Necessary Conditions for Stabilization Agreements

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Abstract

The Climate Convention calls for stabilization of atmospheric concentrations of greenhouse gases. This paper considers the issues that must be faced in formulating a plan to meet any such target, using a proposed CO_2 level of 550 ppmv as an example. We hypothesize a set of "necessary conditions" for such a goal to be achievable, and test set of possible forms of agreement against them using the MIT Emissions Prediction and Policy Assessment (EPPA) model. The results highlight the importance of emissions trading to the feasibility of such a target, and the need for an agreement that can adapt efficiently over time to changing relative economic circumstances in participating nations.

1. The Stabilization Goal of the Climate Convention

Article 2 of the Climate Convention calls for stabilization of atmospheric concentrations of greenhouse gases at a level that will avoid "danger" to economies and ecosystems (United Nations, 1992). The parties to the Convention are now debating how this part of the agreement should be interpreted, and what numerical limit should be set. Building on earlier work by Jacoby, Schmalensee and Reiner (1997), we experiment here with the concept of "necessary conditions" that would have to be met for an international agreement to have hope of achieving such a goal. The resulting analysis can serve as a guide to discussion of the policies and institutions needed to carry out this complex task, and add reality to the setting of the goal itself.

The task of formulating a concentration target has three components. The first is the precise definition of the quantity (greenhouse gases) to be stabilized. Although CO_2 is the most important of the anthropogenic greenhouse substances, account must somehow be taken of other gases, such as methane, nitrous oxide and the chlorofluorocarbons. This is a complex and technical topic in itself, and for purposes of this discussion we simplify, formulating the problem in terms of an atmospheric level for CO_2 alone.

The other two components of the definition concern the ultimate concentration target, and the path to that level from today's condition. Again, to provide a specific example for illustrating the "necessary conditions" approach, we use a target of 550 ppmv, which has been proposed by the European Union (European Union, 1966). Specific path definitions have yet to be introduced into the climate negotiations, but a range of possible definitions is provided by the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 1996). One was defined by IPCC Working Group I (IPCC, 1995) and presented in a study that was a preparatory step in the Second Assessment. It is referred to here as the WG-I path. The other was proposed by Wigley, Richels and Edmonds (1996), and subsequently included in the Second Assessment Report (IPCC, 1996). It is denoted here as the WRE path.

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Stated in terms of emissions from fossil fuel combustion, the limits implied by these two concentration paths are shown in Figure 1, along with the Reference or "no-policy" emissions forecast (discussed below) used in our illustrative calculations. As is evident from the figure, the choice of path has important implications for the emissions reductions that would be required in the near term, and thus for the economic cost of stabilization. The WG-I path requires stringent controls within the next few decades; the WRE path imposes less control in the near term, but implies a stronger effort from the middle of the next century onward.

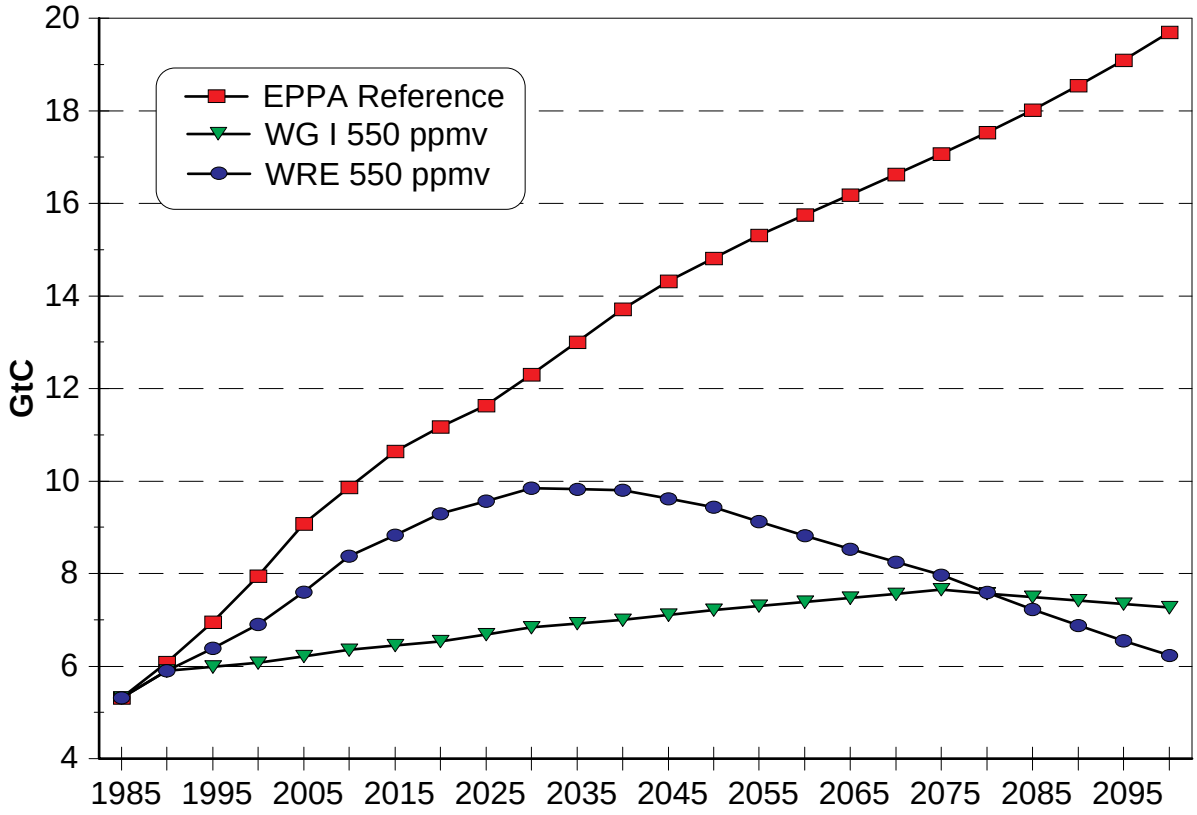

Figure 1. Reference prediction of fossil emissions, with alternative IPCC paths leading to 550 ppmv atmospheric concentration.

There are many forms of international agreement, with differing distributions of burdens among nations, that might bring global emissions into line with one or the other of the 550 ppmv paths shown in Figure 1. Some might prove economically and/or politically feasible, and some would not. A preliminary sorting-out of which is an important prelude to negotiations, and it is to this end that we introduce the concept of "necessary conditions" for agreement. Note we do not seek to identify the "best" solution given any atmospheric goal, or even to define a range of plausible schemes. Our objective is more modest. It is to identify realms of policy agreement that

seem implausible, and thus to guide discussions to more favorable territory and limit the effort devoted to hopeless causes.

We explore these ideas using the Emissions Prediction and Policy Assessment (EPPA) model developed by the MIT Joint Program on the Science and Policy of Global Change, and so we turn in Section 2 to a brief description of that apparatus. Then in Section 3 we develop a set of what we believe are needed conditions for widespread agreement on a stabilization policy, and we use them to test a hypothetical policy designed to achieve the 550 ppmv goal. We close in Section 4 by drawing implications for the challenges faced by negotiators attempting to construct an international regime for this important and difficult issue.

2. The EPPA Model

The EPPA model is a recursive-dynamic computable general equilibrium (CGE) model that is derived from the General Equilibrium Environmental (GREEN) Model developed by the OECD (Burniaux *et al.,* 1992).[1] In the EPPA model, the world is divided into 12 regions linked by bilateral trade flows. Each region has four consumption sectors and eight production sectors, with each production sector expressed as a nested set of constant elasticity of substitution (CES) production functions. Five of the eight production sectors represent components of energy supply, including crude oil, refined oil, natural gas, coal and electricity. In addition, the model includes three "backstop" sectors representing possible future penetration of technologies producing carbon-free electricity (*e.g.*, solar, advanced nuclear), carbon intensive liquid fuels (*e.g.*, tar sands, heavy oils, oil shale), and a hydrogen source. Regional CO_2 emissions are computed from the consumption of fossil energy sources.

The EPPA model covers the period from 1985 to 2100 in five-year steps. In the absence of a CO_2 control policy, the model yields a reference path of regional economic growth, energy use patterns, and fossil emissions. These regional emissions sum to the global total in Figure 1. A more detailed description of the model structure is provided by Yang *et al.* (1996) and Jacoby *et al.* (1997). Within the EPPA model, emissions control policies can be implemented with either price (tax or subsidy) or quantity (quota) instruments. To achieve a prescribed CO_2 emission path, such as the WG-I or WRE paths shown in Figure 1, we employ carbon quota scheme. Quotas are assigned to each individual region, and they can be either non-tradable or tradable among regions. In a trading regime, each region is given carbon emission allowances (or permits) according to a distribution rule set by the modeler. The emission allowance then becomes a tradable commodity. Those regions with higher costs of reducing carbon-emitting activities will end up with buying emissions permits and will emit more CO_2 than the initial allowance, and *vice versa*.

[1] The Model has been developed with the support of a government-industry partnership including the U.S. Department of Energy (901214-HAR; DE-FG02-94ER61937; DE-FG02-93ER61713), U.S. National Science Foundation (9523616-ATM), U.S. National Oceanic and Atmospheric Administration (NA56GP0376), and U.S. Environmental Protection Agency (CR-820662-02), the Royal Norwegian Ministries of Petroleum and Energy Foreign Affairs, and a group of corporate sponsors from the United States, Europe and Japan.

In presenting results, we combine the 12 regions defined in the EPPA model into four groups, shown in Table 1. OECD regions, plus the Former Soviet Union and Eastern European countries (the so-called Economies in Transition), are classified as Annex I countries in the Climate Convention (United Nations, 1992). Under the Berlin Mandate, which is a set of instructions to negotiators agreed at the first Conference of the Parties to the Convention (held in Berlin in 1995), Annex I countries are expected to adopt CO_2 emission controls in the near term, while discussion of possible contributions by other nations has been put off for the time being (United Nations, 1995).

Beyond this dichotomy of Annex I *vs.* Non-Annex I, differences among the component countries of each group, in wealth and economic institutions and in expected future growth, lead to a further breakdown. Annex I regions are separated into the OECD and Other Annex I, the latter group including the nations of the Former Soviet Union and Central and Eastern Europe.[2] Non-Annex I regions are separated into two groups that are suggested by the economic forecast built into the EPPA reference case.[3] 'Non-Annex I, Early' includes fast growing economies. Our criterion is that by 2050 these regions reach or surpass 50% of 1990 GDP per capita of the European Community. The remaining regions are grouped into 'Non-Annex I, Later.'

Table 1. Regional Grouping for Viewing Results

OECD:	United States, European Union, Japan, Other OECD
Other Annex I:	Former Soviet Union, Central and Eastern Europe
Non-Annex I, Early:	China, Dynamic Asian Economies, Energy Exporting LDCs
Non-Annex I, Later:	Brazil, India, Rest of World

3. Application to a Sample Policy

3.1 Necessary Conditions for Agreement

A commitment to either the WG-I or the WRE path will require Draconian changes in energy supply and use, as suggested by Figure 1. Analysis taking account of all the countries that would have to contribute to such an achievement would yield a very long list of necessary conditions for agreement. Here we explore only a small set of the more obvious ones.

The first point to make is that there is no plausible set of changes in technology and/or consumer behavior in the Annex I countries that would make it possible for them to achieve the target acting alone. Thus a commitment to 550 ppmv stabilization places a severe limit on any extension of the agreement in the Berlin Mandate not to discuss commitments by Non-Annex I countries. To emphasize this fact, Figure 2 shows the implied emissions path for Annex I countries

[2] The definition is of the OECD as of 1990, which includes the United States, Japan, the 12 members of the European Community at that time, Canada, Austalia, New Zealand, EFTA (excluding Switzerland and Iceland) and Turkey. Mexico, South Korea, Hungary and the Czech Republic, now members of the OECD, have not joined the Annex I nations under the Climate Convention.

[3] Because of changes in growth assumptions, the sub-components of Non-Annex I differ from an earlier exploration of the stabilization issue by Jacoby, Schmalensee and Reiner (1996). For discussion of uncertainty in this forecast, see Jacoby *et al.* (1997), and Webster (1997).

for a 550 ppmv goal, assuming that the Non-Annex I countries do not participate. Under the WG-I path, the Annex I countries would have to achieve *negative* carbon emissions (*i.e.*, net storage) by 2035. The more relaxed WRE path only delays this point by some 30 years.

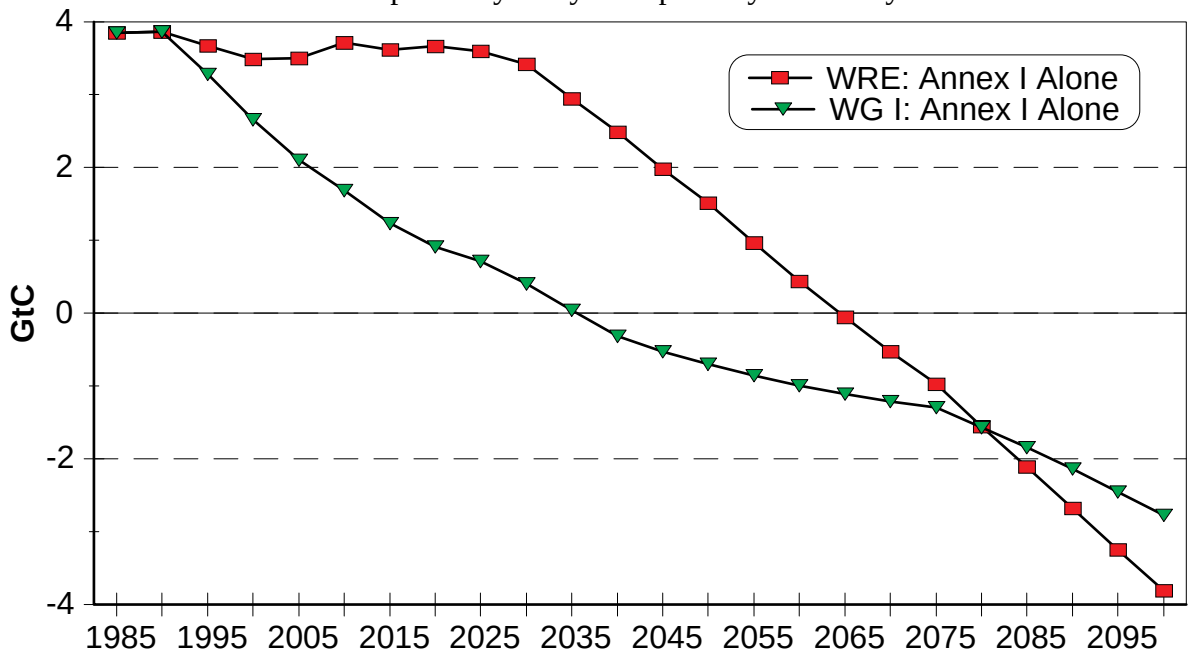

Figure 2. CO_2 Emissions of Annex I, assuming it alone acts to meet alternative 550 ppmv paths.

The example in Figure 2 is fanciful, but nonetheless it makes an important point. It is not just that Annex I cannot attain a 550 ppmv path on its own; it is not reasonable even to contemplate such an objective without a plan that involves participation by Non-Annex I countries. In the section to follow we hypothesize a policy by which this participation might take place.

Having put aside the notion of Annex I acting alone, the remaining conditions concern limits to the burdens that nations can reasonably be expected to bear, and limits to the magnitude of international financial transfers stimulated by this problem. Naturally, this specification and the choice of the limiting levels are a matter of judgment, based in part on one's impression of how countries will perceive the likely economic and environmental impact if climate should change. The greater the threat, the greater burden they might willingly bear. Still, what is important here is not the precise numbers but the way of thinking about the issues. The reader's own judgments regarding the specifics are easily substituted.

As shown in Table 2, we specify three categories of conditions that will have to be met if a stabilization agreement is to be achieved, and prove sustainable. Two of these concern the economic burdens, their absolute levels and some sense of equity among nations. The third relates to the scale of international payments in any permit trading scheme.

Table 2. Necessary Conditions for Agreement

(1) Absolute Burdens
• LDCs enter only after basic income needs have been met
• Regional welfare loss is less than 5% in any period
(2) Progressivity of Burdens
• Annex I regions lead in emissions reductions, and
• Richer regions bear larger welfare loss than poor ones
(3) Limits to the Scale of Payments Under Permit Trading
• Financial outflow is less than 2% of GDP, and
• Financial inflow is less than 4% of GDP

Absolute Burdens. First we assume that less-developed countries will enter into an emissions control regime, and bear economic costs, only after they have achieved some minimal level of income, which has allowed them to deal with more immediate domestic social and environmental problems. This particular condition is implicit in the "Annex I goes first" rule now guiding international negotiations. Second, we assume that nations are unlikely to agree to restrictions that require a sacrifice of more than 5% of welfare in any period. In the calculations below, the welfare index is a function of real consumption.

Progressivity of Burdens. The requirement that Annex I countries take the lead in emissions reductions is explicit in the Berlin Mandate. Not explicit but highly relevant is the condition that, if and when they do finally take a role in emissions reductions, less wealthy countries will want to assume lower burdens than rich ones. This notion can be stated as a principle of equity, which perhaps ought to be reflected in international agreements, but that is not the reason why we include it here. Our view is that nations are simply likely to be unwilling, politically, to maintain a policy that they view as inequitable.

The Scale of Payments. Costs of stabilization may be reduced by a system of trading in emissions permits. However, the volume of emissions trading depends on the initial allocation of the permits. If the allocation differs substantially from the cost-minimizing distribution of emissions, very large volumes of permits will change hands, implying international financial flows that far exceed any historical experience. Because of potential economic disruption and political resistance, there likely are limits to the scale of these payments that countries will tolerate. For purposes of the experiment, we assume that none of our four aggregate regions will support financial outflows that exceed 2% of GDP in any period. By the same token, we assume that the inflows into any region selling permits cannot be sustained at a rate greater than 4% of its GDP.

We have chosen the specific numerical limits taking account of the structure of the EPPA model, particularly its representation of technological change and the difficulty of substitution away from fossil energy as an input to production and consumption. Still, these are judgments, necessarily made in the face of uncertainty about the seriousness of climate damage, future economic and political conditions, and patterns of trade and payments.

For example, we pick 5% as the absolute burden limit, keeping in mind that most studies to date of the impacts of climate change (say, in the mid-range of IPCC projections of temperature change) yield estimates of global economic loss less than 5% (*e.g.*, Nordhaus, 1994; Frankhauser,

1995; Cline, 1992). Even ignoring discounting issues that are relevant in a circumstance where the costs of control come many years ahead of the potential damage avoidance, it seems reasonable to assume that a nation will avoid spending beyond the perceived benefits. Also, recall that in many cases in this analysis the 5% limit applies to groups of nations, as shown in Table 1. Given the likely dispersion of costs among the nations that make up each group, a 5% loss for a group will imply larger losses for some of its members. Given the difficulty of constructing efficient compensation mechanisms, losses for particular sectors or sub-national regions would likely be larger still. On the other hand, as incomes rise over the century (as our analysis assumes) the willingness to sacrifice economic welfare to lower the risk of environmental loss may increase (Grossman and Krueger, 1995; World Bank, 1992). A 5% cost may not seem so big a bite from a larger pie. Given these arguments on both sides of the 5% estimate, it seems a reasonable first approximation for demonstrating the necessary conditions approach.

Similar arguments apply to the limits imposed on volumes of permit trading. In 1992, total exports and imports of the OECD to countries outside the group were roughly balanced, and they constituted only 4% of the OECD GDP (UNCTAD, 1994). Total transfers out of this group (foreign aid and other transfers) were only 0.5% of GDP, so by both of these measures, a 2% limit seems plausible. To be above this level implies that the permit trading alone is larger than total imports and exports of the group, and many times previous experience with transfers not tied to real goods and services.

Looking at the 4% limit on sales of permits, total receipts from exports to the OECD by all non-Annex I countries are about 6% of the total GDP of these countries, and the total inputs of aid flows are only about 0.7%. So, again, whether the limit is thought of as an addition to total trade, or (more likely) to total transfers, the number seems a reasonable one. On the other hand, when thinking of a century, and considering that the changes in trade and payments over the next hundred years might be as large as those over the past century, even this impression of limits to environmental trading could be proved incorrect by unforeseen market developments.

These then are the necessary conditions that we assume must be met for initial agreement on a stabilization target, and for the stability of an implementation scheme to support it over the long term. Next is the question of what kind of control policy might be reached by the diverse set of nations laid out in Table 1.

3.2 A Policy Scenario of Regional Agreement

We investigate just one of the possible policies that might result from international negotiation of reductions tied to a stabilization target. Of necessity, the scheme we study omits most of the richness and complexity that will attend the evolution of the Climate Convention over time. Fortunately, even a very simple policy formulation can give useful insight into the difficulties faced in this situation. Table 3 summarizes the sample policy.

Table 3. A Sample Policy: Annex I Leads, Non-Annex I Follows

(1) Emissions follow one of two IPCC 550 ppmv paths
(2) Each Non-Annex I region caps emissions when
- its GDP per capita reaches 50% of 1995 EEC level, and
- the OECD has made a substantial (5%) reduction,

then reduces its emissions at 5% per decade
(3) Annex I regions abate (in proportion) as needed to follow path

First, the policy is presumed to be designed to achieve one of the two emissions paths laid out in Figure 1. We devote most of our attention to the WG-I case, but also look at the implications of shifting to the WRE path. Second, at the outset we impose two of the conditions in Table 2 that determine the circumstances in which less-developed countries will accept commitments to emissions reduction, and what level of action they will take. Specifically, it is assumed that each country outside Annex I will accept emissions caps only when (1) per-capita GDP has reached a level equal to half that of the European Union in 1990, or roughly the level of Portugal (an absolute-burden condition), and (2) the nations of the OECD have already made a substantial effort to reduce their emissions (a progressivity condition). The first period after these conditions have been met, we assume a Non-Annex I country will cap emissions and begin reducing them at 5% per decade. Further, we assume that the nations now listed in Annex I will abate as necessary, given what the Non-Annex I countries are doing, to keep global emissions on the prescribed path.

Before looking at the implications of this policy scenario, it is worth considering briefly how plausible it is. For developing countries, it seems optimistic considering the tone of discussions to date under the Climate Convention. For example, recent decisions within the European Union give an idea of what is attainable for a country at the income level of Portugal. In allocating reductions to achieve a Union-wide reduction of 10% below 1990, various increases and decreases were agreed for the member nations. For Portugal, the target is not stabilization and 10% reduction (as would be implied by our policy scenario) but *plus* 40% (Blok, Phylipsen and Bode, 1997). The assumption about the "swing" role of the Annex I countries, to fill the gap whatever the developing countries do, is similarly optimistic. But judgments about that aspect are best discussed below when the welfare implications have been presented.

In simulating the case with no trade in emissions permits, each Non-Annex I country is assumed to follow the same path as under Reference assumptions, until the conditions laid out above have been met, when emissions are capped and begin to be reduced. The remaining emissions allowed under the particular case are then allocated to the Annex I nations in proportion to their emissions under the Reference case. In the case with emissions trading, permits are assumed to be allocated to the Non-Annex I countries in the amount of their Reference case emissions, up to the point where they fall under a cap, after which their allocation equals the (gradually falling) cap level. Annex I countries receive permits equal to the emissions constraint as calculated for the no-trading case.

3.2 Exploration of the Sample Policy

The WG-I Path with No Emissions Trading. Figure 3 shows the paths of CO_2 emissions for the four aggregate regions on the assumption that the WG-I path is in effect, and there is no emissions trading. Look first at the nations of 'Non-Annex I, Early.' They grow rapidly up until about 2010, when the Dynamic Asian Economies reach the income criterion (50% of the 1990 EU level) and (after a one-period lag) begin to impose controls. Around 2020 China and the Energy-Exporting Countries reach this threshold, and group emissions begin to decline as a whole. Meanwhile, the emissions of 'Non-Annex I, Later' grow through the first half of the century, gradually slowing down as assumed economic growth rates begin to decline in the latter part of the period.

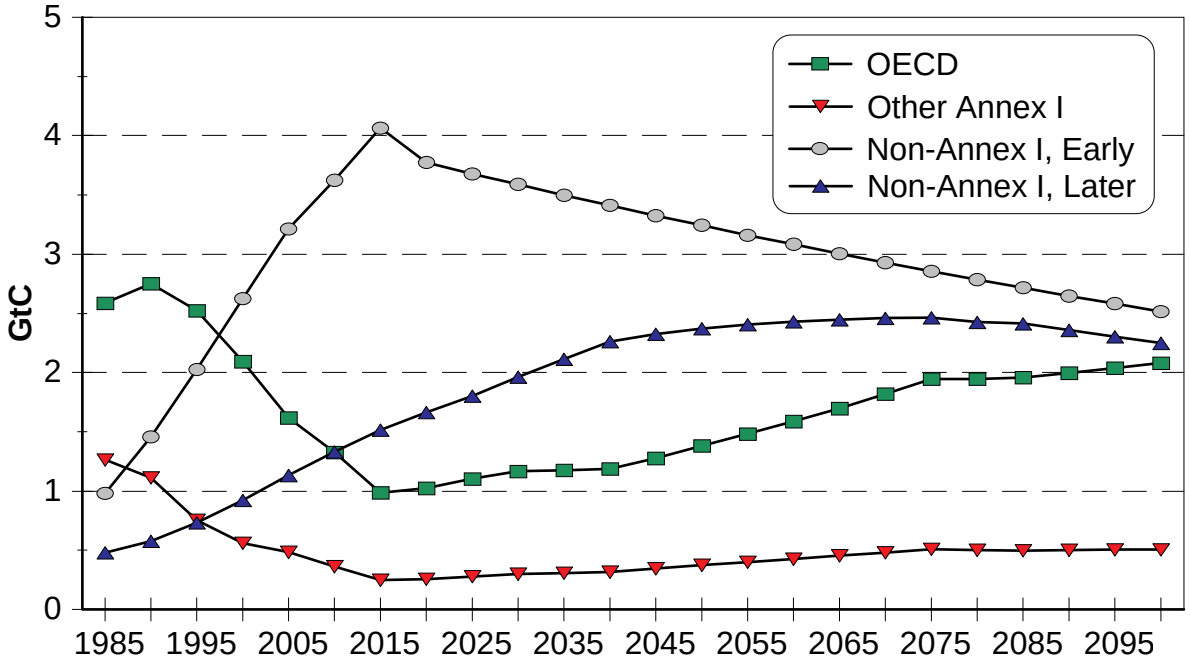

Figure 3. Regional CO_2 emissions on WG-I 550 ppmv path, with no trading.

The regions of Annex I are acting as the balance wheel under the assumptions above, reducing emissions given what Non-Annex I is doing to keep global emissions on the prescribed path. Both the OECD and Other Annex I must reduce emissions sharply, as the world waits for the developing countries to catch up in economic well being. Once the large LDCs begin to participate in the control regime, the Annex I regions are given some room for renewed growth in emissions, as indicated by their rising trajectories after around 2020. Note that emissions of the Annex I countries, even after a century of growth of population and economic output, are substantially below today's levels. Non-Annex I more than doubles emissions over this period, whereas the group that currently has the lowest income increases its total emissions by a factor of about four.

The resulting effect on economic welfare is shown in Figure 4, and the percentage loss refers to the difference between conditions under the control scheme and those under the Reference forecast. Immediately noticeable is the early increase in the welfare of the Other Annex I. Termed the "Economies in Transition" in the Climate Convention, part of this transition is the correction of distortions caused by the mis-pricing of energy under their previous socialist regimes. The imposition of quotas in this example serves to speed up this process, and so it benefits these areas in the short run. Once these gains are past, the emissions controls lead to rapid decreases in welfare, to percentage losses in welfare similar to those of the OECD.

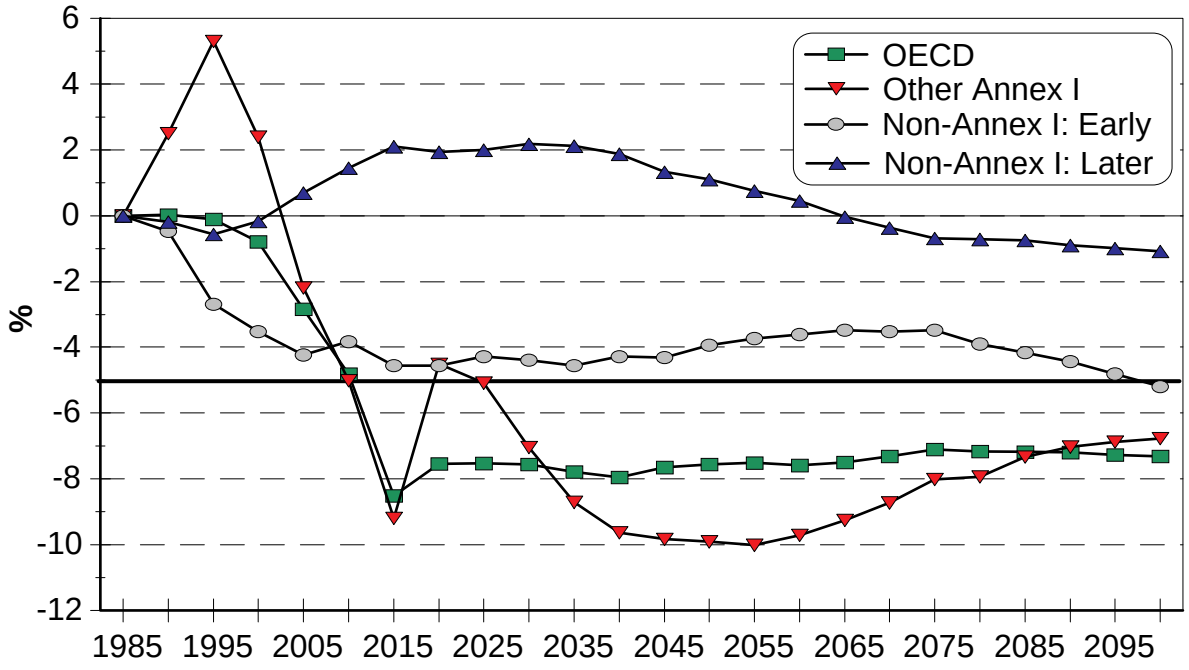

Figure 4. Regional welfare loss for WG-I 550 ppmv path, with no trading.

'Non-Annex I, Later' suffers very little welfare change over the period. After realizing a gain of about 2% early in the century (a result trade effects and carbon leakage[4]) the costs of joining the system erode these gains over time. The 'Non-Annex I, Early' group begins to show losses early in the century, because of the effect of trade changes on their economies, and the imposition of the emissions quota on the more wealthy of its members. Over the long term, total welfare in this group is about 4% lower than under the Reference conditions.

Notice the heavy line on Figure 4, indicating what was assumed earlier about absolute burdens: it is a necessary condition for long-term stability of agreement that the welfare loss not exceed 5%. Yet this condition is violated early in the period for both of the subcomponents of Annex I. The implication of this result is that, in a world without the cost-reducing effects of

[4] For an analysis of these trade effects as represented in the EPPA model, see Jacoby *et al.* (1997).

emissions trading, the WG-I path to 550 ppmv is not feasible if the willingness of Non-Annex I countries to reduce emissions (see Table 3) is no greater than assumed here.

Of course, there are many qualifications to that attend this result. The difficulty of staying on the path is dependent on the total emissions in our Reference forecast, and on the ease with which economies can adjust to emissions limits, all of which are uncertain. (Though, it must be noted, circumstances could be more as well as less difficult than shown here.) And, as suggested earlier, it may be that our assumption of a 5% limit on the welfare loss is too strict. Still, the issue remains, and in our view a number of questionable assumptions are required for the WG-I path to pass the absolute burdens test.

Moreover, the issue of absolute burden is not the only concern with the WG-I 550 ppmv case; this scheme also is in trouble on equity grounds. As can be seen in Figure 4, the Other Annex I bears a substantially greater burden than, say, the 'Non-Annex I, Early' group, beginning around 2015 and continuing to the end of the period. But consider what happens to the relative incomes of some of the component regions of these groups, at least under the growth assumptions in our Reference case. Table 4 shows the ranking of countries by per-capita income. In 1990 the nations of the Former Soviet Union and Central and Eastern Europe were better off than those that comprise the Dynamic Asian Economies. However, over time these Asian economies overtake the Other Annex I group. Our notion of a requirement for some progressivity of burdens is violated, and again the sample policy as summarized in Table 3 is not stable over time, even if nations were willing to tolerate the implied levels of the absolute burdens.

Table 4. Ranking of EPPA Regions by Per-Capita Income

	1990	**2020**	**2050**
OECD			
United States	1	2	2
European Union	3	4	4
Japan	2	1	1
Other OECD	4	3	3
Other Annex I			
Former Soviet Union	5	6	6
Central and Eastern Europe	6	7	7
Non-Annex I, Early			
China	11	10	9
Dynamic Asian Economies	8	5	5
Energy Exporting LDCs	7	8	10
Non-Annex I, Late			
Brazil	9	9	8
India	12	12	11
Rest of World	10	11	12

The WG-I Path with Emissions Trading. Emissions trading may help alleviate some of the conditions that seem to block the attainment of the 550 ppmv goal by this route. If such a system were instituted on a global basis, and if it worked without transactions costs, the results would be as shown in Figures 5 to 7. Figure 5 shows the resulting trajectories of emissions, and they are usefully compared with the no-trading case in Figure 3. By the end of the century, the OECD ends up with somewhat higher emissions than without trading, but in the interim it purchases permits, largely from the 'Non-Annex I, Later' group (but also from the 'Non-Annex I, Early' nations early in the period) in order to avoid expensive domestic reductions. The other Annex I nations also show similar levels of emissions at the end of the century, regardless of the trading opportunity, but they make substantial use of it in the intervening decades.

The effect of these changes on the welfare costs of the 550 ppmv path are shown in Figure 6, and again the 5% loss level is highlighted. The OECD benefits throughout, in relation to a world with no trading. The Other Annex I group benefits in the early years, for the same reasons as before, then begins to realize significant losses (though substantially less than under the no-trading case). The 'Non-Annex I, Later' benefits throughout, through a combination of effects including the improved economic performance of developed nations (through trade effects) and by the fact that the equilibrium permit price is above their average cost of abatement. The 'Non-Annex I, Early' countries also are better off than without trading, until the very end of the period. Given that no group falls much below a 6% welfare loss until very late in the next century, one can say that a universal and efficient trading system would just about meet the necessary conditions, so far as absolute burdens is concerned.

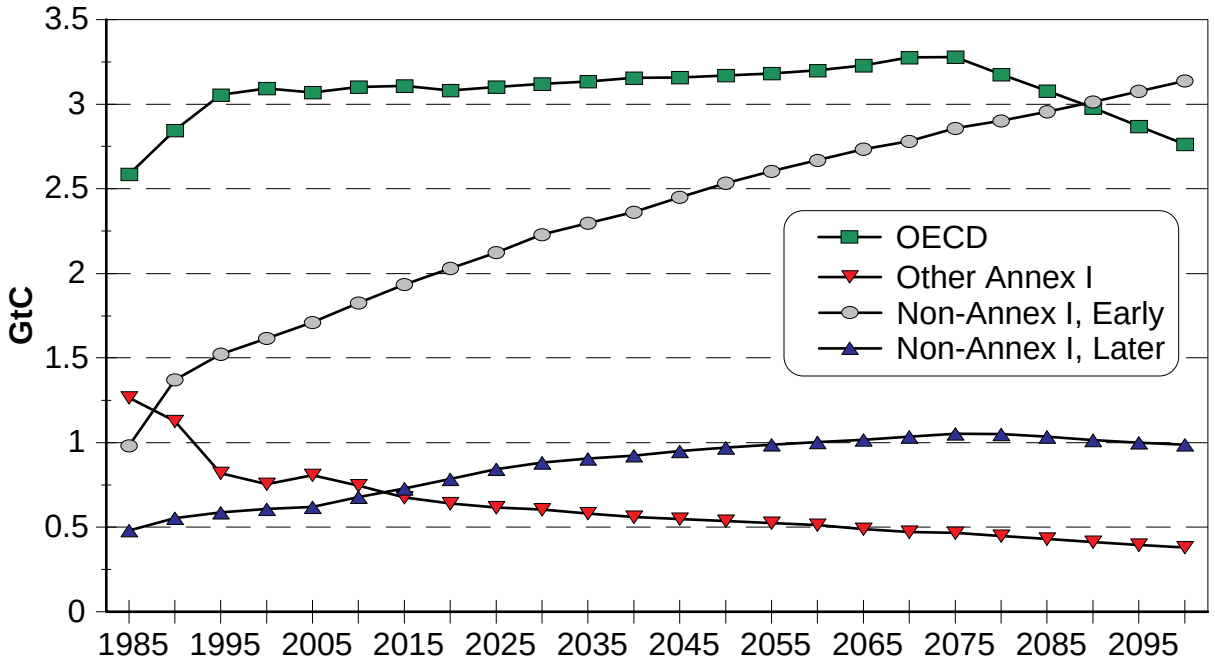

Figure 5. Regional CO_2 emissions on WG-I 550 ppmv path, with global trading.

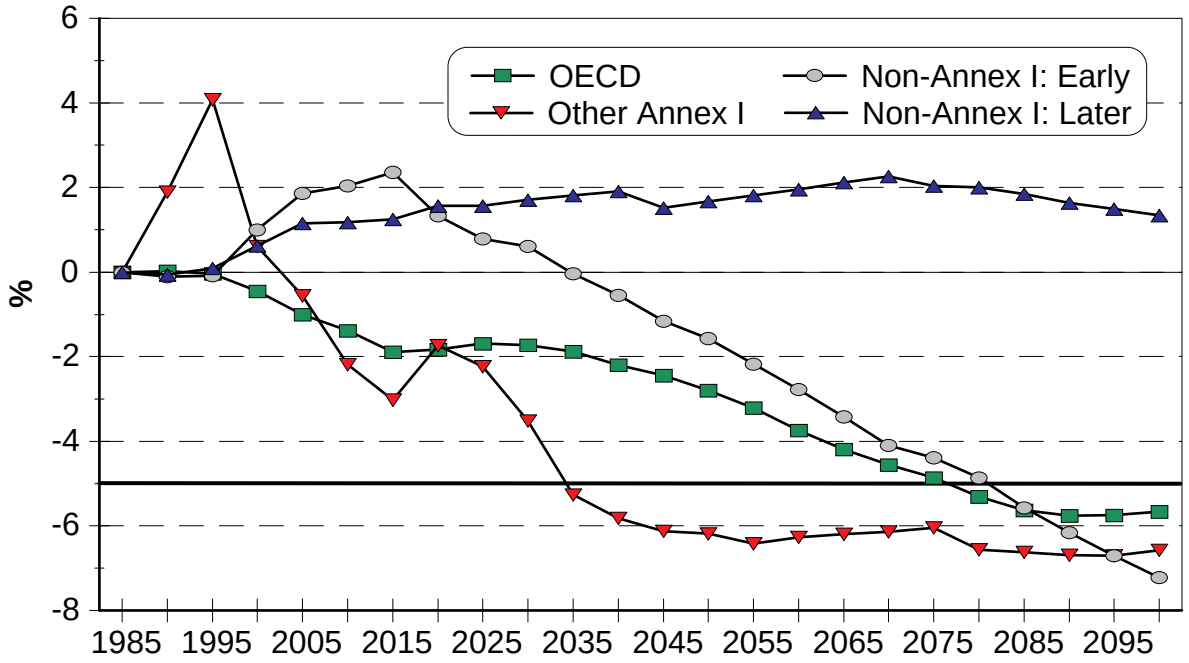

Figure 6. Regional welfare loss for WG-I 550 ppmv path, with global trading.

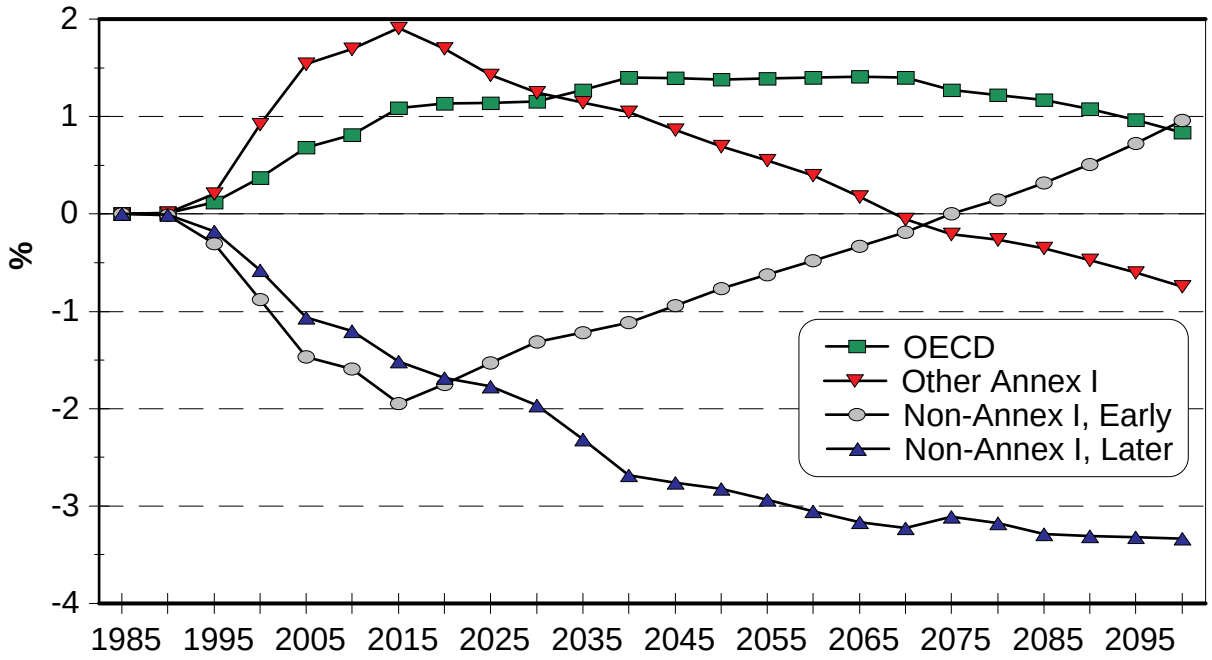

Figure 7. Ratio of permit payments to GDP, for WG-I 550 ppmv path.

The question of progressivity of burdens remains, however. Again, the nations of Other Annex I bear a greater than 'Non-Annex I Early,' when some members of the latter group are much better situated to bear them. This result further calls into question the definition of Annex I that was incorporated into the original Climate Convention definitions.

Finally, there is the question whether the financial flows associated with these permit trades can be supported. Figure 7 presents the relevant results, with payment flows stated as a percentage of GDP. Payments for permits are shown as positive numbers (which we hypothesize cannot rise above 2%), and receipts as negative figures (assumed to be limited to 4%). The OECD is a substantial buyer in each period; Other Annex I also is a buyer heavy in the early to middle part of the period, but by the end of the century its members are selling permits. The 'Early' component of Non-Annex I sells permits through most of the period, but by the last quarter of the century their growth performance has put them in the position to become buyers. The slower growing or 'Later' nations within Non-Annex I group sell emissions permits from beginning to end.

Around 2015, the Other Annex I nations come close to our assumed limit of permit payments staying below 2% of GDP, and in the latter part of the century the receipts by 'Non-Annex I, Later' approach 4% of their total GDP. But at no time is the assumed payment condition violated, which means that, at least by this calculation, the relevant domestic and world financial systems could handle the flows associated with such a permit trading scheme.

WRE Path, With and Without Emissions Trading. As indicated by Figure 1, under the WRE path to 550 ppmv, the restriction on emissions comes decades later than under WG-I. But then the turnaround is more severe. The CO_2 emissions paths for the four groups equivalent to Figures 3 and 5 (not shown here), reflect this difference in that all paths start with higher growth rates, and then turn down more sharply. As one would expect, the welfare losses are lowered in the early portion of the century, but then become much more serious when these restrictions take full effect.

In the welfare loss estimate for the no-trading case, shown in Figure 8, the fact that restrictions actually benefit the Other Annex I group for a number of periods shows up again, and in general the changes from the Reference case are negligible for several decades. Then at around 2045 all but the slower growing LDCs (Non-Annex I, Later) suffer rapidly growing welfare losses. Again, the sample policy fails to meet the necessary condition in the area of absolute burdens, the difference being that the crossover of the 5% loss level comes some decades later than under the WG-I path. It is important to note that this difference implies very great economic savings in present value terms (not computed here) compared with the WG-I case (Wigley, Richels and Edmonds, 1996). Be that as it may, even this more relaxed path is not likely to be feasible under the assumptions in this analysis, because the burdens late in the period are too great.[5] As before, when the burdens come, the sample policy would impact more heavily on the regions of Other Annex I than on those countries aggregated into other regions that are, by then, substantially more wealthy. As noted earlier, a climate regime likely cannot be sustained in the face of this differential imposition of economic pain.

[5] Some analysts (*e.g.*, Wigley, Richels and Edmunds, 1996; Manne and Richels, 1997) argue that the less stringent path offers the possibility that technological breakthroughs will be realized in the interim, drastically lowering the cost, while others (*e.g.*, Grubb, 1997**)** hold that the early restriction of the WG-I path is needed to provide incentive for the investment needed produce such change. These arguments concern the pace of technological improvement (which is considerable) that is built into the EPPA model, not the structure of the argument developed here.

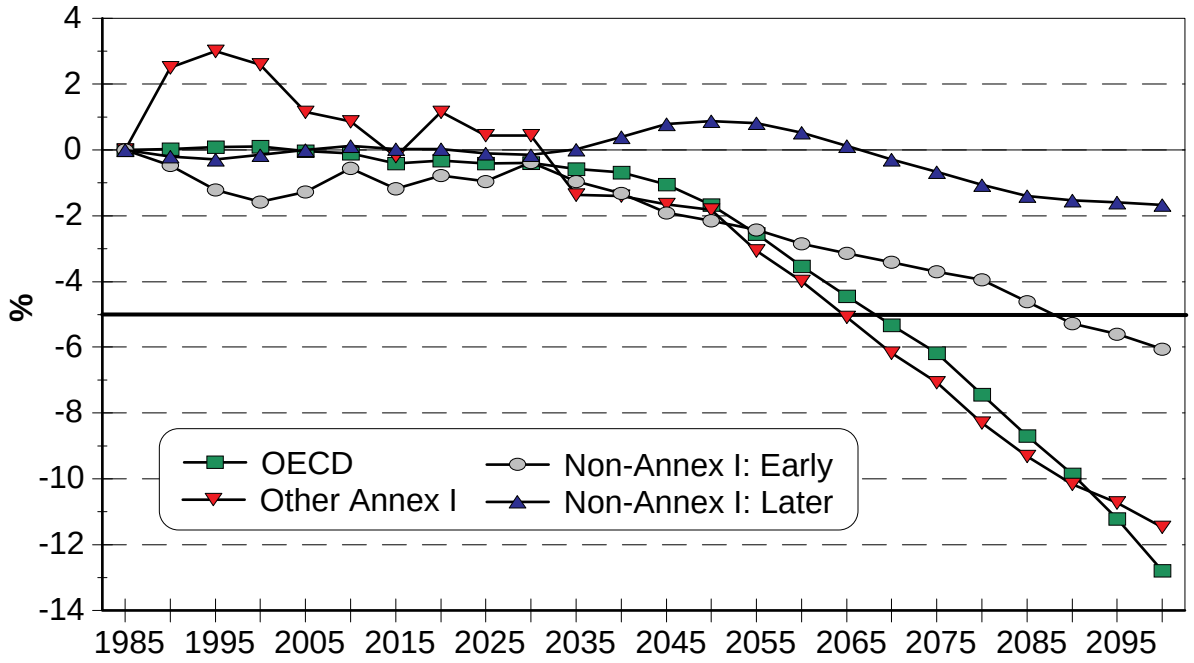

Figure 8. Regional welfare loss for WRE 550 ppmv path, with no trading.

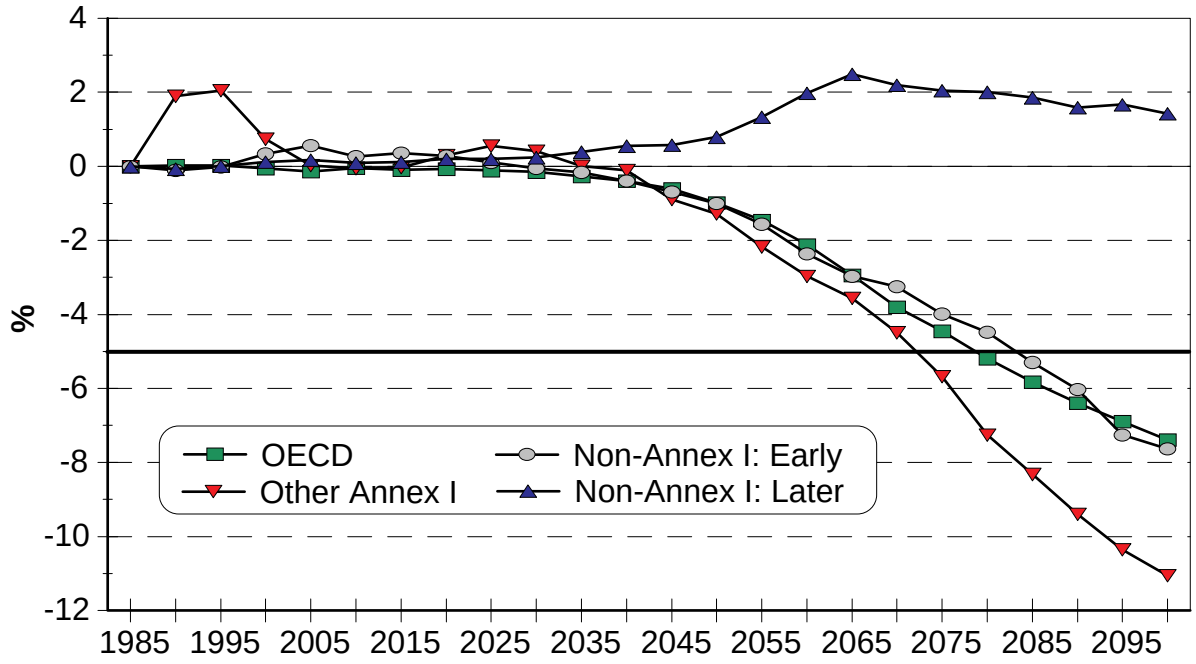

Figure 9. Regional welfare loss for WRE-I 550 ppmv path, with global trading.

Emissions trading would help move the regime toward meeting the necessary conditions, as shown in Figure 9. But the contribution of trading is not as great as in the WG-I case. Severe welfare losses are delayed by a decade or so, again the 'Non-Annex I, Later' group benefits, and

the financial flows remain feasible under the criteria assumed here until the very end of the next century. But the ultimate level of cutback is so severe that even a trading regime cannot keep the absolute burdens anywhere near the 5% threshold assumed above.

4. Conclusions

As the parties to the Climate Convention debate the meaning of their commitment to atmospheric stabilization, it is important to develop procedures for testing the credibility of various implementation schemes that will be proposed. We have explored one approach, applying the concept of "necessary conditions" for a stable agreement. Given these conditions as we have formulated them, a number of conclusions emerge regarding the reasonableness a CO_2 target of 550 ppmv, which is of the most visible of the proposals now before the negotiators. However, as we review these points we re-emphasize our view that the detailed conclusions to be drawn from the analysis are not so important as the procedure itself, as a way to winnow proposals that cannot meet the test of economic and political reality.

First, the WG-I path appears to be infeasible, most clearly if instituted without some reasonably widespread system of emissions trading. Early in the period, an attempt to follow this path would run afoul of the absolute-burden condition. Starting the emissions reductions more slowly as in the WRE case, with greater reductions later to compensate for the late start, can greatly reduce the present value of the control costs. Several factors contribute to the savings, including the avoidance of forced retirement of existing capital and allowance of time for technical improvements to have their effect, but in most analyses the main effect is the effect of discounting on costs pushed decades into the future. Large as they may be, however, these savings do not avoid conflict with the absolute-burden condition. Decisions to stay with a control regime are made along the way, taking account of day-to-day conditions. And if welfare losses rise to very high levels, as they do in the last decades of the century under the WRE path, the stability of the regime is questionable.

Trading can help keep welfare losses within or near the limits assumed, and it appears the international financial flows could be managed. Under the WG-I path, a complete trading regime comes very close, on the assumptions we have made, to bringing welfare losses within the feasible zone. Interestingly, under the WRE case the reductions in emissions are so severe that even a full trading regime cannot hold the welfare losses within the feasible range.

Whatever happens regarding absolute burdens, however, a problem arises with the classification of nations as to their ability to "lead" in abatement efforts. In this analysis we have followed the decision adopted in the Climate Convention whereby the former Eastern Bloc countries, which are relatively poor relative to the OECD, are combined with the OECD into the Annex I group that is supposed to take early (and by some proposals, uniform) action on emissions. Meanwhile, nations who want to discuss possible obligations of the remaining countries have yet to even win a spot for this issue on the negotiating agenda.

On the assumptions underlying this analysis, all of these schemes (WG-I or WRE, with or without trading) will fail to meet the necessary conditions on grounds of progressivity of burdens. Referring to the calculations used here, this condition can only be met if there is some way for the Dynamic Asian Economies to move to the Annex I level of obligation.[6] In addition, it is likely that some new definition, short of the full Annex I, is needed to allow recognition of the divergence of circumstances between most of the OECD countries and the poorer lands of the Other Annex I.

Furthermore, as emphasized by Jacoby, Reiner and Schmalensee (1997), such an adjustment would not be a one-time change. Based on past experience we know that countries will realize very different levels of economic development over coming decades. Unfortunately, we cannot now forecast which will be successful and which may fall into a long period of economic stagnation. Thus, in order to meet the progressivity condition as specified above, it will be necessary for the control agreement to incorporate a flexible system of adjustment, whereby nations can negotiate adjustments to their levels of effort, relative to others, as and when conditions change.

This conclusion has the further implication that attempts to establish numerical concentration targets (and perhaps associated emissions paths) are premature, considering that the parties to the Climate Convention have given so little discussion to an implementation regime and the necessary conditions for long-term stability, including features to allow a flexible response to changing conditions.

[6] Such a scheme is already in discussion in the form of an "Annex Q," which would include the current Annex I countries *plus* others who have achieved some minimum level of wealth (AGBM, 1997).

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