Annex I Differentiation Proposals: Implications for Welfare, Equity and Policy

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Abstract

Drawing upon a variety of different criteria, many nations have introduced proposals to differentiate the reductions in carbon emissions that would be required of industrialized nations in the short to medium term. This paper considers the relationship of these proposals to their underlying conceptions of equity, and to the self-interest of the nations proposing them. The MIT Emissions Prediction and Policy Assessment (EPPA) model is used to analyze the welfare implications of several prominent proposals, considering both cases where nations must carry out all emissions reductions domestically, and situations where trading in emissions permits is allowed. The consequences of applying two prominent differentiation measures to a global regime using a zero-based allocation of emissions rights is also explored. One conclusion is that a trading regime can yield important benefits in reducing potential conflict within developed nations, and help avoid complicated and divisive negotiations over burden-sharing formulas.

1. Introduction

Through the work of the Ad-Hoc Group on the Berlin Mandate (AGBM), parties to the Framework Convention on Climate Change (FCCC) have introduced a variety of proposals for emissions reductions by industrialized countries. In the AGBM terminology, they seek a Quantified Emission Limitation and Reduction Objective (QELRO), and criteria for taking account of special national circumstances. Among the current proposals, the most distinguishing feature may be the principles advanced for differentiating burdens. Several factors play a role in the demands for differentiation, and the form of the proposals. The sense that uniform reductions in emissions would have widely differing economic impacts plays an important part, as does the belief among some states that they have contributed less to the "problem" and thus should be less responsible for a "solution."

A variety of metrics on which differentiation should be based have been put forward. Not surprisingly, states have tended to suggest definitions that favor their own particular circumstances. Those with particularly energy-efficient economies propose carbon intensity of gross domestic product (GDP) as a criterion, poorer countries suggest per capita income as an equitable basis, *etc*. As New Zealand anticipated in a comment on burden-sharing within Annex I, "seeking agreement on apportioning responsibility (*e.g.*, on the basis of emissions per capita, per GDP or specific economic structures or fuel mixes) will rapidly lead towards special pleading on the grounds of individual national circumstances which are unlikely to be either testable or economically efficient" (AGBM, 1997b, p. 16). While one may question whether economic efficiency should be the dominant criterion for policy decisions, at least the *definition* of efficiency is clear. In contrast, differentiation proposals thrive on the ambiguity that results from the absence

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of a universally accepted definition of equity. Indeed, one argument in favor of a uniform rate of reduction for all parties is that, in the absence of a compelling argument for an alternative, it would be the simplest to implement.

The first step in clarifying these differentiation proposals (some of which seem intentionally opaque) is a discussion of the contentious definitions of responsibility and equity that are supposed to underlie them. This review is conducted in Section 2, and we show that a sufficient number of legitimate arguments exist such that different countries can readily attach a philosophical label to any position that happens to align with their economic interests. While the logic of self-interest that shapes the "equity" side of the debate is understandable, the actual welfare implications of these proposals are less so. It is necessary, therefore, to formulate the existing differentiation proposals in a way that facilitates a comparison of their economic effects. These formulations are developed in Section 3. MIT's Emissions Prediction and Policy Analysis (EPPA) model is then used to simulate the welfare changes implied by different proposals, with results presented in Section 4. In addition to the various proposals for differentiation, several parties to the Climate Convention have championed the use of tradable emission permits. As the results show, trading would also have significant implications for the distribution of burdens.

Michael Grubb (1995) has noted that, "to date, the main equity debate about emissions abatement has been cast almost entirely in North-South terms" (p. 478). Our analysis does not address that equity debate directly, because of our focus on the AGBM process, which limits discussion to restrictions within Annex I. Nonetheless, the AGBM discussion may have important implications for the larger question of differentiation on a global scale. Indeed, having witnessed the special pleading among the wealthiest nations, some would despair of any solution at all, when both Annex I and non-Annex I countries are involved. Assuming an Annex I differentiation scheme is agreed upon, the intense political effort required to achieve it will almost certainly affect, if not guide, the development of longer-term, global schemes. Section 5 explores the implications if principles being advanced under the Berlin Mandate were to serve as a precedent for a wider agreement. We argue that developed countries may want to reconsider the relatively modest gains possible under Annex I differentiation proposals if such an agreement sets in motion a global allocation using similar equity principles.

Finally, Section 6 reviews the policy implications of the various differentiation proposals.

2. The Elusive Notion of Equity[1]

Submissions to the AGBM process include proposals both for differentiation of reductions from some base level, and for the reduction target itself. Interestingly, the two are rarely linked, although an exception is the proposal from France discussed below. Even parties proposing a particular emissions target (*e.g.*, 15% below 1990) submit differentiation schemes that make no reference to that target. In practice, of course, the two components are interrelated, because a country's view of any overall target is not independent of the portion it would be expected to bear. Nevertheless, most of the discussion of differentiation proposals concerns their "fairness" to

[1] A more detailed consideration of equity in the context of climate change can be found in IPCC (1996), especially Chapter 3, Grubb (1995), Rose *et al.* (1997), Eckaus (1992) and Shue (1992).

different nations, *given* some overall emissions reduction goal. This is the approach we take in this analysis, using a handful of proposals that reflect the main positions being put forward in the debate over equity and differentiation of burdens.

Two commonly proposed standards of responsibility that have been applied to Annex I reduction proposals are emissions per capita and emissions per unit of GDP, which are usually based on current (or base year) emissions levels. Perhaps the simplest notion is that countries that have high levels of per capita emissions should be asked to cut back in greater proportion than those with low emissions per head. Some oppose linking control obligations to population in this way, because it could be perceived as rewarding population growth, though such concerns are largely absent in discussions limited to developed countries. Moreover, a number of recommendations have been made that could mitigate any such influence (Grubb, 1995).

Further opposition to a per capita criterion comes from wealthy countries with low carbon intensities, who argue that they should not be penalized simply because of their economic success. They may argue, rather, that countries that are profligate in their energy use and emissions should pay the higher penalty, which leads to the second standard mentioned above: those with higher emissions per unit of GDP should be expected to assume the greater burden. Such an idea, of course, can be viewed as unduly punishing to countries that happen to house the carbon-intensive components of the global economy, and unfairly beneficial to those who happen to have abundant non-carbon energy sources, either by nature's gift or because of decisions unrelated to the climate change issue.

A variant on the notion that responsibility for control should be tied to emissions focuses not on current levels but on some integral of past emissions, *i.e.*, on historical responsibility for the current concentration in the atmosphere. This idea is salient in a global context, where some countries have contributed large quantities of atmospheric carbon, and others almost none.[2] It is not frequently raised in discussions limited to Annex I countries, because there is a high correlation between estimates of historical contribution and current emissions levels (whose measurement of is less controversial).

Still another notion is to allocate burdens on the basis of the ability to bear them, whatever the country's particular contribution to global emissions may be. This idea leads to reduction targets being distributed on the basis of some measure of overall economic well-being, such as per capita income. For example, a country's percent reduction in emissions, below some baseline, would be proportional to its per capita income alone. Naturally, such a criterion is viewed as unfairly costly to countries that are relatively wealthy but carbon efficient. Moreover, since an income-based measure is not directly linked to carbon emissions, there is no additional incentive to reduce emissions.

Finally, there is a view that an equitable scheme is one that insures that everybody is bearing the same level of economic pain at any given level of global reduction. Many puzzles arise in constructing such a measure, in particular, it is a heroic leap to say that lost consumption in a poor country can be compared dollar-for-dollar with that in a rich country. The most common

[2] The Brazilian government has submitted a proposal that ties reductions to historical emissions (AGBM, 1997b). See also Grübler and Nakicenovic (1992) for a treatment apportioning responsibility for historical emissions of carbon dioxide.

suggestion is that a control scheme is most fair if it imposes the same percentage GDP loss or the same loss in per capita income on all parties.

Some measures that are based on the concepts outlined above may be negatively correlated, in which case disputes between proponents are clear. In other cases, there may be positive correlations among the measures, *e.g.*, marginal sacrifice of a given percentage reduction and carbon intensity. But in any case, the relations are not perfect, and in the differences are matters of real national interest.

The many ways that these conceptions of equity are combined into proposals for differentiation can be seen in Table 1, which shows a selection of those now before the AGBM. As can be seen, some nations propose alternative, and significantly different, bases for decision or differentiation schemes that combine several different criteria. To be found in the table are all the equity concepts laid out above, with the less-wealthy countries tending to favor per capita income or historical responsibility, richer ones favoring emissions intensity of GDP or emissions per capita, and Australia proposing an equal sacrifice criterion. Examples of criteria near-uniquely favorable to the proposing country can be found in the submissions of Iceland, with its focus on renewable energy (its electricity base is overwhelmingly hydroelectric and geothermal), and of the Russian Federation with its proposal to use land area.

One final point to mention is that actual multi-party political consensus, which implies a form of rough equity, may defy clear analysis using these equity criteria. For example, in deciding upon differentiation within the European Union (EU), none of the suggestions outlined above was used explicitly, although the concepts are scattered throughout the agreement. Intensive negotiations among member states yielded a solution with differentiated responsibilities that allowed for an overall reduction in emissions of 10%, with individual country commitments ranging from a 40% cut by Luxembourg, to a zero change for France, to an increase of 40% for Portugal.[3] Facilitated by pre-existing domestic commitments by several major EU members, agreement was achieved in the context of a comprehensive governance structure that is not available to the Organization for Economic Cooperation and Development (OECD) at large.

3. The Analysis Procedure

3.1. The EPPA Model

We explore the welfare implications of a subset of these proposals using the MIT Emissions Prediction and Policy Analysis (EPPA) model (Yang *et al.*, 1996; Jacoby *et al.*, 1997).[4] EPPA is a

[3] Subject to adjustments based on a final round of negotiations, the analytical basis for intra-EU differentiation was the triptique (or triptych) approach described in Blok, Phylipsen and Bode (1997), which used a complicated formula incorporating detailed differences in national and industrial structure and pre-existing domestic commitments.

[4] EPPA is part of the larger Integrated Global System Model (IGSM) developed by MIT's Joint Program on the Science and Policy of Global Change, which includes a coupled atmosphere-chemistry model and a model of terrestrial ecosystems (Prinn *et al.*, 1997). The IGSM 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 Energy and Petroleum and Foreign Affairs, and a group of corporate sponsors from the United States, Europe and Japan.

Table 1. Sample of Differentiation Proposals Submitted to AGBM

Country	Differentiation Criteria
France and Switzerland	Per capita carbon emissions in 2000
Australia	Equal percentage changes in per capita economic welfare taking into consideration: Projected population growth Projected real GDP per capita growth Emission intensity of exports Fossil fuel intensity of exports Emissions intensity of GDP
Poland *et al.*	GDP per capita Contribution to global emissions Emissions per capita and/or emissions intensity of GDP
Norway	Emissions intensity of GDP GDP per capita Emissions per capita
Iceland	Emissions intensity of GDP GDP per capita Emissions per capita Share of renewables in total energy
Uzbekistan	GDP per capita
Estonia	GDP per capita Responsibility for global warming
Iran	GDP Historical share Dependency on income from fossil fuels Access to renewables Defense budget Population growth Special circumstances Share in international trade
Brazil	Relative historical responsibility
Russian Federation	Land area (as a proxy for sinks) Contribution to global reduction efforts

Sources: AGBM 1996, 1997a, 1997b

recursive-dynamic computable general equilibrium model, with 12 economic-political regions, as shown in Table 2. The calculations here cover the period 1985–2050 in five year steps. The model incorporates eight production sectors (five energy and three non-energy), one government sector, one investment sector, and four consumption sectors. The model also allows for the introduction of two potential future energy supply technologies (or "backstop" production sectors): (1) a carbon-free electric sector, which is meant to represent a bundle of new renewables and advanced nuclear, and (2) a carbon-based liquid fuel derived from shale oil or tar sands, which is a perfect substitute for refined oil. Any carbon constraints imposed on a region will yield rents that are recycled to the region's representative consumer, thus a quota will be equivalent to a (recycled) carbon tax producing the same level of carbon emissions.

Table 2. Regional Breakdown in the EPPA Model

Annex I	Symbol	**Non-Annex I**	Symbol
OECD		China	CHN
United States	USA	Dynamic Asian Economies	DAE
Japan	JPN	Energy Exporting Countries	EEX
European Union	EEC	Brazil	BRA
Other OECD	OOE	India	IND
Non-OECD		Rest of World	ROW
Former Soviet Union	FSU		
Central/Eastern Europe	EET		

3.2 The French Protocol as a Basis for Comparison

As noted above, one proposal that does link an overall target to a differentiation scheme is that from France (Government of France, 1996). It provides a convenient benchmark for comparison because proposals by other nations can be scaled to yield the same reduction in Annex I emissions. The French proposal is actually a long-term proposal that is designed to accomplish the convergence of per capita carbon emissions in all Annex I nations by 2100 according to the formula:

$$E_{2000+x} = E_{2000}^{(100-x)/100} \times Y^{x/100},$$

where E is per capita emissions in a particular year, x is the number of years after 2000 and Y is the convergence target. The French submission suggests that a desirable target would be in the range of 1.6 to 2.2 tons per capita in 2100, which would require cuts substantially below current levels for all Annex I nations.

Since the other national proposals are primarily short-term in nature, some interpretation of the French proposal is required to ensure that results are comparable across all proposals while still adhering to the basic goals of its French proponents. The first question is how to treat the period between 1990 and 2000, since the French proposal does not provide explicit guidance. There is an assumption that by 2000 all parties will have returned their emissions to 1990 levels, which all

Annex I countries pledged was their "aim" under the Framework Convention. Since Germany and the United Kingdom are the only two major OECD countries expected to achieve this goal, this assumption is unjustified, but it is unclear how to treat the many Annex I countries that will not accomplish this goal. If per capita emissions are referenced to 2000, and there is no penalty for failing to return to 1990 levels by 2000, then countries with high emissions growth between 1990 and 2000 would not have to reduce emissions as drastically as those that have actually achieved the goal of returning to 1990 levels. To avoid such a possibility we impose reductions based on emissions in 1990. EPPA's reference carbon emissions are used to establish the year-2000 emissions level for the French formula. By 2005, emissions are assumed to be reduced by half the distance between the level in 2000 and the target emissions in 2010.

Per capita emissions in the six Annex I regions of EPPA are roughly in the range of 3 to 6 tons of carbon per capita. To determine the percentage reductions needed, we choose 2.2 tons per capita for the ultimate target, *Y*, in the formula above. In 2010, applying the French formula directly, we would find that Annex I nations with low per capita emissions would be asked to reduce by roughly 3% below 1990 levels while nations at the high end of current emissions would be asked to cut back by 10 percent. By contrast, in 2050, those percentage reductions increase substantially, to 14% in the former case and 40% in the latter case. For purposes of comparison to the other short-term proposals we take the average reduction that would have occurred from 2000 and 2050, impose it all at once in 2010, and maintain that emissions level for the remainder of the analysis period (to 2050) instead of gradually reducing the gap in per capita emissions over the course of a century. In percentage terms, our stylized French proposal imposes a reduction below 1990 levels of slightly more than 20% for the United States and roughly 5% emissions reductions below 1990 in the other three OECD regions.

3.3 Treatment of the Economies in Transition

As shown in Table 2, Annex I consists of the OECD states and the Economies in Transition of Eastern and Central Europe and the Former Soviet Union. The Berlin Mandate calls for all Annex I states to negotiate a plan for emissions reductions, but the industrialized OECD states have generally been expected to "take the lead." Indeed, Germany and the non-OECD Annex I parties themselves have explicitly asked that a certain degree of flexibility be allowed for the Economies in Transition (AGBM, 1997a). Also, as a result of the political and economic upheavals of the late 1980s and early 1990s, industrial output in Eastern Europe and the Former Soviet Union has declined, resulting in significant reductions in carbon emissions. Given these circumstances, we assume the non-OECD Annex I states are asked to reduce emissions according to the differentiation scheme that would be least burdensome (based on our stylized French scheme) and to maintain that level under all of the differentiation proposals considered here. This assumption simplifies our presentation because it allows for a clear focus on the intra-OECD impacts of the various differentiation proposals.

3.4 Formulation of Other Proposals

Uniform Reduction. The simplest scheme to contrast with the French protocol is a "uniform" proposal that would achieve the same overall reduction by imposing equal percentage

reductions in the four OECD regions. This uniform reduction of 12.2% is calculated as the emissions-weighted average of the combined reductions under the sample French Protocol.

The Norwegian Protocol. A Norwegian proposal combines the three most commonly cited differentiation criteria—per capita emissions, carbon intensity of GDP, and GDP per capita—into a formula that scales the percentage reductions according to the ratio of each country to the OECD average. Our assumption is that an overall reduction target is negotiated first (in our case the French protocol equivalent of 12.2%), and responsibilities are then differentiated according to the formula:

$$Y_i = A\ [\alpha(B_i/B) + \beta(C_i/C) + \gamma(D_i/D)],$$

where Y_i is the differentiated reduction asked of the *i*-th country. The relation of B_i/B is the ratio of emissions per unit of GDP for party *i* relative to the average emission intensity for the OECD, the relation of C_i/C is the ratio of the GDP per capita for party *i* relative to the average for the OECD, and of D_i/D is the ratio of per capita carbon emissions for party *i* relative to the OECD average. The parameter A is adjusted so that the desired overall level of reduction is achieved.[5]

In the Norwegian proposal, the three weighting factors, α, β, and γ, are assumed to sum to 1.0. The proposal offers little guidance as to the weights to be assigned to the three factors, presumably in recognition that ultimately they would be determined in negotiations among the parties. The one suggestion in the Norwegian text is that, "the indicator for emission intensity should be given more weight than the other two indicators" (AGBM 1997a, para 98.3). This condition has been implemented in our analysis by assigning weights of 0.5 to carbon intensity and 0.25 each to per capita carbon emissions and GDP per capita.

Australian Proposal. As can be seen in Table 1, the Australian submission suggests tying the emissions level to a number of different indicators. Some of these criteria may prove contradictory or extremely difficult to achieve in combination. For example, the proposal implies a direct relationship of permitted emissions to emission intensity of exports, but an inverse relationship to carbon intensity of GDP. Rather than attempting to craft a protocol based on these several indicators, it is possible to use the EPPA model to directly model their stated overarching goal, which is the equating of economic burdens across regions. Again, the Economies in Transition are excluded from such a proposal, and held at levels of the stylized French protocol. The Australian proposal is implemented by applying the same overall OECD emissions quota as in the sample French protocol, and then iteratively adjusting emissions quotas within the OECD until each region suffers identical welfare losses in 2010, measured as a percentage loss from the no-policy baseline. As in the other protocols, once emissions are allocated in 2010, they are held at that same level thereafter.

[5] The Norwegian proposal suggests that Annex I be used as the reference group. As discussed above, however, we apply the formula only within the OECD.

4. Comparison of Proposals by Annex I Countries

4.1 Carbon Allocation

Figure 1 presents the emissions implications of the different proposals, relative to a uniform reduction for all OECD regions (the three sets of bars on the left side of the figure). It also shows the distributional effect of three criteria used in the Norwegian proposal if applied individually (the right half of the figure). The EPPA model divides the OECD into four regions: the United States (USA), Japan (JPN), the European Union as of 1992 (EEC), and the other OECD (OOE), which includes Canada, Australia and New Zealand, and the original states of the European Free Trade Area (EFTA). The United States emits roughly half of OECD carbon in 2000, so in percentage terms any reduction in the U.S. quota will produce a roughly equal increase in emissions in the rest of the OECD. This effect is seen most clearly in the French proposal, which, compared to a set of uniform reductions, places a heavier burden on the United States and a roughly equivalent lesser burden on the other three regions. The United States is a net loser in each proposal, compared to uniform reductions, but the magnitude of that loss, and the relative gains by the other regions, depends on the particular scheme chosen.

Breaking down the Norwegian proposal into its components (the right side of Fig. 1) shows that a wealthier region such as Japan will lose to the extent that differentiation is weighted more on a GDP per capita basis, and OOE loses if the scheme is based on carbon intensity. Europe stands to gain under each of the differentiation proposals studied here, although, under the Australian proposal, Japan realizes the largest gain of any region.

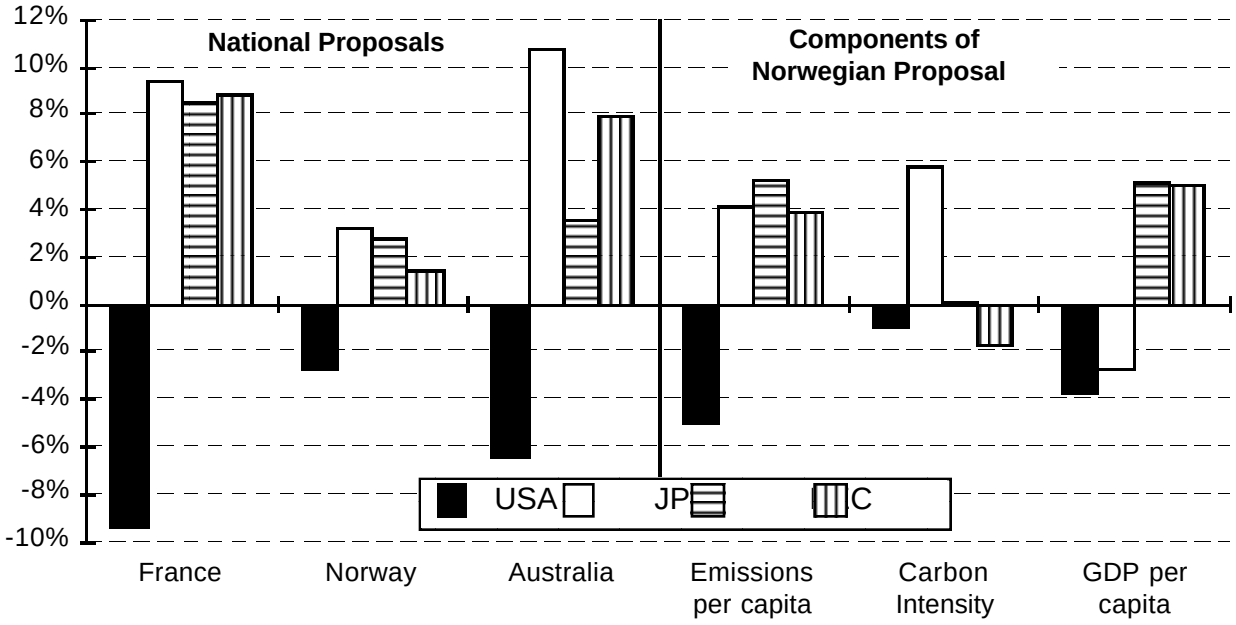


Figure 1. Percent change in emission allocation from a uniform distribution among OECD regions under different burden-sharing proposals.

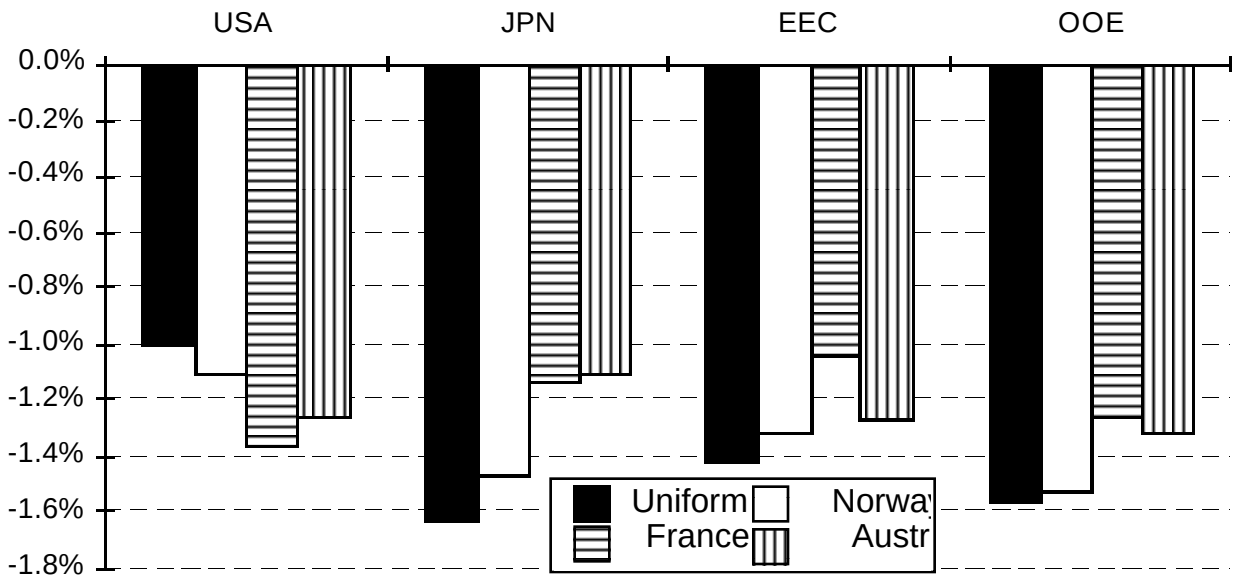


Figure 2. Welfare losses in OECD regions under different burden-sharing proposals. Percent change in discounted consumption, 2000–2050, discounted at 5%.

4.2 Welfare Implication of Proposals

The welfare effects presented in Figure 2 follow directly from the relative carbon constraints in Figure 1. Not surprisingly, the United States suffers most under the French proposal, which requires the greatest U.S. reductions. Comparatively, the Norwegian proposal has a milder impact on the United States because half of the total weight is placed on carbon intensity, which is the metric along which the United States fares best (U.S. carbon intensity is higher than the OECD average, but to a far lesser extent than for the other two measures, as can be seen in the right half of Fig. 1). Note that all other OECD regions fare worst under a uniform protocol, but that the choice among the other schemes implies differential impacts. The range in outcomes among proposals can be large: note the 60% difference between the Uniform and Australian proposals for Japan. Further, the range is likely to expand significantly if account is taken of national-level variation (within the aggregate OOE group, for example).

Since by definition the objective of the Australian proposal is to equate economic burdens across regions, it may seem curious that (as shown in Figure 2) it has a differential impact among OECD regions. This occurs because, in order to be consistent with the methodology used for the other proposals, our procedure allocates emissions so that welfare losses are equivalent in 2010. Differences in economic performance in subsequent decades leads to divergent welfare losses, so considering the whole period from 2000 to 2050 some regions fare better than others.

4.3 Differentiation Within EPPA Regions

It also may seem a puzzle that the OOE loses under the Norwegian proposal, since Norway is included in OOE. By examining variability within EPPA regions, we can explain this apparent anomaly. Our representation of the two aggregated regions are a coarse-grained rendition of the

actual burdens that would be in practice. As noted above, the European Union appears able to differentiate internally, so treating the region as an aggregate is less problematic than for OOE. It must be noted, however, that applying the differentiation criteria, and then aggregating, is not likely to result in the same burdens as if the differentiation criteria are applied directly to the aggregated region. For example, average emissions per capita in the EEC and OOE are both roughly 3 tons per capita, which calls for roughly 5% reductions in emissions in each region under our stylized French proposal. Since both regions contain several major countries with emissions substantially greater than the regional average, and the reductions demanded of countries increases significantly for higher emission rates, simply applying the aggregate reduction understates the adjustments that a full national treatment would require.

In addition, the Other OECD region has no mechanism for devising its own internal allocation, as does the European Union, so it is useful to illustrate the differences across this region, if subjected to the Norwegian proposal, that are shielded in EPPA when the entire region is simply asked to undertake identical burdens. Figure 3 shows the resulting burdens, relative to the OOE average, if the Norwegian formula is applied at the national level. Losses are expressed as a fraction of the average for the group. The calculation uses national-level data for GDP and population from WRI (1996). The information on national carbon emissions is from Marland, Andres and Boden (1997). Clearly, while OOE does not benefit appreciably from the Norwegian scheme, Norway itself would benefit substantially under our assumed factor weightings. Benefits to Norway increase further as the formula is weighted toward carbon intensity of GDP.

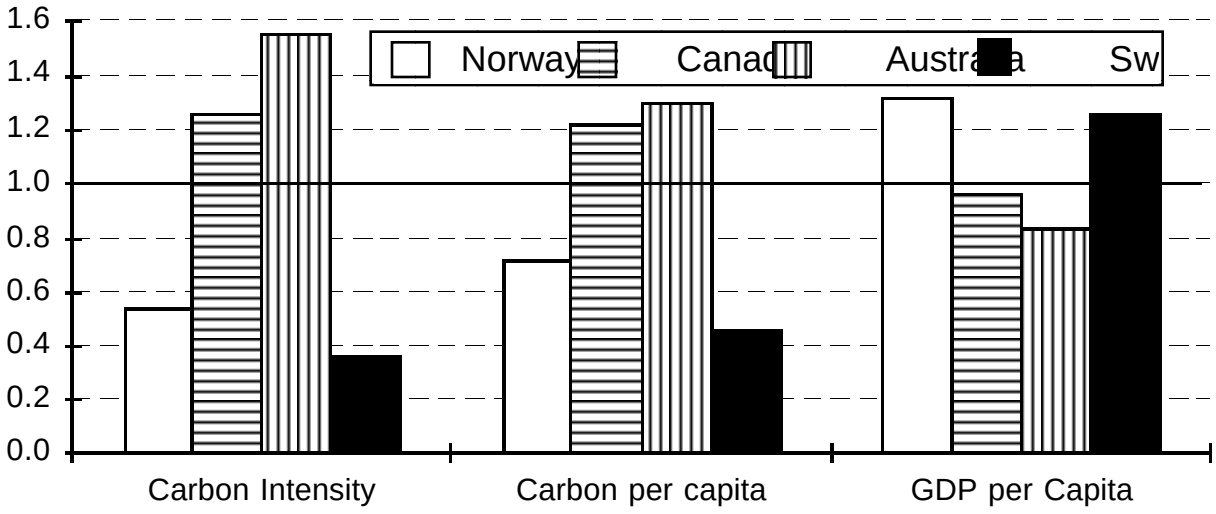


Figure 3. Disaggregating OOE: National-level weighing factors relative to the 1993 OOE average.

4.4 The Addition of Permit Trading

Led by the United States and New Zealand, a number of parties have called for trading in emissions permits. One justification is that markets encourage efficient allocation of resources, and that the costs of any protocol can thereby be substantially reduced. A second reason is that trading would provide a means by which major developing countries might be brought into an emissions

reduction and limitation regime. Since international agreements are voluntary, substantial reductions in emissions from developing countries are likely only if developed countries help fund them. Joint Implementation or Activities Implemented Jointly can in this context be thought of as an incomplete form of trading where "trades" are completed on a project-by-project basis. Further, individual developed countries (or their individual enterprises) can be expected to carry out substantial reductions activities only if they receive credit for such activity against potentially expensive domestic reductions. A trading regime can serve these functions.

These benefits are usually balanced against the practical difficulties in setting up a market in emissions permits, the sensitive nature of any allocation process, and the opposition to the concept from parties who see trading mainly as a way to evade domestic reductions.

Here we show a third potential benefit from emissions trading: that it can reduce the conflict over differentiation proposals within the OECD.[6] Figure 4 presents the discounted welfare losses associated with the different proposals when full global trading is allowed. The presence of a large reservoir of low-cost abatement options in the developing world significantly reduces absolute welfare losses, and in so doing dampens relative losses. Comparing Figure 4 to Figure 2, the gains in efficiency are apparent, but also the divergence in burdens across differentiation proposals virtually vanishes. The gains result from the availability to all OECD nations of a large number of inexpensive carbon abatement options in the six non-Annex I regions that (in our analysis) are only constrained to their baseline carbon emissions. The marginal cost of abatement in these non-Annex I regions increases at a very slow rate over the range of carbon emissions reductions needed to accomplish the differentiated protocols, and so differences in welfare losses between OECD regions are greatly reduced.

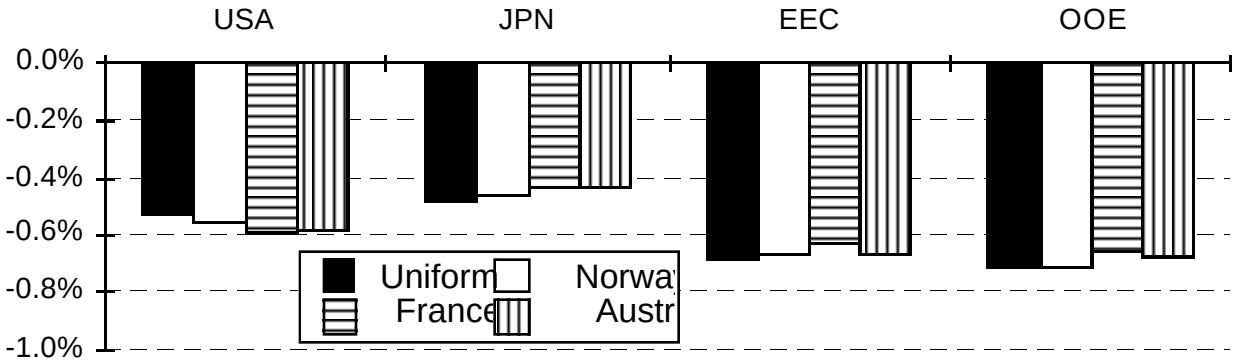


Figure 4. Distribution of burdens in OECD regions under different burden-sharing proposals with full global trading, discounted consumption, 2000–2050, discounted at 5%.

[6] In the context of a full global emissions limitation regime, Rose and Stevens (1994) show that the range of welfare effects is reduced, and draw implications for policy similar to ours.

Of course, analysis such as that we conduct with the MIT EPPA model provides an idealized picture of emissions trading because it ignores transaction costs, which could be significant.[7] Yet even if transaction costs were to eliminate a substantial part of the perceived benefits of trading seen in Figure 4, such costs are unlikely to reproduce the divergence in *relative* burdens characteristic of differentiation proposals without trading. Thus, even if a substantial share of the absolute gains disappears, trading will still reduce the conflict over relative losses. Further, it is not necessary for all world regions to participate in the trading regime for this conflict-reducing effect to be realized. As an example, we assume that only the Economies in Transition and China join with the OECD in such a system. Figure 5 presents the welfare losses for the different proposals with permit trading restricted to these regions. Although absolute gains are reduced from the full global trading case, the dispersion of losses among OECD nations is still significantly dampened.

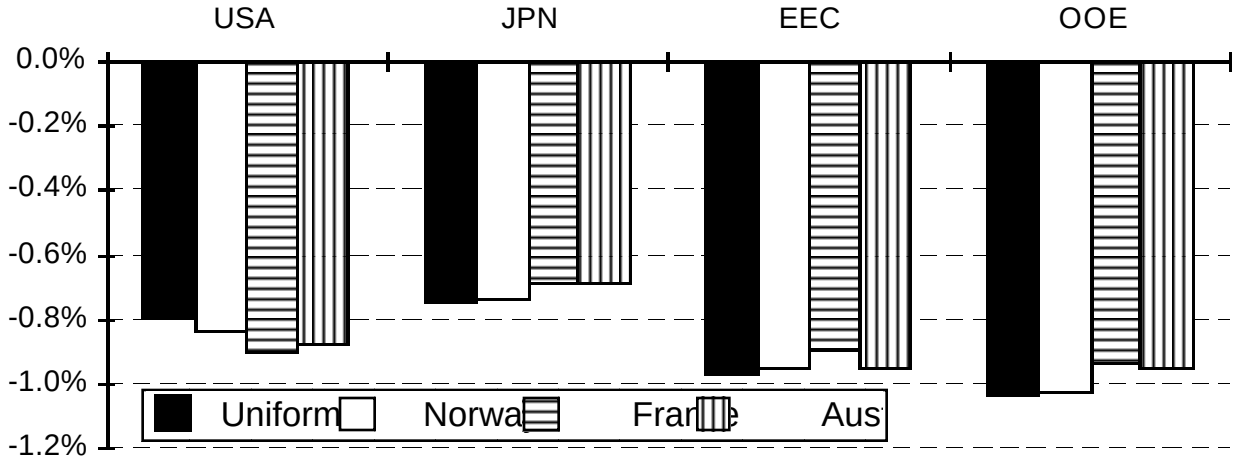


Figure 5. Distribution of burdens in OECD regions under different burden-sharing proposals with partial global trading (OECD, non-OECD Annex I, and China), discounted consumption, 2000–2050, discounted at 5%.

5. Reductions Versus Allocations

Whether applied to the OECD nations only or to all of Annex I, any system of emissions controls that hopes to eventually stabilize atmospheric CO_2 concentrations makes sense only if it is extended to cover all nations (Jacoby, Schmalensee and Reiner, 1997). If and when discussions of such a prospect begin in earnest, the issue of differentiating burdens will re-appear, only on a larger scale and with more contentious choices.[8] To some degree, principles of equity that are given prominence in the distribution of burdens under Berlin Mandate restrictions will provide a

[7] For a discussion on transaction costs, see Stavins (1994). UNCTAD (1994) provides a discussion of many of the practical difficulties of implementing a tradable permits regime.

[8] How a transition from short-term considerations to a longer-term regime occurs has only just begun to be studied. See Schmalensee (1996) for a useful discussion of the main features of such a transition. Also, this analysis has focused on CO_2, over the longer term it will be necessary to incorporate other greenhouse gases (Swart, 1992).

precedent for these negotiations to come. Therefore, it is useful to look again at the ideas underlying the proposals above, and ask what their implications would be if extended to a global scale.

The first thing to notice in analyzing this question is that proposals now under discussion are framed in terms of degrees of reduction from some historical (1990) emissions level. Because of the huge differences in emissions rates among nations if developing countries are included, it seems clear that a system based on reduction from an historic baseline is not likely to be feasible (as discussed below). More likely, the discussion will be framed in terms of *allocations*, measured not from some recent historical point but from zero.[9] As in the reduction schemes, a "zero-based" allocation would then need a rationale for differentiating among nations, using some measurable characteristic.

Of course, the proposals for differentiated reductions considered in previous sections can also be thought of as implicit allocations, measured not from zero but from 1990 levels. In effect, the sample AGBM proposals presented here allocate to Annex I regions roughly 80 to 95% of their 1990 carbon emissions. In these proposals, where developing countries are unconstrained, non-Annex I nations are simply allocated their baseline or "no policy" emissions in our analysis, which in each case rise significantly above 1990 levels. In principle, a full global scheme could be negotiated using the 1990 baseline, with Annex I nations agreeing to restrict emissions to some fraction of their 1990 levels, and developing countries agreeing to a restriction that would be some (likely differentiated and increasing) multiple of their 1990 levels. Using 1990 levels as a basis in a global system is, thus, even more arbitrary than it is in the current AGBM application, and the resulting system is unnecessarily complicated. It is for this reason that we expect that the discussions of wider differentiation issues are likely to begin from a zero base.

To explore the implications of moving to a zero-based allocation *and* a global regime we compare the implicit global allocation associated with OECD reduction regimes for certain differentiation schemes to the allocation of global emission rights using similar criteria. In order to facilitate comparison of the different types of arrangements we assume that the *global* carbon quota is equal to Annex I emissions, constrained according to our stylized French protocol, plus the reference emissions in the developing countries. To compare reduction-type proposals to zero-based allocations we choose the two differentiation measures that are most readily translated into a system of allocation of emissions permits: per capita emissions and carbon intensity of GDP.[10] Whereas a reduction arrangement is usually based on modifying the *average* percentage reduction using some agreed-upon measure, a *de novo* allocation would distribute emissions rights according to that same measure with no regard to history. Although related, the philosophical basis underpinning reductions is *not* identical to that of a zero-based allocation. Consider a population-based measure: a reduction scheme does not assert that each individual is endowed with a right to

[9] For analysis that anticipates this framing of the discussion, see Manne and Richels (1997).

[10] As in the reduction schemes, other criteria could also be used, which would parallel the national proposals. For example, Wirth and Lashof (1990) suggest attaching equal weight to population and GDP, while Cline (1992) argues in favor of an allocation scheme that includes population, GDP, and current emissions. Such 'consensus-seeking' proposals bear a resemblance to the Norwegian proposal, which allows parties to negotiate over the relative importance of different criteria. The Australian proposal also could be operationalized by devising an allocation that would equalize losses in per capita GDP.

emit a certain amount of carbon dioxide, since those at lower emissions rates are still asked to cut back, albeit at a slower rate. By contrast, a zero-based proposal usually allocates emissions rights based on a constant per capita emissions for all nations, which would require some nations to cut back dramatically while others would remain unconstrained for the foreseeable future.

Once rights to emit carbon are allocated from a base of zero, OECD regions are no longer guaranteed that emissions will be confined to a narrow region defined by historically high levels of emissions. For example, as shown in Figure 6, the United States will suffer far more under a population-based scheme, and Japan benefits significantly more under a GDP-based allocation, than under any of the previously discussed differentiation proposals. Under a population-based scheme, the United States would only be allocated 32% of total OECD allocations compared to receiving 44 to 49% under the different national reduction schemes considered earlier. By contrast, under a GDP-based allocation scheme, Japan would receive 17% of total OECD allocations compared to an equivalent allocation of 10.5–12% under the various national reduction proposals.

In the context of a global regime, however, even these intra-OECD shifts are dwarfed by the disparity between the OECD as a whole and other nations. Thus, a GDP-based allocation would allow *all* OECD regions to emit considerably *more* than their 1990 emissions in 2010. Indeed, Japan would be allowed to *exceed* its projected emissions in 2010 under the no-policy case by 50 percent, while all other OECD regions would be permitted to emit roughly their projected 2010 emissions, *i.e.*, no OECD region would have to reduce below reference emissions. By contrast, under a population-based allocation the United States would be asked to cut its emissions by over 70% below 1990 levels by 2010, while other OECD regions would each be asked to reduce by over 50% below 1990 levels.

We do not advocate either position, noting the concerns over fairness and feasibility that would plague either proposal. Nevertheless, if a global regime is eventually to emerge, the international community will at some point need to address equity, whether by using an explicit formula or as part of a complex series of negotiations. This exercise highlights the substantially different character of differentiation within the OECD or Annex I, as compared to a full global differentiation. This illustration thus serves as a call to recognize the precedent-setting potential of any near-term, Annex I- or OECD-only differentiation. We would also note that, here too, trading could play an important role in reducing the contentiousness of even such widely disparate burden-sharing proposals.

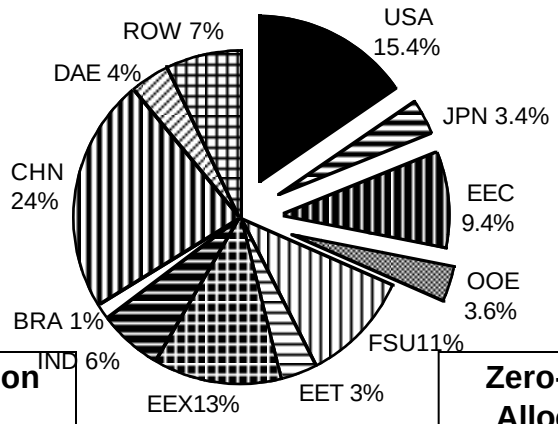
6. Concluding Thoughts

The push for differentiation within Annex I began with dissatisfaction among several nations over the national welfare implications of proposals for uniform proportional reductions. A sense of "fairness" would argue that any agreement should take account of national circumstances or a country's contribution to existing atmospheric concentrations. Several alternative paths to differentiation have emerged:

- Differentiate along a single measure that is accepted as a proxy for the equity goal being pursued;
- Use a combination of measures and seek a negotiated arrangement that is still tied to commonly accepted measures of equity; or

- Differentiate carbon reductions such that relative burdens, measured relative to some baseline, are equated across nations.

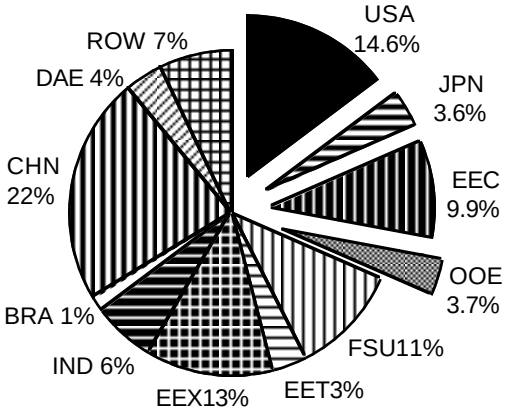
Uniform Reduction by OECD



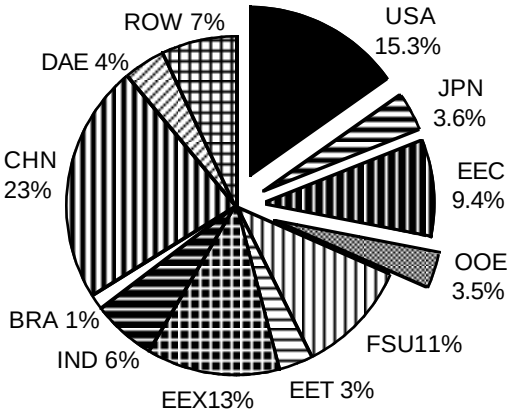
OECD Reduction Schemes

Zero-based Allocation

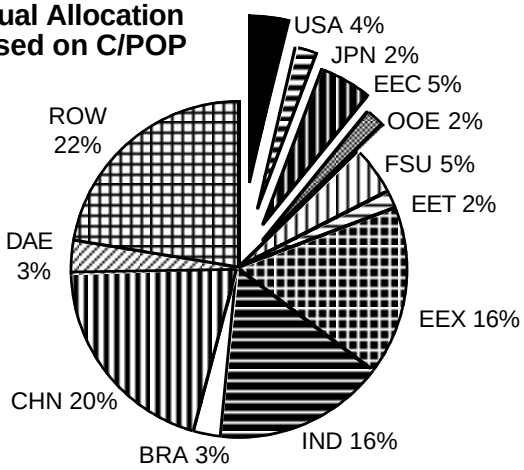
OECD Reduces based on C/POP



OECD Reduces based on C/GDP



Equal Allocation based on C/POP



Equal Allocation based on C/GDP

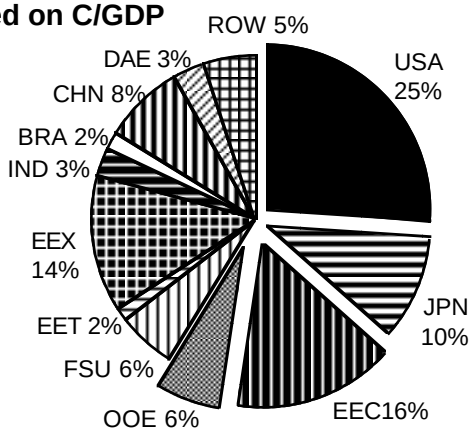


Figure 6. Regional implications of alternative burden-sharing formulations in 2010 for zero-based global allocations and reduction proposals with OECD-only differentiation.

The French proposal has the merit of combining the debate over differentiation with a calculation of the overall reduction target, recognizing that ultimately the two must be reconciled. The guiding premise of the scheme is that reducing disparities in per capita carbon emissions is the appropriate standard. The additional reductions required of nations with higher per capita emissions can be construed as either a penalty for being profligate or simply as a way of atoning for disproportionate responsibility for the carbon in the atmosphere. Such a proposal is transparently disadvantageous to nations with higher per capita emissions who can argue that their higher emissions can be traced to geography or industry structure or natural resource endowment. Potentially disadvantaged nations will likely vigorously oppose any scheme based on per capita emissions (or any other single metric). Moreover, as discussed in Section 5, if differentiation based on per capita emissions is proposed to promote the relative gains of OECD nations with low per capita emissions, then it should be anticipated that this principle could be enshrined as the basis for future differentiation that would disadvantage *all* OECD nations. More generally, the proliferation of differentiation measures proposed as part of the AGBM process reveals that there is little agreement on what constitutes equitable burdens.

The Norwegian proposal accepts that there is no consensus on what defines equity in the OECD or Annex I context. Instead, it provides a format within which a negotiated differentiation scheme can emerge. This approach is hampered by the fact that willingness to assume particular burdens is not only dependent on the three variables cited in the Norwegian proposal but on the perceived damages from climate change, domestic political pressures, natural resource endowment and fuel mix, industrial structure, and anticipated losses from complying with a QELRO including terms of trade effects. The relative inflexibility of having many nations to accommodate, but only three parameters to adjust, will constrain the solution set in such a way that, although the goal of this proposal is to facilitate consensus *via* negotiation, the desired consensus is likely to be infeasible or at least more difficult than it would be in the case of a negotiation without such structure.

The Australian proposal attempts to address some other (but not all) variables, not considered in the Norwegian proposal, that affect the willingness of a nation to participate in a reduction regime. In particular, relative economic burdens, including terms of trade effects, are equated. Three problems plague such a proposal, one ethical and two practical. This proposal assumes that equating welfare losses (measured in percentage terms or in per capita income) is a desirable goal, although many would argue that higher per capita income should imply a *greater* proportional burden.

The second troublesome aspect of this proposal is that it requires that a baseline be established from which equal percentage losses in welfare (or in per capita GDP) might be measured. In this study we have presented one such analysis, using a baseline derived from one economic model, from a particular data set, having valued an assortment of parameters at reference values. We have argued elsewhere (Jacoby *et al*., 1997) that, given uncertainties in key parameters, it is not prudent to rely on a single baseline, even within a given modeling framework. For the purposes of comparing proposals as we have done in this paper, differences in baselines would not lead to

significantly different conclusions. However, attempting to base actual national quotas on losses forecast from a baseline requires that there be both a durable consensus within the scientific community regarding modeling strategy, and dramatic improvements in our ability to determine key parameters, both of which are unlikely.

It appears then, that there are difficulties in the exclusive application of any of these differentiation proposals. But the question remains as to what form of differentiation is either likely or desirable. More specifically, aside from a deeper understanding of the main proposals now under discussion, does the preceding analysis provide any insights that could help resolve the contentious issue of differentiation?

Before attempting to draw out policy recommendations, however, it is useful to mention at least two real-world complications that should be factored into any recommendation. First, it should be acknowledged that in our discussion of equity we have neglected the fact that all countries will not have equal willingness to pay for carbon abatement measures. Some countries may be more willing to bear heavier burdens while others may be willing (or able) to pursue only minimal measures regardless of relative costs. Victor (1996) has argued, on positive rather than normative grounds, that nations pay relatively little attention to equity and instead are simply concerned with domestic costs. If this is true, fairness would have little influence on a decision to undertake international commitments, and instead costs of compliance and willingness to pay will determine differences in burdens rather than more formal burden-sharing formulae.

Second, as the original French proposal has highlighted, the debate over differentiation cannot be easily divorced from the debate over targets and timetables. Calls for differentiation often conceal disagreements over the appropriate target.

Accepting these complications, one might argue that all these various positive and normative considerations will yield a complex blend of differentiated reduction targets and side compensation arrangements (not all of which may be explicitly identified as related to climate). Some might cite the example of the European Union's internal differentiation, which was not based on any explicit definition of differentiation measures but liberally drew on a mixture of measures. The complicated formula took into account differences in industrial structure and used per capita reductions as a basis in the household sector, but also explicitly incorporated willingness-to-pay in the form of pre-existing domestic commitments by several major emitters to substantially reduce emissions. While not unreasonable, this argument neglects the fact that EU differentiation could only allocate two-thirds of their desired reduction of 15% below 1990 levels, and that this internal agreement was carried out in the context of a long-established governance mechanism that is capable of providing compensation not just to national governments but to specific regions and sectors. There is of course no such mechanism within the OECD or Annex I as a whole.

Instead, we return once more to our starting point of uniform proportional reductions and ask if a protracted battle over differentiation is not better avoided. It should be noted that there are precedents for such a proposal. The Montreal Protocol, the original goal of the FCCC of returning Annex I carbon emissions to 1990 levels by 2000, and common OECD environmental standards on a wide range of pollutants, belie the argument (at least within the OECD) that national circumstances should be a dominant factor in determining the burdens that different *industrialized* countries should be willing to assume.

Further, it might be viewed as a desirable feature that uniform reductions would *not* provide any guidance for the differentiation that may be needed for a longer-term, global reduction regime**.** Instead, such a decision would postpone the arduous task of debating notions of equity and seeking consensus on differentiation schemes, and place it in the more appropriate forum, where disparities are great. Returning to Michael Grubb's original point, the global stage *is* the appropriate forum for a discussion of equity.

Of course, as already noted, even at the level of the OECD or Annex I, there are legitimate reasons to move away from uniform reductions. Seeking refuge in the simplicity of uniform reduction would seem to abandon these many valid (albeit contending) approaches to burden-sharing. In answer, we refer back to our analysis of trading, which, even if not global, has the joint advantage of lowering overall costs of achieving any target and reducing the conflict over the distribution of its burdens, whatever scheme is agreed upon. If a trading regime is viewed as a desirable goal, for reasons including lower costs and the ability to entice developing countries to participate in a reduction regime, then one might question why the international community would want to engage in a complicated effort to differentiate burdens among developed nations. If any meaningful mitigation action against climate is truly being sought, then reducing the costs of action and bringing developing countries into any emissions limitation regime would seem to be two of the most important steps. Debates over complicated burden-sharing formulae to achieve results that are restricted to the OECD or Annex I are an unfortunate diversion from much-needed efforts to design an equitable global system to accomplish meaningful reductions at lower cost.

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