide (N_2O), PFCs, hydrofluorocarbons (HFCs), and sulfur hexafluoride (SF_6)—arguing for a policy that provides incentive to focus on those whose reduction yields the greatest climate bang for the buck.[26] In addition, a ton of CO_2 permanently 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.[27]

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.

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 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 energy price increases and, thus, the relative cost of compliance. A second set of 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.[28] Another form of leakage may occur if GHG reductions in industrialized countries lower international fuel prices, triggering higher fossil fuel use and emissions in other countries.[29] (From a competitiveness standpoint, OPEC countries could take measures to maintain export revenues.[30]) In all, estimates of leakage under Kyoto (assuming U.S. participation) ranged from 5 to 20 percent.[31] The magnitude of potential leakage would of course be reduced if commitments covered a wider group of countries.

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. These constituencies can strongly influence the position a country takes to international negotiations and its willingness to accept an 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 and users of various types of fossil fuel resources.[32] However well an international agreement can minimize differences in relative costs across countries, it ultimately falls to national policy to redistribute the burden domestically in order to allay competitiveness concerns and perhaps compensate those activities that stand to lose the most.

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 projected costs, the probability of non-compliance would increase. Further, some countries may use unexpectedly high costs as a rationale to opt out of the agreement. This could undermine the credibility of the international policy regime and the prospects for stronger commitments and broader participation in subsequent rounds. Conversely, 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.[33]

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) that affect their competitiveness. 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.

IV. Shaping the Long-Term Climate Regime

Economists and others have advanced many ideas for addressing cost concerns in an international climate regime.[34] This section assesses how several of the more prominent proposals would perform vis-à-vis the three dimensions of cost described above. They include both quota–based approaches (international emissions trading, a safety valve, indexed targets, sectoral targets, and non-binding targets) and non-quota-based approaches (harmonized taxes and technology standards). Some of these instruments can complement each other. For instance, developed countries could pursue binding economy-wide emission targets while developing countries adopt sectoral or non-binding targets, all linked to international emissions trading. Similarly, commitments could progress from one form to another as the regime evolves. This analysis, however, looks at these approaches individually and not sequenced or in combination.

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. While either an emissions tax or a tradable emissions allowance program can result in this equalization of marginal costs, the international negotiations have favored trading. This in part reflects a reluctance to subject domestic economies to an international taxing authority. Trading, however, also has the advantage of allowing a negotiation over the distribution of cost, via the setting of country targets.

An abundant literature supports the cost-minimization advantage of international GHG emissions trading.[35] 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.[36] 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.[37]

These remain, nevertheless, modeling results assuming that all sources in all countries with commitments effectively participate in a perfectly efficient international emissions trading regime.[38] In practice, however, while some governments may allocate some of their emissions commitments to large industrial sources and allow them to trade on that basis (e.g., as currently envisioned in the European Union), they may regulate emissions from other sources and sectors through alternative approaches. Some governments, attempting to come closest to the ideal reflected in economic models, may address all emissions from all sectors through "upstream" trading regimes (where the introduction of carbon into the economy is subject to an aggregate quota, and upstream firms such as coal mine operators and crude oil suppliers would trade among themselves). Still other governments may decide to implement domestic 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 modeling picture, the international market may be characterized by transactions among large industrial sources and governments of those countries with commitments.[39] There may also be barriers to international transactions or biases introduced by different regulatory regimes, such as domestic commitment periods of different durations, different penalty levels, and limited access to the international regime.[40] 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 issues. By allowing sources access to the same least-cost potential to comply with their objectives, 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 whose jobs may be jeopardized. A government also could return some of the auction proceeds to adversely impacted industries and leave them no worse off. Similarly, a free allocation of some or all allowances would compensate sources for the negative effects of an emissions constraint.[41]

International emissions trading also can reduce some of the uncertainty about costs. A well-functioning international emissions market can help absorb country-level spikes in emissions (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 will reduce cost uncertainty depends on how the institution evolves over the next decade and countries' participation decisions. An emissions market that is not liquid and efficient may not offer many cost-saving opportunities or insurance against unexpectedly high abatement costs. The actions of countries likely to be large buyers or sellers 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 emissions commitments in the Framework Convention and the Kyoto Protocol take the form of fixed quantitative targets. A variant that may offer greater cost certainty would maintain quantitative targets but incorporate a "safety valve" mechanism to insure against unexpectedly high costs. Countries would have initial emission allocations but would have the option of buying additional allowances at a predetermined price.[42] This 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.

To function as insurance against unexpectedly high mitigation costs, the safety valve price must be set above the forecast marginal cost of meeting the agreed emissions targets. 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. Some may then view—or characterize—the safety valve as an indirect way to impose a harmonized emissions tax.[43] If the price is set "too low"—i.e., below the forecast cost of the quantity target —it could reduce the incentive for the near-term R & D investment necessary to produce lower-cost abatement technologies. With less price-induced innovation, the long-run cost of abating GHG emissions could then be higher with a safety valve than with fixed targets.[44]

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. It 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, cost certainty. 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 likelihood of achieving at least some environmental benefits.

Indexed Targets

The emission targets in the Kyoto Protocol require absolute reductions from a base year by an agreed 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 GHG emissions to GDP to 151 million metric tons per million dollars by 2012 (from the 2001 ratio of 183).[45]

Indexing can reduce uncertainties stemming from the unpredictability of future economic and emissions trends. Many developing countries, for instance, argue that they cannot adopt fixed targets, even targets allowing emissions growth, because their emissions cannot be accurately forecast and an absolute target could constrain economic development. Under a target pegged to economic growth, if a country grows faster than expected, its total allowable emissions would also rise. However, since a GDP-based formula includes only one factor influencing the effective stringency of an emissions commitment, it neither eliminates cost variability nor provides certainty on the marginal cost of compliance.[46] 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”—an allowance that exceeds a country’s emissions even in the absence of any 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.

Integrating such an approach with international emissions trading may present challenges. For instance, a country may find it easier to allocate trading allowances to industrial sources on the basis of an absolute, Kyoto-type quantitative target than on the basis of an indexed emissions target in which the absolute reduction required is 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 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 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 GHG 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 commitment to various predictors of emissions may be too difficult to effectively negotiate. The U.S. and Argentine indexing approaches simply use economic growth as the indexing measure.

The level of effort ultimately required (i.e., the percentage reduction from projected emissions) depends on the form of the indexing approach, the rate of economic growth, and the structure of a country's economy. In some cases, the target will be progressive, requiring stronger abatement when economic growth is faster than expected and less abatement if growth is slower. The type of target proposed by the Argentine government—which allows emissions to grow with only the square root of GDP—will under most circumstances produce that result. Other targets, depending on an economy's structure, can have the opposite effect. An example is the Bush Administration target, which pegs emissions to GDP as a simple linear function, or ratio. Because any faster-than-expected growth in the United States is likely to be in activities (e.g., services and high-tech sectors) that are less carbon-intensive than the economy-wide average, the U.S. target effectively requires less abatement if the economy does better than projected. For instance, 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 level of abatement required would be cut by nearly half. A linear target would work progressively, however, in a different economy—for instance, a rapidly industrializing country with rising GHG intensity.[47]

Sectoral Targets

One way to reduce uncertainty is to narrow the scope of an emissions target from the entire economy to certain sectors. Some activities and industries responsible for a large fraction of a country's emissions may be more amenable to emissions mitigation in the near term. A sectoral approach may be especially suited for developing countries without the capacity to monitor emissions throughout their economies.

The issues associated with the aggregate costs of a sectoral target are essentially the same as those in taking on an economy-wide commitment.[48] 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.[49] Sectoral commitments do not specifically promote cost certainty, but such an approach could be integrated with a safety valve or indexing.

A sectoral target could allow a country to engage in international emissions trading, at least based on the activities in the covered sector, providing a potential source of financing for emissions abatement and technology improvements.[50] Such an approach could also be integrated in a CDM 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 economic 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.[51] First, agreement must be reached on a country's business-as-usual emissions forecast for the commitment period.[52] Then the country can consider implementing various mitigation policies. At the end of the commitment period, if the country's actual emissions are lower than the forecast baseline, it could sell the "excess" allowances 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 likely do so only 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 CDM: projects are only submitted if they achieve reductions and have something to sell.[53] 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.

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.[54] While emissions targets can provide 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 or subsidies to help low-income households pay for more expensive heat and electricity. 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, some may be concerned that emissions taxes trade emissions certainty for cost certainty.[55] 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.[56] Third, a harmonized emissions tax would make an equitable distribution of the mitigation burden more difficult. 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.

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. The strong aversion in some countries to taxes generally—and the notion of an international tax in particular—helps explain why this option has never been seriously pursued in the climate negotiations.

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.[57] Such a technology development effort would likely aim to deliver the breakthroughs necessary to significantly abate GHG emissions in the medium to long term, but offer 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. Allowing governments 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 standards agreement provides no certainty about the costs of climate policy.

Some have argued that technology standards could address a fundamental problem in international environmental negotiations: securing participation and promoting compliance.[58] 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. Achieving participation and compliance requires an agreement 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.[59] 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 cost, 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 (e.g., by cutting energy taxes), yielding 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.[60] Emissions taxes could equalize marginal cost as well as a system of quantitative emissions targets, so long as fiscal cushioning is not pursued. In the end, however, while international regime design may have a significant bearing on relative cost, 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. Similarly, an emissions tax would provide full certainty on the marginal cost of compliance. 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 obviously can only be pursued by a subset of countries—otherwise, there would 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.

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.[61] 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 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. 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 becomes 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. Even in the absence of better data, economics can still 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 at present 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 (SO_2) 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. IPCC (2001).

4. See Weitzman (2001); Newell and Pizer (2001); and Philibert (2003).

5. Hourcade (1993); Grubb (1997).

6. Hourcade and Shukla et al. (2001).

7. IPCC (2000).

8. IPCC (2001).

9. See Nordhaus and Boyer (2000) for a recent attempt to monetize the costs of global climate change.

10. See Jorgenson et al. (2000).

11. These estimates assume full participation of all countries listed in Annex B of the Kyoto Protocol in the trading regime, including the United States. See Weyant and Hill (1999).

12. Fisher (2000).

13. Dixit and Pindyck (1994).

14. Pindyck (2000).

15. Arrow and Fisher (1974).

16. Chichilinsky and Heal (1993).

17. Webster (2002).

18. Aldy et al. (2001).

19. Weyant and Hill (1999); Hourcade and Shukla et al. (2001).

20. See Hourcade and Shukla et al. (2001) for a discussion of negative cost potentials.

21. Hourcade and Shukla et al. (2001).

22. IPCC (2000).

23. See Hourcade and Shukla et al. (2001) for a survey of studies on the ancillary benefits of GHG mitigation.

24. ABARE (1995), (1997); Richels et al. (1996); Weyant and Hill (1999).

25. 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 require a lesser constraint, if more emissions were released early. A critique of this approach on economic grounds was provided by Grubb (1997).

26. 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 six gases are taken into account instead of CO_2 only, if the U.S. were to meet its objective under Kyoto through purely domestic measures.

27. The comparability of a ton of sequestration and a ton of abatement depends on the long-term integrity of the sequestration effort.

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

29. 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.

30. 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; see Ghanem et al. (1999).

31. Hourcade and Shukla et al. (2001). In contrast to this literature on leakage, some recent research has shown the potential for positive technology spillovers to reduce GHG 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.

32. Pershing (2000).

33. IEA (2002a).

34. See Aldy et al. (2003) for a review of these proposals.

35. Hourcade and Shukla et al. (2001); IEA (2001); Edmonds, Scott et al. (1999); Weyant and Hill (1999); Richels et al. (1996).

36. Weyant and Hill (1999).

37. 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 have chosen the tax approach, as this provides full certainty about the marginal cost of reduction.

38. 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 2002b).

39. 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. 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 and 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).

40. See Hahn and Stavins (1999) for a discussion of the difficulties in integrating international emissions trading with domestic policy regimes.

41. See Bovenberg and Goulder (2000); Burtraw et al. (2002); Goulder (2001); and Kopp et al. (1999).

42. See Kopp et al. (2000). This concept has received substantial attention from economists for three decades. See IEA, (2002a) 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.

43. 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 1000 Mt CO_2 to pay for 25 Mt CO_2: the price signal on energy users would be much lower than the safety valve.

44. 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.

45. 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, see the Argentina National Communication, First Revision at http://unfccc.int/resource/docs/natc/argnc1e.pdf. For details on the Bush Administration proposal, see http://www.whitehouse.gov/news/releases/2002/02/climatechange.html. For more information on indexing, refer to Lutter (2000) and Baumert et al. (1999).

46. Pizer (2003) illustrates the variability in GHG intensity and questions how well these types of commitments would mitigate cost uncertainty.

47. 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.

48. 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.

49. IEA (2002a).

50. Interestingly, the EU emissions trading directive may create a precedent of sectoral targets for countries otherwise without commitments under the Protocol. Some industrial activities in Cyprus and Malta, two accession countries, fall under the jurisdiction of the trading directive and as such should be allocated absolute caps to allow trading with other industrial companies in the rest of the EU.

51. Philibert (2000).

52. 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.

53. See IEA (2002a) for further details on this option.

54. See Cooper (1998) and Nordhaus (2002).

55. This tradeoff, however, 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).

56. Wiener (1999a).

57. See Barrett (2001), (2003); and Benedick (2001).

58. Barrett (2003).

59. Wiener (1999b).

60. 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.

61. Ashton and Wang (2003).

References

ABARE. 1997. *The Economic Impact of International Climate Change Policy*. Australian Bureau of Agriculture and Resource Economics, Commonwealth of Australia.

ABARE. 1995. *Global Climate Change—Economic Dimensions of a Cooperative International Policy Response Beyond 2000*. Australian Bureau of Agriculture and Resource Economics, Commonwealth of Australia.

Aldy, J.E. 2003. Saving the Planet Cost-Effectively: The Role of Economic Analysis in Climate Change Mitigation Policy. In: R. Lutter and J. Shogren (Eds.). *Painting the White House Green: Rationalizing Environmental Policy Inside the Executive Office of the President*. Washington, DC: Resources for the Future Press (forthcoming).

Aldy, Joseph E., S. Scott Barrett, and Robert N. Stavins. 2003. "Thirteen Plus One: A Comparison of Global Climate Policy Architectures," *Climate Policy* 3(4): forthcoming.

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

Arrow, K.J. and A.C. Fisher. 1974. "Environmental Preservation, Uncertainty, and Irreversibility." *Quarterly Journal of Economics*, Vol. 88, May, 2: 312-319.

Ashton, John and Xueman Wang. 2003. "Equity and Climate: In Principle and Practice." In: *Beyond Kyoto: Advancing the International Effort Against Climate Change,* Pew Center on Global Climate Change, Arlington, VA.

Barrett, S. 2003. *Environment and Statecraft*. Oxford: Oxford University Press.

Barrett, S. 2001. Towards a Better Climate Treaty, Policy Matters 01-29, November, AEI—Brookings Joint Center. http://www.aei-brookings.org/policy/page.php?id=21.

Baumert, K., R. Bhandari, and N. Kete. 1999. "What Might a Developing Country Climate Commitment Look Like?" *Climate Notes*. World Resources Institute, Washington, DC.

Benedick, R.E. 2001. "Striking a New Deal on Climate Change." *Issues in Science and Technology,* Fall: 71-76.

Bovenberg, A.L. and L.H. Goulder. 2000. "Neutralizing the Adverse Industry Impacts of CO_2 Abatement Policies: What Does it Cost?" NBER Working Paper no. 7654.

Burtraw, D., K. Palmer, R. Bharvirkar, and A. Paul. 2002. "The Effect on Asset Values of the Allocation of Carbon Dioxide Emission Allowances, Resources for the Future," Discussion Paper 02-15.

Chichilinsky, G. and G. Heal. 1993. "Global Environmental Risks." *Journal of Economic Perspectives* 7(4): 65-86.

Cooper, R. 1998. "Toward a Real Treaty on Global Warming." *Foreign Affairs* 77(2): 66-79.

Dixit, A. and R. Pindyck. 1994. *Investment Under Uncertainty*. New York: Princeton University Press.

Edmonds, J. and M.J. Scott et al. 1999. "International Emissions Trading and Global Climate Change." Pew Center on Global Climate Change, Arlington, VA.

Fisher, A.C. 2000. "Investment Under Uncertainty and Option Value in Environmental Economics." *Resource and Energy Economics* 22: 197-204.

Ghanem, S., R. Lounnas, and G. Brennard. 1999. "The Impact of Emissions Trading on OPEC." *OPEC Review* 23(2): 79-112.

Goulder, L.H. 2001. "Confronting the Adverse Industry Impacts of CO_2 Abatement Policies: What Does it Cost?" In: *Climate Change Economics and Policy: An RFF Anthology*. Michael A. Toman (Ed.). Resources for the Future, Washington, DC.

Grubb, M. 1997. "Technologies, energy systems and the timing of CO_2 abatement—An overview of economic issues," *Energy Policy* 25 (2) 159.

Grubb, M., T. Chapuis, and M. Ha Duong, 1995. "The Economics of Changing Course: Implications of Adaptability and Inertia for Optimal Climate Policy." *Energy Policy* 23(4/5).

Grubb, M., C. Hope, and R. Fouquet. 2002. "Climatic Implications of the Kyoto Protocol: The Contribution of International Spillover." *Climatic Change* 54(1/2).

Hahn, R.W. and R.N. Stavins. 1999. "What has the Kyoto Protocol Wrought? The Real Architecture of International Tradable Permit Markets." AEI Press, Washington, DC.

Hourcade, J.C. 1993. "Modelling long-run scenarios: methodology lessons from a prospective study on a low CO_2 intensive country," *Energy Policy* 21 (3):309.

Hourcade, J.C. and Shukla P. (coordinating lead authors). 2001. "Global, Regional and National Costs and Ancillary Benefits of Mitigation," Chapter 8. In: *Climate Change 2001: Mitigation*. Intergovernmental Panel on Climate Change, Metz B., Davidson O., Swart R., Pan J. (Eds.), Cambridge University Press, Cambridge, UK, and New York, NY.

IEA. 2002a. Beyond Kyoto—*Energy Dynamics and Climate Stabilistation*. International Energy Agency, OECD, Paris.

IEA. 2002b. *Dealing with Climate Change—Polices and Measures in IEA Member Countries*. International Energy Agency, OECD, Paris.

IEA. 2001. *International Emissions Trading: From Concept to Reality*. International Energy Agency, OECD, Paris.

IPCC. 2000. "Emissions scenarios—Summary for Policymakers." *Intergovernmental Panel on Climate Change Special Report*, WMO-UNEP. http://www.ipcc.ch/pub/sres-e.pdf.

IPCC. 2001. *Climate Change 2001: The Scientific Basis*. Intergovernmental Panel on Climate Change, Cambridge, UK: Cambridge University Press.

Jaffe, A., S.R. Peterson, P.R. Portney, and R.N. Stavins. 1995. "Environmental Regulation and the Competitiveness of US Manufacturing: What Does the Evidence Tell Us?" *Journal of Economic Literature*, Vol. XXXIII (March).

Jorgenson, D.W., R.J. Goettle, P.J. Wilcoxen, and M.S. Ho. 2000. "The Role of Substitution in Understanding the Costs of Climate Change Policy," Pew Center on Global Climate Change, Arlington, VA.

Kopp, R.J., R.D. Morgenstern, and W. Pizer. 2000. "Compliance: Limiting Cost, Assuring Effort, and Encouraging Ratification." Weathervane, August 2000. Resources for the Future, Washington, DC.

Kopp, R., R. Morgenstern, W. Pizer, and M. Toman. 1999. "A Proposal for Credible Early Action in U.S. Climate Policy." Weathervane Feature no. 60. Resources for the Future, Washington, DC.

Lutter, R. 2000. "Developing Countries' Greenhouse Emissions: Uncertainty and Implications for Participation in the Kyoto Protocol." *Energy Journal* 21(4): 93-120.

Newell, R. and W. Pizer. 2001. "Discounting the Benefits of Climate Change Mitigation: How Much Do Uncertain Rates Increase Valuation?" Pew Center on Global Climate Change, Arlington, VA.

Nordhaus, W.D. 2002. "After Kyoto: Alternative Mechanisms to Control Global Warming." Presented at joint session of American Economic Association and Association of Environmental and Resource Economists, Atlanta, GA, January 2.

Nordhaus, W.D. and J. Boyer. 2000. "The Impacts of Climate Change." In: *Warming the World: Economic Models of Global Warming*. Cambridge: MIT Press.

OECD. 2000. "A Multi-gas Assessment of the Kyoto Protocol." Economics Department, Working Papers, No. 270, ECO/WK(2000)43.

Pershing, J. 2000. "Fossil Fuel Implications of Climate Change Mitigation Responses." In: L. Bernstein and J. Pan (Eds.), *Sectoral Economic Costs and Benefits of GHG Mitigation, Proceedings of an IPCC Expert Meeting*, IPCC WGIII, RIVM.

Philibert, C. 2003. Discounting the Future, Online Encyclopedia of Ecological Economics, http://www.ecoeco.org/publica/encyc.htm (forthcoming).

Philibert, C. 2000. "How could emissions trading benefit developing countries," *Energy Policy*, 26 (12).

Philibert, C. and J. Pershing. 2001. "Considering the options: Climate targets for all countries," *Climate Policy* 1 (2).

Pindyck, R.S. 2000. "Irreversibilities and the Timing of Environmental Policy." *Resource and Energy Economics* 22: 233-259.

Pizer, W. 2003. "Intensity Targets in Perspective," Presentation at IFRI-RFF Conference How to Make Progress Post-Kyoto, Paris, 19 March 2003, http://www.rff.org/post_kyoto/pizer.pdf

Pizer, W.A. 2002. "Combining Price and Quantity Controls to Mitigate Global Climate Change." *Journal of Public Economics* 85(3): 409-434.

Reilly, J.M., H.D. Jacoby, and R.G. Prinn. 2003. "Multi-gas Contributors to Global Climate Change: Climate Impacts and Mitigation Costs of Non-CO_2 Gases," Pew Center on Global Climate Change, Arlington, VA.

Richels, R., J. Edmonds, H. Gruenspecht, and T. Wigley. 1996. "The Berlin Mandate: The Design of Cost-Effective Mitigation Strategies," Working Paper 3, Energy Modelling Forum-14, Stanford University, Stanford CA.

Webster, M. 2002. "The Curious Role of "Learning" in Climate Policy: Should We Wait for More Data?" *Energy Journal* 23(2): 97-119.

Weitzman, M.L. 1974. "Prices vs. Quantities." *Review of Economic Studies* 41, October.

Weitzman, M.L. 2001. "Gamma Discounting." *American Economic Review* 91(1): 260-271.

Weyant, J.P. and J. Hill. 1999. "Introduction and Overview, The Costs of the Kyoto Protocol: A Multi-Model Evaluation." Special Issue of *The Energy Journal*.

Wiener, J.B. 1999a. "Global Environmental Regulation: Instrument Choice in Legal Context," *Yale Law Journal* 108(4): 677-800.

Wiener, J.B. 1999b. "On the Political Economy of Global Environmental Regulation," *Georgetown Law Journal* 87(3): 749-794.

Wigley T., R. Richels, and J. Edmonds. 1996. "Economic and Environmental Choices in the Stabilisation of Atmospheric CO_2 Concentrations," *Nature* 379: 240-243.