MIT Joint Program on the Science and Policy of Global Change

Rethinking the Kyoto Emissions Targets

Mustafa J. Babiker and Richard S. Eckaus

Report No. 65
August 2000

The MIT Joint Program on the Science and Policy of Global Change is an organization for research, independent policy analysis, and public education in global environmental change. It seeks to provide leadership in understanding scientific, economic, and ecological aspects of this difficult issue, and combining them into policy assessments that serve the needs of ongoing national and international discussions. To this end, the Program brings together an interdisciplinary group from two established research centers at MIT: the Center for Global Change Science (CGCS) and the Center for Energy and Environmental Policy Research (CEEPR). These two centers bridge many key areas of the needed intellectual work, and additional essential areas are covered by other MIT departments, by collaboration with the Ecosystems Center of the Marine Biology Laboratory (MBL) at Woods Hole, and by short- and long-term visitors to the Program. The Program involves sponsorship and active participation by industry, government, and non-profit organizations.

To inform processes of policy development and implementation, climate change research needs to focus on improving the prediction of those variables that are most relevant to economic, social, and environmental effects. In turn, the greenhouse gas and atmospheric aerosol assumptions underlying climate analysis need to be related to the economic, technological, and political forces that drive emissions, and to the results of international agreements and mitigation. Further, assessments of possible societal and ecosystem impacts, and analysis of mitigation strategies, need to be based on realistic evaluation of the uncertainties of climate science.

This report is one of a series intended to communicate research results and improve public understanding of climate issues, thereby contributing to informed debate about the climate issue, the uncertainties, and the economic and social implications of policy alternatives. Titles in the Report Series to date are listed on the inside back cover.

Henry D. Jacoby and Ronald G. Prinn,
Program Co-Directors

For more information, contact the Program office:

MIT Joint Program on the Science and Policy of Global Change
Postal Address: 77 Massachusetts Avenue
MIT E40-271
Cambridge, MA 02139-4307 (USA)
Location: One Amherst Street, Cambridge
Building E40, Room 271
Massachusetts Institute of Technology
Access: Telephone: (617) 253-7492
Fax: (617) 253-9845
E-mail: *globalchange@mit.edu*
Web site: *http://web.mit.edu/globalchange/*

Printed on recycled paper

Rethinking the Kyoto Emissions Targets

Mustafa J. Babiker and Richard S. Eckaus[†]

Abstract

The international allocation of responsibilities for reductions in greenhouse gas emissions, as foreseen in the Kyoto Protocol, would create a public good. Yet the 1990 level of emissions that is used in the Protocol, as the base from which the reductions would be made, and the reductions targets themselves, are quite arbitrary and not based on a specific target for the future world climate. In addition, the particular allocations of greenhouse gas emissions restrictions among countries do not have a principled logic. This arbitrariness has led to allocations that impose sharply different costs on the participating countries that have no consistent relation to their income or wealth.

Calculations are presented of the implications of alternative allocations of emissions reductions that do have a plausible ethical basis: equal per capita reductions, equal country shares in reductions, equalized welfare costs, and emulation of the allocations of the United Nations budget. All of these would reach the overall Kyoto target at lower overall costs than the emissions allocations in the Protocol itself. This would be achieved through the participation of the developing countries, in which the costs of emissions reductions are relatively low. In addition, use of any of the alternative allocations analyzed here would eliminate the wholly capricious accommodation given to the countries of the Former Soviet Union and Eastern Europe.

The additional costs to the developing countries, for most of the alternative allocations, are so low that the Annex B countries could pay them to accede to a new emissions reduction schedule and still have lower costs than those imposed by the Kyoto allocations. This conclusion puts the Annex B countries in the anachronistic position of advocating an arbitrary and relatively high cost allocation of emissions reductions. The lower cost alternative is to make such an unequivocal commitment for reimbursement to the non-Annex B countries that they would be persuaded to reduce their own emissions. Everyone would gain from that.

Contents

[†] MIT, Joint Program on the Science and Policy of Global Change. The authors are indebted to Denny Ellerman, Chris Forest and other members of the Joint Program on the Science and Policy of Climate Change for useful suggestions.

1. Introduction

The international assignment and acceptance of responsibilities for constraints on greenhouse gas emissions remain controversial in spite of the agreement signed at Kyoto in 1998. The meetings of SBSTA, the Subsidiary Body for Scientific and Technical Advice of the Conference of Parties, continue to examine closely the issues related to the differential economic impacts among countries of the Kyoto agreement.[1] The strong opinions that have been expressed in the U.S. Congress that the developing countries should commit themselves to participate in some fashion in emissions reductions demonstrate the persistence of the controversy over burden sharing. Still another example is in the insistence in the European Union that there should be a limit on the extent to which domestic emissions reductions can be avoided through international trading. These disagreements suggest that the debate over principles has not, in fact, been closed, but only barely submerged.

The approach to international allocation of responsibilities for emissions constraints that is explored here is to consider reductions in greenhouse gas emissions as a public good. The allocations of the economic burdens of such restrictions are self-imposed regulations or taxes.[2] This is not a new idea, of course. Previous analyses have focused on issues of efficient implementation, which become questions of tax rates, pricing and trading of emissions permits and, perhaps, offsetting side payments among countries. This paper will consider the character of the public good and alternative ways in which it might be created.

National taxes that support the provision of national public goods carry an element of compulsion. By comparison, international agreements on emissions restrictions have, to this point, been made voluntarily with voluntary observation of the agreement. So each participating country must agree that the value of the public good is at least equal to the costs it must bear. It is, however, at least plausible that some of the differences among countries in their support for international emissions restrictions agreements reflects political gaming. Apart from this, the difficulties involved in obtaining international agreement on limiting greenhouse gas emissions must have their sources in differences among countries in: 1) appraisals of the likelihood of greenhouse warming, 2) assessments of the costs of its consequences, 3) the desired distribution of the burdens of emissions constraints, and 4) proposed methods of implementation of policies. This paper will deal with only the third of these three issues.

2. The Characteristics of Emissions Restrictions as a Public Good

2.1 Differential harms and benefits

Although the impacts of global warming are understood less well than other major aspects, there is general agreement that they would be quite uneven across the regions of the earth. For

[1] See the reports at http://www.cop5.unfccc.de/resource/rep5bsta.html.

[2] See Hinchey and Fisher (1977) for a brief survey of the uses of this approach in environmental economics.

example, while warming and heavier precipitation would affect some regions negatively, there is strong evidence that some regions, especially in the northern temperate zones, would show positive benefits in total agricultural production.[3] In principle, it is necessary to know both costs and benefits in order to place a value on the public good created by emissions constraints. Thus, it is striking that the differential impacts have, with only few exceptions, hardly been recognized in the international negotiations.

There are two important exceptions to the lack of recognition of differential regional impacts of global warming. The fates of the low lying island states in the event of sea level rise brought on by global warming have captured public attention and may also capture some special international assistance.[4] In addition, recognition that there might be significant negative impacts in many of the non-Annex B countries may have contributed to the willingness in the international negotiations to exempt these countries from greenhouse gas emissions restrictions. It may also be the case that the northern developed countries have implicitly adopted a code in which they accept responsibility for the fact that, historically, they are sources for the greatest part of the accumulated anthropogenic greenhouse gases. Or alternatively, the exemption may reflect the desire to create some progressivity with respect to income in the tax burdens.

2.2 The intertemporal character of the public good

A special feature of the public good created by restriction of greenhouse gas emissions is that it is "intertemporal" in character. Every kilogram of CO_2 contributes to greenhouse warming rather quickly. But, since the greenhouse gases have long, though varying lifetimes, the major and cumulative effects are likely to be in the distant future and will impact future generations. This creates different interests among generations and countries in using or preserving the atmospheric public good.

The selfish interest of older generations is in not expending current resources on a future benefit that they will not directly enjoy and the older generations are usually the political leaders and decision makers. On the other hand, older generations consistently demonstrate a generational altruism that stands virtually as a moral tenet. It is tempered by the recognition that younger and future generations will have scientific and technological advantages, if not natural resource endowments, that exceed those of the older generations. On the other hand, the selfish interest of younger generations goes in the direction of using current resources to preserve the atmospheric public good in order to enjoy its benefits over their longer future. However, younger generations also display a generational altruism, as in their acceptance of pay-as-you-go social security programs.

Future generations are not represented directly in the current debates, but might be expected to have both selfish and altruistic motives as well. Under certain circumstances there will be a

[3] See Reilly (1995).
[4] See article 4.8 of the Kyoto Protocol at http://www.unfccc.de/resource/convkp.html.

cooperative equilibrium between old and young generations in which the older generation will face a generational tax, if it had not provided for the intergenerational public good in their youth.[5]

The fact that the public good would be demanded differently by different age groups complicates the problem of pricing and trading emission permits, because of the difficulties in creating an efficient market that would permit trading in futures.

2.3 The substitutability of international atmospheric public goods and other public and private goods

The estimation of the economic costs of restricting emissions has been the subject of concentrated attention by economic and engineering analysts. By comparison, there has been relatively little attention, in international negotiations and otherwise, to the costs of adapting to climate change by the provision of other public and private goods. Mitigation is an international public good and must be undertaken by significant groups of countries to be effective, while adaptation measures can be either public or private goods and, in important cases, can be undertaken within nations. If the overall objective is to minimize the damages associated with climate change, the potential costs of adaptation should be considered in the process of deciding on the size of the costs that should be incurred in mitigating climate change.[6] While it may be politic to avoid recognition of adaptation possibilities, if some significant degree of climate change actually occurs, it will be impossible to avoid their consideration. In that case, as the costs become concrete, there will surely be attempts to find ways of adapting to them. So the essential issue is whether adaptation costs are considered before the fact of global warming or after.

One reason for the lack of attention to adaptation measures could be the belief that their consideration would divert attention and resources from mitigation policies. However, since climate change is already at hand, the neglect of adaptation measures is the pose of an ostrich.

3. The Kyoto Protocol Emissions Constraints: The Absence of a Rationale

Rather than placing a tax on carbon dioxide emissions, the Kyoto agreement would impose an emissions constraint on each country. A rational approach to setting this constraint would start with an agreement on an allowable level of global warming, perhaps even zero. That would imply a specific level of radiative forcing. This, in conjunction with the estimation of current atmospheric concentrations of greenhouse gases, would determine the acceptable level of total emissions of greenhouse gases. Certainly it is difficult to make these calculations and the values finally chosen would depend as well on other economic goals. However, the progress in the sciences of atmospheric chemistry, global climate change modeling and economic analysis make the procedure feasible, to a reasonable approximation. By comparison, the 1990 level of

[5] This and other interesting results are contained in a paper by Rangel (1997).

[6] For an attempt to integrate the analysis of emissions reductions and global warming impacts see Nordhaus and Boyer (1999).

emissions that serves in the Kyoto Protocol as the base from which reductions are to be made is quite arbitrary and has no scientific or economic rationale. Perhaps it has persisted simply because it would now be politically difficult to establish another base. Yet, it is surprising that the intense negotiations have not resulted in more rational targets.

The next logical step after the determination of overall targets for emissions restrictions is the specification of the tax rates or quantity restrictions necessary to achieve the targets.[7] That requires prescription of a tax base, or a basic output level, and tax rates or differential emissions constraints. With respect to the base, it was decided at Kyoto that the emissions to be included in the constraints should include not only carbon dioxide but other trace gases. The global warming potentials of the latter should be used to convert the trace gas emissions to equivalent amounts of carbon dioxide. While there are difficult scientific and economic problems that are neglected in this procedure, it is relatively straightforward compared to the implications of the ambiguous decision to also include some carbon dioxide sinks in trees.

The prescribed emission allocations require, with important exceptions, that all countries commit to a general rollback of the carbon dioxide emissions, or their equivalent, to 92% of the 1990 levels. The exceptions for particular countries aside, the common quantitative restrictions might appear to be a flat tax, like a highway toll, except that the same percentage of emissions reductions has different cost burden implications for each country. A pursuit of the highway analogy may help make this clear. In that analogy a limit on the number of times each vehicle could use the road would correspond to emissions restrictions. Such limits would have, at best, only a rough correspondence to opportunity costs involved in using the road and the strength of a user's demand, just as the levels of emissions restrictions across countries have only a rough correspondence to the costs of meeting them. Moreover, because of international trade relations, the emissions restrictions would impose costs even on some of those non-Annex B countries, which do not have to observe them, although other countries would benefit.

The exceptions to the uniform rollback are of two types. The first is the complete exemption that has been granted to the non-Annex B countries. On the plausible assumption that the non-Annex B countries will also benefit from the public good created by emissions restrictions, this amounts to a grant to these countries, as it provides the public good free of charge. Moreover, if the non-Annex B countries are allowed to trade their emissions, they are, in effect, given property rights to their emissions. The second type of adjustment included in the Kyoto agreement is a set of exceptions for particular Annex B countries. These allow for "differentiation" by recognizing, to a limited degree, the "particularity" of countries, which is the fact that the same emissions constraint level would impose different degrees of economic burden on each country.

[7] The issue as to whether price or quantity instruments are best used to achieve the desired emissions levels, although important, will not be addressed here.

The grant to non-Annex B countries in the Kyoto Protocol is hidden and neither explicitly recognized nor estimated, which may contribute to making it more acceptable. It can be justified in various ways.

1) Just because they are poor, the economic costs involved in restricting emissions in non-Annex B countries would impose a relatively high current welfare burden.

2) Such restrictions would also increase the difficulties of their development, which requires relatively energy intensive production in its early stages. This is, in effect, an extension of the first point, since it also reduces the size of the cost burden.

3) The imminent problems of greenhouse warming have been created by the Annex B countries, which have not only been the first developers but also have been profligate in their use of carbon intensive energy sources. So the burdens of adjustment should be put on them.

The rationale of the first argument seems transparent. Yet there are important counterexamples to the complete exemption of poor countries from the costs of provision of international public goods. The services of the United Nations, the World Bank and the International Monetary Fund, for example, are also, in many ways, public goods. However, all members, rich and poor, are required to contribute to the budgets of these institutions. The levels of the individual country contributions do vary with per capita income levels, as well as size, but a minimum contribution is required. While there is disagreement as to whether the relative contributions are equitable, there has been little controversy over the fact that each member country, no matter how poor, must contribute something to each institution.

The precedents of contributions by all member countries to the IMF, the United Nations and the World Bank are not necessarily applicable to the distribution of the burdens created by restrictions on greenhouse gas emissions. That is because the public goods involved are of different types. Yet the examples are relevant, since the income progressivity argument for the exemption for non-Annex B countries in the Kyoto Protocol is applied in these other institutions as well. It might be argued that the non-Annex B countries should be exempt from the burdens of emissions restrictions, because they do not value that public good. Yet that would be contrary to the public expressions of these countries and their intensive participation in the United Nations Framework Convention on Climate Change.

The rationale of the second argument appears to have general support in the record. To a considerable extent, development requires increasing energy intensity, although new technologies are often energy saving. Because of lack of materials, small size, unfavorable location, *etc*., many of the non-Annex B countries will not have steel mills, a chemical industry, or other energy intensive industries. But development involves the replacement of human energy with non-human energy. So all developing countries can look forward to a flourishing electric power sector, improved road and, perhaps, rail transport, and increasing substitution for mechanical and electrical power for human power. Restrictions on greenhouse gas emissions will make growth more difficult for developing countries. Because “unconventional energy” *e.g*.,

windmills and solar power, are still relatively high cost sources in most places, carbon fuels will supply most of the new power that will be required in developing countries.

The third argument, though popular and often summarized with the assertion that, “the polluter should pay,” is suspect. If it is simply a matter of resentment over wealth differences, the emotion is understandable, but not a rational basis for discrimination. Moreover, the argument raises the ethical question as to whether the “sins of the fathers” should be visited on their sons and daughters. Presumably the answer is, “No,” on the grounds that it is not the current generations that produced most of the accumulated greenhouse gas emissions. On the other hand, each nation may be regarded, like a corporation, as having an immortal life, in which all past, present and future members have an equal responsibility. It may seem that the principle exists because it is applied to the international debts of nations, for which they are held liable by creditors when their governments change or their economic circumstances diminish, although their liabilities may be reduced by international negotiation. But this is a tenuous analogy, since responsibility for historic emissions, unlike international debt, was never the subject of an explicit contract.

Finally, even if it were accepted that the Annex B countries were extravagant in their use of energy and emissions of carbon dioxide during their development periods, it would be difficult to estimate the economic benefits that were gained thereby. Presumably not all of their present income differentials as compared to non-Annex B countries would be due to that profligacy.

Turning to the differences in the emissions allocations that are specified in the Kyoto Protocol for the Annex B countries, they are a partial recognition of the differential costs that those restrictions would impose. The exceptions appear to recognize three specific conditions that make reductions in emissions particularly costly and, therefore, deserving of special consideration: 1) a high degree of dependence on non-carbon energy sources that reduces the potential for reductions in carbon energy use; 2) a high degree of energy efficiency in the use of carbon fuels, which also limits the potential for further reductions; and 3) a high degree of dependence on domestic coal, which makes the cost of emissions reduction relatively high.

There are other economic conditions that are not taken into account. Each country would react somewhat differently to restrictions on their emissions, due to differences in their production structures and their patterns of consumption. The relative costs of the restrictions will depend not just on relative energy intensities, but also on the ease with which they can substitute less for more emission intensive activities.

Thus, there is an open question as to why did the Kyoto Protocol not go further in differentiating the emissions constraints among countries. There are at least two possible explanations for this. First, it might have been impossible to obtain agreement on a broader range of differentiations and finer distinctions. Although some models exist that could have been used to calculate such distinctions, these were not already in hand. In addition they operate at rather high degrees of approximation and are, therefore, particularly susceptible to becoming another focus for contention. Even so, it would not have been hard to have a somewhat more refined discrimination among countries than exists in the Kyoto Protocol.

A second potential explanation lies in the international political processes behind the Kyoto Protocol. It is possible that negotiators believed that it would be possible to obtain some kind of international agreement only if it was kept relatively simple and exceptions were allowed only for those few countries that complained most loudly. Alternatively, the negotiators may have wanted to avoid an allocation of emissions restrictions that recognized very explicitly the differences among countries in the opportunity costs of emissions restrictions. That is because the official policy in many countries, including the United States, has simply avoided the subject.

4. Quantitative Implications of the Kyoto Allocations and Alternatives

There have been a number of estimates of the direct and indirect costs of the Kyoto Protocol constraints.[8] In each case the reference has been a "business as usual" scenario, in which there are no constraints at all. There are, however, many alternative allocations of emissions constraints among countries that would achieve the same overall constraint level and, some of these, unlike the Kyoto constraints, do have a rationale. Examination of four of these alternatives will also illuminate some of the implications of the Kyoto constraints. This examination will be undertaken here using the MIT EPPA model.[9]

First, however, it is useful to characterize the incidence of the Kyoto constraints. **Table 1** and **Figure 1** show the emissions constraint levels in percentage terms relative to their 1990 emissions levels for each of the Annex B countries, not listed alphabetically but by their per capita incomes. Figure 1 also shows both a linear and a quadratic regression line fitted to the data points. The linear regression, which is not a very good fit, seems to indicate some progressivity in the emission constraint percentages. The quadratic regression, which provides only a slightly better fit, shows regressivity in the intermediate per capita GNP ranges and progressivity at the upper ranges.

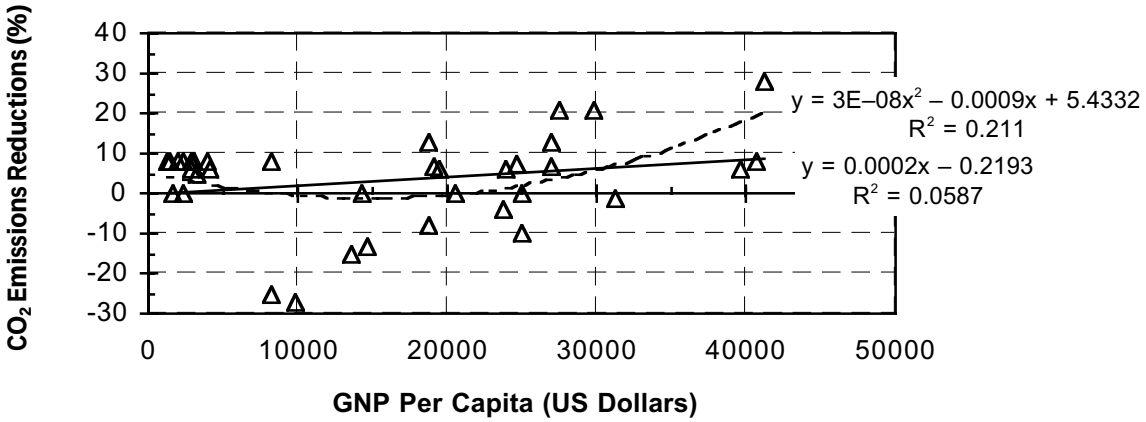

Figure 1. *Per Cent Reduction in Emissions vs GNP Per Capita: Kyoto Allocation*

[8] See the special issue of the *Energy Journal*, "The Costs of the Kyoto Protocol: A Multi-Model Evaluation," 1999.
[9] See Babiker, Reilly, Sue Wing and Eckaus (2000).

Table 1. Kyoto Emissions Reductions and GNP Per Capita

Country/Region	**Kyoto and EU Reduction Allocations** *(Per Cent)*	**GNP per capita** *(1995- US Dollars*)*
Luxembourg	28.0	41210
Germany	21.0	27510
Denmark	21.0	29890
Austria	13.0	26890
United Kingdom	12.5	18700
Bulgaria	8.0	1330
Romania	8.0	1480
Lithuania	8.0	1900
Latvia	8.0	2270
Estonia	8.0	2860
Slovakia	8.0	2950
Czech Republic	8.0	3870
Slovenia	8.0	8200
Switzerland	8.0	40630
Belgium	7.5	24710
United States	7.0	26980
Italy	6.5	19020
Poland	6.0	2790
Hungary	6.0	4120
Canada	6.0	19380
Netherlands	6.0	24000
Japan	6.0	39640
Croatia	5.0	3250
Ukraine	0.0	1630
Russian Federation	0.0	2240
New Zealand	0.0	14340
Finland	0.0	20580
France	0.0	24990
Norway	-1.0	31250
Sweden	-4.0	23750
Australia	-8.0	18720
Iceland	-10.0	24950
Ireland	-13.0	14710
Spain	-15.0	13580
Greece	-25.0	8210
Portugal	-27.0	9740

** Valued in current US dollars, converted at exchange rates.*

All of the modest progressivity is due to the re-allocations of constraints within the European Community. If the EC is taken as a whole, there would be virtually no relation between the levels of emissions constraints and per capita GNP.

The alternatives to the Kyoto emissions constraints which are considered here are:

1) constraints which equalize the emissions reductions per capita across all countries;

2) constraints in which countries share equally in total emissions reductions;

3) constraints which equalize the consequent reductions in per capita welfare across countries;

4) constraints that allocate the GNP costs per capita in the same manner as the costs of supporting the United Nations budget are allocated.

The first criterion would treat each person in each country equally, in terms of current emissions constraints. While this equality has the appeal of a kind of current equity, it has some implications that could be regarded as defects. First of all, if it were based on the population of a recent year, the rule could be faulted for rewarding recent high population growth rates. Secondly, the equal per capita constraint applies only to current emissions and ignores issues of historical responsibility. Finally, it would ignore the fact that equal per capita emissions constraints across countries would imply different per capita costs.

The second rule would treat each country the same, but would have the second and third defects of the first rule. The third rule focuses on a central issue in the imposition of tax burdens: equality in welfare costs. Its special vulnerability is in the disagreements that would inevitably arise over the choice of the welfare function to be considered.

The fourth rule requires some explication. As noted above, there are precedents for an international progressive tax to finance international undertakings. While the public goods created by emissions restrictions are different, comparison of the implications of the Kyoto allocations with the allocation of responsibilities for the budget of the United Nations may be enlightening. Both costs are justified by their support for a public good that provides benefits for all countries and in both cases, as well, it can be argued that the industrialized nations have special responsibilities because of their past histories. Yet, in neither case can the contributions by each country be linked directly to the value of the public good to the individual member.

The consequences of these alternative allocations of emissions restrictions have been estimated using the MIT EPPA model, although the computations are not straightforward and require iterating toward a solution. In the calculations 1995 is used as the base year for emissions and 2010 is taken as the representative year, for purposes of comparison. In addition, the computations presume that there will be trade in emissions permits among the Annex B countries. The cases of equalized per capita emissions reductions and equalized country shares in reductions are the most straightforward, as they only require changing all the respective shares until the overall Kyoto target reduction is achieved. The case of equalized welfare is roughly similar, but requires choosing the emission reduction separately in each country, to keep the per capita welfare changes in every country the same, while achieving the overall target. The consequences of reproducing the shares in the UN budget allocations are more difficult to calculate, because those require not only that each country's costs of emissions reduction satisfy the allocation rules of the United Nations, but also that the associated emissions constraints must, in total, satisfy the desired overall goal of emissions reduction.

Table 2 shows the total costs in terms of foregone GNP of achieving the overall emissions reductions target of Kyoto with the alternative emissions allocation rules, as calculated with the EPPA model. It is striking that the costs of the four alternatives to the Kyoto allocations are all about the same and that in each case the costs are only slightly more than half of the total costs of the Kyoto allocations.

The individual country costs of each of the alternative criteria in terms of reduction in per capita GNP are shown in **Table 3** and in **Figures 2 and 3**. The negative signs indicate gains in GNP, that are a consequence of the changes in the international trading patterns that result from the emissions restrictions in the Annex B countries. The results are again quite striking. For the industrialized

Table 2. Overall Costs of Achieving the Aggregate Kyoto Emissions Reduction Using Alternative Reductions Criteria (US dollars, in billions)

Kyoto Criteria	336.6
Equalized Welfare Costs	188.0
Equalized Reduction Shares by Country	187.2
Equalized Per Capita Reductions	197.1
Percentage Reductions in Proportion to United Nations Budget Shares	187.9

Table 3. Annual GNP Costs Per Capita of Alternative Allocations of Emissions Constraints (US$)

Country/Region	Kyoto Allocations	Equalized Welfare Costs	Equal % Reductions	Equal Per Capital Reductions	UN Budget Share Allocations
Rest of Subsahara	1.9107	0.51	1.97	-45.37	0.52
India	-1.4135	4.11	5.25	-33.21	0.49
Rest of World	-0.2657	3.06	2.71	-40.61	1.20
Philippines	-0.5581	1.41	0.40	-44.63	1.48
China	-0.4263	8.09	10.29	-3.67	1.23
Indonesia	5.2988	4.74	7.94	-28.65	1.34
Morocco	0.1484	2.88	0.12	-40.74	2.23
Rest of North Africa	22.9312	5.50	20.77	-5.47	5.25
Colombia	7.2414	7.57	12.71	-18.86	4.11
Former Soviet Union	-91.3011	11.75	7.04	87.85	33.46
Rest of Middle East	53.2321	27.08	58.85	59.78	13.79
Thailand	-2.8805	8.72	2.88	-14.67	4.39
Mexico	10.8029	15.17	20.16	13.59	15.38
Venezuela	55.5872	14.94	52.70	64.00	15.44
East.European Transition	18.9483	30.64	26.24	73.06	14.50
Malaysia	26.9752	11.31	30.77	28.78	11.42
South Africa	-2.1307	25.78	22.90	90.53	14.34
Chile	-17.4222	24.18	9.48	-4.39	12.33
Brazil	-7.6530	16.12	8.07	-21.48	14.24
Argentina	0.6403	34.38	32.11	24.85	34.87
Korea	-18.3423	37.56	17.69	95.56	34.92
Other OECD	226.6205	77.98	94.81	152.23	81.77
EEC	593.2130	226.83	255.07	368.76	188.63
USA	204.1139	94.66	38.71	300.77	159.33
Japan	316.0936	176.12	100.43	213.63	262.03

countries, any one of the alternatives would be less costly than the Kyoto restrictions, with only three exceptions. In general, the costs to the Former Soviet Union and the Eastern European Countries in Transition would rise quite sharply with the alternative allocations.

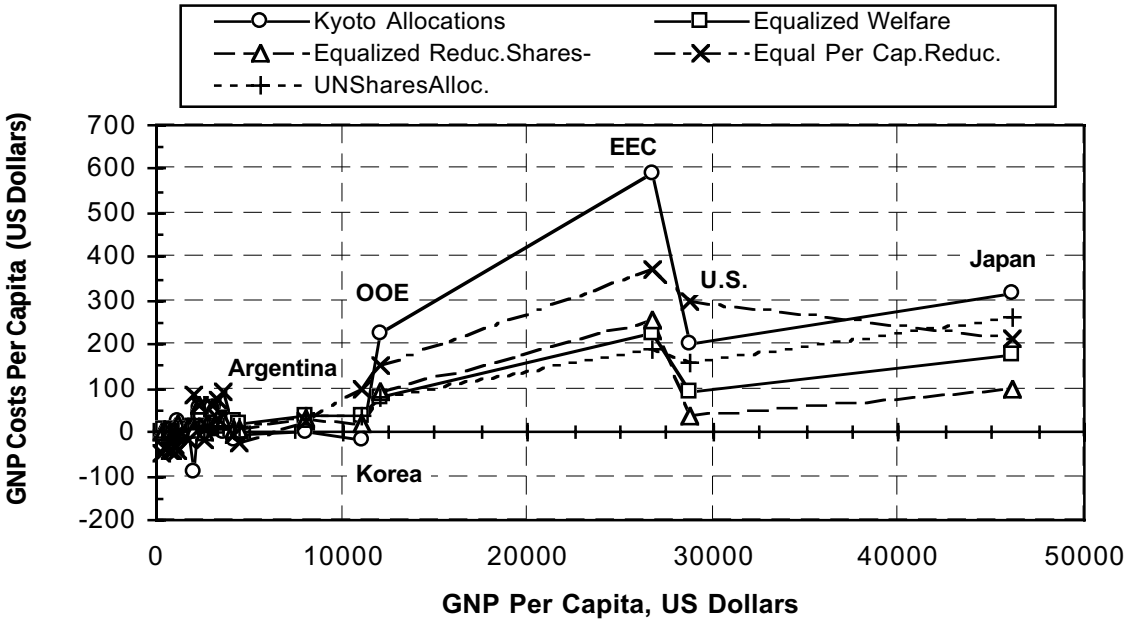

Figure 2. *GNP Costs of Alternative Allocation Rules*

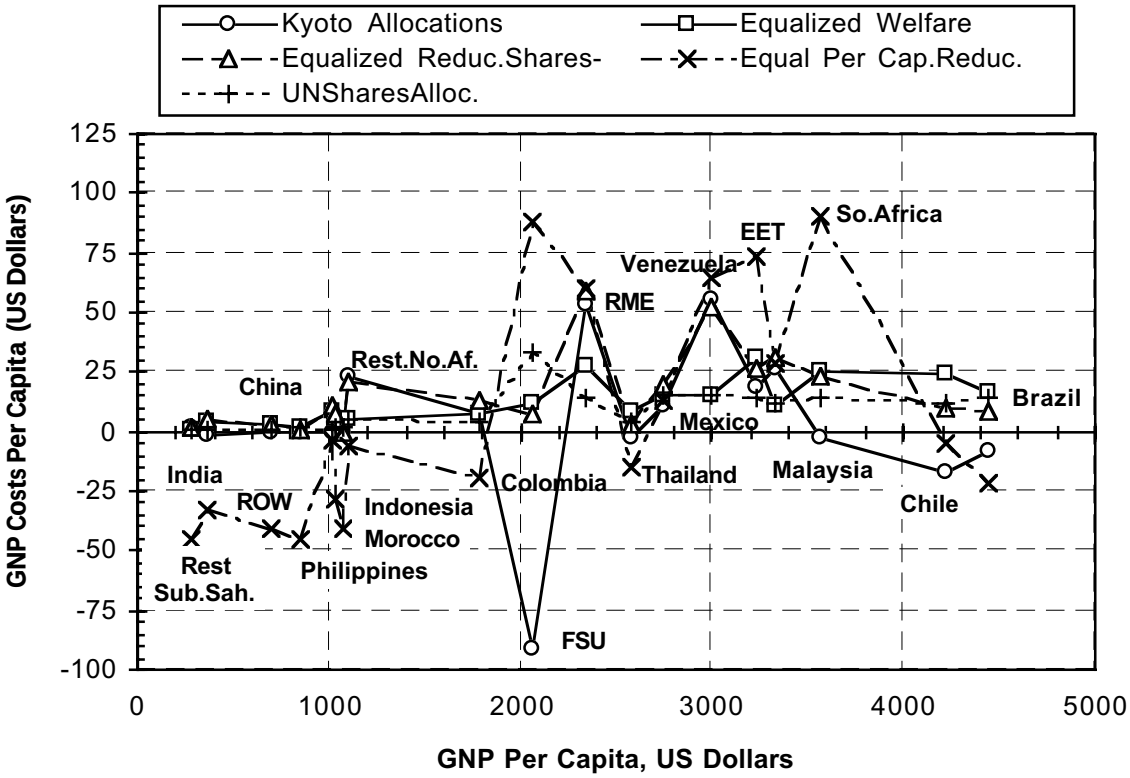

Figure 3*. GNP Costs of Alternative Allocations -Low Income Countries*

Also, if per capita reductions were equalized, there would be an increase in per capita GNP losses in the U.S. The explanation for the overall cost reductions with the alternative allocations, again, is the increased participation of the non-Annex B countries, whose costs of reducing emissions are generally less than in the already industrialized countries.

As noted, although the non-Annex B countries have been exempted from emissions constraints in the Kyoto Protocol, some of the countries would actually gain from it or if the emissions allocations were distributed equally on a per capita basis as the result of reorientations of international trade flows among countries. The GNP costs of the emissions restrictions applied by the other criteria are relatively modest for most of the non-Annex B countries. In particular, applying the United Nations shares in budget support would increase the costs to all non-Annex B countries while reducing the costs to the industrialized countries. Table 3 shows, in another way, the special treatment of the Former Soviet Union.

That is the result of the use of the wholly arbitrary 1990 emissions base from which emissions reductions are calculated. The reduction in overall economic activity in the FSU since 1990 and modest improvements in energy efficiency have already reduced its emissions substantially

Table 4. Reductions in GNP Due to Alternative Emissions Allocations Relative to Reductions Due to Kyoto Allocations (US dollars, in millions)

Country/Region	Equalized Welfare	Equal % Reductions	Equal Per Capita Reductions	UN Budget Share Allocations
Rest of Subsahara	913	-36	30830	907
India	-6315	-7608	36326	-2177
Rest of World	-3422	-3063	41455	-1510
Philippines	-187	-91	4185	-194
China	-11482	-14461	4379	-2237
Indonesia	134	-629	8078	942
Morocco	-92	1	1378	-70
Rest of North Africa	2279	282	3713	2311
Colombia	-16	-265	1265	152
Former Soviet Union	-29583	-28231	-51429	-35816
Rest of Middle East	6438	-1384	-1612	9712
Thailand	-769	-382	782	-482
Mexico	-493	-1056	-315	-516
Venezuela	1140	81	-236	1126
East.European Transition	-1380	-860	-6386	525
Malaysia	425	-103	-49	422
South Africa	-1310	-1175	-4349	-773
Chile	-702	-454	-220	-502
Brazil	-4529	-2996	2634	-4170
Argentina	-1370	-1278	-983	-1390
Korea	-2819	-1817	-5744	-2686
Other OECD	22819	20235	11421	22238
EEC	129515	119533	79342	143020
USA	31662	47846	-27960	12954
Japan	17708	27284	12963	6840

below the 1990 levels. As a result it could sell emissions permits, the so-called "hot air," at considerable economic gain and without further reductions in its own emissions. It is hard to believe that this flagrant irrationality will be allowed to persist, if emissions restrictions are adopted.

Table 4 relates the GNP costs in each country of the four alternative emissions reductions rules to the costs of the Kyoto constraints and **Table 5** presents all the costs as a percentage of total GNP in each country.

As noted, the exemption from emissions restrictions in the Kyoto Protocol for the non-Annex B countries amounts to an implicit grant to them for the support of the public good that would be created. A quantitative estimate of size of the depends on the "counterfactual" that is adopted for the purposes of comparison. The MIT EPPA model was used to make a rough estimate of this grant with the alternative allocations taken as counterfactuals. First, the total costs of adopting the levels of constraints specified in Kyoto are calculated, taking account of the complete exemptions for the non-Annex B countries. Next, the total costs for each counterfactual are calculated. The differences are estimates of the implicit grant in the Kyoto allocations as compared to the counterfactual allocation. The results are shown in **Table 6**.

Table 5. GNP Costs of Alternative Allocation Criteria, as a Percentage of Total GNP

	Kyoto Constraints	Equalized Welfare	Equal % Reductions	Equal Per Capita Reductions	UN Budget Share Allocations
Rest of Subsahara	0.67	0.18	0.69	-15.91	0.18
India	-0.39	1.14	1.45	-9.21	0.14
Rest of World	-0.04	0.44	0.39	-5.78	0.17
Philippines	-0.07	0.17	0.05	-5.26	0.17
China	-0.04	0.80	1.01	-0.36	0.12
Indonesia	0.52	0.46	0.77	-2.78	0.13
Morocco	0.01	0.27	0.01	-3.78	0.21
Rest of North Africa	2.07	0.50	1.88	-0.49	0.48
Colombia	0.41	0.42	0.71	-1.06	0.23
Former Soviet Union	-4.44	0.57	0.34	4.27	1.63
Rest of Mid.East	2.27	1.16	2.51	2.55	0.59
Thailand	-0.11	0.34	0.11	-0.57	0.17
Mexico	0.39	0.55	0.73	0.50	0.56
Venezuela	1.86	0.50	1.76	2.14	0.52
East.Eur.Transition	0.59	0.95	0.81	2.26	0.45
Malaysia	0.81	0.34	0.92	0.86	0.34
South Africa	-0.06	0.72	0.64	2.53	0.40
Chile	-0.41	0.57	0.23	-0.10	0.29
Brazil	-0.17	0.36	0.18	-0.48	0.32
Argentina	0.01	0.43	0.40	0.31	0.43
Korea	-0.17	0.34	0.16	0.87	0.32
Other OECD	1.88	0.65	0.79	1.26	0.68
EEC	2.23	0.85	0.96	1.38	0.71
USA	0.71	0.33	0.13	1.05	0.55
Japan	0.69	0.38	0.22	0.46	0.57

Table 6. Total GNP Costs of Alternative Emissions Allocations and Implicit Grants to Non-Annex B Countries (US dollars, in millions)

	Kyoto Allocations	Equalized Welfare	Equal % Reductions	Equal Per Capita Reductions	UN Budget Share Allocations
Total GNP Costs	336567	188003	187194	197099	187941
Annex B Countries	319548	148807	133741	301597	169787
Non-Annex B Countries	17019	39196	53453	-104498	18154
Size of Grant to Non-Annex B Countries in Kyoto allocations relative to alternatives		22177	36434	-121517	1135

All the differences are quite substantial. The largest, a negative amount indicating a positive real increase in GNP, would come from equalizing the per capita allocations. That result reflects the much higher burden that would be placed on the Annex B countries from this allocation and their increased leakage through international trade, from which the Non-Annex B countries would benefit. This suggests again the potential gain for both groups of countries in finding some means for the Annex B countries to recompense the non-Annex B countries for reducing their emissions.

5. Conclusions

The overall emissions reduction target of the Kyoto Protocol is not based on any agreed target for the future world climate, but is an arbitrary way of reducing potential climate change. Moreover, the particular allocations of greenhouse gas emissions restrictions among countries do not have a principled logic. This arbitrariness has led to allocations that impose sharply different costs on the participating countries that have no consistent relation to their income or wealth. It is possible that the consumer-voters in the overburdened countries will accept their extra burden, since the costs are relatively small and the goal of a stable climate is large. However, it is also possible that, if the goal cannot be achieved with small costs, those voters will demand a reallocation.

Calculations are presented of the implications of alternative allocations of emissions reductions that do have a plausible ethical basis: equal per capita reductions, equal country shares in reductions, equalized welfare costs, and emulation of the allocations of the United Nations budget. All of these would reach the overall Kyoto target at lower overall costs. This conclusion is another example of the well-known result that the overall cost of reducing emissions would be lowered through the participation of the developing countries, in which the costs of emissions reductions are relatively low. In addition, use of any of the alternative allocations analyzed here would eliminate the wholly capricious accommodation given to the countries of the Former Soviet Union and Eastern Europe.

The additional costs to the developing countries, for most of the alternative allocations, are so low that the Annex B countries could pay them to accede to a new emissions reduction schedule and still have lower costs than those imposed by the Kyoto allocations. This conclusion puts the

Annex B countries in the anachronistic position of advocating an arbitrary and relatively high cost allocation of emissions reductions. The lower cost alternative is to make such an unequivocal commitment for reimbursement to the non-Annex B countries that they would be persuaded to reduce their own emissions. Everyone would gain from that.

References

Babiker, M.J., J. Reilly, I. Sue Wing and R.S. Eckaus, 2000, The MIT Emissions Prediction and Policy Analysis (EPPA) Model, MIT Joint Program on the Science and Policy of Climate Change Report (in preparation).

Energy Journal, Special Issue, "The Costs of the Kyoto Protocol: A Multi-Model Evaluation," (1999).

Hinchey, M., and B.S. Fisher, 1997, Negotiating Greenhouse Abatement and the Theory of Public Goods, Nota di Lavoro, 58.97, Fondazione Eni Enrico Mattei, Sept., p. 18.

Nordhaus, W., and J. Boyer, 1999, Requiem for Kyoto: An Economic Analysis, *The Energy Journal*, Special Issue—*The Costs of the Kyoto Protocol: A Multi-Model Analysis*.

Poterba, J.M., 1993, Global Warming Policy: A Public Finance Perspective, *The Journal of Economic Perspectives*, **7**(4): 47-64, Fall.

Rangel, Antonio, 1997, *Intergenerational Public Goods* (unpublished).

Reilly, John, 1995, Climate Change and Global Agriculture, *American Journal of Agricultural Economics*, **77**: 727-733.