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Richard N. Cooper*

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*Harvard University, Cambridge, MA

Fondazione Eni Enrico Mattei
Corso Magenta, 63, 20123 Milano, tel. +39/02/52036934 – fax +39/02/52036946
E-mail: letter@feem.it
C.F. 97080600154

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In 2001 the Intergovernmental Panel on Climate Change issued its Third Assessment Report on the prospects for and likely impact of increases in global average temperature over the next century. The summary report of Working Group 1, on science, widened the range of likely temperature increase, compared with the IPCC's Second Assessment Report five years earlier, to 1.4 - 5.8 degrees centigrade, with the increase in the upper end of the range receiving wide public attention. The summary report of Working Group 2, on impacts, sketched a somber picture of how both human settlements and non-human ecologies might be adversely affected by the rise in temperature and an accompanying rise in sea level.

A close reading of the WG 1 Report, however, reveals that the wider range, and in particular the increase in the upper end of the range, was not at all due to a reassessment of the scientific evidence accumulated and closely studied since the mid-1990s. Rather, it was due to a change in the way that emissions over the next century of greenhouse gases (GHG), mainly carbon dioxide (CO2) from fossil fuel consumption and deforestation, and methane (CH4) from agriculture and waste disposal, were characterized. Instead of the single "business as usual" emissions trajectory used in the Second Assessment Report(SAR), the Third Assessment Report(TAR) produces six different scenarios, depending on the evolution both of the world economy and of its energy system over the next 100 years. This refinement is in some respects an improvement over the single

assumed trajectory, but to present the outlook as more likely more serious than the previous assessment is, to say the least, misleading. The judgement about the likely temperature effect of a given GHG "forcing" was actually narrowed modestly in the Third Assessment Report, not widened.

Shortly after release of the latest IPCC summaries, but presumably not because of them, newly elected President Bush of the United States announced, in an especially clumsy way, that his Administration would not support the Kyoto Protocol to the Framework Convention on Climate Change (FCCC) adopted in 1992. The Kyoto Protocol, negotiated in late 1997, established emissions ceilings on six specified greenhouse gases for 38 countries, with the 15 members of the European Union treated as a single unit, to be reached on average in the five year accounting period 2008-2012. It is not yet in force, in that the requisite countries (55, covering at least 55 percent of the established ceilings) have not yet ratified it. But it established a specific framework and timetable for the countries covered (those listed in Annex B) to reduce their GHG emissions. The Protocol contained a number of other features, such as possibilities for emissions trading, cooperation across national boundaries in emissions reduction, and sequestration of GHG in "sinks," some of which will be described further below. But it lacked many operational details, which were left to be worked out following Kyoto, and over which there was still substantial disagreement at a follow-up conference in the Hague in November 2000, three years after Kyoto.

President Bush gave as his reason for dropping Kyoto that achieving the targets would be too costly to the American economy, and to American workers, without elaboration or analysis. He left entirely open how his administration would approach the problem of global climate change, or indeed whether it considered this to be a problem that needed to be addressed. Bush's rejection of

Kyoto caught off guard both foreign governments and American environmentalists, including some of his own senior officials, since when campaigning for the presidency he had signaled his concern with global climate change and his commitment to limiting emissions of CO2.

However, for reasons I hope to make clear, dropping the Kyoto Protocol represents no great loss to the international community, since it is fatally flawed as an instrument to deal substantively (as distinguished from symbolically) with the potential problem of global climate change. The faster this is recognized, the better, so work can begin on alternative, prospectively more successful, approaches.

The paper is organized as follows: the next section analyzes the basic structure of the task of mitigating global warming. The following section evaluates the Kyoto Protocol in terms of the structural issues. Then comes a section on the advantages of permit trading, combined with the conditions that must be met to achieve it. This is followed by sections on an alternative approach to that embodied in the Kyoto agreement, and on contingency plans for action in case the international community discovers that it has moved far too slowly to deal with climate change. A final section offers brief conclusions.

Structure of the Problem

Concerns about global climate change have led to pleas and indeed to some national commitments to slow or reverse the growth of greenhouse gas emissions. It is useful to identify the structural characteristics involved in attempting to mitigate global warming through formal collective action. There are three key features:

First, climate change brought about through an increased atmospheric concentration of

greenhouse gases is a global issue, since whatever their earthly origin the gases are widely dispersed in the upper atmosphere, and CO2 is long-lived. Effective restraint must therefore involve all (actual and prospective) major emitters of greenhouse gases. The rich industrialized countries account for most of the emissions today, but the Soviet Union was a major contributor before its dissolution and economic collapse in 1991, and with economic growth its successors can be expected again to become a major source. Rapidly growing developing countries will become major contributors within a time frame that is relevant for managing the issue.

Second, the rewards from restraints on greenhouse gas emissions will come in the (politically) distant future, while the costs will occur in the political present. Moreover, the rewards are highly uncertain. Much controversy still surrounds the expected impact of further greenhouse gas emission on the earth's ecological system, and in particular on conditions of habitability for humans. The residents of some of today's states, e.g. Canada, Russia, perhaps the United States, may even expect to benefit from moderate climate change. It will thus be difficult to persuade publics that they should make sacrifices in living standards in the near future for the sake of uncertain gains to their grandchildren and great-grandchildren, much less for the grandchildren of people living at remote distance. The wide distribution of expected but distant benefits in response to collective action today provides an incentive for every country to encourage all to act, but then to avoid acting itself -- the so-called free-rider problem.

Third, the pervasive sources of greenhouse gas emissions -- notably use of fossil fuels, rice cultivation, and raising cattle -- imply that restraint will involve changes in behavior by hundreds of millions if not billions of people, and not merely restraints by 180 or fewer governments, as in the typical treaty. Thus the most important part of an effective regime to limit climate change involves

not the relationships among states, but the effective influence of governments on the behavior of their domestic publics. Moreover, the pervasive sources of CO2 and methane are at the heart of modern economies, which depend intimately on productive agriculture and on non-animate sources of energy.

No major legally binding regulatory treaty involves all of these characteristics to the same degree. Typically either governments themselves are the major actors, or a relatively few firms in a relatively few countries, as in the cases of halting nuclear testing or limiting production of CFCs.

These three structural factors make collective decisions regarding actions to mitigate global climate change exceptionally difficult. The benefits of mitigation actions encompass the adverse impacts of climate change that are thus avoided. Serious mitigation necessarily involves major reductions in the actual and prospective consumption of energy based on fossil fuels (especially coal-fired electricity generation and use of oil products for heat and motive transportation). Since such consumption is at the very heart of modern industrialized economies, the costs of mitigation are both the economic and the psychological adjustments that must be made to move away from current energy systems; and, secondarily, the adjustments that must be made to move away from wet rice and cattle production, the main man-made sources of methane (in addition to methane leaks from gas and oil refining and distribution systems). Moreover, the likelihood that the distribution of costs and benefits will be greatly uneven across nations complicates further the task of reaching international agreement.

Evaluation of Kyoto

The emissions targets of the Kyoto Protocol, as noted above, cover only 23 countries, plus

the 15 members of the European Union taken together. These countries in 1996 accounted for nearly 64 percent of world emissions of carbon dioxide, leaving over one-third uncovered.[1] Moreover, the uncovered portion is expected to grow more rapidly in the coming decades than the covered portion. By 2010 developing countries are expected to contribute 45 percent of total greenhouse gas emissions, and China and India together will experience greater growth in emissions than all OECD countries combined. China alone in 1996 accounted for over 13 percent of CO2 emissions, second after the United States, and on plausible projections for the two economies can be expected to reach US emissions in 2013, with no allowance for US compliance with the Kyoto Protocol, sooner if the US attempts to comply. The rest of Asia (minus Japan) exceeded China in emissions; Latin America and Africa, taken together, emitted about half as much as China.

Thus effective action cannot be taken by a small group of countries alone, as was possible for example with agreement to cease atmospheric testing of nuclear weapons. Here, while the same requirements need not be imposed on all countries from the beginning, the agreement needs to be structured so that all countries will eventually participate. On one estimate, for example, full implementation of the Kyoto Protocol and continuation at the prescribed lower emission levels of Annex B countries would, on IPCC SAR(1996) main assumptions, reduce the increase in average global surface temperature in 2050 by only 0.05?C, from an increase of 1.4? to 1.35?.[2] It was such considerations that led the US Senate, which must ratify treaties for the United States by a vote of two-thirds, to insist before the conference at Kyoto, by a vote of 95-0, that there must be "meaningful participation" by developing countries in any treaty to limit GHG emissions.

Lack of comprehensive coverage creates another potential problem: economic activities

might re-locate from countries with GHG emission ceilings to countries without ceilings. Through such "leakage" even the impact on GHG concentrations of effective action by the Annex B countries would be reduced. Apart from weakening the effectiveness of the Kyoto agreement on climate change, such leakage would also involve costly adjustments by workers, firms, and towns that were brought about not by changes in economic efficiency, but by a regulatory system with incomplete coverage.

Proponents of the Kyoto Protocol would not deny the fundamental point that key developing countries must eventually participate. They would argue, however, that someone must start the process, and it is natural that the world's richest and most heavily emitting countries do so. Kyoto is only a first step toward a serious approach to the problem.

If Kyoto is acknowledged to be only a first step, we must anticipate what the next step might be. For those covered in Annex B, the natural next step is to lower the emissions ceilings now set for 2012, to achieve, for example, 80 percent of 1990 emissions by 2022. But if the Kyoto targets are reached, developing countries as a group (those not covered by Annex B) on plausible assumptions will have CO2 emissions equal to those of the Annex B countries by 2013, and continuing to grow. How are these countries to be brought into the Kyoto framework, as they must be if climate change is to be avoided?

The answer, in brief, is that they cannot be brought into the Kyoto framework without compromising its purpose. The Kyoto framework for setting national targets is base-weighted, focussed on emissions in 1990. This is in fact standard practice when allocating quotas, to choose a "representative" year and allocate them according to the activity of the relevant agents (e.g. fishermen, banana importers) in that year. Kyoto deviated slightly from normal practice in that the

target reductions are modestly differentiated among agents, ranging from 92 percent of 1990 emissions for the European Union and some eastern European countries to 108 percent for Australia and 110 percent for Iceland. This differentiation reflected in part special circumstances in 1990 (e.g. recent unification of West Germany with the collapsed East German economy), in part different reliance on fossil fuels (e.g. heavily geothermal in Iceland, which cannot easily be used for mobile transport), and in part different expected growth trajectories (e.g. recovery of the collapsed Russian and Ukrainian economies). Moreover, Kyoto involved the usual political bargaining, with targets adjusted to ensure adherence of all the Annex I countries of the 1992 FCCC. Developing countries insisted at Kyoto on their exemption from targets, as already foreshadowed in the FCCC; a provision of the Kyoto Protocol actually prohibits targets being set for developing countries.

Base-weighted targets, even with some differentiation, are completely unacceptable to poor countries with high aspirations for economic development. It is well-known that modern economies rest on the consumption of much energy, and in practice most such energy is provided by fossil fuels. Even major sources of non-fossil fuel energy, such as hydro and nuclear generation of electricity, have become controversial, at least among some environmentalists in rich countries. Indeed, those given to conspiracy theories suggest that the modern environmental movement in Europe and America purposefully wants to keep poor countries poor -- a position given credence by the apparent environmentalist opposition to all forms of inexpensive energy accessible on any scale.

Developing countries insist that their first priority should be economic development. They are not against environmental improvement, and indeed some island countries are fearful of global climate change, particularly if it entails higher sea levels or more serious storms. But relative priority is accorded development, and indeed developing countries insisted that the Rio conference,

which was seen by its initial supporters as a follow-on to the Stockholm conference on the environment of 1972 (which established the UN Environmental Program, UNEP), be devoted to Development as well as to Environment.

This raises the question whether the priorities of the developing countries can be accommodated in the next step after Kyoto. A natural way to do this would be to agree on "business as usual" emissions trajectories for each developing country, which would of course reflect the process of development with its dependence on higher energy consumption. Targets could then be defined in terms of agreed reductions from each national BAU trajectory. If the trajectories themselves adequately reflected the special circumstances of each country, the targeted reductions could even be uniform, e.g. two percent a year.

At Kyoto the European Union negotiated an overall target for the EU. But it faced the problem how to allocate this target among agents within the EU. Instead of adopting a uniform policy for all firms within the EU, as it might have done, the EU members elected to allocate the overall EU target to member states, leaving each member state the task of achieving its target in its own way, within constraints imposed by EU policy. The result of this European negotiation was even greater differentiation than at Kyoto, with national targets ranging from 72 (Luxembourg) and 79 percent (Denmark and Germany) to 125 (Greece) and 127 percent (Portugal) of 1990 emissions. Again, the differentiation reflected different initial conditions and different expected growth trajectories for member states. Luxembourg steel production was already in extensive decline. Germany could accept a deep cut because of its artificially high 1990 base, including the collapsed high-energy-intensive east German economy; and Denmark wanted to demonstrate its green credentials by accepting a similarly deep cut. Acknowledgement was given to high initial reliance

on nuclear power by France (no cut required) and by Sweden, which was committed to phasing out its nuclear power (a four percent increase over 1990 was allowed). The poorest members of the EU -- Ireland, Spain, Greece, and Portugal -- were all allotted generous increases in emissions over 1990 levels, of 13, 15, 25, and 27 percent respectively, all higher than any country received at Kyoto itself. A similar negotiation at the global level, outside a common framework for discussion and deciding on economic policy, presents a mind-boggling challenge.

The suggestion that uniform reduction targets from differentiated BAU trajectories be established is easy to state, hard -- probably impossible -- to execute, at least while preserving the ultimate objective of Kyoto, which is to forestall serious climate change by controlling GHG emissions. The problems are twofold. First, given the high priority accorded to development, developing countries will want to ensure that under no circumstances will the targets impede their development. They will insist on a generous BAU trajectory, either by pleading special circumstances or by aspiring to an ambitious rate of growth, or both. Several countries in East Asia have demonstrated an ability to grow in excess of 8 percent a year for several decades. Many countries would like such success, even though few will achieve it. But they will certainly not agree to forego the possibility in the name of their contribution to mitigating global GHG emissions. To gain their agreement, they must be given generous BAU trajectories. Yet if all developing countries are given generous trajectories, the objective of limiting atmospheric concentration of GHGs, which is necessary to forestall serious climate change, will not be achieved.

Some hypothetical but plausible numbers can be associated with the argument above. Suppose, as suggested above, emissions from developing countries equal those of Annex B countries in 2013. Suppose further that they insist as a condition for accepting national targets that

they have growth trajectories of eight percent a year; and suppose that the GDP-growth elasticity of demand for primary energy is .75 (historically it has been closer to unity), implying an allowable growth in emissions of six percent a year.[3] Assume further that the Annex B countries hold to their Kyoto targets in subsequent years, i.e. they continue to grow economically without any increase in GHG emissions. Under these circumstances, CO2 emissions will be 10.9 billion metric tons a year by 2025, 83 percent above global emissions in 1996, the year before Kyoto.[4] Reduction targets could be set from this level for both Annex B and developing countries, but given their priorities developing countries are not likely to agree to severe targets -- unless new technologies make possible rapid growth without GHG emissions --, and political "equity" will then prevent the Annex B countries from agreeing to severe targets for themselves.

In short, the ultimate objective will not be achieved, either without the participation of developing countries, or with such participation on terms that are likely within the Kyoto framework.

There is a second problem with the Kyoto framework. It envisages establishing a market for emission rights (more on this below), a necessary condition within the framework of national targets for reducing GHG emissions at lowest real cost. Such a market should be established and in effective operation well before 2008, the first year of the agreed five-year accounting period. Emission permits will command a value in the market, and will be traded. Firms or countries that find it more costly than the price of the permit to reduce emissions further will buy permits from other Annex B countries that have reduced their emissions below their targets. Firms or governments will plan their actions taking into account this market, and their estimates of future prices of permits. If in a post-Kyoto phase II many more countries are to be admitted to the scheme,

with targets yet to be negotiated but likely to be generous, that will lower the prospective value of emission permits and discourage firms (or governments) from investing aggressively to reduce their future emissions. Firms will be discouraged from holding unused permits.

Kyoto is base-weighted, as noted. But the problem of allocating valuable resources through global negotiation is a more general one. Emission rights will have value -- not just hypothetical value, but actual money value under a system of tradable permits. This value is created by virtue of placing binding limits on emissions. The value commanded will of course depend on how severe the limits are, on the real costs of reducing emissions, and on any conditions imposed on the tradability of the permits.

We require some principle for allocating scarce resources. Kyoto elected the principle of an historical base, but as we have seen that is unsatisfactory to countries with high aspirations for growth and development. In sharp contrast to reliance on recent history, some observers have suggested that simple distributive justice would require that emission rights be based on population. Such an allocation would favor heavily populated poor countries such as China, India, Indonesia, Bangladesh, and Nigeria. To be meaningful in limiting climate change they would require drastic cutbacks in emissions by today's rich countries, implying radical reductions in living conditions there if implemented quickly. Targets based on population would of course be insensitive to varying resource endowments (e.g. for hydro-electric power) and to the fact that countries depend on vastly different fuel mixes as well as different levels of fuel consumption.

Reductions in living standards could be mitigated, but not avoided, by sale of unused emission rights from poor to rich countries. Trading emission rights will be discussed further below. But the financial transfers involved if emission rights were based on population would be

immense relative to foreign assistance today, far more than is likely to be politically tolerable. If carbon emissions were to take a plausible value of $100 a ton, for instance, a typical American family of four would have to pay $2000 a year to sustain its current (direct and indirect) average level of emissions of about 24 tons a year, 20 tons over its per capita allocation (roughly 6 billion tons of carbon emissions a year divided by a world population of roughly 6 billion people). Total US transfers to the rest of the world would amount to $120 billion a year, roughly ten times current US foreign aid expenditures. Moreover, the transfers in practice would be made to governments, not individuals, despite the underlying moral rationale for basing targets on population, and many these days would question the desirability of transferring large sums to governments whose responsiveness to the needs of their own citizens has been indifferent or worse (think of contemporary Iraq or Burma).

A natural compromise has been suggested: base the national targets on GDP (or recent past emissions) initially, and gradually convert them to targets based on population over, say, 25 years, to avoid the wrenching impact on life styles in the rich countries and the implausibly large transfers to governments of developing countries. Here, however, we encounter some unpleasant arithmetic with respect to population-based emission rights. In 1995 India's per capita income (on a purchasing power basis) was about 5.2 percent that in the United States. Suppose that per capita income in India grows at 5 percent a year over the next 25 years, and per capita income in the United States grows at 1 percent a year (this is a plausible scenario, although in reality the gap in growth rates is not likely to be so wide). Under those assumptions, Indian per capita income 25 years later (in 2020) would still equal only 14 percent of per capita income in the United States, and per capita consumption of energy would be many times higher in the United States than in India.

Thus under national emission targets converging on population after 25 years either India would not be effectively constrained or the United States would be very tightly constrained or (under tradable emission permits) there would be huge transfers from the United States and to India. The sense of global community is not likely to be great enough by 2020 to sustain such large transfers -- it is not that great within the United States today -- and in any case such large transfers either to governments or directly to citizens, by fostering a rentier mentality, would probably not be desirable, as some of the highly oil-dependent countries have discovered.

My general conjecture is that there is no widely acceptable basis for allocating scarce resources -- here, emission rights -- among all countries by international negotiation. The fact that the resource is known to be valuable will lead many countries to hold out for generous treatments as a condition for their binding agreement, and the sum of such generous treatment will undermine the purpose of the agreement, namely to limit significantly the growth in atmospheric concentration of GHGs.

International Trading

While climate change is indifferent to the source of GHGs, because of rapid mixing through the upper atmosphere, the costs of reducing emissions of CO2 and other GHGs differ greatly from one place to another, and from one activity to another. So long as resources are scarce, we need to be concerned with the costs of GHG mitigation, and in particular we should reduce emissions at least cost, wherever that might be. Thus, if the costs of CO2 reduction are higher in Sweden than in Poland, there should be some way for Sweden to help achieve its national target by reducing emissions in Poland, so long as Poland is within its national target. Indeed, Kyoto envisions the

possibility of "Joint Implementation" to take account of such possibilities, without however specifying how joint implementation is to be implemented.

This notion of cross-border cooperation in reducing emissions, so long as the targets are met collectively, is an excellent one. But to be effective it requires careful accounting. One way to achieve joint implementation automatically is to create a market in emission rights. Kyoto is couched in terms of setting national ceilings for GHG emissions; but the same framework can be interpreted as allocating emission rights to the Annex B countries, not to be exceeded. Each country "owns" the right to emit a certain maximum of greenhouse gases. Then Sweden, in the example above, can buy some of these emission rights from Poland; Poland's rights would of course decline by the amount it sold to Sweden.

Creating an effective trading regime in emission rights poses a host of practical problems. First, who exactly is to participate in the market? In particular, should it be 38 governments, or should it be thousands of firms? Markets work best if there are many participants, none of them dominant. But if firms are to trade, each relevant firm needs to have a clear and unambiguous right to emit GHGs.[5] Thus each country with an emission quota under Kyoto needs to develop a system for allocating these rights to participating firms. Three principles of allocation are known (and of course combinations among them): on the basis of historical emissions (the principle used for countries at Kyoto, with modest differentiation), on the basis of political favoritism (with the strong temptation to bribe, directly or indirectly, the officials who control the process of allocation), and competitive auction, whereby the highest qualified bidders acquire the emission rights, and the sales revenues accrue to the government, or to some party designated by the government.

If the principle of allocation is based on historical performance, as it almost always is in

practice, should the historical basis last forever? The issue of global climate change is a long-term issue, not a transitory one; a scheme to deal with it must have great durability. Are those with emission rights based (say) on 1990 emissions to keep their rights forever? Even if they go out of business? Indeed, if the permits command a sufficiently high price, it may make economic sense for some of the owners to go out of their original (emitting) business, and sell all of their permits. They, and their distant descendants, could become rentiers, living off the earnings of sales of perpetual emission rights, earned on the basis of activity way back in 1990. If the emission rights are not to be perpetual, i.e. they are to decay over time, how often should they be reallocated, and what should be the principle of reallocation? Simply re-basing the allocation, e.g. from 1990 to 2000, would create a perverse incentive not to reduce emissions. In short, public authorities will be allocating valuable resources (emission rights) within countries, either forever or from time to time, and any historical basis will have some perverse or anti-social effects. These can be avoided by auctioning the rights, with revenues accruing to the government. So as to mitigate the economic costs to those parties who will be required to have emission rights, the revenues could initially be used in some form of compensation, so long as the compensation is not based on actual emissions. The compensation could then be gradually phased out over time, e.g. a decade.[6] Of course, similar problems of allocation and reallocation arise among countries, as discussed above. Bringing new countries into the scheme will require a principle of allocation to new entrants. And even Annex B countries will require a new allocation beyond 2012: should it still be based on 1990, or should a new principle be introduced, and if the latter what should it be?

A market in emission permits would establish a price for them, e.g. per ton of carbon emissions. That price would then provide useful information for all emitters covered by the

scheme: if they can reduce emissions at a cost below the permit price, they should do so, and sell their rights in the market. If the costs of reducing emissions by a particular firm exceed the permit price, the firm will be better off continuing to emit, and buying a permit to do so. The price of the permits would fluctuate with overall net demand for them.

Various estimates have been made of the price of such permits. The estimates inevitably involve much conjecture, particularly about the schedule of costs associated with different levels of reduction of emissions. Because costs can plausibly be expected to differ sharply from one country to another, the price of the permit will also depend on the nature of the trading scheme, and in particular on what countries are included and what restrictions are placed on trading -- as well as on the severity of the overall emissions target.[7] In general, the more countries that are included, the lower will be the price for any given overall target; and the tighter the restrictions on trading, the higher will be the price.

The US Council of Economic Advisers (1998) estimated that the price per ton of carbon under the Kyoto targets would be about $200 in 2012 if the trading scheme were confined to the United States, but would decline to $56 if all Annex B countries were included in the scheme, and to $23 if China, India and other key developing countries could be brought in under reasonable terms.[8] Under the latter two conditions, Americans would not meet their Kyoto target in the United States, but would buy permits from other Annex B countries, or from developing countries if they were brought into the scheme. One concern with this arrangement is that Russia and Ukraine were granted emission rights at Kyoto that they are unlikely to use fully. (Kyoto was negotiated before Russia's financial crisis of 1998, which set back Russia's prospects for economic growth by several years. Even then, the Russian and Ukrainian targets were on the generous side,

designed no doubt to ensure the participation of those two countries in the Kyoto commitments.) If this is so, an unrestricted trading regime would lead to higher emissions by the Annex B countries in 2012 than would occur if all countries met their targets domestically. The European Union has therefore proposed that countries be allowed to buy from abroad permits no greater than the GHG abatement they have actually achieved, in effect allowing trading for no more than half of a country's target (with an analogous rule to apply to sellers). Ironically, under the intra-EU country allocation reached in 1998, 10 of EU's 15 members would violate the rules the EU proposes for other countries (CEA, 2000, p.271). Moreover, the EU proposal could have the consequence, by restricting the trading market, of much lower permit prices than would obtain without the restriction, thus discouraging some abatement that would occur under an unrestricted trading regime (see Victor, p.115).

Cross-border purchases of emission permits of course would involve corresponding transfers of funds from the buying country to the selling country, or from firms in the buying country to firms in the selling country. Assume that the EU proposal was adopted, and that American firms purchased from Russia and Ukraine permits amounting to half the reductions the United States required to meet its Kyoto target. At the CEA estimated price, that would imply transfers from Americans to Russians and Ukrainians in excess of $13 billion annually to buy emission rights. Given the recent history in those two countries, the allocation of emission rights to domestic firms is likely to be riddled with corruption. Foreign purchasers would be complicit in sustaining and (given the values involved) possibly enhancing this corruption. Would such transfers, or even the prospect of them, be politically acceptable in the United States, or in Europe? I strongly doubt it. So here is another flaw of Kyoto: the ceilings are too stringent to be applied

nationally -- at least in the United States, given its rapid growth in 1990-2000; but the flexibility allowed by Kyoto is likely to result in politically unacceptable large transfers among countries, in particular to Russia and Ukraine.

The Kyoto Protocol requires a system for monitoring emissions of GHGs, and for enforcing compliance with the targets. Monitoring fossil fuel emissions in the Annex B countries perhaps poses no insurmountable problems. But monitoring net CO2 emissions from other sources (e.g. soils and forests), and emissions of the other five GHGs will be much more problematical, as Victor (2001) has emphasized. How will we know whether or not the targets have been reached?

Suppose a country by its own acknowledgement has not reached its target, or, worse, claims to have reached its target but on impartial assessment has not? What if anything will be done about it? The problem arises especially with a trading regime, under which a country has sold some of its permits to others, and then claims unconvincingly to have cut its own emissions below its target by the amount of the permits sold. How can the money be recovered? Again, Russia and Ukraine come to mind, but the problem could arise with any selling country. Suppose in the meantime the selling firms have disappeared? Should the government be liable? Can we anticipate future analogues of the debt crises of the 1980s and 1990s, in which country debts were rescheduled, under painfully negotiated conditions? Victor (2001) ingeniously suggests that the buyers should be liable, implying that the permits would be continually be labelled by the seller (like bonds). Thus some permits could sell at a discount to others, depending on the reputation of their source. But he does not explain how past wrong-doing would be rectified. And buyer liability would fragment and make much less liquid the market in emission permits, which at least in its early years might be fatal to its basic purpose.

Taken together, the flaws of the Kyoto Protocol -- incomplete coverage, inappropriate basis for allocation of valuable emission rights, inadequate provision for monitoring and enforcement, politically unacceptable transfers under (necessary and desirable) trading -- render that agreement fatally flawed, and therefore functionally moribund.

An Alternative Approach[9]

There is an important alternative to setting national emissions targets. That is to agree internationally on a set of actions, calibrated to achieve the desired emissions (ultimately, as stated at Rio, set to stabilize the atmospheric concentration of greenhouse gases, an objective that is too radical for specification in the near future). Since to accomplish their quantitative objectives governments must in any case create the appropriate behavior-altering incentives for their citizens, and since as we have seen setting a national allocation of global emission rights is likely to prove so contentious as to be impossible, it may be far easier simply to agree on a common use of instruments.

For problems such as reducing emissions, the favorite instrument of economists is to tax the offending activity. All countries would agree to impose a common carbon tax, which would increase the price of fossil fuels in proportion to their carbon content (with possible tax exemptions for uses that do not produce carbon dioxide, such as production of some plastics). Such a tax would have at least two major advantages. First, it would encourage reduction of emissions to take place where that can be done at least cost, since all emitters would have the same incentive to reduce emissions, but only those who saved more in tax payments than it cost to reduce emissions would undertake reductions; others would simply pay the tax. It would provide encouragement

everywhere for fuel switching toward natural gas, and more importantly to conserve generally on the use of fossil fuels.

Second, it would generate revenues for governments. All governments have trouble finding sources of revenue that do not have negative effects on economic incentives to work, save, or undertake commercial risks. Here is a tax with the right incentives. That should make a carbon tax attractive to finance ministries everywhere. Where the revenues are large, as they eventually would be, the new tax should be phased in gradually, and growth can be encouraged by reducing other taxes, e.g. those on foreign trade or on earnings. Taxes on fossil fuels would of course have some undesirable effects, such as delaying the switch from fuel wood to fossil fuels in poor countries. But it would be impractical in most cases to tax fuel wood.

In principle, it would be possible to extend the idea of a common carbon tax to methane as well, covering wetland rice production, decomposable refuse, gas pipeline losses, and cattle raising, but that more difficult step could perhaps wait until a later stage, or even be treated in a different way (see Victor, chapter 4).

Differential treatment could be extended to developing countries by allowing them more time to phase in the carbon tax, although those with growing need for revenue might choose to introduce it earlier than required by the agreement.

The imposition of a common carbon tax would be easy to monitor. Enforcement of the tax would also be possible to monitor, since 183 countries (which however exclude Taiwan, Hong Kong, North Korea, and Cuba) hold annual consultations with the International Monetary Fund on their macroeconomic policies, including the overall level and composition of their tax revenues. The IMF could by agreement provide reports on energy revenues collected to the monitoring agent

of the treaty governing greenhouse gas emissions. Such reports could if necessary be supplemented by international inspection both of the major tax payers (e.g. electric utilities) and the tax agencies of participating countries. Large emitters such as generating stations could be monitored by satellite.

Imposition of taxes by international agreement imposes a major problem for democratic countries, however, since taxation goes to the heart of parliamentary prerogative, and most will not welcome taxation by international agreement, even with a requirement for parliamentary ratification.

Moreover, as 1993 experience in the United States with a btu-based energy tax illustrates, even modest energy taxes can be politically unpopular. In 1992 the European Commission proposed a somewhat more ambitious tax for energy, rising to the equivalent of about $10 a barrel (roughly 50 percent) of oil by 2000. That tax was never enacted. Moreover, the EU proposal paradoxically but not surprisingly gave special preference to coal (which is produced at high cost in a number of EU countries), the most carbon-intensive of the fossil fuels, and would also levy a tax on nuclear power, the least carbon-intensive major source of energy. Several European have introduced energy taxes, usually however taxing industrial uses at significantly lower rates (see, e.g., Kirkpatrick et al., 2001, on Germany, and parallel OECD studies on energy policies in other European countries).

But this political calculus could change dramatically. If we are to act seriously to reduce GHG emissions, a rise in price of emitting activities is necessary to encourage large-scale conservation. It is better that the revenues from the price increase go into the hands of governments that represent the entire public than into unnecessary economic inefficiency, such as would be

brought about by a command and control system, or into the hands of the owners of large corporations that are allocated emission quotas. Furthermore, the imposition of carbon taxes would not necessarily imply additional revenues for governments. One possible disposition of revenues from emission taxes would be to reduce other taxes, such as income taxes or payroll taxes that arguably discourage useful economic activity. Each country would be free to dispose of the emission tax revenues as it judged best. In the United States, introduction of emission taxes would be easier if coupled with reduction of other taxes. Other countries, particularly developing countries, might need the additional revenue and welcome these taxes in lieu of having to raise additional revenues in other ways. Negotiation along these lines has no assurance of success. But since the national target approach of Kyoto has no prospect of accomplishing its ultimate purpose, it is better to abandon the impossible for the merely difficult.

We do not know how responsive economies will be to any given tax level. The cuts in emissions could be either greater or less than initially projected. Thus a regime based on mutually agreed emissions taxes must allow for subsequent adjustment in tax levels, up or down, as new scientific evidence on the significance of GHG emissions for climate change becomes available, and as we learn how effective a given level of taxation is in reducing emissions. The latter effects will become clear only after the passage of some years, so the taxes could be adjusted, by mutual agreement, at five to ten year intervals. That is not a decisive disadvantage when the objective concerns decades and perhaps centuries.

Contingency Plans

Many adverse developments could occur as a result of global climate change. It is much

more difficult -- today, impossible -- to forecast with confidence what will happen. Some analysts have projected benign effects from global warming, and easy adaptation to the adverse effects -- especially for those whose income is enough above subsistence to give them room for manoeuver. Thus for this among many reasons developing countries give higher priority to economic development than to averting climate change if the latter in any way inhibits development.

The great uncertainty about impacts, the prospect of serious gainers as well as losers, the high apparent cost of near-term actions to reduce emissions significantly, for benefits both more distant in time and more uncertain in magnitude, and the need for eventual wide participation by countries with substantially different initial circumstances and hence greatly different priorities -- all these factors make early action to stop growth of greenhouse gas emissions, much less to lower them, highly problematic.

Suppose the best guesses about climate change turn out to be too optimistic; or suppose that despite accurate forecasts the international community is unable to reach agreement on costly, effective mitigation actions; or suppose that despite international agreement countries prove unable to implement the agreements. What then will the community of nations do if accumulating experience suggests the climate change is likely to be great and clearly adverse? This possibility suggests the need for some contingency planning to supplement research to develop cheap low-emitting sources of energy and ways to satisfy human wants with lower requirements for energy. Such contingency planning can take two broad paths.

The first concerns how best to adapt to more serious climate change. It means inter alia pushing ahead with both the basic science and applied research for genetic engineering in many areas, especially agriculture, but also to provide potential substitutes for possible useful species that

may be lost. That could be supplemented by a systematic program for collecting, cataloguing, and storing genetic material, mainly but not exclusively from plants, in the form of seed banks and DNA.

The second concerns how to slow further warming as rapidly as possible. One route involves sequestration and even withdrawal of greenhouse gases, mainly carbon dioxide, from the atmosphere on a scale at least equal to continuing emissions. That will involve good stack absorbers and storage depositories of carbon dioxide. But it also might involve mobilizing the biosphere. Rapidly growing trees could be planted on a massive scale, especially as climate change extends the areas that can support them, for example by dropping seeds by air. More unconventionally, barren portions of the oceans could be fertilized with the requisite minerals (the main deficiency is thought to be iron) so that microscopic carbon-loving plants can thrive.

A different approach would involve reducing the incidence of sunlight on the earth's surface, for example by placing reflecting surfaces in space or by increasing the albedo by altering cloud formation or by placing particulates in the atmosphere, e.g. through jet engine exhaust or by using cannons or rockets from the surface.[10]

Other possibilities will no doubt emerge over time. It is of course premature to commit to any particular method for rapid mitigation. Some suggestions will be impossibly expensive, and others will have unacceptable side effects. The point here is merely to encourage imaginative work on possible emergency actions.

Conclusions

Proposition 1: the problem of global warming cannot be solved without the cooperation

both of China and of the United States, where "China" here is a metaphor for all large, growing developing countries, and " USA" is a metaphor for all large and prosperous rich countries.

Proposition 2: there is no formula for quantitative national targets for GHG emissions, under existing technology and knowledge about global climate change, that will be acceptable both to China and the USA that will address satisfactorily the problem of global climate change, where that issue is defined by preventing atmospheric GHG concentrations from rising above, say, 720 ppm carbon dioxide equivalent (= 2.5 times pre-industrial levels, and twice current levels, implying an increase in global average surface temperature of 2.1? - 6.6? C on current scientific knowledge).

Proposition 3: if propositions 1 and 2 are correct, no scheme based on binding national targets can succeed in dealing with the problem, at least in the next decade or two. Therefore if anything is to be done soon at the international level, an alternative approach to Kyoto is required.

Proposition 4: the approach most likely to succeed is international agreement on common actions, in particular agreed taxes on GHG emissions.

Proposition 5: tax policy is sensitive in every country; success at negotiating common actions based on taxation is not assured of success.

Proposition 6: in view of proposition 5, countries should position themselves for adaptation to climate change; and the world should position itself for emergency actions, mainly involving the rapid sequestration of GHGs, if climate change seems seriously to threaten society.

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Endnotes

1... Detailed quantitative information is not available for the other GHGs, which together accounted for an estimated 30 percent of the increase in atmospheric GHG concentration since the beginning of the industrial era. Figures here will focus on CO2, and on its major sources in fossil fuels, deforestation, and cement making, as is usually done. But the other GHGs should not be neglected. CFCs are also important greenhouse gases, but are not covered by Kyoto because they were already being phased out under the Montreal and London Protocols dealing with stratospheric ozone depletion.
2... Private communication from Fred Singer.
3... An elasticity of .75 seems to be implied in the EU target for Greece, based in Greece's actual growth in the 1990s. It is about 0.5 for Portugal.
4... The literature on GHG emissions is confusing with respect to units of measurement. GHGs other than CO2 are usually converted into CO2 equivalents in terms of their warming potential, itself a somewhat uncertain exercise because of imperfect knowledge of the atmospheric lives of different gases. CO2 is then measured in metric tons. But some sources (e.g. Kyoto Protocol) use the weight of CO2, while others (e.g. the work of the IPCC) use the weight of the carbon in the CO2. I will adopt the latter practice. Oxygen is heavier than carbon: the carbon content in CO2 is about 27 percent, such that the 1990 base of the Kyoto Protocol (Annex B) is 14.5 billion metric tons of CO2 from fossil fuels, which translates into 3.96 bmt carbon content. This measurement ambiguity must be born in mind when addressing carbon taxes.
5... The US Administration under President Clinton made clear its intention to create a domestic market for tradable permits by 2008, and urged other countries to do likewise, arguing that an international mixture of permit trading in some countries with command and control systems in others could significantly weaken the efficiency advantages of a system of permit trading. See CEA (2000), pp.270-72. Ironically, one of the advantages alleged for the national targets set at Kyoto is that they would allow each country to pursue the common objective in its own ways.
6... Under the US sulfur dioxide emissions control program, tradable and bankable permits were allocated initially to 263 high emission generating units at 110 power plants (with fewer owners),

on the basis of energy use in 1985-87, adjusted through the very political process of congressional negotiation. Phase II, covering 2000-2009, involved extending the coverage to all fossil fuel generating units over 25MW, also involved allocation on the basis of a formula focussed on historical emissions as adjusted by political bargaining, with a consciousness that valuable permits were being issued. Emission permits are issued annually, but can be saved for future use. The SO2 trading system so far has worked well within the United States, with permit prices being much lower than originally estimated. See Ellerman et al.(2000).

7... See Dean and Hoeller, 1993, p.153, where the results of several studies of a hypothetical reduction of GHGs by two percent a year from BAU trajectories are compared, across five regions of the world. The cost of a further reduction in 2050 ranges from a low of $67 (1990$) per ton of carbon (in China) to $2245 (in the Former Soviet Union). These differences suggest both major uncertainty (across models) in the costs of mitigation, and major efficiency gains (across regions) from allowing cross-border permit trading.

8... These prices are per ton of carbon; the equivalent price per ton of CO2 would be about 27 percent of these prices.

9... This and the following section draw on Cooper (2000).

10... A study by the National Research Council (1991) suggested that placing reflectors in space would be very costly compared with alternative ways to reduce the incidence of sunlight, but relative costs might be very different in three or four decades.