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The Provision Status of Global Environmental Protection

A UNDP/ODS Background Paper

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Introduction

Protection of the earth's ozone layer and climate change mitigation are both pure global public goods. No country can be excluded from provision of either good, and no country's consumption of these goods diminishes the amounts available to other countries. However, the incentives for provision differ as between these two public goods. Indeed, this difference in the underlying economics helps explain why protection of the ozone layer has been a spectacular success whereas very little has yet been done to mitigate global climate change. This note summarizes the essential economics of both global environmental problems.

Framework

How much provision is desirable? Consistent with the approach used in the note on disease eradication and elsewhere in this book, the most desirable provision level maximizes net benefits for the world. While simple in concept, however, estimation of this desired level poses a number of challenges, some conceptual and some empirical. As we shall see, the answer is pretty clear for ozone protection, much less so for global climate change. Empirical estimates are provided later in this note. Here I discuss briefly the more important conceptual challenges.

Why take account of both benefits and costs? The rationale isn't obvious. Indeed, the Framework Convention on Climate Change establishes a goal for global mitigation involving "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." There is no mention here of benefits and costs. The Vienna Convention for the Protection of the Ozone Layer enjoins parties to "take appropriate measures…to protect human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer." This agreement also does not mention the need to balance benefits and costs.

At the same time, it is not obvious what level of concentrations would prevent dangerous interference with the climate system, or what measures would be appropriate for preventing depletion of the ozone layer.

The expression "dangerous interference" implies a discontinuity, with slightly less interference being safe and with slightly more being dangerous. Atmospheric concentrations today are around 370 parts per million (ppm). So how high a level is dangerous?

O'Neill and Oppenheimer (2002) illustrate how this level of interference might be identified by focusing on three discontinuous changes that would plainly be very serious: the destruction of large scale coral reef ecosystems; the disintegration of the West Antarctic Ice Sheet (WAIS); and the collapse of the thermohaline circulation (THC). However, as O'Neill and Oppenheimer also explain, the targets required to avoid each discontinuous change are different and uncertain. A target of 450 ppm would probably not protect coral reefs. It may protect disintegration of the WAIS, but this is uncertain. It would likely prevent collapse of the THC, but even this is not guaranteed. Why then should we adopt 450 ppm as a goal? Why not aim for 400 ppm? Or 500 ppm? Or some other level?

Another problem with this approach is that it ignores the consequences of mitigation. Pacala and Socolow (2004) explain that a higher target of 550 ppm (about twice the pre-industrial level of 280 ppm) would require an expansion in nuclear power. A lower target would require a substantial increase in nuclear power. Mitigation thus introduces risks of its own. Rather than ignore the risks of mitigation, it would seem more sensible to adopt a framework that balances the different risks.

Ignoring the costs of mitigation is also a morally empty logic. One argument for mitigation is that that the poor countries would be especially vulnerable to climate change. Concerns for equity could justify greater global action to mitigate climate change, as discussed later in this note. But resources can also be devoted to reducing vulnerability and not only mitigation. Of course, the choice is not whether to invest in one activity *or* the other. The choice is how much to spend on reducing vulnerability *and* how much to spend on mitigation. Still the trade off must be confronted. Money spent on mitigation cannot also be spent reducing vulnerability.

Climate mitigation and ozone layer protection also involve tradeoffs across generations. They involve taking actions now at some cost, with the benefits of these actions being realized only far in the future. A single CFC molecule takes about 50 years to reach the stratosphere. Carbon dioxide lasts more than twice as long. Temperature mixing by the oceans takes longer still. Discounting at positive rates over these time scales would favor taking little action, and for this reason it is sometimes argued that we should not discount these benefits. Not discounting, however, implies a zero discount rate. And the question then arises, why discount at this rate and not at another? To be sure, we should not discount at a positive rate simply because alternative investments yield positive returns. This only means that there is an opportunity cost to the money invested in global environmental protection. The opportunity cost plainly needs to be charged against the investment, but this is different from discounting the benefits of mitigation at a rate plucked from the *Financial Times.*

More broadly, we should see these matters for what they are: development challenges. In this setting, an important consideration is whether future generations will be better of or worse off than the current generation. Suppose that, even with climate change, future generations can sustain a higher standard of living. Then we should ask the question, why should a dollar of consumption sacrificed by the current generation (to mitigate climate change) be equated with a dollar of consumption gained (as a consequence of the mitigation) by a future generation (an implication of zero discounting)? If the future is going to be better off anyway, is this an ethical allocation? Moral reasoning here would commend positive discounting. Suppose, however, that, because of climate change, future generations are expected only to be able to sustain a lower standard of living than the current generation. Shouldn't the current generation then make a greater sacrifice for the future generation? Here, moral reasoning favors negative discounting. The essential point is that choices have to be made. Positive discounting need not be unethical, just as zero discounting need not be ethical.

Ozone layer protection

Estimates of the costs and benefits of protecting the ozone layer, prepared by the United States Environmental Protection Agency, are shown in Table 1. Three scenarios are evaluated: a situation in which nothing is done to control emissions (a “business as usual” scenario); a situation in which the United States and other countries comply with the restrictions incorporated in the original Montreal Protocol; and a situation in which only the United States complies with these restrictions. The study first predicts ozone depletion for all three scenarios. It then attaches values to shifting from the first scenario to the latter two scenarios.

The top rows in Table 1 show that the Montreal Protocol was predicted to have a substantial effect in reducing depletion relative to the “no controls” scenario, especially in the long run. The reason, of course, is that there is a lag between the time at which emissions are cut and the time at which ozone depletion is reduced. This analysis also indicates that the US on its own can reduce depletion significantly in the medium term but not in the long run.

The bottom set of rows in Table 1 show the costs and benefits to the US of undertaking the emission cuts required by the Montreal Protocol assuming either that other countries also comply with Montreal or that they do not. These estimates are for the United States only. Since the US undertakes the same actions under either of the last two scenarios, the costs of taking the action are assumed to be the same. These costs are relatively low, indicating that there exist, or could be expected to exist, substantial substitution possibilities. The benefit estimates are larger, especially for the scenario in which other countries join the US in meeting the Montreal Protocol targets. The US would certainly prefer that other countries join the US. However, the numbers shown in the bottom right of Table 1 indicate that the US would gain by undertaking the Montreal cuts even if other countries did not participate in the agreement.

The main benefit of reduced ozone layer depletion is avoided cancer deaths. According to the EPA study, the Montreal Protocol would avoid more than 5 million cancer deaths in the US by 2165. People are willing to pay a lot to avoid the risk of premature death. Multiplying a large number of avoided deaths by a high value per death avoided results in a large benefit to protecting the ozone layer. This mainly accounts for the high benefit figures shown in the Table.

Table 1
Net Benefits of to the United States of Ozone Protection

	No Controls	Montreal Protocol	Unilateral implementation of Montreal by the US
Ozone Depletion (percent)			
By 2000	1.0	0.8	0.9
By 2050	15.7	1.9	10.3
By 2100	50.0	1.2	49.0
Payoffs to the US (billions of 1985 $US)			
Benefits	--	3,575	1,373
Costs	--	21	21
Net Benefits	--	3,554	1,352
Benefit-Cost Ratio		170:1	65:1

Source: United States Environmental Protection Agency (1988).

The global benefits and costs of the Montreal Protocol were calculated once again in 1997, on the tenth anniversary of the agreement, and these estimates are shown in Table 2. This analysis differs from the earlier one in a number of respects. First, the estimates are for the world, and not only the United States. Second, the estimates are not only for the original Montreal Protocol, but the amendments and adjustments to this agreement. Since the agreement in 1997 required much greater reductions, and on a shorter timetable, than the original agreement, all else being equal, costs and benefits should be higher. Third, the estimates are only for the period 1987-2060, whereas the EPA analysis extended farther into the future. Finally, the study summarized in Table 2 did not attempt to place monetary values on avoided cancer deaths. As noted earlier, this was the largest component of the EPA study. It is, however, remarkable, that even with these differences, the analysis summarized in Table 2 shows that the Montreal Protocol delivered the entire world a benefit in excess of the cost.

Table 2
Global Benefits and Costs of the Montreal Protocol Phase-Out, 1987-2060
(US dollars)

	Amount
Health Benefits	
Avoided cases of non-melanoma cancers	19.1 million
Avoided cases of melanoma cancers	1.5 million
Avoided cases of cataracts	129.1 million
Avoided skin cancer deaths	333,500
Monetized Benefits	$459 billion
Costs	$235 billion
Net Benefits	$224 billion + non-monetized health benefits

Source: ARC Research Consultants (1997).

The two cost-benefit analyses of protection of the ozone layer summarized above consider discrete options: the original Montreal Protocol and the same agreement, incorporating a number of amendments and adjustments. These studies do not aim to determine the level of protection that maximizes the difference between benefits and costs (the level at which the marginal benefit of ozone layer protection equals the marginal cost). However, the economics of ozone layer protection are so overwhelming that I would guess that the marginal benefit of ozone layer protection exceeded the marginal cost, even for the most ambitious target incorporated within the Montreal Protocol. In other words, the Montreal Protocol targets probably *are* optimal.

All of this might seem to imply that countries had a unilateral incentive to phase out CFCs. However, developing countries benefited less from ozone layer protection than industrialized countries—partly because depletion would be less near the equator, and partly because people with dark skin would be less vulnerable. To gain the participation of developing countries, Montreal was amended in 1990 to compensate these countries for the “incremental costs” of their participation and compliance. As I have explained elsewhere (Barrett 2003), the Montreal Protocol ingeniously manipulated incentives, changing the behavior of many other key players, to the benefit of all countries. The success of Montreal was helped by the underlying economics of ozone depletion, but Montreal exploited this favorable situation, to sustain global collective action. As we shall see, the economics of global climate change mitigation are not as favorable, and this partly explains why the Kyoto Protocol has proved less successful than Montreal.

Climate change mitigation

What are the expected consequences of climate change, in economic terms? And how might these consequences be distributed? Table 3 summarizes the ‘first generation’ estimates (in the Pearce *et al*. 1996 column) and the most recent estimates available for a benchmark doubling in the atmospheric concentration of greenhouse gases. The more recent estimates reflect smaller damages, even for the same mean global temperature change. Indeed, two of the studies indicate that the world may possibly gain from climate change. The reason for the difference is that these newer estimates reflect opportunities to adapt to climate change—for example, by farmers switching to more climate-resistant crops. Notice, however, that developing countries are expected to be more vulnerable to climate change.

Table 3
Aggregate Climate Change Damage
(Percent of GNP)

Benchmark temperature increase for 2×CO_2	Pearce *et al.* (1996)	Mendelsohn *et al.* (1996)		Nordhaus and Boyer (2000)	Tol (2002)
	2.5°C	1.5°C	2.5°C	2.5°C	1.0°C
Industrialized countries	NA	+0.12	+0.03	-0.5 to +0.4	NA
Developing countries	NA	+0.05	-0.17	-0.2 to –4.9	NA
World	-1.5 to –2.0	+0.10	NA	-1.5	+2.3

Source: Pearce (2004). The studies cited in the paper are given in Pearce (2004).

Mitigation cannot avoid all of these damages, and a primary focus of policy must be on the costs and benefits of mitigation—that is emission reductions (plus, possibly, sequestration).

Kyoto only limits the emissions of a relatively small number of countries by a small amount for a short interval of time (five years). However, Kyoto was meant to be a first step. It was meant to initiate a process whereby the first agreement was to be succeeded by another and so on in serial fashion. As I have explained elsewhere (Barrett 2003), my view is that Kyoto will fail to sustain substantial reductions in emissions. Here, however, I limit my attention to the economics of the Kyoto target—that is, to a discussion of ends, not means.

Nordhaus and Boyer (2000) examine a number of alternative scenarios, a reference case of no controls; an optimal scenario in which the global net benefits of mitigation are maximized; and a number of "Kyoto Forever" scenarios. These last scenarios assume that the emission limits for the Annex I (industrialized) countries hold indefinitely (under Kyoto, they hold only until 2012). These scenarios are not meant to be realistic. For example, they assume that the United States is bound by the Kyoto limits, and it is certain that the US, a non-party to Kyoto, will exceed its Kyoto limits by a substantial margin. As well, the evolution of Kyoto is uncertain. It is possible that Kyoto will be both deepened (greater emission cuts) and broadened (with the emissions of more countries being limited) over time. It is also possible that Kyoto will not be able to sustain the limits it now incorporates let alone build on these. The purpose of this exercise is not to predict the future but simply to show the economics of alternative possible evolutionary courses.

The Global Trading scenario assumes that the emission limits imposed on Annex I countries are implemented at least cost globally, an outcome requiring that the marginal costs of implementation be equal for both Annex I and non-Annex I countries. This scenario essentially assumes that the Clean Development Mechanism in the Kyoto Protocol could be implemented perfectly and with no transactions costs. The Annex I Trading scenario limits trading to the Annex I countries but again assumes that trading is perfect and that there are no transactions costs. Under this scenario, marginal costs will be equal for all Annex I countries but for all non-Annex I countries marginal costs will equal zero. The No Trading scenario assumes that the Annex I countries meet their emission limits unilaterally. For this scenario, marginal costs will differ among the Annex I countries and not just between Annex I and non-Annex I countries. Under the Kyoto Forever Concentration and Temperature scenarios, the concentration and temperature levels associated with Kyoto are assumed to be met cost effectively. These last scenarios imply even greater flexibility than the others, which explains why the costs of sustaining these outcomes are so much lower.

Table 4 summarizes the results from Nordhaus and Boyer (2000). There are a number of important lessons to emerge from this summary. First, the effect of the different Kyoto Forever scenarios on temperature is extremely modest. This is partly because of the assumption underlying this analysis that emissions growth in the Annex I countries will be low under the No Controls scenario, while emissions growth in the non-Annex I countries will be substantial (these emissions are not constrained by Kyoto). Second, the provisions for trading have a huge effect on costs. Third, the trading arrangements also affect benefits. This is because the emission limits for Russia and other non-OECD countries exceed existing emission levels (“hot air”). Trading with these countries thus reduces the magnitude of global emission reductions. Fourth, achievement of the atmospheric concentrations or temperature change implicit in Kyoto Forever yields an improved net benefit. This is because these scenarios not only benefit from the cost savings of global abatement. They also benefit by being able to alter the timing of abatement. These scenarios yield large benefit-cost ratios. The Global Trading scenario also yields a benefit-cost ratio above one. However, the Annex I Trading scenario—the scenario that come closest to Kyoto’s actual design—sustains a low benefit-cost ratio.

Table 4
Aggregate Economics of “Kyoto Forever”

	No controls	Kyoto Forever					Optimal
		Concen-tration	Temp-erature	Global Trading	Annex I Trading	No Trading	
Global mean temperature increase (°C from 1990)							
2055	1.46	1.45	1.46	1.45	1.45	1.43	1.43
2105	2.53	2.49	2.50	2.50	2.50	2.47	2.44
Benefits and costs (billions of 1990 US dollars)							
Benefits	--	107	83	108	96	161	296
Costs	--	12	5	59	217	884	98
Net Benefits	--	95	78	49	-121	-723	198
Benefit-cost ratio	--	9.07	15.22	1.82	0.44	0.18	3.02

Source: Nordhaus and Boyer (2000), Tables 8.3 and 8.8.

Table 5
Distributional Economics of “Kyoto Forever”
(Difference from No Controls scenario; billions of 1990 US dollars)

	No controls	Kyoto Forever					Optimal
		Concen-tration	Temp-erature	Global Trading	Annex I Trading	No Trading	
US	--	12	10	-78	-313	-833	22
OHI	--	10	9	3	-15	-26	26
Europe	--	47	36	47	46	54	126
EE	--	-1	0	29	113	3	-9
MI	--	8	7	11	11	18	19
LMI	--	6	5	13	13	21	5
China	--	0	1	5	4	6	-10
LI	--	12	9	19	21	34	20
Annex I	--	69	56	0	-170	-801	164
Row	--	26	21	48	49	78	34
World	--	95	77	49	-121	-723	198

Source: Nordhaus and Boyer (2000), Table 8.7. Note: US United States; OHI other high income; EE Eastern Europe; MI middle income; LMI lower middle income; LI low income; Annex I non-industrialized countries identified in the Kyoto Protocol.

Table 5 presents a distributional analysis of the aggregate estimates shown in Table 4. Even under the optimal policy, Table 5 shows that some countries may lose relative to the No Controls baseline. This is either because these countries may benefit from climate change or because they may be required to reduce their emissions substantially under this scenario. The United States loses substantially under many of the Kyoto Forever scenarios, mostly because its emissions would be more severely constrained than other countries. Russia and Eastern Europe, by contrast, gain under these same scenarios because their emissions are little constrained and they can sell their emission reductions for a profit under the trading scenarios.

Cline (2004) provides a different analysis of the aggregate impacts of climate policy, making two adjustments to the Nordhaus-Boyer model. First, he assumes that business-as-usual emissions for the Annex I countries increase more rapidly—meaning that emissions are reduced by more in the future. Second, he applies a lower discount rate—implying a higher value to future benefits. The combination makes Kyoto appear more favorable. In particular, Cline (2004: 26) obtains a benefit-cost ratio for a scenario akin to Nordhaus-Boyer's Annex I trading scenario of 1.77. Importantly, however, Cline finds that the benefit-cost ratio for the Annex I countries under this scenario is just 0.58. The countries expected to implement the scenario lose, even while the world as a whole gains.

The optimal policy that maximizes net benefits for the world equates the marginal global benefit of mitigation with the marginal cost. The marginal global benefit of mitigation is the benefit of reducing atmospheric concentrations by a small amount, usually expressed in dollars per ton of carbon. This marginal benefit increases over time because atmospheric concentrations are expected to increase. In the optimal policy developed by Nordhaus and Boyer (2000), and reported in Table 3, the marginal benefit of mitigation rises from about $13 per metric ton of carbon in 2015 to about $25 in 2105.

Once again, Cline (2004), using the same model but making different assumptions, finds that the economics of mitigation are more favorable. Under his optimal program, the marginal benefit rises from about $130-$170 per metric ton of carbon through 2015 to about $600 by 2100 and $1,300 in 2200 (Cline 2004: 20). This optimal policy yields a benefit-cost ratio of about 2:1.

These are extreme values when compared to the broader literature. Pearce's (2004) review of this literature suggests that the current value of the marginal benefit of mitigation is about $4 to $9 per tonne of carbon (expressed in 2000 US dollars). This range is broadly consistent with Nordhaus and Boyer's (2000) optimal policy (for which marginal benefit of mitigation is $9 in 2005, expressed in 1990 US dollars). But Pearce also explains why these figures may need adjusting. Recognizing that developing countries will be relatively more vulnerable to climate change, and (for ethical reasons) attaching a greater weight to the losses suffered by developing countries relative to rich countries, the upper bound on marginal benefit would increase to about $23. Uncertainty about discounting would raise this upper bound yet more, perhaps to $42. Other adjustments, such as for the potential for catastrophic damages, could raise this figure even higher.

This range may seem large, but the variation in estimates of marginal costs is at least as high. Estimates for meeting the Kyoto targets in 2010 (expressed in 1990 US dollars per tonne of carbon) range from $5-$123 (with a median value of about $23), depending on the model, assuming global trading; and from $14-$224 (with a median value of about $65-$70), assuming Annex I trading (IPCC 2001: Table TS.4).

Taken together, all these results indicate that current Kyoto targets can be justified in cost-benefit terms—provided implementation is cost-effective or the future is little discounted or adjustments are made for ethical considerations and the uncertainty in discount rates. The ends expressed in Kyoto are thus less contentious than the means. This same point can be put differently. All the above analyses assume that the US participates in Kyoto, and the US will plainly not be a party to this agreement. Taking into account non-participation by the US, the additional allowances given to Canada, Japan, and Russia for sequestration (adjustments that essentially raise the emission ceilings for these countries), and the lifting of restrictions on Annex I countries, Kyoto may not succeed in reducing emissions at all (Buchner, Carraro, and Cerosimo 2001). The bigger question about Kyoto is thus likely to be about means—that is, about whether Kyoto can succeed in reducing global emissions. If it can, then future emission limits can be chosen that roughly balance marginal benefits and costs, with a feedback included for learning. If it can't, then a different approach will need to be tried, but this approach will also have to balance costs and benefits.

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