

International Approaches to Reducing Greenhouse Gas Emissions*

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ABSTRACT

This paper examines international policy options for dealing with the prospect of global climate change. We analyze a number of policies embraced by the Kyoto Protocol (including international trading of emissions permits, “Joint Implementation,” and the “Clean Development Mechanism”) as well as policies (such as an international carbon tax) not covered by the Protocol. We compare policies in terms of their cost-effectiveness, indicating how international coordination and flexibility can reduce costs of meeting international emissions targets. We also consider issues of fairness and political feasibility associated with different policies. Finally, we explore a number of policy design issues, addressing questions concerning the breadth of policies in terms of nations involved and the greenhouse gases covered.

KEYWORDS

International environmental policy, climate change policy, policy instrument choice, international emissions trading, carbon tax, Kyoto Protocol

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GLOSSARY[†]

“Additionality” Property: The condition that emissions reductions associated with a policy intervention must be over and above the reductions that would have occurred in the absence of the policy. International policies that fail to achieve additionality do not in fact bring about reductions in emissions.

Cost-Effectiveness: The extent to which a policy achieves a given target at low cost.

Carbon Tax: A tax on fossil fuels in proportion to their carbon content. For most uses of fuels (with feedstock uses as an exception) this is equivalent to a tax on CO₂ emissions from fossil fuels.

Emissions Permit: A document entitling the owner to emit one unit of pollution (where a unit is defined by the permit). From an economic and legal perspective, a permit assigns a property right—the right to emit a specified amount of pollution—to the owner of the permit.

Flexibility Mechanisms: A set of policies that coordinate international emissions-reduction efforts and thereby expand nations’ options for meeting their agreed-upon limits for greenhouse gas emissions. Under the Kyoto Protocol, the flexibility mechanisms are international emissions permit trading, Joint Implementation, and the Clean Development Mechanism.

“Hybrid” Policy: In this paper, an environmental regulatory policy that combines features of a permit (i.e., quantity-based) system with those of a tax (i.e., price-based) system.

International Emissions Trading System: A regulatory system that issues property rights (generally called permits) to national governments or firms and allows owners of permits to trade those permits in an international market.

Intertemporal: Involving several time periods. In this paper we refer to intertemporal flexibility with respect to emissions. Such flexibility is achieved when firms have the options of “banking” some current permits in order to authorize additional future emissions or of borrowing from future permits in order

[†] For a description of general terminology surrounding the economics of climate change and climate change in general, see the Resources for the Future Weathervane glossary at <http://www.weathervane.rff.org/glossary>.

to authorize additional current emissions.

Marginal Cost of Emissions Reduction (also referred to as Marginal Cost of Abatement): The cost incurred by a firm to reduce (or abate) its current pollution level by one additional unit (termed the “marginal unit”).

“Supplementarity” Requirement: The condition that whatever emissions-reduction credits a nation achieves through purchases of emissions permits must be “supplemental” to a certain level of domestically-achieved emissions reductions. The supplementarity requirement is seen as a way of assuring that nations will meet at least part of their international obligations through reductions in emissions at home.

1. INTRODUCTION

Climate change is a global problem, and dealing successfully with this problem will require the efforts of many nations. Although some climate policies can be implemented unilaterally, international coordination of national efforts is crucial to addressing the prospect of climate change in the most effective and equitable manner.

In recent years, policy analysts have put forth a number of potential international approaches for confronting the prospect of climate change. These policies include different proposals for “burden sharing,” that is, the international division of responsibilities for dealing with climate change. The policies also include mechanisms for coordinating the various national efforts to reduce emissions of greenhouse gases. Among the coordination devices are “flexibility mechanisms” that give nations additional options for addressing the climate change problem. Flexibility mechanisms have the potential to reduce the global cost of achieving reductions in greenhouse gases, relative to the cost that would apply if countries acted in a unilateral, uncoordinated fashion. As we shall discuss below, the cost-savings from giving additional flexibility can be quite significant: studies indicate that in some situations international flexibility mechanisms can reduce by more than 50 percent the costs of achieving certain global targets for reducing emissions.¹

The centerpiece for recent international policy discussions has been the Kyoto Protocol, an international agreement formulated in December 1997. Under the Protocol, industrialized nations commit themselves to national targets (or ceilings) for their emissions of greenhouse gases; these targets would need to be reached by the “commitment period” of 2008-2012. The Protocol embraces a number of flexibility mechanisms, including a system of international emissions permit trading as well as various credits for the international transfer of “clean” (that is, low-carbon) technologies. While these mechanisms have many adherents, some policy analysts prefer alternatives such as an international carbon tax.

This chapter examines a number of possible international policies to address global climate change. It considers the approaches contained in the Kyoto Protocol and others as well. Our focus is broader than the policies covered under the Kyoto Protocol partly because at the present time it is unclear whether the Protocol will be ratified by the legislatures of enough nations to be implemented as an

¹ See Weyant and Hill (1999) for a review of thirteen computer modeling studies of abatement costs for industrialized nations.

international policy.² A second and possibly more important reason for our broader focus is that the Protocol almost certainly will not be the last international initiative to deal with climate change. It is likely to be the first in a series of international efforts along these lines. Thus, it makes sense to consider a range of leading policy alternatives, not just the ones articulated as part of the Protocol.

We begin in Section 2 with a discussion of what underlies national costs of emissions reductions, starting with a situation where no international flexibility mechanisms are in place. Section 3 then focuses on one flexibility mechanism – international emissions trading – and shows how this mechanism can reduce the costs of dealing with climate change to all participants in such trading. Sections 4 and 5 describe other mechanisms – an international carbon tax, “Joint Implementation” schemes, and the “Clean Development Mechanism” – and discuss their potential attractions and limitations. Section 6 discusses some key policy issues related to the design and coverage of various mechanisms, and the final section offers conclusions.

2. NATIONAL COSTS OF REDUCING GREENHOUSE GAS EMISSIONS

As discussed in Stephen H. Schneider’s chapter in this volume on the science of global climate change, the proximate cause of climate change is the atmospheric build-up of heat-trapping greenhouse gases. To mitigate future climate change, nations will have to reduce this build-up. A principal way to do this is to reduce emissions of greenhouse gases, although expanding carbon sinks can also help address this problem.

There may be some opportunities for nations to reduce emissions at no cost – this is the “no-regrets” situation that politicians love. But most studies indicate that large-scale reductions in such emissions will entail costs.³ Industrialized nations

² As of January 2001, although 84 parties had signed, only 31 had ratified the treaty. Article 25 of the Kyoto Protocol states that the Protocol will become international law when at least 55 of the parties to the Convention, incorporating Annex I countries which account for no less than 55 percent of the total carbon dioxide emissions for 1990, have ratified the treaty (United Nations Framework Convention on Climate Change, 2000. “The Convention and Kyoto Protocol.” <http://www.unfccc.de/resource/convkp.html>. Accessed 15 January 2001.).

³ For instance, all 11 of the models reporting data for the U.S. in the 1999 Kyoto Special Issue of *The Energy Journal* predict positive and increasing costs to emissions reductions beyond approximately a 1 percent reduction from the 2010 baseline projection for the U.S. (Weyant, John P. and Jennifer N. Hill, 1999. “Introduction and Overview.” *The Energy Journal*, Kyoto Special Issue: Figure 10(a), xxxvii).

currently are highly dependent on fossil fuels, whose combustion is a principal contributor to the release of carbon dioxide (CO₂) into the atmosphere. Reducing CO₂ emissions generally requires reductions in the use of coal and other fossil fuels. Such reductions, in turn, require the adoption of alternative industrial processes that in many cases are more expensive for firms than the existing processes. Advances in knowledge may lead to the discovery of new technologies that allow for cheap production with reduced input of fossil fuels, but developing these new technologies often involves a cost as well. Thus, there may be national costs of reducing emissions even if the channel for such reductions is the advent of a new, “carbon-free” technology that proves useful for a given industry.

Figure 1a below indicates a typical relationship between CO₂ abatement and national cost. The figure indicates that national costs increase with the extent of abatement. The figure shows that costs may be zero or below zero within a range, but eventually become positive. Costs rise at an increasing rate, as indicated by the fact that the slope of the total cost curve gets steeper.

A central concept in evaluating climate change policy is the *marginal cost* of emissions reductions. The marginal cost is the cost of a given increment to the amount of abatement. For example, it is the cost associated with augmenting the reduction in CO₂ from five tons to six, or from 30 tons to 31, or from 150 to 151. Marginal cost is represented by the slope of the total cost curve. Figure 1b displays the marginal costs corresponding to the various levels of abatement in Figure 1a. In this figure, at any given point in time it is relatively cheap to reduce the first units of CO₂, and much more costly to make incremental reductions beyond that (at the same point in time).

In Figure 1b, the marginal costs increase with the amount of abatement. This corresponds to the fact that the slope of the total cost curve in Figure 1a increases as the amount of abatement gets larger. Rising marginal costs are consistent with the idea that it’s relatively easy to remove the first units of carbon from the economy, but that removing additional units becomes increasingly difficult. An example of rising marginal costs can be found in the electric power industry. In the U.S., carbon emissions can be reduced to some extent by substituting natural gas in the generation of electric power. Natural gas has much lower carbon content per unit of energy than does coal, and thus the substitution of natural gas for coal reduces emissions. This is a relatively inexpensive way to reduce emissions. However, further emissions reductions could be more costly, requiring perhaps the replacement of existing power plants with new plants.

Sophisticated computer models have aimed to measure the marginal costs of reducing CO₂ emissions in various countries. These models take account of

substitution possibilities in industrial, commercial, and household activities throughout the economy. Figure 2 shows the marginal costs of emissions reductions in the United States, as predicted for the year 2010 by 11 models that participated in a study by the Stanford University Energy Modeling Forum. The figure shows significant variation in the marginal cost projections from the various models. However, each model projects rising marginal costs. Projections for other industrialized nations follow a similar pattern.⁴

The Importance of the National Targets: The Problem of Burden Sharing

The costs of abatement will depend on the stringency of the national target: other things equal, reducing emissions by eight percent will cost more than reducing emissions by four percent. One of the most difficult political challenges is to achieve an international consensus on “burden sharing” – how responsibility for the global reduction in emissions is to be allocated across nations.

Decisions about burden sharing (or national targets) can be based on a number of different country-characteristics, including current or past emissions, population, and GDP. Each of these characteristics implies differences in the distribution of responsibilities for emissions reductions (as well as differences in the gains from permit trades). Table 1 gives a glimpse of how much difference it would make to the selected countries if allocation of national targets depending on whether the allocation is based on GDP, population, or emissions. For some countries, it makes a huge difference. For example, China’s share of world population is over 20 percent, while its share of world GDP is less than two percent. The U.S. accounts for over a quarter of global GDP, but for less than five percent of its population. Thus, China would bear a much smaller share of the global responsibility for emissions-reductions if national targets were based on population rather than GDP. The situation is the opposite for the U.S.

Pointing out the political difficulties of reaching international agreements on burden-sharing, Schelling (1992)⁵ and Cooper (1996)⁶ argue against the use of national targets. They claim that efforts to reach international agreements on quantity limits (national targets) ultimately will be fruitless, in part because of vast uncertainties about the ultimate costs of achieving given quantity targets and in

⁴ Weyant, John P. and Jennifer N. Hill, 1999. “Introduction and Overview.” *The Energy Journal*, Kyoto Special Issue.

⁵ Schelling, Thomas C., 1992. “Some Economics of Global Warming.” *American Economic Review* 82(March): 1-14.

⁶ Cooper, Richard N., 1998. “Toward a Real Global Warming Treaty.” *Foreign Affairs* 77(March/April).

part because nations fundamentally disagree on the principles that should apply to determine relative commitments. They maintain that, instead, nations should negotiate the use of instruments (such as carbon taxes, technology subsidies, etc.) rather than the ultimate targets (emissions reductions). Although the Kyoto Protocol has embraced national targets, the use of such targets remains highly controversial. An alternative policy – the international carbon tax – avoids national targets. We discuss this alternative in Section 4 below.

As noted, the Kyoto Protocol specifies national targets. Under the Protocol, each of the industrialized nations would be required to reduce its emissions of greenhouse gases by a certain percentage relative to its emissions in 1990.⁷ Each of these countries would have to achieve this reduction by 2008 and maintain the reduction through the compliance period 2008-2012. The greenhouse gases are all expressed in terms of “carbon equivalents.” That is, a unit of each gas is meant to imply the same contribution to the greenhouse effect.⁸ The U.S., in particular, would need to reduce its greenhouse gas emissions by seven percent relative to its 1990 emissions. This constitutes an emissions reduction of about 30 percent relative to annual business as usual projections during the period 2008-2012. Thus, the far-right portions of the curves in Figure 2 seem relevant to the commitments the U.S. would face under the Kyoto Protocol.

3. THE POTENTIAL TO REDUCE COSTS THROUGH INTERNATIONAL TRADES IN EMISSIONS PERMITS

The projections in Figure 2 assume that there are no international “flexibility mechanisms,” such as provisions for trading rights to emit greenhouse gases. Under these conditions, when nations meet their national targets, they will usually have different costs of emissions-reduction for that last, or marginal, unit of reduction. This can be seen with the following example. Consider the marginal costs that the U.S. and Japan would face if they needed to reach their Kyoto targets without international trades in emissions rights. The emissions reductions required under the Protocol are approximately 30 percent and 24 percent for the U.S. and Japan, respectively. If we focus on the results in Figure 2 for the MS-

⁷ More precisely, Annex B nations are required to reduce their emissions. Annex B countries are delineated in Annex B of the Protocol and include the OECD and the nations of the former Soviet Union and Eastern Europe.

⁸ The conversion of one gas to another (in this case to carbon dioxide) is not a simple task. Differences in the residence times of various gases and uncertainties regarding the damage of different gases make determining the “exchange rates” between gases difficult. We discuss this issue more fully at the end of Section 6.

MRT model, in the United States the marginal cost associated with a 30 percent reduction is \$240 per metric ton: that is, the last increment of GHG reduction necessary to bring the overall reduction to 30 percent costs \$240. In contrast, Figure 3 indicates that, according to the same model, the marginal cost associated with Japan's meeting its required 24 percent reduction is about \$400 per metric ton. The lower marginal cost in the U.S. reflects fact that the U.S. currently uses a lot of fossil fuels in its production processes, whereas Japan tends to use less. Achieving reductions in emissions is relatively less costly for the U.S. than for Japan because there are more opportunities in the U.S. for cheaply switching to processes less dependent on fossil fuels.

Gains from Trade

Now consider what happens if a particular "flexibility mechanism" is introduced – a system allowing for international trades in CO₂ emissions rights, such as the system authorized under Article 17 of the Kyoto Protocol.⁹ Specifically, assume that the U.S. is obliged to reduce its emissions to a level of 1,243 million metric tons per year (during the years 2008-2012), and that Japan is required to reduce its emissions to a level of 290 million metric tons per year during that period. A system of international trades in greenhouse gas emissions rights would involve the following. First, each country would give out carbon emissions permits to firms, with each permit entitling the recipient firm to a unit of emissions, say one metric ton. In the U.S., 1,243 million permits would be given out, so that the total allowable emissions would be 1,243 million metric tons, the same as its national target. Similarly, Japanese firms would receive from their government a total of 290 million permits. Recall that the marginal cost of reducing emissions was considerably higher in Japan than in the U.S. If there were no trades of permits between the U.S. and Japan, then at least some Japanese firm would incur a cost of \$400 to reduce its emissions to the level associated with the number of permits owned.

However, if firms are offered the opportunity to trade permits internationally, the costs of reducing emissions can be brought down, and all parties involved in the trade can benefit. Consider, in particular, the situation where the Japanese firm that faces marginal abatement costs of \$400 buys a permit from a U.S. firm. If the Japanese firm can buy a permit for anything less than \$400, it will be better off. Since it would now own one more permit, it would be entitled to emit one more

⁹ The interaction between international institutions that facilitate the permit trading system and domestic actions taken by national governments can have a significant effect on the benefits of an international emissions permit trading system. See Hahn and Stavins (1995) and Hahn and Stavins (1999) for a discussion of these issues and their effect on the cost-savings of flexibility mechanisms.

unit of CO₂. This means the firm would avoid \$400 in abatement costs. The net savings to the firm from this trade is thus \$400 minus the cost of the permit.

U.S. firms can also benefit from the trade. Suppose the U.S. firm faces marginal abatement costs of \$240. If it can sell the permit for anything above \$240, it will benefit from the trade. Selling the permit obligates the U.S. firm to reduce its emissions by one more unit (since its ownership of permits has now been reduced by one). This means the firm will suffer a cost of \$240. But the firm will make money on the deal if it sells the permit for more than this cost. Let's assume that the firms agree on a price of \$300 for the permit. In this case, the Japanese firm benefits by paying \$300 to avoid a cost of \$400, thereby gaining $\$400 - \$300 = \$100$. The American firm benefits by receiving the \$300 permit price less the \$240 required to abate the additional unit of emissions, thereby gaining $\$300 - \$240 = \$60$. Thus, the purchase and sale of permits at prices in between the marginal costs of different countries can make firms in both countries better off than they would be with no such flexibility.

International trades in permits also reduce the *world's* cost of reaching given emissions targets. When Japan buys permits from the U.S., it compels the U.S. to engage in additional emissions abatement (since fewer permits are now owned by U.S. firms), and enables Japan to emit a bit more. In essence, the trades promote reductions in emissions by those firms that can achieve the reductions most cheaply. Since the total number of permits in circulation hasn't changed, there is no change in total emissions – only the distribution of the emissions around the globe changes.

Figure 4 heuristically depicts the impact of emissions trading on the abatement achieved in the U.S. and Japan. In the absence of trading, the U.S. would need to achieve abatement level A_1 , and Japan would need to achieve level A_1^* . By purchasing permits from the U.S., Japan can move to abatement level A_2^* . The sale of permits obliges the U.S. to expand abatement to A_2 . After purchases and sales have moved the U.S. and Japan to A_2 and A_2^* there is no further potential for gains from trade, since marginal abatement costs are the same. In theory, the ultimate price of permits (p) will be equal to the marginal abatement costs of each country (which, we have just seen, will be equal to each other when there is no further potential for gains from trade).¹⁰

¹⁰ Figure 4 also indicates the gains from trade. U.S. firms collectively gain area W . This is the revenue from sale of permits ($W+X$) minus the cost of additional abatement (X). Japanese firms collectively gain area Y . This is the benefit ($Y+Z$) associated with avoiding the need to extend abatement beyond A_2^* to A_1^* , minus the cost of purchasing additional permits (Z). These national gains correspond to global savings.

We have illustrated the potential savings from trades by focusing on trades between the U.S. and Japan. But the same principles apply when many countries are simultaneously involved in trades. In general, countries with high costs of emissions reductions will tend to purchase permits from countries with low marginal costs of such reductions. For the high-marginal-cost countries, the price of the permit is lower than the cost-savings associated with the ability to generate more emissions. For the low-marginal-cost countries, the receipt from the sale of permits more than compensates for the obligation to reduce emissions a bit more. Trades are attractive not only because they lower costs to participating countries but also because nations as a whole achieve emissions reductions at lower cost. Thus, a virtue of emissions permit trading is *cost-effectiveness*: the ability to achieve a given target (in this case, a given reduction in emissions by participating countries) at low cost. An international agreement involving tradable emissions permits is considered more cost-effective than one without trades because emissions-reduction goals can be achieved at lower cost with trades than without.

Trades can yield cost-savings whenever there are differences among potential traders in the marginal costs of emissions reduction. Trades help “iron out” these differences, yielding gains from trade to the parties involved. In our example with the U.S. and Japan, the sale of permits by U.S. firms forces the U.S. to move outward (to the right) along its marginal cost curve – hence U.S. marginal costs rise. In contrast, the purchase of permits causes Japan to move to the left on its marginal cost curve, thus reaching a portion of the curve with lower marginal costs. In theory, permits trades continue until there no longer are any differences in the marginal costs among potential traders.

Computer models have examined the potential of international permit trading to reduce costs. Table 2 indicates the cost-savings from such trades, based on four of the eleven models included in a recent study by the Stanford Energy Modeling Forum and reported in *The Energy Journal*. The results indicate significant reductions in the cost (as described by year 2010 GDP loss in 1990 U.S. dollars) of meeting the Kyoto targets in the presence of trading. Cost savings for the U.S., for example, range from roughly \$16 billion to approximately \$94 billion when a no trading scenario is compared with trading between Annex B nations only. The cost savings are from \$31 billion to \$153 billion when the no trading scenario is compared with a global trading system.¹¹ Global trading offers the greatest opportunities to exploit gains from trade, and thus the cost-savings potential is highest in this case.

These computer analyses tend to assume that the emissions-trading system

¹¹ Numbers are estimated from graphs appearing in Weyant, John P. and Jennifer N. Hill, 1999. “Introduction and Overview.” *The Energy Journal*, Kyoto Special Issue: xxxiii-xxxiv (Figure 9).

functions well – that nations meet their obligations and that firms comply with the rules by emitting no more than the amount justified by the number of permits they possess. In fact, such compliance is unlikely to occur unless there is an effective international mechanism for enforcement. The enforcement agency needs to be able to detect violations of the rules and to impose stiff penalties for violations. Developing the international institutions for such enforcement is no easy task, yet doing so is crucial for emissions trading to work.¹²

The Significance of the Breadth of the Trading System

The costs of achieving given global reductions in greenhouse gas emissions also depend on the breadth of the international agreement – that is, on the number of countries that take part in international trades in emissions permits. When more countries participate, there is greater potential to exploit gains from trade by concentrating the abatement among enterprises than can reduce emissions most cheaply. The results in Table 2 illustrate this principle. Under global trading (with all countries involved), the gains from trade are significantly larger than in the case where the only Annex B countries are involved in the trading system.

The breadth of the agreement also affects the directions of trades. If only the Annex B countries are involved, and if emissions targets are based on their 1990 emissions, then Eastern European nations and the nations of the former Soviet Union would be the primary sellers of permits. The reason is that the carbon emissions in these countries have declined by about 40 percent, due to the nearly 50 percent decline in their GDPs since 1990. Because permits are (assumed to be) distributed based on 1990 emissions, these countries will have permits in excess of their actual emissions, and will thus be willing to sell a large share of their permits.

As indicated in Table 3, the central forecast of the Energy Information Administration of the U.S. Department of Energy indicates that emissions from the former Soviet Union will not reach 1990 levels until after 2015. A crucial and highly controversial issue is whether special provision should be made in emissions allocations to account for the significant reductions in emissions by the former Soviet Union and Eastern Europe since 1990. In most analyses, the U.S. is perceived to have relatively low costs of emissions abatement, and most simulation studies indicate that, under an emissions-trading system involving only the Annex B countries, the US will be the main seller of permits other than the former Soviet Union.

If developing countries are involved in trades, however, the direction of trading is

¹² For an insightful discussion of the enforcement issue and other institutional issues associated with international climate-change policy agreements, see Victor (2001).

likely to differ. A typical scenario for a broader agreement stipulates that the initial allocation for LDCs is simply their projected “baseline” emissions, that is, the level of emissions in the absence of regulation. The LDCs would be able to sell permits if they reduced emissions below this baseline. Under virtually every projection of trades under a broader agreement, China would be a major player. China would be a huge seller of permits for two reasons. First, China’s carbon emissions are projected to grow quite rapidly over the next several decades. As shown in Table 3, China’s carbon emissions in 1995 were about 821 gigatons, a bit more than half of U.S. emissions (1424 gigatons). The table shows that, in the unconstrained baseline, China’s emissions are projected to surpass U.S. projected levels before 2015. Under any agreement that confers permits to LDCs on the basis of (unconstrained) baseline projections, China would obtain a very large share of the global total. Second, studies show that China’s energy use (in particular, its use of coal) is highly inefficient, implying that significant reductions could be made at very low cost. Thus, most simulation studies show China with a very large number of permits that could be sold at a profit, since her abatement costs would be well below those of most industrialized nations.

Under a broader agreement, other LDCs would also be permit-sellers, along with the former Soviet Union and Eastern European countries. Thus, under typical assumptions for the global allocations of permits, a broader agreement effectively amounts to an arrangement whereby the OECD nations pay non-OECD nations to reduce CO₂ emissions. This situation has led some analysts to question the fairness of emissions trading. We shall address the issue of fairness and several other criticisms of a tradable permits system shortly, but first we will examine one last aspect of the design of an international emissions trading system: the banking and borrowing of permits across different time periods.

Banking and Borrowing

Thus far, we have focused mainly on “static” issues in the design of an international emissions trading system, but climate change is a dynamic problem that will take many years to combat. Adding an intertemporal analysis that considers economic effects over time is therefore necessary. Many analysts have endorsed introducing intertemporal flexibility in international emissions trades through “banking” and “borrowing” provisions. Under banking, a nation that reduces emissions below the level implied by its holdings of emissions allowances can bank the difference — that is, apply the difference to future abatement obligations. Similarly, under borrowing, a nation can exceed the level of emissions implied by its current allowance in a given year by borrowing on future emissions allowances.

In theory, the added flexibility provided by these banking and borrowing provisions enables nations and firms to lower the overall discounted costs of achieving given emissions reductions. There is fairly strong empirical evidence that banking can generate large cost-savings. Banking already seems to play an important role in the performance of the SO₂ trading program under the 1990 Clean Air Act Amendments, and it was important to the success of the lead rights trading program of the 1980s.^{13, 14} In the climate-change context, numerical simulations by Manne and Richels (1997) indicate that intertemporal emissions trading – or “when” flexibility – is nearly as important as the “where” flexibility from enabling nations or firms to trade permits with each other.¹⁵

In the Manne-Richels analysis, borrowing leads to substantial reductions in the present value of abatement costs. Because national targets are relatively tighter in the short run (i.e., the present value cost of meeting earlier targets is greater than the present value cost of meeting subsequent ones) it is financially prudent for nations to borrow from their future permit holdings. In theory, nations would borrow to the point where the present value costs are equal across all time periods because doing so minimizes the aggregate present value cost of emissions reductions for all periods.

Two potential difficulties arise in connection with intertemporal flexibility. First, the time profile of firms’ abatement can affect long-run concentrations of CO₂. There is a natural “removal” rate of CO₂ from the atmosphere. Consider two alternative abatement paths that involve the same cumulative abatement. The abatement path that involves less abatement in the near term will exploit the natural removal process more, and therefore contribute less to the concentration of CO₂ over the long term. Thus, borrowing reinforces efforts to reduce CO₂ concentrations, while banking weakens such efforts. Hence banking and borrowing can affect concentrations and impacts on climate.¹⁶

¹³ Ellerman, A. Denny, Richard Schmalensee, Paul L. Joskow, Juan Pablo Montero, and Elizabeth M. Bailey, 1997. “Sulfur Dioxide Emissions Trading Under Title IV of the 1990 Clean Air Act Amendments: Evaluation of Compliance Costs and Allowance Market Performance.” MIT Center for Energy and Environmental Policy Research, May.

¹⁴ Kerr, Suzi, and David Mare, 1997. “Efficient Regulation through Tradeable Permit Markets: The United States Lead Phasedown.” Working Paper 96-06, Department of Agricultural and Resource Economics, University of Maryland, College Park, January.

¹⁵ Manne and Richels (1997) compare the costs of a fixed-quota system (with no provision for international or intertemporal trading) with systems involving international trading and intertemporal trading. Allowing intertemporal trading (banking and borrowing) lowers costs by about as much as allowing international trading.

¹⁶ In the above discussion we have implicitly assumed that impacts are based on the stock of greenhouse gases; however, impacts on climate can depend both on the stock of greenhouse gases and on the rate of change of the stock. For a discussion and critique of this assumption and other climate

Second, nations that do not plan to comply with their emissions quotas can disguise this intention through continual “borrowing.” Because of the difficulty in enforcing an international agreement, this could be a serious source of tensions.

Some Criticisms of International Emissions-Trading Systems

We have emphasized a key virtue of international trading in CO₂ emissions rights – the ability to lower the overall costs of achieving given overall targets for emissions reductions. Notwithstanding this attraction, many participants in policy debates are uneasy with the prospect of emissions trading. Note that under emissions trading, nations that purchase additional permits are able to avoid reducing their own emissions by as much as they would have in the absence of trades. Some participants in international discussions have raised an ethical objection to emissions trading, asserting that it is immoral to grant nations the ability to “buy their way out” of emissions-reductions on their own soil. This criticism has been raised by representatives from LDCs and by representatives of some European countries as well.¹⁷

Others have criticized emissions trading in light of its implications for the speed of transition to a low-carbon or carbon-free economy. Some participants in the international discussions have argued that, for nations that purchase emissions permits, the ability to meet national targets through purchases of permits slows down the transition away from dependence on fossil energy, and that a faster transition is preferable.

Motivated by the idea that nations have an obligation to reduce emissions on their own soil, some policymakers have recommended that a principle of *supplementarity* be followed in international agreements. Under the supplementarity principle, whatever emissions reductions a nation achieves through purchases of emissions permits must be “supplemental” to a certain level of domestically-achieved reductions.¹⁸ In the recent Conference of Parties held at the

change modeling assumptions, see Schneider (1997) and Schneider (2000).

¹⁷ Kopp, Toman, and Cazorla (1998) describe this and other criticisms of international emissions trading in Part 1 of their study. (Kopp, Raymond, Michael Toman, and Marina Cazorla, 1998. “International Emissions Trading and the Clean Development Mechanism.” Climate Issue Brief No. 13, Resources for the Future, Washington, D.C., October.)

¹⁸ The language of the Kyoto Protocol is inexact on the issue of supplementarity. Article 17 states that “Any such trading shall be supplemental to domestic actions for the purpose of meeting quantified emission limitation and reduction commitments under [Article 3].” However, the criteria for determining whether a purchase is “supplemental” to domestic actions are presumably left to the political process.

Hague in November of 2000, European representatives advocated adherence to the supplementarity principle, arguing that nations should not be able to meet the bulk of their required reductions by purchasing permits.¹⁹ To enforce the supplementarity principle, policymakers have launched proposals under which each industrialized nation must achieve a certain pre-specified fraction of its national emissions-reduction target through domestic reductions. This effectively puts a limit on the number of emissions permits a nation could purchase.

From a strictly financial point of view, it is hard to justify restrictions on emissions trading. Such restrictions reduce the abilities of both purchasers and sellers to benefit financially, and they raise the global economic cost of meeting given targets. Buyers benefit from trades because the ability to generate additional emissions is worth more than the cost of the additional permits purchased. Sellers benefit because the revenues from the sale of permits exceed the costs of additional abatement. Thus, restrictions on trades hurt potential buyers and sellers and raise the global economic costs.

The “transition” argument – that restrictions on emissions trading are necessary to avoid unacceptable slowdowns in the transitions away from a fossil-based economy – does not seem fully convincing. It is indeed likely that such restrictions would induce faster development of low-carbon or carbon-free technologies in countries that otherwise would meet most of their national commitments through purchases of permits. However, these same restrictions also would imply a more prolonged reliance on fossil fuels by nations that otherwise would sell more permits. It is not clear whether, for the world as a whole, such restrictions would promote a faster weaning from fossil fuels.

Still, some critics of trades argue that financial gain, global economic cost, and the speed of transition away from a carbon-dependent economy are not the only relevant considerations. They maintain that trades produce a moral cost that overrides the financial gains to participating parties. There is no simple answer to this point. Is it immoral to shift the international locus of abatement to those places where abatement can be achieved at the lowest cost? And if so, does this justify restricting or eliminating the possibility for trade, when doing so eliminates financial benefits to potential traders? These are questions that must be addressed in the policy debate and, ultimately, through the political process.

¹⁹ Anderson, John W., 2000. “Why the Climate Change Conference Failed: An Analysis.” Weathervane Feature, Resources for the Future, Washington, D.C., December 4. http://www.weathervane.rff.org/negtable/COP6/analysis_anderson.htm.

4. AN ALTERNATIVE: THE INTERNATIONAL CARBON TAX

Thus far we have focused on international approaches involving national emissions targets, perhaps accompanied by provisions for emissions permit trading. A key alternative to these approaches is an international carbon tax. Under this policy, every participating country would impose a tax on its emissions of carbon dioxide. The effective tax rate on emissions would be the same for all countries. The simplest form of the international carbon tax would impose the tax on suppliers of fossil fuels – coal, crude oil, and natural gas – with the tax based on the carbon content of each fuel. This tax would cause the prices of fossil fuels to rise, which in turn would cause the prices of various fuel-based products to go up, as the amount of carbon dioxide released from combustion of refined fuel products (e.g., gasoline) is proportional to the carbon content of such products. Hence by imposing a tax on fossil fuels in proportion to their carbon content, governments effectively impose a tax on emissions of carbon dioxide.

Under the international carbon tax, the higher prices of carbon-based products provide incentives for industrial, commercial, and residential users to reduce their demands for such products. The higher the carbon tax rate, the greater the reduction that would be achieved. Studies indicate that to achieve the 7 percent reduction in CO₂ emissions stipulated under the Kyoto Protocol, the U.S. would need to impose a carbon tax of \$50-\$150 per ton. This would cause coal prices to rise by over 100 percent, and would cause oil and natural gas prices to rise by 35-40 percent. The price of gasoline would rise by 12-14 percent.

Under an international carbon tax policy, there would be no need for internationally traded emissions permits. In principle, if the tax is introduced on an international basis, then, in all countries, users of carbon-based products will reduce their demands until the marginal cost of doing so is just equal to the benefit from doing so. This benefit is the value of the avoided tax. If the tax rate is the same in all countries, then the benefit from reducing demands will be the same in all countries, and the marginal costs of reducing carbon use will be equated across countries as well. Thus, in theory, the tax automatically causes marginal costs of emissions-reduction to be the same across participating countries – so there are no opportunities for gains from trade in emissions permits.

These ideas are expressed by Figure 5. Like Figure 4, this figure shows the marginal costs of abatement in the U.S. and Japan. Here the international carbon tax is at a rate of t . Firms in the U.S. and Japan will pursue abatement until the marginal cost of abatement is equal to the tax rate. If firms pursued less than that amount of abatement, then the potential tax savings (given by the tax rate) for an additional unit of abatement would exceed the cost of abatement. Since abating

the unit of emissions is cheaper than paying the tax on it, firms would reduce their emissions further to avoid tax. Similarly, if firms pursued more than the amount of abatement indicated by A and A^* , the cost of the last units of abatement would exceed the tax-savings associated with those units. Firms would therefore be better off paying the tax on those units than abating them. Thus, costs are minimized by abating up to the point where the marginal cost of abatement equals the tax rate. Note that when the U.S. and Japan are at A and A^* , the marginal costs of abatement are the same for the two countries – hence there are no potential gains from permit-trading.

Suppose that the international carbon tax is equal to the value of p in Figure 4. In this case, Japan's abatement level A^* in Figure 5 is exactly the same as its abatement level A_2^* in Figure 4 under emissions trading. But Japan is worse off under the carbon tax than under emissions trading. (Can you show why?²⁰) Therefore, although the emissions under both policies are the same, the distributional impacts are different.

Evaluating the International Carbon Tax

Three issues are relevant in comparing an international carbon tax to a tradable permits system: 1) the ability to address distributional concerns, 2) differences in the locus of uncertainty, and 3) differences in transactions costs. We discuss each of these areas in turn.

1. Distributional Concerns and the Need for Explicit Transfers

We have seen that under a system involving national targets, the relative cost of emissions reductions depends heavily on the stringency of a country's target – the greater the reduction required, the higher the cost. While, the global cost of meeting a given global reduction might be quite similar under two policies in which national targets differed, the distribution of this cost across various countries could

²⁰ Under both emissions trading and the international carbon tax, Japan must endure abatement costs equal to the area under its marginal cost curve MC^* from the origin to A^* (which is equal to A_2^*). But under emissions trading, Japan enjoys in addition a net gain of Y from trading (see footnote 10). Thus, it is better off under emissions trading. The U.S. is worse off under emissions trading than under the international carbon tax. Note that if the initial allocations of permits had been different, with Japan receiving fewer (less than A_2^*) permits initially, and the U.S. receiving more (greater than A_2) permits initially, the situation would be reversed: in this case the emissions-trading scenario is better for the U.S. and worse for Japan than the international carbon tax scenario. Thus, the initial allocation of permits importantly influences national costs both absolutely and relative to an equivalent international carbon tax.

differ dramatically.²¹ Thus, the allocation of national targets affects the distribution of costs among nations and can, in principle be used to address distributional concerns.

In contrast, a (uniform) international carbon tax by itself is not flexible in its distributional impact. If the international distribution of the burden of this carbon tax were politically unacceptable, a set of explicit international monetary transfers would be necessary to alter the distributional impacts. One way to accomplish such international transfers would be through an international agency that collects carbon tax revenues and then recycles them in agreed-upon ways.

There might be stiff political opposition to entrusting an international agency with funds transfers of the magnitudes that would be anticipated, and the transparency of the transfers itself could generate controversy. Based on these considerations, some have argued that the need for explicit international transfers constitutes a basic disadvantage of an international carbon tax relative to a system of national targets with emissions permit trading.²²

2. Differences in the Locus of Uncertainty

A system of national targets makes it clear what the total emissions by participating countries will be. This total is simply the sum of the reductions called for by each of the participating countries. This is the case whether or not the system of national targets is accompanied by provisions for international trades in emissions permits. Allowing for emissions-permit trading does not affect the emissions total because (assuming full compliance by participating countries) the total number of permits in circulation is simply the sum of allowable emissions under the original national targets. Although permit trading has no effect on the total emissions, it does alter where the emissions are generated. Thus, under a system involving national targets (whether or not this is accompanied by permit trading), there is relatively little uncertainty about the *quantity* of emissions. What is uncertain is the marginal cost of achieving the emissions reductions necessary to realize this quantity.

²¹ In theory, under a perfectly functioning emissions trading system, the global costs of achieving a given global reduction will be the same regardless of the distribution of national targets.

²² See, for example, Weiner, Jonathan Baert, 2000. "Policy Design for International Greenhouse Gas Control." RFF Climate Issues Brief No. 6, Revised July, page 6. Others worry that nations could dilute the effectiveness of an international carbon tax in various ways. For example, if the international tax rate is \$25 per ton, a country could offset its impact by introducing a domestic subsidy to coal production. In order to prevent abuses of this sort, an international carbon tax agreement must take notice of the full set of tax policies introduced in the participating nations.

Under an international carbon tax, the locus of uncertainty is different. In principle, the tax makes it clear what the marginal cost of reducing emissions will be – this is simply the carbon tax rate. For example, if the carbon tax is effectively \$25 per ton of CO₂ emissions, then producers will find it advantageous to reduce demands for carbon-based fuels until the marginal cost of doing so is equal to the avoided tax payment – \$25 per ton. What *is* uncertain under the carbon tax is the quantity of emissions that will be generated. This depends on how much producers can reduce their use of carbon-based fuels before the marginal cost of doing so reaches the carbon tax rate.

Which uncertainty is worse? There is no easy answer. Some scientists and environmentalists show concern that allowing emissions and concentrations of CO₂ to cross a critical threshold could lead to calamitous climate impacts. These individuals might prefer the approach involving national targets, assuming that the targets imply total emissions and concentrations below the threshold value. To these analysts, an international carbon tax is too risky because it does not indicate in advance what level of emissions will result. On the other hand, many business groups express concern about the uncertainties inherent in the national-targets approach, pointing out that such an approach does not make clear what it will cost to reach the targets. These groups would prefer the international carbon tax, since the tax rate indicates the maximal marginal costs of abatement. These differing viewpoints about uncertainty continue to be expressed in debates about climate policy.²³

3. Differences in Transactions Costs

Transactions costs are the costs of finding buyers and sellers in a market as well as the costs of coordinating transactions, and are another relevant issue. Once implemented, a carbon tax might involve relatively small transactions costs, particularly if the tax is applied at the source (at the mine mouth for coal, at the wellhead for oil and natural gas). Transactions costs would be low in this case because the tax could be incorporated in the price of the fuel, just as sales tax is added to the cost of consumer goods. This does not make it more difficult to obtain the good or trade the good, and therefore would not cause significant transactions costs. Transactions costs associated with permit trades might be more

²³ Several studies have formally analyzed the relative strengths of quantity-based (like national targets) and price-based (like the carbon tax) approaches to environmental regulation. Weitzman (1974) and Stavins (1996) offer highly technical, general treatments. For a less technical general discussion, see Kolstad (2000). For an analysis in the context of climate-change policy, see Newell and Pizer (2000) and Pizer (1997), who finds that a price-based policy offers expected efficiency gains that are approximately five times greater than a quantity-based policy.

significant, although much depends on the particular institutional arrangement involved. While a well functioning international market in which permits are traded could involve low transactions costs, regulations and other barriers to trade could increase the cost of finding a trading partner and thus discourage advantageous trades. If these costs are significant, the overall attractiveness of an emissions-trading system will be reduced.

A Hybrid Approach: National Targets with a “Safety Valve”

We have thus far focused on an international emissions permit trading system and on an international carbon tax in isolation of each other. What would happen if we combined these approaches?

As mentioned, under a system with national emissions targets, it is not clear in advance what the marginal costs of abatement (or equilibrium permits price) will be. In contrast, under the international carbon tax, one cannot tell in advance what the emissions levels will be. Some analysts have proposed a “hybrid” approach that is claimed to combine the best features of the national-targets and carbon tax systems.²⁴

The hybrid approach is a national-targets system with a “safety valve.” Each participating nation would agree to a national target for emissions. Within each nation, emissions permits would be allocated to firms, with the total number of permits equal to the national target. Permits would be bought and sold on the international market. However, once the price of permits reaches a given “trigger price,” governments in each country would offer to sell additional permits to firms at that price. This prevents the permit price from exceeding the trigger price – this is the safety value of the system.

An attraction of this hybrid approach is that it puts a ceiling on – and thus reduces uncertainty about – the marginal costs of abatement. In addition, since national costs under this policy are determined largely through the allocation of national

²⁴ See, for instance, Pizer (1997), McKibbin and Wilcoxon (1997), Hahn (1997), and Kopp, Morgenstern, and Pizer (2000). For a more technical discussion of the benefits of hybrid approaches over target and tax systems, see Roberts and Spence (1976). As indicated by Roberts and Spence, a hybrid policy of the type described here dominates a pure price-based instrument (such as a carbon tax) or pure quantity-based instrument (such as a carbon quota) on average, assuming there are no implementation costs, no transactions costs, and no other real-world complications. Using an extended version of William Nordhaus’s DICE model, Pizer (1997) indicates that this hybrid approach produces slightly larger expected efficiency gains than a carbon tax and significantly larger expected gains than a carbon quota.

targets, it avoids the explicit financial transfers that might have to accompany an international carbon tax. At the same time, the hybrid approach introduces uncertainty about the equilibrium level of emissions. Once governments begin to sell additional permits, the global quantity of permits is increased beyond the quantity associated with the sum of the national targets. Thus, this policy allows global emissions to rise beyond the amount initially prescribed under the national targets.

Environmental groups in the U.S. have already expressed strong criticism of this scheme on the grounds that it leaves open the possibility that emissions will not be reduced substantially: possibly, producers would purchase a substantial number of additional permits if the trigger price was set too low. Indeed, in late October of 1997 several prominent U.S. environmental groups wrote an open letter to the Clinton Administration condemning the hybrid system on these grounds.

For the safety valve approach to work, it needs to be implemented by all countries that participate in emissions trading. To see why, suppose just one country – say, France – introduced the safety valve. If this were the case, then as soon as the permit price reached the ceiling price, all potential purchasers of permits would buy permits from France, since the French government was promising to sell at the ceiling price and other potential sellers would require higher prices. This would be great for the French Treasury – it is as if France were levying a tax on emissions from all over the world! But many countries are likely to be unhappy with this outcome, which redistributes much global wealth to France. This problem can be overcome only if all governments agree to sell permits at the ceiling price.

Thus, the safety valve needs to be implemented internationally. An effective safety valve mechanism also requires careful attention to how the revenues from permit-sales are used. If such revenues are controlled by national governments, the effectiveness of the international mechanism might be jeopardized. For example, a given nation could use these revenues to finance subsidies to producers of fossil fuels. This obviously would contravene the purposes of the international agreement. Recognizing this potential problem, Kopp, Morgenstern and Pizer (2000) urge that the revenues from the additional permit sales should go directly to an international fund rather than to national governments. The revenues in this fund would then be used to finance emissions-related projects in various countries, based on a “reverse auction.”²⁵ In theory, such an auction would assure that the revenues are devoted to projects that complement rather than undermine the objectives of reducing greenhouse gas emissions.

²⁵ See Kopp, Mortenstern, and Pizer (2000) for details.

5. PROJECT BASED MECHANISMS

While the approaches we have discussed above focus on putting a price on emissions of greenhouse gases, there is another set of flexibility mechanisms that can be used to reduce the overall cost of emissions abatement. These mechanisms are based on private investment in projects that lead to emissions-reductions in other countries. These mechanisms can thus be referred to as “project-based” mechanisms. Two such mechanisms are included in the Kyoto Protocol: Joint Implementation and the Clean Development Mechanism.

Joint Implementation

Joint implementation (JI), described and endorsed under Article 6 of the Kyoto Protocol, is an example of a project-based mechanism for reducing the global costs of achieving emissions reductions. Like emissions-permit trading, it operates with a backdrop of national commitments to reduce emissions to specified targets. However, in the case of JI, permits are not exchanged. Rather, a firm in one nation (Country A) sponsors a project – for example, the construction of a modern electricity-generating plant – to reduce emissions in another nation (country B). Both parties indicate in a contract how much emissions are reduced in the latter country as a result of the project. Suppose the emissions reduction is X. Based on this contract, the firm in Country A gets credit for X units of emissions reductions, while the total allowable emissions in Country B are reduced by X. Both parties benefit. For firms in country A, it is cheaper to finance the project in country B than to reduce emissions on its own (or buy additional emissions permits). For country B, gaining technical and financial assistance from the Country A firm is worth the “price” of having to reduce emissions by X more units.

The ultimate basis for cost-savings under Joint Implementation is the same as under emissions trading: the policy encourages emissions reductions where they can be implemented most cheaply. Both parties in the JI transaction benefit, and the global costs of achieving given emissions targets are reduced.

JI can be introduced in parallel with emissions-permit trading. If both mechanisms are in place, a given firm holding emissions permits can choose among a number of options. If the firm finds it exceptionally costly to reduce emissions to the level dictated by its current holdings of emissions permits, it can purchase additional permits at the market price. Alternatively, if it can sponsor a JI project in another country at low cost (that is, at lower cost than the cost of achieving comparable emissions reductions and lower than the cost of purchasing permits), it will be

financially more attractive for the firm to take this option.

The Clean Development Mechanism

In Article 12, the Kyoto Protocol articulates and endorses another “flexibility mechanism” – the Clean Development Mechanism (CDM). This mechanism is similar to JI in certain respects. Like JI, the CDM gives emission reduction credit to firms in an industrialized nation for the reductions that occur as a result of its financing of an investment project in another country. However, unlike JI, the CDM gives credit for emissions-reducing projects in countries that do not face national caps. Under the Kyoto Protocol, it is the developing countries that do not face such caps. Therefore, in the context of the Protocol, CDM represents a means for developed nations to receive emissions reductions credits through the financing of projects in developing nations.

The CDM has been embraced as an important vehicle for involving developing countries in the global effort to reduce greenhouse gas emissions. In principle, both the investing firm and the developing country benefit from a CDM project that is voluntarily agreed upon by both parties: the investing firm benefits from the emissions reduction credits and the developing nation benefits from the transfer of technology and the increased sustainability of their economy.

However, the CDM faces some difficult problems that do not appear under JI or emissions permit trading. The most important seems to be that of assuring that CDM projects do indeed reduce emissions in the developing country where the project is undertaken. To see how this problem arises, compare what happens under a JI program with the situation under the CDM. When a JI project is undertaken, the country receiving financial assistance has its allowable national emissions total reduced by the emissions reduction identified with the JI project. This is the “price” that the recipient country pays for the project’s financing. Likewise, the firm that finances the project is entitled to increase its emissions by the same amount: this is its compensation for financing the JI project. The changes in entitlements in the financing country and the country receiving assistance offset each other, so there is no change in global emissions.

Ideally, a similar situation would arise under the CDM: the presence of a CDM project hopefully would cause emissions in the developing country to be reduced relative to what the emissions would otherwise be, exactly offsetting the financing firm’s entitlement to generate more emissions. However, because there are no national caps on the developing country’s emissions, it is difficult to know in practice whether developing country emissions indeed are reduced by the CDM

project. Furthermore, it is possible that the CDM project would have been undertaken anyway – so that the CDM project has no real impact on national emissions. This is sometimes called the problem of *additionality*: the emissions reductions under a CDM project are supposed to be additional to any emissions reductions that otherwise would have occurred.

Some analysts suggest that these problems can be overcome if “sector-specific baselines” are established for developing countries.²⁶ Such baselines would indicate total emissions that the developing country could generate in connection with a given industrial sector (e.g., the electricity-generating sector). Under this plan, a precondition for a developing country’s involvement in CDM would be the establishment of sector baselines. If a developing nation wished to accept a CDM project in a particular sector, its emissions from that sector would have to be reduced below the sector baseline by an amount equal to the emissions-reduction associated with the CDM project. In other words, there must not be an increase in emissions elsewhere in the sector that offsets the reduction from the CDM project.

To many analysts, sector baselines make the CDM a viable and effective option. However, others express skepticism about this mechanism. They argue that the CDM cannot be counted on to yield global reductions in emissions without specific baselines, and express doubts as to whether sector-specific baselines are workable or politically acceptable.

Another design issue, which can potentially ameliorate the baseline problem, is the extent to which CDM projects are regulated and approved by some sort of international governing body. While institutional oversight may help prevent the baseline problem, it will increase the cost of undertaking a CDM project, thereby reducing the cost-effectiveness of CDM – cheap CDM projects that would have been undertaken in the absence of institutional oversight will no longer be viable. The reduced cost-effectiveness that accompanies stricter oversight has led some analysts to argue against such oversight, despite the baseline problem.²⁷

In theory, the CDM benefits all parties that participate in it. The decision by a developing country to participate, in particular, suggests that the value of the technological assistance exceeds the developing nation’s own sacrifice in undertaking the project. However, several developing country representatives and analysts from developed nations are skeptical about the benefits of CDM. Two major concerns have been raised by analysts:

²⁶ See, for instance, Hargrave, Tim, Ned Helme, and Ingo Puhl, 1998. “Options for Simplifying Baseline Setting for Joint Implementation and Clean Development Mechanism Projects.” Center for Clean Air Policy, Washington, D.C., November. <http://www.ccap.org>.

²⁷ For an excellent discussion of this and other design issues related to CDM, see Toman (2000).

1. If decisionmakers do not consider all of the national sacrifices involved, or if the financial transfers are not put to good use, participation could fail to benefit the developing country, they argue. The benefits of CDM to developing countries could be offset by misuse of financial transfers or by weakening the bargaining position of the developing country in future negotiations that might include emissions targets for developing countries.²⁸

2. If developing countries will eventually have to face binding national targets in the future, the CDM could increase developing countries' cost of meeting those targets because the CDM projects "may end up using most of the cheapest mitigation opportunities."²⁹ This so-called "low-hanging fruit" problem could be addressed by giving developing nations the option to buy back the emissions reductions credits from the sponsoring Annex I country at a pre-specified price.³⁰

6. "COVERAGE" ISSUES

Two further issues deserve emphasis in the design of international mechanisms to address climate change. We have already alluded to these issues in our previous analysis, but a more explicit treatment is necessary given their importance. These issues address the "coverage" of an international agreement and focus on which nations should be included and which gases should be controlled.

National Coverage: How Broad Should an Agreement Be in Terms of Nations Included?

The Kyoto Protocol includes binding commitments by the industrialized (Annex B) countries to reduce their greenhouse gas emissions. The developing countries have no binding commitments. In general, a system of national targets with emissions permit trading becomes more cost-effective as it becomes broader,

²⁸ van t' Veld, Klass, 2000. "Incentives for Developing Country Participation in CDM." Weathervane At the Negotiating Table Article, Resources for the Future, Washington, D.C., November. <http://www.weathervane.rff.org/negtable/cop6/cop6%5Fvantveld.htm>.

²⁹ Cullet, Philippe, 1999. "Equity and Flexibility Mechanisms in the Climate Change Regime: Conceptual and Practical Issues." *Review of European Community & International Environmental Law* 8(2): 177.

³⁰ van t' Veld, Klass, 2000. "Incentives for Developing Country Participation in CDM." Weathervane At the Negotiating Table Article, Resources for the Future, Washington, D.C., November. <http://www.weathervane.rff.org/negtable/cop6/cop6%5Fvantveld.htm>.

encompassing more countries. A broader trading system yields more opportunities for gains from trade. Thus, in terms of cost-effectiveness, it would be preferable to include developing countries within a system of tradable emission permits.

From a practical point of view, LDC participation is *ultimately* crucial, since their baseline emissions are projected to grow very rapidly over the next few decades. The growth in baseline emissions is particularly striking for China and India. As mentioned, China's baseline emissions are expected to overtake U.S. emissions before 2015 (see Table 3). No serious reductions in the growth of GHG concentrations can take place without significant contributions by China, India, and other LDCs.³¹

Although the ultimate importance of LDC participation is clear, thorny issues remain as to the timing and extent of LDC participation. The timing issue remains a key source of controversy as nations consider whether to ratify the Kyoto Protocol. Some analysts argue that it makes most sense to push from the beginning for a broad agreement with LDC participation, instead of starting with an agreement involving Annex B countries alone that might later be expanded to bring in the LDCs.³²

Jacoby, Prinn and Schmalensee (1998) provide two main arguments to support the "start out broad" approach:

1. Under a narrow agreement, carbon "leakage" will undo much of the desired global emissions reduction. If the Annex B countries act alone, their reductions in carbon use will tend to decrease demand for fossil fuels, thereby depressing world prices. This will increase non-Annex B countries' demand for such fuels and lead to higher consumption of fossil fuels outside of the Annex B countries. Reduced pre-tax fuel prices also will imply lower prices for goods and services produced with fossil fuels, particularly carbon-intensive goods such as refined petroleum products. This will stimulate higher consumption of these goods and services outside of the Annex B countries, again potentially offsetting the carbon reductions of the Annex B countries. Bernstein et al (1999) argue that carbon leakage could be a significant problem under the Kyoto Protocol, and estimate the ratio of the increase in carbon emissions in non-Annex I countries to the reduction of emissions in Annex I countries in 2010 to be around 16 percent. Their analysis

³¹ In this connection, Jacoby, Prinn, and Schmalensee (1998) point out that if the Annex B nations were solely responsible for achieving the IPCC-endorsed global emission path that leads to a 550 ppmv concentration target, their emissions would have to become negative by the middle of the next century. (Jacoby, Henry D., Ronald G. Prinn, and Richard Schmalensee, 1998. "Kyoto's Unfinished Business." *Foreign Affairs* 77(July/August): 54-66 .

³² See, for instance, Jacoby, Prinn, and Schmalensee (1998) and Stavins (1997).

suggests that the carbon leakage ratio will increase through time as well.³³

2. A narrow agreement promotes an increase in the share of global fossil fuel production and consumption by non-participating countries. This can expand dependence on fossil fuels by these countries, which could make it more difficult to attain their future participation in global carbon abatement efforts.

These authors argue that, in the short term, the breadth of an international agreement is far more important than its depth. A broad agreement involving only very modest emissions reductions is viewed as preferable to a narrow one with more substantial emissions cuts.

However, other analysts argue that it is more realistic to start out with a narrower agreement, and bring the LDC's into the fold later on. The Kyoto Protocol clearly is more consistent with this latter approach. Opponents of immediate LDC commitments raise two major arguments:

1. Industrialized nations largely have caused the problem of elevated GHG concentrations. From this notion two distinct conclusions are often drawn:

a) LDC participation should take place later. Brazil, China, India, Indonesia, and other LDCs should not face emissions limits until their emissions reach parity (in terms of total tons) with the major industrialized nations.

b) Emissions-trading would be unfair to LDCs. As mentioned earlier, some LDC representatives find it onerous that industrialized nations would "buy their way out" of abatement – in effect, paying for the privilege of maintaining high consumption of fossil fuels. Moral considerations indicate that industrialized nations should not buy their way out – even if emissions trading could lower the financial costs of achieving given emissions-reductions and even if it could be financially advantageous to LDCs.

2. Binding commitments could harm the LDCs in ways that are not acknowledged by advocates from industrialized nations. Stavins (1997) and Weiner (1997) indicate that LDC representatives at times express a fear of "carbon colonialism" and a belief that industrialized nations would use an international emissions permit trading system strategically to their own advantage.³⁴

³³ Bernstein, Paul M., W. David Montgomery, and Thomas F. Rutherford, 1999. "Global Impacts of the Kyoto Agreement: Results from the MS-MRT Model." *Resource and Energy Economics* 21(3-4): 375-413.

³⁴ Stavins, Robert N., 1997. "Policy Instruments for Climate Change: How Can National Governments Address a Global Problem?" *The University of Chicago Legal Forum* Volume 1997:

Any attempts to involve LDCs in international agreements will need to confront these arguments and objections.

Pollution Coverage: What Pollutants or Activities Should Be Covered under an International Agreement?

Most discussions of international abatement efforts center around carbon dioxide (CO₂), the most important anthropogenic contributor to radiative forcing. However, the most cost-effective abatement policy would be one that causes marginal costs of reducing GHGs (in carbon-equivalents) to be equated across all types of greenhouse gases. Thus, other things equal, it would enhance cost-effectiveness to include other GHGs in an international agreement. A recent study by Reilly et al (1999) estimates that the total annual abatement cost in 2010 under the Kyoto Protocol targets could cost upwards of 60% more when only CO₂ is regulated compared with an agreement that includes other GHGs and carbon sinks.³⁵

However, the other GHGs are more difficult to monitor than CO₂. A detailed analysis by Victor (1991) concluded that monitoring problems effectively prevented including any GHGs other than CO₂ in an international agreement.³⁶ While the inclusion of other GHGs has become more feasible with advances in monitoring technologies, the Kyoto Protocol is still inexact in its treatment of the breadth of gases covered. The Protocol refers to a basket of gases rather than focusing solely on CO₂ but gives little insight into how these gases are to be monitored. The potential monitoring problems with respect to greenhouse gases other than CO₂ raise questions as to whether Kyoto can be effectively implemented.

Another problem is how to establish the exchange ratios for different greenhouse gases.³⁷ These ratios determine how reductions in emissions of different gases can

293-329; Weiner, Jonathan Baert, 1997. "Policy Design for International Greenhouse Gas Control." Climate Issue Brief No. 6, Resources for the Future, Washington, DC, September.

³⁵ Reilly, J., R. Prinn, J Harnisch, J. Fitzmaurice, H. Jacoby, D. Kicklighter, J. Melillo, P. Stone, A. Sokolov, and C. Wang, 1999. "Multi-gas Assessment of the Kyoto Protocol." *Nature* 401(6735) October: 549-555.

³⁶ Victor, David G., 1991. "Limits of Market-Based Strategies for Slowing Global Warming: The Case of Tradeable Permits." *Policy Sciences* 24:199-222.

³⁷ The Kyoto Protocol uses Global Warming Potentials (GWPs) to convert emissions into carbon equivalents. However, GWPs are linear approximations of a non-linear climate system and therefore are inexact. The accuracy of the GWP approximation approach has been called into question recently, and there is no clear cut answer to whether GWPs are an "accurate enough" index of

be added up or converted into “carbon equivalents.” Suppose a given nation reduces methane emissions by four million tons. How many units of carbon dioxide emissions is this equivalent to? In principle, the different gases should be exchanged according to their impact on the environment and human welfare. If a ton of methane does twice as much damage as a ton of carbon dioxide, a nation should get twice as much credit for a ton of methane reduced as it gets for each ton of CO₂ reduced. But the relative impact of a ton of CO₂ and a ton of methane can vary at different points in time, because of different residence times in the atmosphere and because of interactions between the (varying) stocks of different gases. Moreover, there are huge uncertainties as to the damages produced by the different gases. These complications pose severe challenges to the task of coming up with exchange ratios across greenhouse gases.³⁸

Thus, there are significant difficulties in extending the coverage emissions agreements to incorporate other gases in addition to CO₂.³⁹

A parallel “breadth” question applies to carbon sinks: should an international agreement give credit to carbon sequestration through afforestation? The Kyoto Protocol includes carbon sequestration as a means of reducing national emissions, effectively making countries’ obligations in terms of net emissions (carbon emissions minus the absorption of carbon attributable to expanded sinks).

Carbon sequestration raises a “baseline” problem analogous to that which arises under the CDM: some forest expansion would occur even in the absence of an international agreement, and it is difficult to determine which expansion is linked to the agreement.

The sequestration issue was a sticking point at the Conference of Parties meeting at the Hague in November of 2000. Representatives from the United States viewed sequestration credits as essential to meeting the US emissions targets as mandated by the Kyoto Protocol. European representatives and environmental groups, however, felt that the American proposals would illegitimately relax US obligations to cut back on greenhouse gas emissions and would prevent the Protocol from achieving its environmental goals. The impasse on sequestration credit ultimately dominated the discussion at COP-6 and was never satisfactorily resolved.⁴⁰

warming potential. See Smith and Wigley (2000a) and Smith and Wigley (2000b).

³⁸ For a discussion of these issues, see Hammit, Jain, Adams, and Wuebbies (1996), Lashof (2000), and Bradford and Keller (2000).

³⁹ The discussion here is on converting greenhouse gases under policies involving national targets. The same challenges arise in attempts to expand an international emissions tax to include other greenhouse gases in addition to CO₂.

⁴⁰ Anderson, John W., 2000. “Why the Climate Change Conference Failed: An Analysis.”

Very recently, researchers have explored the possibility of chemical sequestration of carbon, which involves capturing CO₂ after it is generated by the combustion of fossil fuels or refined fuels. This sequestration is still in the experimental stage, but at some point it might make sense to consider incorporating it in international arrangements to control atmospheric CO₂.⁴¹

For the near term, however, the most promising approach for international agreements may be to focus on CO₂ emissions abatement, as monitoring is not such a problem for CO₂ – emissions can fairly reliably be linked to domestic consumption of fossil fuels.⁴² In subsequent agreements, the breadth of GHGs and of GHG-related activities (e.g., emissions abatement, sequestration) could be expanded as the scope of the problems of monitoring and baseline-definition become clearer.

7. CONCLUSIONS

A decade ago there were no broad-based discussions of international approaches to the problem of global climate change. Now, with the Kyoto Protocol as the centerpiece, there is a great deal of discussion worldwide of a great many policy options. Substantial uncertainties remain as to what will be the shape of an international agreement on global climate policy. Indeed, given that few nations have ratified the Kyoto Protocol since its adoption three years ago and the inability of the Parties to agree on the implementation details of the Protocol, the possibility exists that no agreement will be reached and implemented for quite a while, if at all.

The Kyoto Protocol has focused on a system of national targets combined with various flexibility mechanisms. In this paper we have described and evaluated the various potential features of this system. In addition, we have explored significant alternatives to the Kyoto approaches -- including an international carbon tax and a

Weathervane Feature, Resources for the Future, Washington, D.C., December 4.
http://www.weathervane.rff.org/negtable/COP6/analysis_anderson.htm.

⁴¹ For information on the current state of research into carbon sequestration, see U.S. Department of Energy, 1999. *Carbon Sequestration Research and Development*. Available online at http://www.ornl.gov/carbon_sequestration/.

⁴² Some adjustments would be needed for the use of fossil fuels as petrochemical feedstocks, since in this use the fuels are not combusted and no CO₂ is generated. Such uses represent less than 5 percent of total consumption of fossil fuels in the U.S. For a useful discussion of monitoring and enforcement issues arising in the context of global climate policy, see Hahn (1997).

hybrid policy that combines features of national targets and emissions trading with elements of an international carbon tax.

It is possible to become overwhelmed by divergence of opinion on the relative merits of different policy options, and the associated uncertainties about what the future will bring. However, the wider scope and increased sophistication of the international discussion of policy options are encouraging signs.

Three points seem to deserve emphasis. First, while the Kyoto Protocol does not include binding emissions targets for LDCs, the participation of LDCs ultimately will be crucial for any serious global reductions in GHG concentrations. The LDCs are likely to resist committing to significant sacrifices in the near future. Given this situation, it may be fruitful to pursue a policy that currently engages the LDCs in a legally binding way, without committing them to significant near-term emissions reductions. One such policy would include the LDCs in an emissions trading system, while making the allocations of emissions to LDCs ample enough to avoid requiring any significant reductions in the short term. (For example, the allocation to LDCs could reflect the projected unconstrained baseline for these countries.) Even if this has little or no effect on near-term emissions by LDCs, it has the significant virtue of involving LDCs in the global abatement process, which may enhance the prospects for serious LDC emissions reductions in the more distant future.

A second point is the importance of flexibility in global efforts to address the prospect of climate change. There are great uncertainties about current and future benefits and costs of reducing GHGs. This gives value to flexibility. It seems sensible to design policies that can adjust as scientific information and nations' circumstances change. The most attractive international approach would allow for periodic adjustments concerning future global emissions targets, for changes in the range of GHGs and abatement activities it embraces, and for modifications to the obligations of various countries.⁴³

A final point is that it may be useful to keep a perspective on the likely time frame of the climate-change problem. If an international agreement is reached and implemented in the near term – whether it be the Kyoto Protocol or some other agreement – it is likely to be just a first step in a series of international efforts

⁴³ Stressing the importance of flexibility, Hahn (1997) recommends that industrialized nations adopt an agreement involving several different approaches to emissions reduction, including both a modest domestic carbon tax and tradable permits. He claims that this would provide more information than any single approach and would help nurture the development of appropriate institutions necessary for dealing effectively with the prospect of climate change.

stretching over decades. One potential goal of current policies might be to lay the groundwork for future policies by helping develop appropriate legal and fiscal institutions for dealing with the problem of climate change – institutions that will remain useful even as the specific policies change through time.

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Figure 1a: Total Cost of CO₂ Abatement

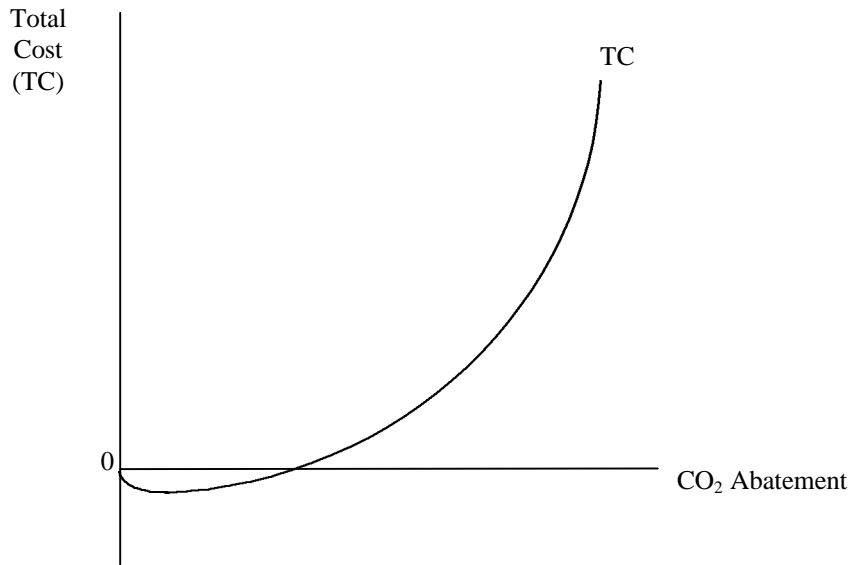


Figure 1b: Marginal Cost of CO₂ Abatement

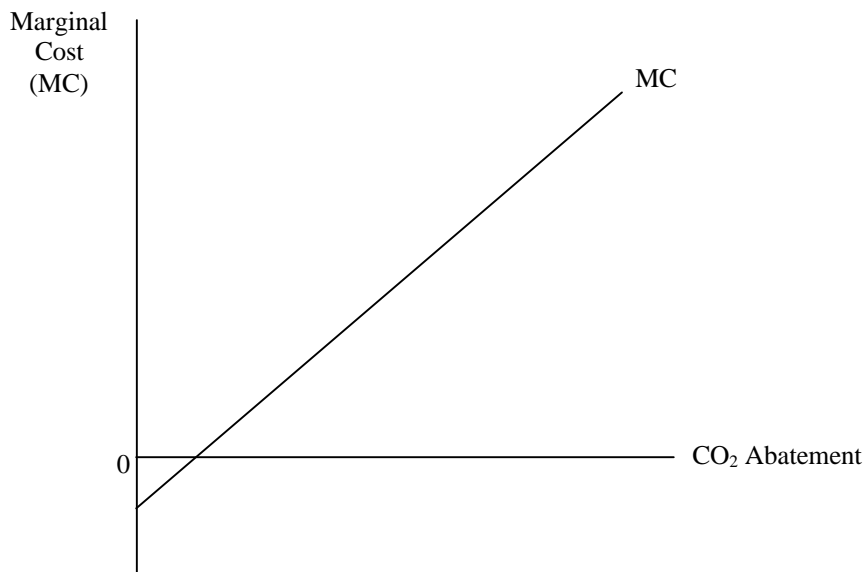


Figure 2: Marginal Cost of CO₂ Abatement in the United States

Source: Weyant, John P. and Jennifer N. Hill, 1999. "Introduction and Overview." *The Energy Journal*, Kyoto Special Issue. Marginal cost data estimated from Figure 10(a), page xxxvii

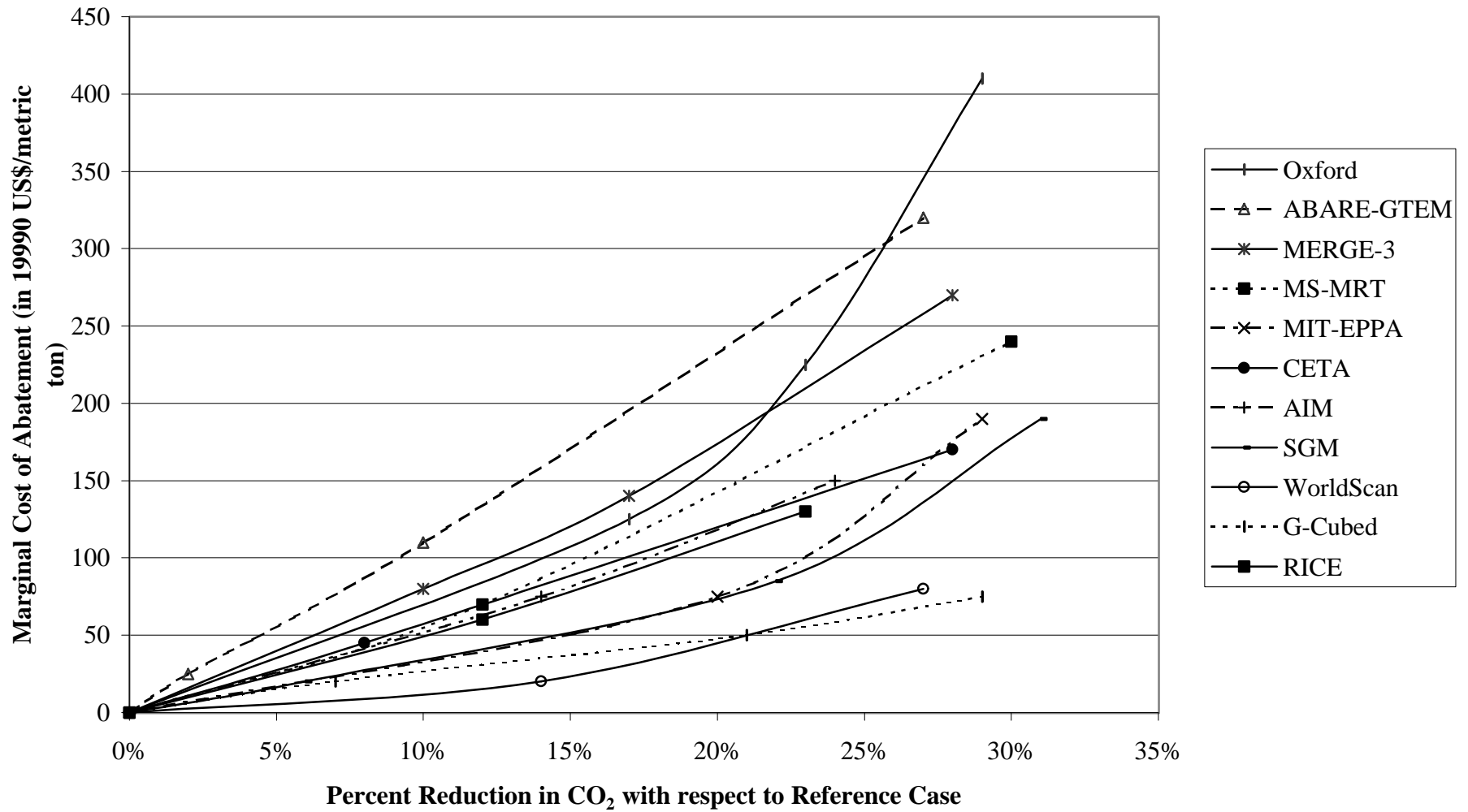


Table 1: Implications of Alternative Allocation Criteria

Country	Percentage Share of World Industrial CO ₂ Emissions, 1992	Percentage Share of World GDP, 1993	Percentage Share of World Population, 1993
USA	21.85	27.08	4.69
China	11.94	1.84	21.42
Russian Federation	9.41	1.43	2.70
Japan	4.89	18.23	2.26
Germany	3.93	8.27	1.47
India	3.44	0.98	16.33
United Kingdom	2.53	3.54	1.05
Canada	1.83	2.07	0.52
Italy	1.83	4.29	1.04
France	1.62	5.42	1.05
Poland	1.53	0.37	0.70
Mexico	1.49	1.49	1.64
Australia	1.20	1.25	0.32
Spain	1.00	2.07	0.72
Brazil	0.97	1.92	2.84
Indonesia	0.83	0.63	3.40
Netherlands	0.62	1.34	0.28
Czech Republic	0.61	0.14	0.19
Romania	0.55	0.11	0.41
Sweden	0.25	0.72	0.16

Sources: *World Resources, 1996-97*; *World Development Report, 1995*

Figure 3: Marginal Cost of CO₂ Abatement in Japan

Source: Weyant, John P. and Jennifer N. Hill, 1999. "Introduction and Overview." *The Energy Journal*, Kyoto Special Issue. Marginal cost data estimated from Figure 10(c), page xxxix.

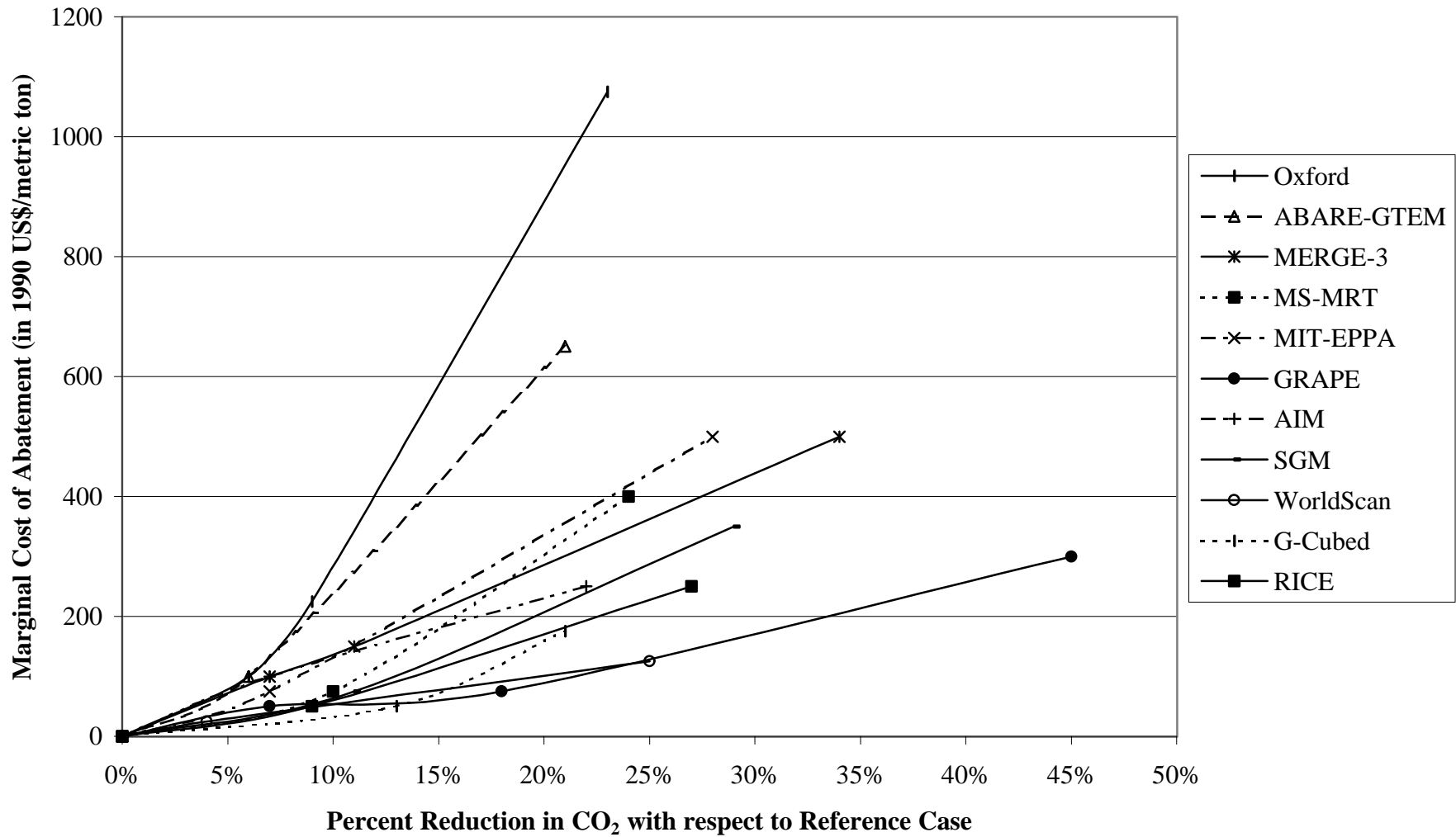


Figure 4: Abatement under Emissions Permit Trading

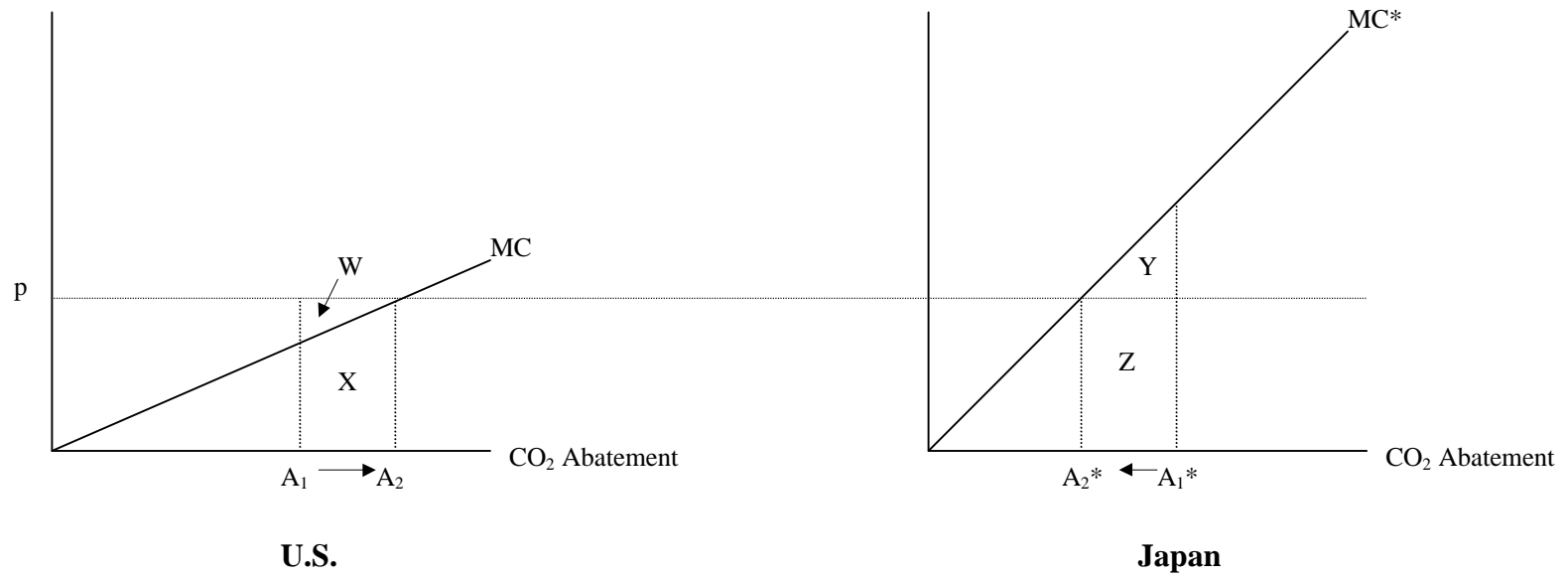


Table 2: Cost of Meeting Kyoto Protocol Targets in the Presence and Absence of Permit Trading

	No Trading	Annex B Trading		Global Trading	
Model	GDP Loss*	GDP Loss*	Percentage Cost-Saving Relative to No Trading	GDP Loss*	Percentage Cost-Saving Relative to No Trading
MS-MRT					
US	181	87	52%	28	85%
Japan	78	14	82%	2	97%
EU	60	10	83%	4	93%
Oxford					
US	158	90	43%	49	69%
Japan	83	23	72%	14	83%
EU	195	60	69%	45	77%
MERGE3					
US	90	42	53%	18	80%
Japan	34	8	76%	0	100%
EU	105	50	52%	20	81%
G-Cubed					
US	36	20	44%	5	86%
Japan	23	19	17%	5	78%
EU	170	60	65%	25	85%

* In Billions of 1990 US Dollars

Models Included in Table 1:

- MS-MRT (Multi-Sector – Multi-Region Trade Model), developed by Charles River Associates and the University of Colorado
- Oxford, developed by Oxford Economic Forecasting
- MERGE3 (Model for Evaluating Regional and Global Effects of GHG Reductions Policies), developed by Stanford University and the Electric Power Research Institute
- G-Cubed (Global General Equilibrium Growth Model), developed by Australian National University, University of Texas, and the U.S. Environmental Protection Agency

For more information, please see the special issue of *The Energy Journal* cited below.

Source: Weyant, John P. and Jennifer N. Hill, 1999. "Introduction and Overview." *The Energy Journal*, Kyoto Special Issue. GDP losses are estimated from Figure 9, pages xxxiii-xxxiv.

Table 3: Historical and Projected Carbon Emissions by Region
(millions of metric tons)

Region/Country	History			Projections				Average Annual Percentage Change 1995-2015
	1990	1994	1995	2000	2005	2010	2015	
Industrialized								
North America	1,561	1,634	1,663	1,826	1,956	2,066	2,170	1.3
United States	1,337	1,397	1,424	1,543	1,638	1,721	1,798	1.2
Canada	137	140	143	160	172	182	192	1.5
Mexico	87	97	97	123	146	163	180	3.1
Western Europe	1,016	987	1,014	1,081	1,147	1,208	1,279	1.2
Industrialized Asia	408	449	473	514	553	593	625	1.4
Japan	308	354	361	401	432	466	492	1.6
Australasia	100	95	112	114	121	127	133	0.8
Total Industrialized	2,985	3,069	3,151	3,421	3,656	3,868	4,074	1.3
EE/FSU								
Former Soviet Union	1,029	711	653	733	802	872	933	1.8
Eastern Europe	309	239	240	278	293	306	318	1.4
Total EE/FSU	1,339	949	893	1,012	1,095	1,178	1,251	1.7
Developing Countries								
Developing Asia	1,092	1,401	1,475	1,865	2,295	2,735	3,232	4.0
China	625	784	821	1,031	1,257	1,523	1,838	4.1
India	159	205	221	276	350	421	490	4.0
Other Asia	307	412	432	557	688	792	904	3.8
Middle East	203	241	254	265	291	315	344	1.5
Africa	205	239	248	267	294	322	352	1.8
Central and South America	189	212	220	263	319	382	452	3.7
Total Developing	1,687	2,092	2,197	2,660	3,199	3,755	4,379	3.5
Total World	6,012	6,111	6,241	7,093	7,950	8,800	9,704	2.2

Notes: EE/FSU = Eastern Europe/Former Soviet Union. The U.S. numbers include carbon emissions attributable to renewable energy sources.

Source: United States Department of Energy, 1997. *International Energy Outlook 1997*: Table A9.

Figure 5: Abatement under an International Carbon Tax

