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OECD results from three burden sharing rules

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Abstract

An important feature of the Protocol concluded in Kyoto, Japan, in December 1997 is the differentiation of the climate targets of the industrialized countries. A more systematic approach to burden sharing than that leading to the Kyoto Protocol could help negotiating targets after 2012, and when including developing countries in the group of countries with climate targets at a later stage.

The article discusses a number of concepts of equity, examines three specific burden sharing rules and formulae, and presents cost calculations on the burden sharing rules. The three formulae that are explored have some ability to adapt to national circumstances, but none of them creates a burden sharing arrangement that completely equalizes the national income losses as percentage of GDP across the OECD. Nonetheless, the results show that burden sharing rules can be useful tools and provide some, but not all, of the guiding framework for climate policy negotiations.

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1 Introduction

An important feature of the Protocol concluded in Kyoto, Japan, in December 1997 is the differentiation of the climate targets of the industrialized countries, the so-called Annex B countries listed in the Protocol.[1] The differentiated Kyoto targets partly reflect some of the significant dissimilarities and asymmetries existing across the Annex B countries, and the Kyoto protocol may set a significant precedence for climate target negotiations in the future.

In fact, post-Kyoto it seems likely that future attempts to renegotiate and strengthen the climate targets of Annex B countries will have to differentiate targets across Annex B countries. Differentiation of targets will probably also be important when negotiations to include developing countries in the group of countries with climate targets are undertaken at a later stage.

Not surprisingly, the achievement of 'fair' burden sharing among OECD countries became a key issue in the climate protocol negotiations from 1995 to 1997.[2] Some suggested that all OECD countries should cut greenhouse gas (GHG) emissions by the same percentage, or that the OECD countries should stabilize their emission levels in some future year relative to their emissions in a specific base year.

Others however, notably Australia, France, Iceland, Japan, Norway and Switzerland, were opposed to non-differentiated, across-the-board approaches that presumably would place an unfair economic burden on them.[3] They insisted that a future climate protocol should differentiate among OECD countries so that certain countries would not incur abatement costs that were more burdensome than those incurred by others. OECD countries differ in terms of GHG abatement costs, energy efficiency, GHG emissions rates, wealth, population, resource endowments and in other ways as well, and the countries supporting differentiation emphasized that such dissimilarities should be dealt with systematically.

To help the creation of a fair differentiation regime, some suggested developing burden sharing rules. Indicators for differentiation were never seriously discussed during the protocol negotiations, but some countries nonetheless proposed to differentiate between industrialized countries and so-called economies in transition (EIT).[4] With respect to differentiation within the OECD group, Norway suggested to use emissions per capita, emission intensity of GDP, and level of economic development as basic criteria.[5]

[1] The Annex B countries are: Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, European Community, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom of Great Britain and Northern Ireland, and United States of America.

[2] Whereas a number of studies have examined the general issue of fairness in the area of international climate policy, relatively few studies have looked at fairness among OECD countries. For a 'North-South' perspective on fairness, see Shue (1992). See also Harris (1996). For a good overview of equity principles and approaches to burden sharing, see Grubb et al. (1992). Ten studies in climate policy and burden sharing are reviewed in Ringius, Torvanger and Meze (1996).

[3] France submitted its own proposal before the common EU position was established.

[4] For summary of proposals made by a number of countries, see United Nations, Framework Convention on Climate Change (1996).

[5] 'Submission by Norway'. 16 October 1996.

The burden sharing rule proposed by Norway is almost identical to Formula I examined in this article.[6] An Australian proposal identified five criteria for burden sharing – projected population growth, GDP per capita growth, emission intensity of GDP, emission intensity of exports, and fossil-fuel intensity of exports – but made it clear that countries could suggest additional criteria.[7] Apart from emission intensity of exports and fossil-fuel intensity of exports, the proposals of Norway and Australia contained a number of similar features.[8] Other countries, however, especially the United States and Germany, made it explicit that they feared that establishing burden sharing rules would complicate and jeopardize the protocol negotiations.[9]

The differentiation in the Kyoto Protocol was hammered out under extreme time pressure during the last negotiation round in Kyoto. These negotiations were not guided by or informed by a particular burden sharing rule or fairness principle; rather, an acceptable climate package deal was constructed after a series of negotiations on single issues.[10] However, the Kyoto Protocol marks a definite shift in policy issues from 'What is the likelihood of differentiated climate targets?' to 'What are the most appropriate ways to differentiate climate targets?'

In this article we explore burden sharing rules, also called formulae, and indicate the distributive effects of their implementation. We compare three different burden sharing rules and examine how they would distribute abatement costs across OECD countries, calculated as national income losses from emission reductions. The targets indicate which national circumstances are important when a country's share of emission reduction is determined by each of the formulae. We primarily focus on the achievement of horizontal equity. The principle of horizontal equity calls for all persons in the same group to be treated equally. In the context of climate target negotiations it would imply the equalization of per capita national income losses across OECD countries or an equal percentage reduction in welfare (e.g. measured as gross domestic product).

First we review the literature on burden sharing related to climate policy agreements and describe a number of equity principles. Then we examine the way in which the United Nations Framework Convention on Climate Change (FCCC) and the Kyoto Protocol address the issues of equity and burden sharing. After that, we show how the three different types of burden sharing rules would differentiate targets across the OECD. In addition, we use a numerical economic model to calculate the way in which the rules distribute national income losses across the OECD, making the simplifying assumptions that only CO_2 is included in the

[6] The Norwegian burden sharing rule is based on the report Torvanger et al. (1996). The burden sharing formulae in this paper are based on this report. Formula I includes a GDP indicator which is left out in the Norwegian proposal. See also ETSAP (1997) for an evaluation of the Norwegian burden sharing rule compared to the alternative strategies 'uniform carbon tax' and 'individual stabilization'.
[7] 'Further Submission by Australia'. 15 January 1997.
[8] Australia's negotiation approach was somewhat different from the approach taken by Norway. Australia argued, without explicitly referring to the Norwegian proposal, that 'because of variations in the importance of indicators for individual parties, the application of indicators in a systematic process of negotiation, rather than by a mathematical construct, offers the most realistic and achievable means of arriving at a set of differentiated commitments which meet the governing equity principle ['equal percentage changes in per capita economic welfare']. 'Further Submission from Australia'. 15 January 1997, Article 4(b).
[9] See statement by Cornelia Quennet-Thielen, German Delegation. 6 March 1996. In Kyoto, however, the US accepted the differentiation of climate targets.
[10] For the negotiations on differentiation at the Kyoto conference, see *Earth Negotiations Bulletin* (1997).

agreement and that the national quotas are non-tradable. In the final section we discuss the usefulness of the three burden sharing rules and the prospects for creating rules that will be satisfactory and useful in international climate negotiations. We conclude that burden sharing rules will be a useful tool in climate negotiations. However, it is unlikely that differentiated climate targets will be based on such rules alone. Political considerations and other factors will also influence international climate target differentiation.

2 Literature review

The literature on burden sharing in the context of international climate policy agreements is of a rather recent date. The first contributions have addressed the burden sharing issue in the context of allocating carbon entitlements or quotas among countries, whereas more recent contributions analyze target differentiation.

Rose (1992) presents a thorough examination of ten international equity principles. The principles are used to allocate carbon entitlements with and without trading to eight major countries and world regions. Both static reference bases and dynamic reference bases taking into account cumulative emissions are employed. Alternative equity principles are shown to lead to widely different welfare implications for the world regions. Trading reduces these differences significantly.

Barrett (1992) observes that ethical rules often serve as focal points when negotiating international agreements. He presents a brief overview of thirteen allocation rules for tradable carbon emission entitlements, before undertaking an analysis in a game-theoretic framework of outcomes for the United States, the Soviet Union, China and rest of the world. A 'Kantian' rule, where countries choose abatement levels at least as high as the uniform abatement level they would like all countries to observe, is also explored. This rule outperforms all other rules, and the outcomes come close to the cooperative solution, and all countries are better off than in the case of no agreement.

Ridgley (1996) describes an approach to find the 'relative accountability' of multinational regions for reducing GHG emissions. Various approaches are discussed and divided into indices and target based approaches, on the one hand, and equity based approaches, on the other. Next, a survey of multiple criteria decision making methods is presented in which the methods are divided into principle or performance based methods, and interactive or non-interactive methods. Such methods are seen as having a high potential for developing compromise burden sharing schemes. The author illustrates the multiple criteria methodology by defining eleven equity indicators and combining them by employing a lexicographic optimization method. The resulting accountability profile over the eleven multinational regions produces a high degree of fairness.

The point of departure for Kawashima (1996) is differentiation of targets for the Annex I countries (i.e. industrialized countries) defined in the FCCC. As the first step she determines CO_2 'emission needs' based on the three countries with lowest emissions. A population based rule, a GDP based rule, and a multi-criteria rule (population, GDP, carbon intensity, temperature and area) specifying five sectors are examined. In the second step the emission baselines developed in the first step are employed to set targets. One alternative is to set targets in proportion to the emission baselines. The other alternative is to set targets in proportion to the difference between actual emissions and the baseline. The main finding is that the multi-criteria rule yields less difference between the smallest and largest target for a country than single-criterion rules.

Rose et al. (1997) analyze alternative equity criteria for global warming policy. The criteria are divided into allocation-based, outcome-based and process-based criteria. By employing a

nonlinear programming model they examine the welfare implications of the alternative criteria for major world regions. The results indicate that the net abatement cost is similar for several criteria. However, criteria such as the egalitarian principle and consensus equity show rather extreme outcomes.

Rowlands (1997) examines rules for the allocation of GHG emissions among OECD countries. The rules are divided into six categories according to the relevance of historical emissions (i.e. reactive historical, proactive historical, and ahistorical) and emphasis on equality or efficiency. After calculating the emission reductions generated for each country and rule, he concludes that the rules produce very different results for the various OECD countries. Finally he proposes a twin-track strategy, consisting of flat-rate targets in the short term and a differentiated approach in the longer term.

Finally, the European Union (EU) followed a so-called Triptych approach in its internal pre-Kyoto negotiations on differentiated member states' targets (Blok, Phylipsen and Bode, 1997). This 'bottom-up' approach separated the member state economies into three broad economic sectors; the domestic sector, the heavy industrial sector, and the electricity generation sector, respectively.[11] National obligations for the member states were calculated by adding up individual allowances for each of the three sectors and by taking into account economic growth, population changes and climate-adjusted energy use.[12] The sectoral allowances would not be regarded as sectoral targets themselves.

A per capita approach was used to calculate emission allowances in the domestic sector. The Triptych Approach assumed that these emissions would converge to the same level in the year 2030 in the member states, and that emissions allowances per head should be identical in all EU member states in 2030. Energy efficiency improvement targets were established for heavy industry. The largest differences existed in the electricity sector where a tailor-made approach, combining a country-to-country approach and general guidelines, was followed.

[11] The domestic sector was defined as including households, services, light industry, agriculture, and transportation. The heavy industrial sector consisted of the following industries: building materials, chemical, iron and steel, non-ferrous metals, pulp and paper, refineries, coke ovens (if they were not a part of the iron and steel industry), gasworks and other energy transformation branches, electricity generation excluded.

[12] In March 1997, agreement was reached on the following targets: Belgium (-10%); Denmark (-25%); Germany (-25%); Greece (+30%); Spain (+17%); France (0%); Ireland (+15%); Italy (-7%); Luxembourg (-30%); the Netherlands (-10%); Austria (-25%); Portugal (+40%); Finland (0%); Sweden (+5%), and the UK (-10%). These targets were formulated as changes in emissions of carbon dioxide, methane, and nitrous oxide in 2010, compared to 1990 emission levels. After the adoption of the Kyoto Protocol these targets were re-negotiated in June 1998. Targets for countries with emission reductions were lowered, whereas countries with emission increases got targets implying smaller emission increases. The UK was the only country to accept a higher target.

3 Equity principles and burden sharing rules

This section briefly reviews those concepts or principles of equity that are most likely to be relevant and influential in post-Kyoto policy discussions on climate target differentiation. There is no commonly accepted definition of equity. Equity principles refer to more general concepts of distributive justice or fairness.[13] As already mentioned, statements made by countries during the protocol negotiations indicated that they were concerned about achievement of fairness and equity, and showed that equity principles served as a benchmark against which countries evaluated and compared their GHG reduction commitments.

Equity principles should be distinguished from specific burden sharing rules or formulae, and from criteria or indicators. A distinction based on level of generality can be drawn between i) equity principles, ii) burden sharing formulae or rules, and iii) criteria or indicators. Equity principles refer to more general justice and fairness principles and can be operationalized by linking them to rules or formulae. Burden sharing formulae or rules are operational functions that generate a specific burden sharing scheme given input from one or more criteria or indicators.

A formula defines 'national emissions entitlements, or changes from the status quo, on the basis of national characteristics such as population, GNP, current emissions, or factors plausibly associated with national responsibility, sensitivity, or need for various emitting activities'.[14] Thus such formulae or rules must both specify the relevant criteria and how these criteria should be combined. Criteria and indicators contribute 'hard' data, for example CO_2 emissions per capita and GDP per capita.

Table 1: Selected equity principles and related burden sharing rules.

Equity principle	Interpretation	Example of implied burden sharing rule
Egalitarian	Equal rights of people to use the atmospheric resources	Reduce emissions in proportion to population or equal per capita emissions
Sovereignty	Current rate of emissions constitutes a status quo right now	Reduce emissions proportionally across all countries to maintain relative emission levels between them
Horizontal	Similar economic circumstances have similar emission rights and burden sharing responsibilities	Equalize net welfare change across countries (net cost of abatement as a proportion of GDP is the same for each country)
Vertical	The greater the ability to pay the greater the economic burden	Net cost of abatement is positively correlated with per person GDP
Polluter pays	Carry abatement burden corresponding to emissions (eventually including historical emissions)	Share abatement costs across countries in proportion to emission levels

Sources: Rose (1992), ABARE and DFAT (1995), Bureau of Industry Economics (1995), Burtraw and Toman (1992).

[13] Rose (1992).
[14] Parson and Zeckhauser (1995), 99.

A number of principles of fairness and equity have been identified as relevant in the broader context of global climate change. The most prominent principles are summarized in Table 1.[15] The egalitarian principle - 'the principle of equal rights etc. for all persons' - is concerned with equality.[16] In the context of global climate change, the principle would imply that every individual has the same right to use the atmosphere and should be allowed the same right to emit greenhouse gases. This principle would mean that targets would be set in proportion to population. Similarly, emission permits would be distributed to individuals, not governments, and each individual would be entitled to the same amount of permits.

The sovereignty principle implies that each individual, or entity, is guaranteed some rights and resources. The principle of sovereignty is commonly observed in international environmental treaty-making and institution-building, and is adopted in the FCCC.[17] One way to interpret the sovereignty principle is reducing GHG emissions in proportion to given or existing emissions. It is also possible to interpret the sovereignty principle to mean equal percentage emission reductions in all countries, e.g. countries reduce their emissions by 10% in 2010 compared to the 1990 level, or another across-the-board policy.

The principle of horizontal equity, which calls for all persons in the same group to be treated equally, resembles to some degree the principle of sovereignty. The principle of horizontal equity implies equal treatment of the members that belong to a group. It is quite clear that this was the most influential equity principle in the climate protocol negotiations among OECD countries. The principle would require the equalization of the burdens of abatement cost across nations, or an equal percentage reduction in welfare.

Vertical equity is intended to make improvement for those with fewer resources relative to those with more resources. Progressive income taxation is a well-known example of application of the principle of vertical equity. There exist many such examples of use of the vertical principle, but there is no obvious or clear-cut set of rules to follow when dividing individual countries into different groups, and specific rules may be somewhat arbitrary. Vertical equity refers to the ability to pay and implies greater economic burden to be carried by richer countries. It is by now a well-known principle of international environmental law.[18]

The polluter pays principle implies that the burden is distributed in accordance with an individual's contribution of emissions. The amount to be paid by polluters increases as

[15] An additional distinction can be drawn between procedural fairness, i.e. whether all countries are able to participate effectively in the climate change negotiations, and consequential fairness of allocation, i.e. whether the outcome of the global climate policy process is considered fair. The above does not examine procedural equity. For a summary discussion of procedural equity, see, for example, Bruce, Lee and Haites (1996), 85-86 and 116-118.
[16] Oxford University Press (1982).
[17] According to one of the FCCC's preambles: 'States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction'.
[18] For example, the Montreal Protocol on Substances That Deplete the Ozone Layer distinguishes between developed and developing countries. Because of their 'basic domestic needs', the latter group is entitled to delay its compliance with the control measures specified in this protocol by ten years. In effect, a transition period is allowed for developing countries in order to lessen the burden imposed on them. See Benedick (1991).

emission levels rise.[19] One example of applying this principle in a burden sharing formula would be to make the burden proportional to carbon dioxide emissions or by taxing the carbon content of fossil fuels.

Burden sharing rules will necessarily have to be developed through an international negotiation process. Rules and formulae would identify individual countries' emission entitlements or their amount of emission reduction. Some equity principles could be consistent with more than one burden sharing rule, and particular rules or formulae could be consistent with more than one equity principle.[20] For example, a population based rule assigning reduction targets or emission permits on a per capita basis would be consistent with the egalitarian principle with its equal per person emissions and with the sovereignty principle if emissions are cut back proportionally on a per capita basis.

Some burden sharing rules might be more operational than other rules. Rules might be static and focus on one point in time, for example, population or land area, or they might be more dynamic, indicating cumulative emissions, development, future growth rates, etc. Rules can use a single criterion, such as population, GDP or abatement costs, or can combine different criteria, e.g. emissions per capita or abatement costs as a percentage of GDP.

A recent theme among analysts is to examine in what ways several combined criteria could be incorporated into a single multi-criteria burden sharing rule. A significant advantage of multi-criteria rules over single-criterion rules is that they are more 'robust' in the sense that they yield less difference between the smallest and largest target for a country.[21] They are less sensitive to peculiar circumstances in individual countries. Rules may be expressed in absolute terms, for example reduction of emissions by 20% compared to the 1990 levels, or in relative terms, for example uniform percentage abatement per capita or equal emissions per unit of GDP. They may also be expressed in marginal terms, for example equal marginal abatement cost.

Our three formulae for allocating emission reductions incorporate both allocation-based and outcome-based equity principles.[22] CO_2 emissions per capita reflect the sovereignty and the polluter pays principles, and the GDP per capita criterion reflects the vertical equity principle. Our aim of equalizing national income losses as a proportion of GDP across OECD countries reflects an outcome-based equity principle. CO_2 emissions per unit of GDP, which is as an indicator for energy efficiency, are included in Formula I and Formula III. A distinguishing feature of our study is that we calculate national income loss estimates for all OECD countries for the three different burden sharing multi-criteria formulae (and variants of these putting different weights on the specific indicators).

[19] For discussion, see Grubb (1995), 490.
[20] Rose (1992).
[21] See Kawashima (1996).
[22] For a discussion of various principles, see Rose et al. (1997).

4 Burden sharing - an important issue in the Kyoto Protocol

A significant outcome of the 1995 Berlin Conference of the Parties to the FCCC was agreement on a mandate for further negotiations.[23] The Berlin mandate initiated a process aimed at elaborating policies and measures and setting quantified emissions limitation and reduction objectives (QELROs) for developed countries over specified time-frames such as 2005, 2010 and 2020. As proposed by the Berlin Conference, strengthened commitments of developed countries were adopted in form of a protocol by the third Conference of the Parties in Kyoto, Japan, in December 1997.

Some studies done before Berlin had indicated that abatement costs would fall unequally on OECD countries in case a climate protocol inadequately reflected important dissimilarities among countries. For example, it was estimated that Australia would experience an annual loss of 0.79% in Net Domestic Product from stabilizing its own CO_2 emissions at the 1990 level, while the EU would only suffer a loss of 0.19%.[24]

It was quite clear that such possible inequalities could create a serious obstacle to reaching agreement on a protocol. As the Intergovernmental Panel on Climate Change (IPCC) noted:

'Although the results of any specific modeling studies need to be treated with caution because of the inherent uncertainties and scope for biasing assumptions towards national interests, there is no doubt that there are complex issues of fair burden sharing among OECD countries that the next stage in negotiation will have to start addressing'.[25]

The Kyoto Protocol identifies several equity principles that might play a role in future differentiation processes among the OECD countries. First and foremost, however, it distinguishes explicitly between developed and developing countries. It refers to the FCCC in which it is underlined that full consideration should be given to 'the specific needs and special circumstances of developing country Parties'.[26]

The Protocol underlines, in reference to FCCC Article 3.2., that full consideration should be given to 'Parties that would have to bear a *disproportionate or abnormal burden* under the Convention'.[27] Pursuant to Protocol Article 2.3 (which refers to the FCCC):

'The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof'.[28]

[23] United Nations, Framework Convention on Climate Change (1995).
[24] Chisholm and Moran (1994), 6. See also ABARE and DFAT (1995).
[25] Bruce, Lee, and Haites (1996), 104.
[26] FCCC, article 3.2.
[27] FCCC, article 3.2. (Italics added).
[28] FCCC, article 3.1. (Italics added).

Consequently, countries should take into account the principle of intergenerational equity, and they should furthermore acknowledge their difference in regards to ability to pay. Thus the Kyoto Protocol underscores the significance of the achievement of vertical equity, especially between developed and developing countries.

Following the Protocol, when OECD countries implement policies and measures, they should do this in such a way that these 'minimize adverse (…) effects on international trade, and social, environmental and economic impacts on other Parties'.[29] A reference is also made to FCCC Article 4.8, according to which it is necessary to pay attention to, among other things, impacts on:

'Countries whose economies are highly dependent on income generated from the production, processing and export, and/or on consumption of fossil fuels and associated energy-intensive products.'[30]

The Berlin mandate underscored also the significance of the achievement of equity among OECD countries. It underlined that individual circumstances of developed countries and differences in starting points should be taken into account when strengthening commitments to reduce GHG emissions and it implicitly adopted the principle of horizontal equity.[31] However, the Berlin Mandate did not specify in detail which national circumstances should be taken into consideration or whether this should or could be done in the form of specific burden sharing rules or formulae.

To conclude, the FCCC and the Kyoto Protocol stress fair burden sharing as an important issue. At the general level, they separate the issue of the achievement of equity among OECD countries from the issue of the achievement of equity between developed and developing countries. Horizontal equity seems the most relevant equity principle in the OECD context, but neither this nor any other principle has yet been made operational in the form of specific burden sharing rules or formulae.

The FCCC and the Kyoto Protocol lack rules and mechanisms for achieving equity in the sense of sharing income losses equally amongst countries with a similar ability to pay. It is therefore useful to test burden sharing rules for the OECD countries, a group of relatively comparable countries. As well, they clearly are the most likely candidates for climate commitments.

The EIT countries, which constitute a quite different group of countries, are not examined in this article since they are expected to take on a smaller burden then the OECD countries. Targets are allocated to the EIT countries under the Kyoto Protocol but, due to lowered emissions during the period of economic restructuring since 1990, the related costs are likely to be smaller than the costs to OECD countries. Moreover, the largest countries in the group, Russia and Ukraine, have very generous targets since they in 2008-2012 can emit the same volume of GHGs as in 1990. In addition, EIT countries are allowed some additional flexibility in implementing the Kyoto Protocol. Finally, because the Kyoto Protocol clearly shows that

[29] Kyoto Protocol, Article 2.3.
[30] Article 4.8.
[31] See Article 2(a).

binding commitments for developing countries are further into the future, they have not been included either.

5 Rules for distribution of burden among OECD countries

This section explores different kinds of burden sharing rules and formulae. Our intention is to explore how different types of formulae distribute climate policy targets and national income losses across the OECD. The results indicate which national circumstances are important when a country's share of emission reduction is determined by specific burden sharing formulae.

While a number of equity principles were discussed in the previous section, this section is mainly concerned with horizontal equity. There are two reasons for choosing this outcome-based equity principle. First, countries opposing uniform measures and measures applied across-the-board stress the importance of horizontal equity. Second, the principle is implicitly adopted by the FCCC and the Berlin Mandate.

Table 2: Data on OECD countries (except Iceland, Czech Republic, Hungary, Korea, Mexico and Poland), 1993.

	CO_2 emissions (energy related, mill. tons)	**GDP (bill. 1990 USD)**	**Popu-lation (in 1000)**	**CO_2 emissions/GDP (in kg CO_2/1990 USD 1000)**	**GDP/ capita (USD)**	**CO_2 emissions per capita (tons)**
Australia	283	309.3	17840	915	17337	15.9
Austria	57	166	7990	343	20776	7.1
Belgium	113	196.8	10010	574	19660	11.3
Canada	443	573.8	29100	770	19718	15.2
Denmark	59	134	5200	440	25769	11.3
Finland	55	118.3	5090	470	23242	10.8
France	368	1205	57960	310	20790	6.3
Germany	897	1718	81410	520	21103	11.0
Greece	74	69	10350	1072	6667	7.1
Ireland	33	50	3560	660	14045	9.3
Italy	408	1109	57100	368	19422	7.1
Japan	1091	3094	124960	350	24760	8.7
Luxem-bourg	11	11	380	1000	28947	28.9
Netherlands	171	294.6	15400	580	19130	11.1
New Zealand	28	47	3460	596	13584	8.1
Norway	32	114.5	4337	280	26401	7.4
Portugal	46	69	9860	667	6998	4.7
Spain	223	500.9	39140	440	12798	5.7
Sweden	52	218.2	8770	240	24880	5.9
Switzerland	43.2	223.3	6940	190	32175	6.9
Turkey	150	173	59490	867	2908	2.5
UK	558	971	58375	580	16634	9.6
USA	5095	5765	260730	880	22111	19.5

Sources: OECD (1995a); OECD (1995b).

Three burden sharing rules or formulae are explored. It is assumed that the overall level of abatement remains 20% of total 1993 OECD emissions. This target can be interpreted as a 20% reduction compared to 'business as usual' emissions of a future target year, like 2010. It is estimated, first, how each formula would distribute emission reductions across OECD countries and, second, how much individual countries would need to reduce in order to contribute their share of the total amount of emissions reduced by the OECD. Third, it is calculated how costly the three formulae would be for individual countries and, fourth, the total OECD cost is calculated.

All OECD countries (except Iceland, the Czech Republic, Hungary, Korea, Mexico and Poland) are examined.[32] For absolute and relative figures on population, GDP and CO_2 emissions in OECD countries, see Table 2 and Table 3, respectively. [33]

Table 3: CO_2 emissions, population and GDP as percentage of OECD total (except Iceland, Czech Republic, Hungary, Korea, Mexico and Poland).

	CO_2 emissions	GDP	Population
Australia	2.8	1.8	2.0
Austria	0.6	1.0	0.9
Belgium	1.1	1.1	1.1
Canada	4.3	3.3	3.3
Denmark	0.6	0.8	0.6
Finland	0.5	0.7	0.6
France	3.6	7.0	6.6
Germany	8.7	10.0	9.3
Greece	0.7	0.4	1.2
Ireland	0.3	0.3	0.4
Italy	4.0	6.5	6.5
Japan	10.6	18.1	14.2
Luxembourg	0.1	0.1	0.04
Netherlands	1.7	1.7	1.8
New Zealand	0.3	0.3	0.4
Norway	0.3	0.7	0.5
Portugal	0.4	0.4	1.1
Spain	2.2	2.9	4.5
Sweden	0.5	1.3	1.0
Switzerland	0.4	1.3	0.8
Turkey	1.5	1.0	6.8
UK	5.4	5.7	6.7
USA	49.5	33.7	29.7

Sources: OECD (1995a); OECD (1995b).

The allocations of emission reduction commitments that follow from implementation of Formula I, II and III will imply a certain distribution of national income losses. A numerical

[32] It has not been possible to obtain comparable data for Iceland. The Czech Republic, Korea and Mexico are not included since they have only recently become members of the OECD and are not included in the Annex I group of countries. However, Czechoslovakia is included in the Annex I group. The OECD members Hungary and Poland are not included since they are EIT countries.
[33] The most recent data from 1993 have been used.

model is used to estimate how Formula I, II and III would distribute these losses across OECD countries as well as the resulting level of cost-effectiveness within the OECD.[34]
To compare the formulae and the resultant cost distributions, the national income changes following a 20% reduction in each OECD country are included as a reference case (see Figure 1). This case is rather similar to the policy proposal made by the German delegation in the spring of 1996.[35] The income loss for the OECD is 0.21% of GDP if each country cuts its emissions with 20%.

In the following, three figures illustrate the emission reductions as percentage of national emissions based on the formulae. The detailed emission reductions are presented in Annex A as a percentage of OECD total emissions and as a percentage of national emissions. The corresponding national income changes are presented in the three remaining figures and in Annex B.

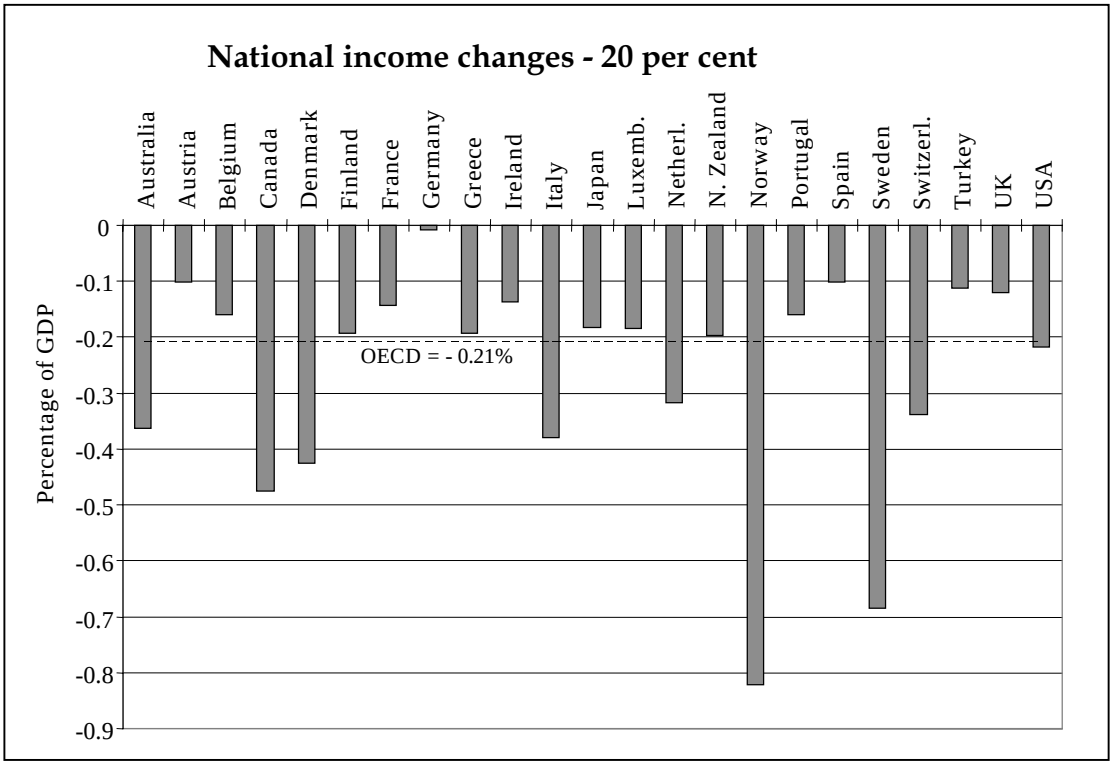

Figure 1: National income changes in percentage of GDP from a 20% uniform emission reduction.

[34] See Holtsmark (1997). The model analyzes to what extent resource rents are transferred from fossil fuel exporting countries to fossil fuel importing countries when governments take into account benefits from revenue recycling. Furthermore the structure of the countries' energy demand, prior tax distortions, and the size of the marginal excess burden of taxation in the different countries are important for the model's estimates of the simultaneous national income losses. A game theoretic approach is used to analyze how countries' policy choices are interdependently linked to the markets for oil, coal and natural gas. Each OECD country is incorporated into the model by national welfare functions. The indicators in these functions are the fossil fuel taxes, the production and consumption of fossil fuels, and the amount of public revenue generated by fossil fuel taxation.
[35] Germany proposed a 10% reduction in CO_2 emissions by the year 2005, and a 15-20% reduction by the year 2010, both against the base year of 1990. Statement by Cornelia Quennet-Thielen, German Delegation. 6 March 1996.

6 Formula I

Formula I is based on the premise that a country which is identical to the average OECD country, so to speak, should reduce its emissions by exactly 20%.[36] A country that exceeds the OECD average with respect to one or more of four indicators should reduce its emissions with more than 20%. Similarly, if a country is below the OECD average with respect to one or more of the indicators its target will be below 20%.

Formula I's four indicators are CO_2 emissions per capita, GDP, CO_2 emissions per unit of GDP and GDP per capita. These are understood as indicators for emission entitlements, size of countries (the size of economies of countries), energy efficiency, and ability to pay. Each indicator is given a certain weight, and the sum of the weights is 100. The indicators are listed in Table 2.

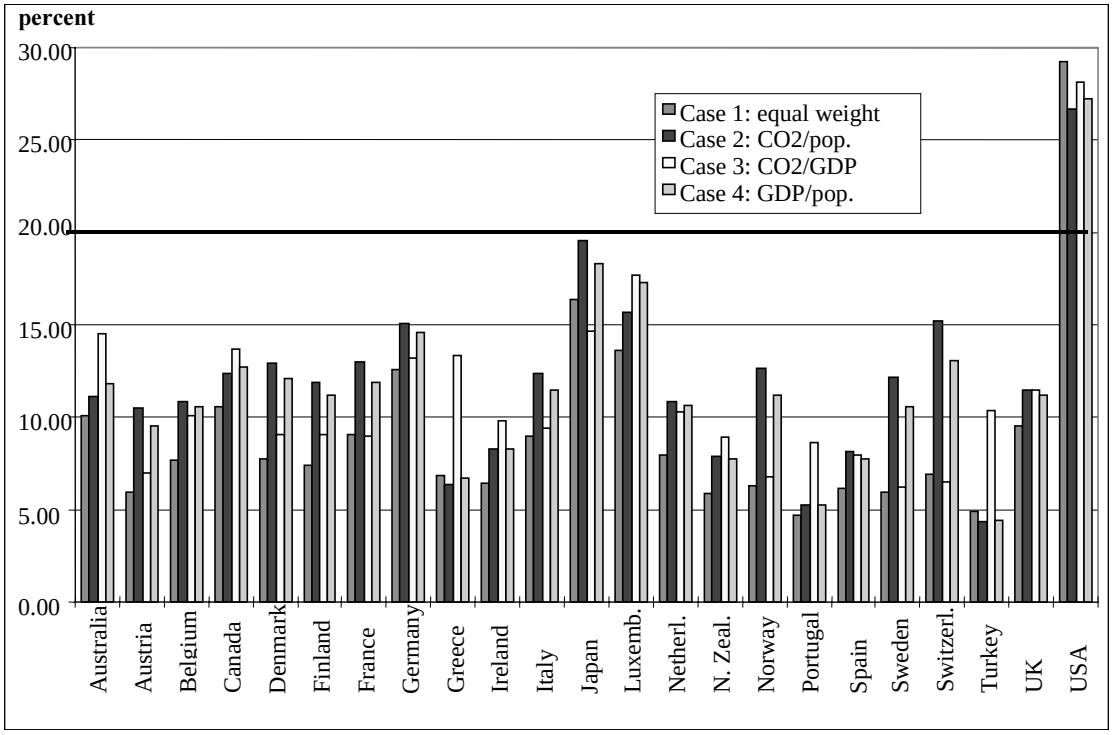

Figure 2: Formula I. Emission reduction as percentage of national CO_2 emissions (OECD reduction 20% of 1993 level).

[36] The formula is: $Y_i = \{w_A A_i/A + w_B B_i/B + w_C C_i/C + w_D D_i/D\} Z$, where Y_i is the percentage emission reduction target for country i. A_i is emissions per capita for country i, B_i is GDP for country i, C_i is emissions per unit of GDP for country i, and D_i is GDP per capita for country i. A, B, C and D represent OECD averages for the same indicators. The weights for the indicators are represented by the w-weights, and where the sum $w_A + w_B + w_C + w_D = 100$. Z is a scaling factor which is determined so as to make the total emissions abatement for OECD equal to 20% (Z varies between 0,0965 and 0,1218 in different cases).

Four ways to distribute weights on the indicators, referred to as Case 1, 2, 3, and 4, are calculated.[37] The base case gives equal weight, namely 25, to the four indicators. In each of the three other cases an additional weight of 55 or 70 is given to one indicator, and the other three indicators have weights of either 10 or 15. In Figure 2, the results of Formula I are presented as percentage reduction in each country's emissions.

To achieve the 20% reduction in total OECD emissions, as Figure 2 shows, the United States reduces its present emissions from between 27% to 29% and Japan reduces from between 15% to 20%. Furthermore, Luxembourg reduces from between 14% to almost 18%, Germany 13-15%, and Canada 11-14%.

It is evident that putting different weights on the indicators results in considerable differences in the amount of emissions reduced by countries. In Case 1, the United States reduces its emission with 29%, Japan reduces its emission with about 16%, and Germany and Luxembourg reduce their emission with 13% and 14%, respectively. In this case most countries, except United States, reduce at a relatively low level compared to Case 2, 3 and 4. Case 2 puts more emphasis on countries' emission per capita and, as a consequence, the United States reduces about 27% of its emissions, Japan reduces almost 20%, and Germany, Luxembourg, and Switzerland reduce slightly above 15%.

For the majority of wealthy European countries and Japan, Case 2 results in considerable emission reductions relative to Case 1, 3 and 4, while the United States reduces less. Case 3 puts emphasis on energy efficiency as measured by how much a country emits relative to the size of the economy. Case 3 results in considerable reductions in relatively poor countries such as Turkey, Greece, Portugal and Ireland, but also in Australia, Canada and New Zealand, and in Luxembourg. Case 4 results in larger emission reductions in countries with high GDP per capita, and therefore with more ability to pay, and results in relatively larger reductions in relatively wealthy European countries and in Japan, but less reductions in the United States. The United States reduces its emissions by 27%, and Sweden, Norway, Denmark and Canada reduce their emissions between 11% and 12%.

Returning to the issue of horizontal equity, it could be argued that Case 3 is unfair to relatively poor countries, and that Case 1 and 4 are favorable to most European countries, but unfair to the United States. Of these four cases of Formula I, therefore, Case 2 represents the most equitable distribution of emission reductions across OECD countries. Consequently, the cost implications of Case 2, which implies that the United States reduces slightly less while almost all other relatively wealthy OECD countries reduce more, are estimated.

In Figure 3 Norway, the United States, Sweden, Canada, Switzerland and Australia experience the largest national income loss in percentage of GDP. The national income loss of the United States is explained by its large emission reduction. The large national income loss of Sweden and to some extent Norway is related to the high taxes on fossil fuels in these countries in the

[37] Case 1: $25*(CO_2/pop.+GDP+CO_2/GDP+GDP/pop.)$;
Case 2: $55*CO_2/pop.+15*(GDP+CO_2/GDP+GDP/pop.)$;
Case 3: $55*CO_2/GDP+15*(CO_2/pop.+GDP+GDP/pop.)$;
Case 4: $70*GDP/pop.+10*(CO_2/pop.+GDP+CO_2/GDP)$.

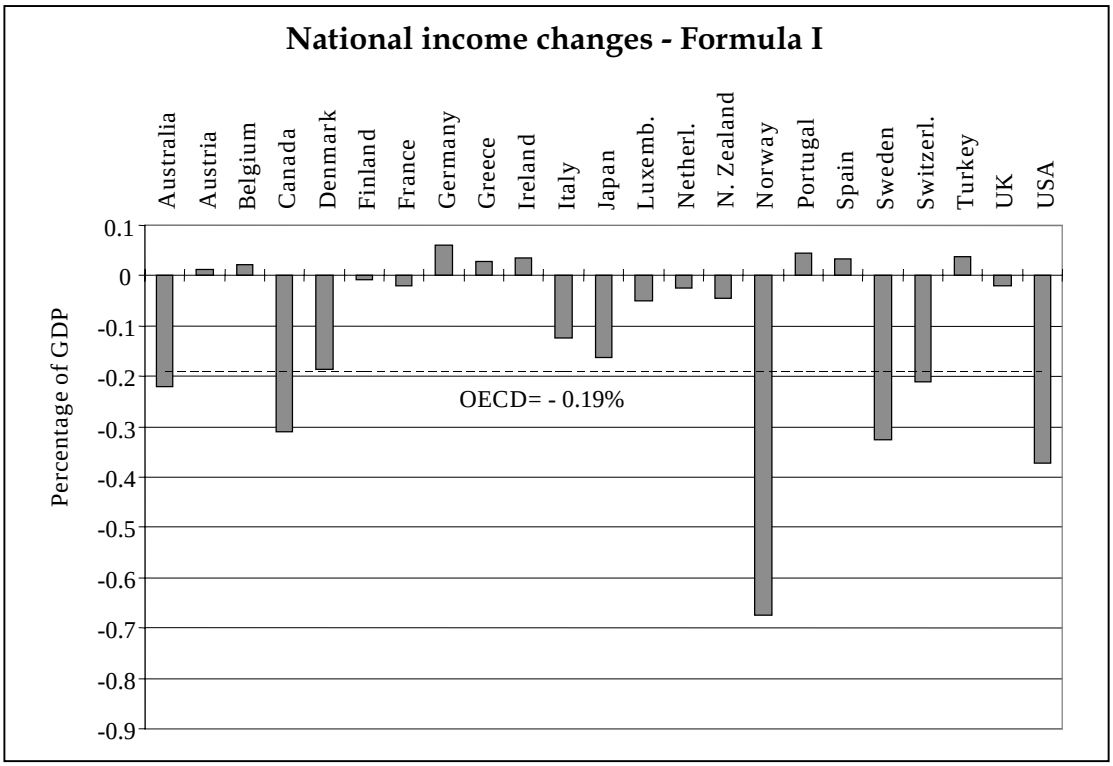

Figure 3: National income changes in percentage of GDP from implementation of Formula I.

reference situation which result in high marginal abatement costs. The Norwegian national income loss is also related to a price drop of 7.3% in the European natural gas market.[38] Canada's national income loss is almost as big as the national income loss of the United States, in spite of the fact that Canada reduces much less than the United States.

This result must be seen in relation to those two countries' role in the fossil fuel markets, especially the North American gas market. The United States is assumed to impose taxes on natural gas consumption of 31 USD/ton CO_2 in this scenario and the producer price of natural gas drops by 27.1% in the North American gas market. This causes a national income loss to Canada as the net gas exporter in the North American gas market.

Significantly, the model simulation shows that a number of countries will experience net national income gains from the implementation of this type of burden sharing formula, especially Germany receives large net gains.

The total income loss amounts to 0.19% of the total GDP of the OECD area. Hence, Formula I is more cost-effective than the reference case's uniform reductions resulting in a total income loss of 0.21%. This is mainly due to the large reductions in USA which, according to the model, has relatively low marginal abatement costs.

[38] The oil price is almost unchanged in this scenario and this explains the relatively small national income loss of Norway. This result is based on the assumption that OECD countries introduce efficient taxation of fossil fuels which means reduced taxes on oil products in several countries.

7 Formula II

Formula II is based on each OECD country's percentage share of population, CO_2 emissions and GDP of the OECD total. For the indicators used in Formula II, see Table 3. Again, weights are given to each of the three indicators.[39] Case 1 puts equal weight on the three indicators, but the other three cases give low weight to population.[40] Case 2 puts more weight on CO_2 emissions, and Case 3 increases the weight on CO_2 emissions even more, but reduces the weight on GDP. Case 4 puts relatively more weight on GDP and less weight on emissions.

Figure 4 shows the reductions in the OECD countries' emissions that follow from implementing Formula II where the overall target is to reduce 20% of 1993 total OECD emissions. Again, it is evident that putting different weights on the indicators results in considerable differences in the amount of emissions that countries reduce. In Case 1, the biggest cuts are made by countries with large populations and modest emissions, and in relatively rich and energy-efficient countries. Case 1 results in very high reductions in Turkey, and Austria reduces with 29%, France 32%, Italy 29%, Japan 27%, New Zealand 23%, Norway 32%, Spain 29%, Sweden 37% and Switzerland 40%. However, it results in relatively less reduction in the United States, Australia, Canada, and Luxembourg, by 15%, 16%, 17%, and 13%, respectively.

In Case 2 the differences in how much countries reduce emissions generally are smaller. Austria, Denmark, Finland, France, Germany, Italy, Japan, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey and the United Kingdom all reduce at a level higher than the average 20%, whereas Australia, Canada, Luxembourg and the United States reduce below 20%. Some of the relatively poor OECD countries also reduce below 20%.

Case 3 further increases the weight on emissions compared to Case 2. Australia, Canada, Luxembourg and the United States, as well as Greece, Ireland, Portugal and Turkey, increase their reductions some. Austria, Belgium, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland and United Kingdom reduce less than in Case 2.

In Case 4, relatively wealthy and energy-efficient countries cut their emissions most. Case 4 implies considerable reductions in Austria, Denmark, Finland, Germany, Italy and Japan, and especially in France, Norway, Sweden and Switzerland. Smaller reductions are made in Australia, Canada, Greece, Luxembourg, Portugal, Turkey and the United States.

When comparing these four cases, it could be argued that Case 3 is most fair as it results in the most equal percentage distribution of emission reductions across OECD countries. Case 1 and 4 result in relatively high emission reductions in some countries and similarly low

[39] The formula is $X_i = \{w_E E_i + w_F F_i + w_G G_i\}$. X_i is the percentage share of country i of the total emission reduction commitment for OECD. E_i is the percentage population share of country i, F_i is the percentage CO_2 emission share of country i, and G_i is the percentage GDP share of country i. The sum of the w-weights is equal to 1.

[40] Case 1:1/3*(CO_2+pop+GDP);
Case 2: 0,05*pop+0,6*CO_2+0,35*GDP;
Case 3:0,05*pop+0,8*CO_2+0,15*GDP;
Case 4: 0,05*pop+0,35*CO_2+0,6*GDP.

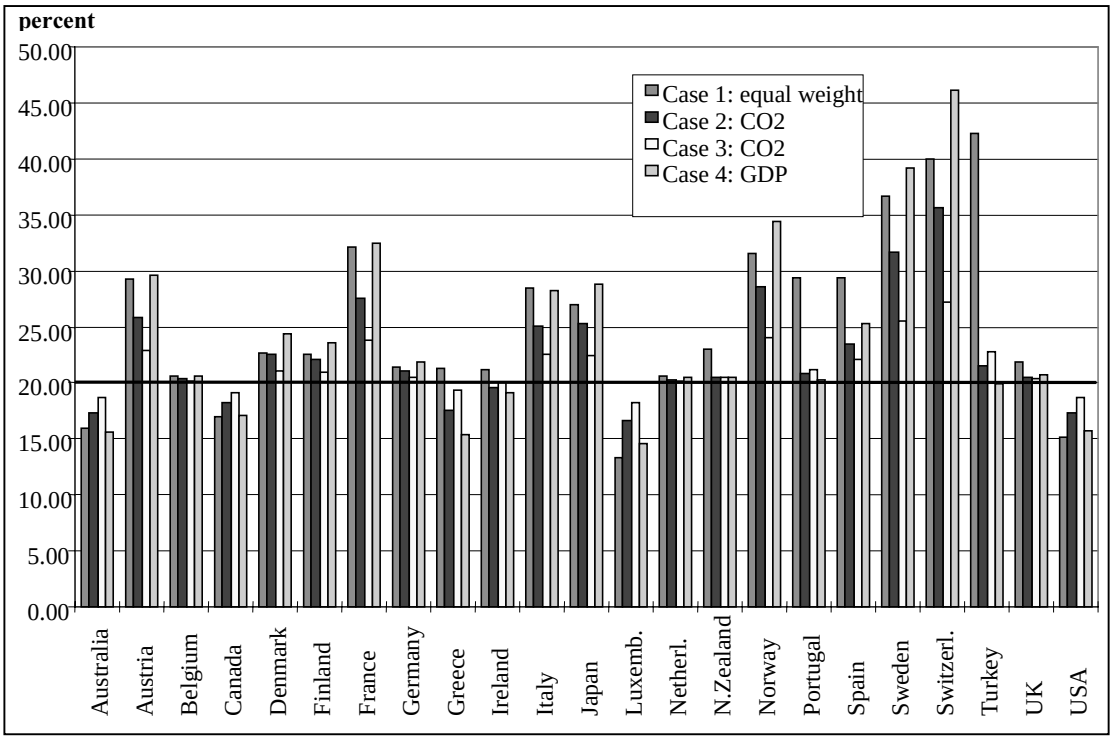

Figure 4: Formula II. Emission reduction as percentage of national CO_2 emissions (OECD reduction 20% of 1993 level)

emission reductions in others. Case 3 results in a more equal distribution of percentages relative to Case 2. Because Case 3 best conforms with the horizontal equity principle, the implications of this case with respect to national income levels are calculated.

Relative to Formula I, Formula II gives rise to quite different quantitative emission reduction commitments. This is reflected in the changes in national income levels that follow from the implementation of the commitments (see Figure 5). First of all, it is noteworthy that Formula II produces a less cost-effective solution compared to Formula I; the total income loss for the OECD is 0.23% of GDP, as compared to 0.19% in Formula I, and 0.21% in the reference case. This is because Formula II shifts some emission reductions from USA to especially France, Italy, Sweden, Norway and Japan. The result is a transfer of commitments from a country with low marginal abatement costs, such as the United States, to countries with substantially higher abatement costs, such as Norway and Sweden. At the same time, the bigger reduction commitment for Germany results in a larger amount of relatively low-cost reductions being realized.

To conclude, under Formula II, Norway, Sweden, Italy and Switzerland are committed to reduce their emissions by a higher percentage than the OECD average and their national income losses consequently are high. This formula could be said to have relatively unfair burden sharing consequences when judged against the principle of horizontal equity. In addition, it is less cost-effective. However, Formula II could to some extent satisfy the principle of vertical equity since most of these countries have high GDP per capita and therefore a higher capacity to pay (see Table 2).

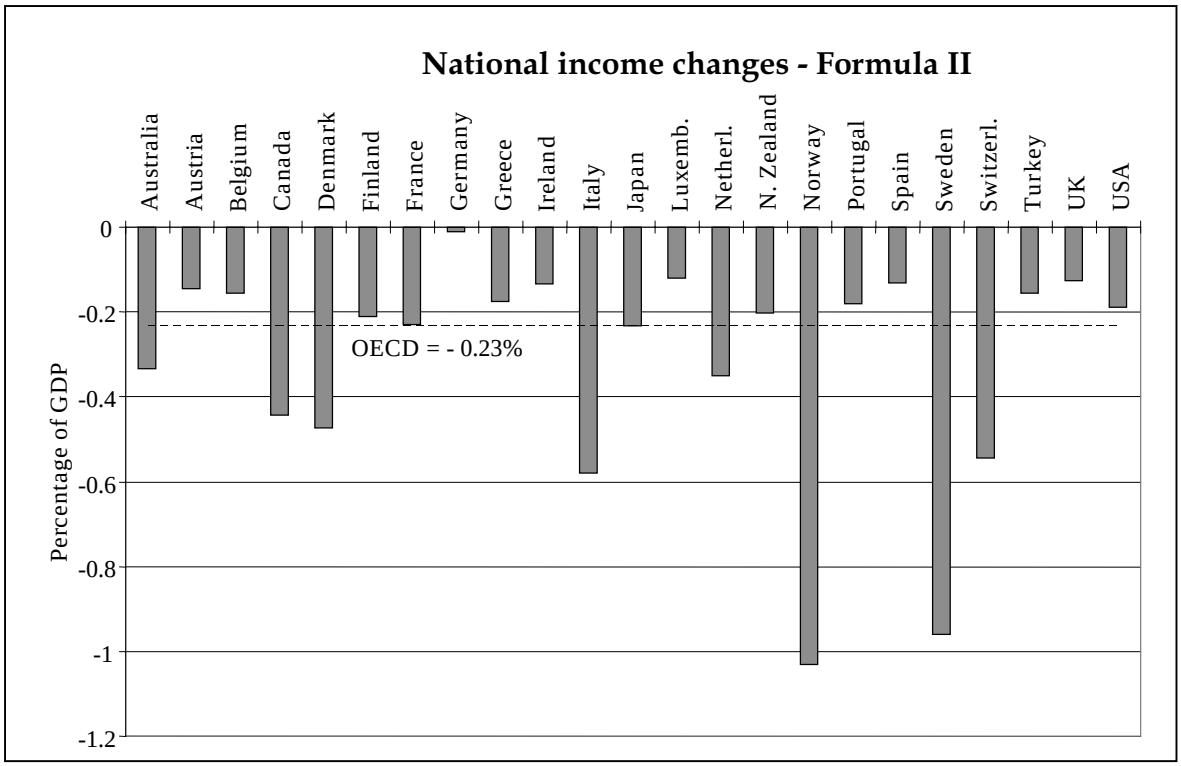

Figure 5: National income changes in percentage of GDP from implementation of Formula II

8 Formula III

Formula III includes GDP, emissions per unit of GDP, and GDP per capita. Apart from CO_2 per capita, the same indicators were included in Formula I. Weights that sum up to 100 are given to each indicator. The weighted sum of the indicators is calculated for each country and it is divided by the sum over all OECD countries.[41] In this way the percentage share of the OECD total is calculated for each country. In Case 1, the three weights are equal to 33,3.[42]

The other cases put more weight, either 60 or 80, on one of the indicators, and the weights on the other indicators are either 20 or 10. The implications of the 20% reduction of total OECD emissions target are presented as percentage reduction in each country's emissions, see Figure 6.

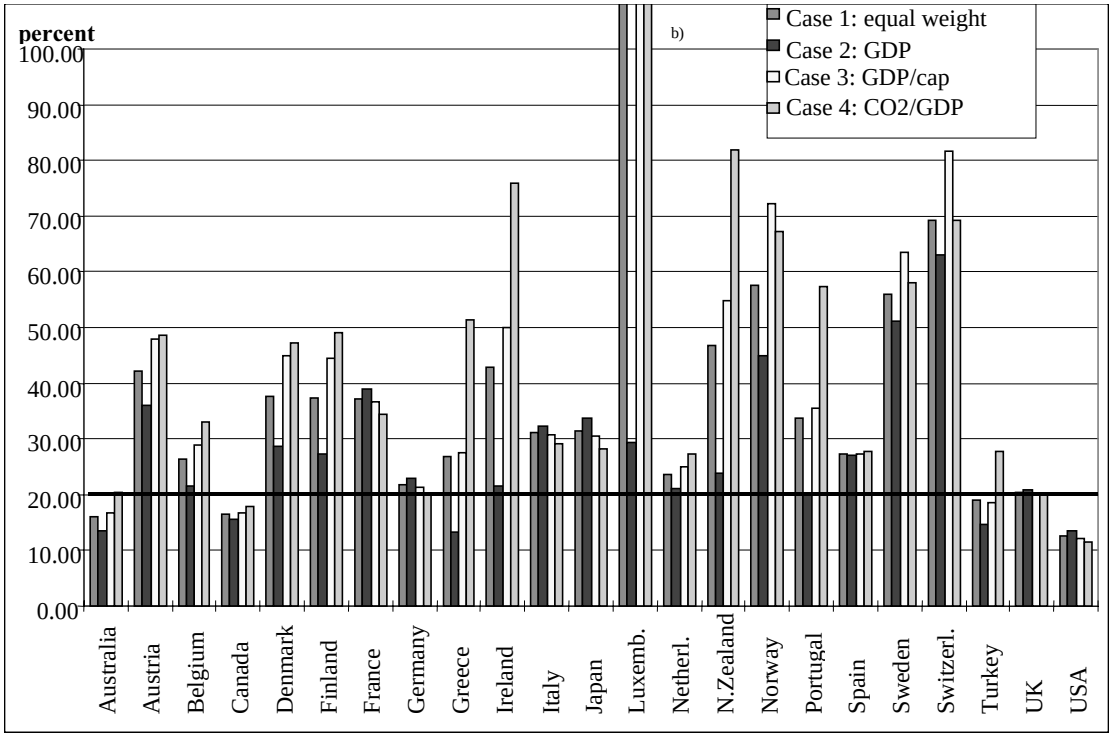

Figure 6: Formula III. Emission reduction as percentage of national CO_2 emissions (OECD reduction 20% of 1993 level).
Emission reduction for Luxembourg as a percentage of national emissions: Case 1: 139%, Case 3: 187%, Case 4: 296%.

[41] The formula is $V_i = \{w_B B_i + w_C C_i + w_d D_i\} / \Sigma_j \{w_B B_j + w_C C_j + w_d D_j\}$. V_i is the percentage share of country i of the total emission reduction commitment of OECD. B_i is GDP for country i, C_i is emissions per unit of GDP for country i, and D_i is GDP per capita for country i. The w's are weights that sum up to 100. The divisor represents the sum over all OECD countries. Due to the different units of the indicators the scale of the data is adjusted so as to make the range (i.e. the lowest value up to the highest value found for different countries) comparable across the indicators. One example of this is that the GDP figures are divided by 100.000 since they are much larger than the other indicators.

[42] Case 1: 33,3*(GDP+CO_2/GDP+GDP/pop.);
Case 2: 10*(GDP/pop.+CO_2/GDP)+80*GDP;
Case 3: 20*(GDP+CO_2/GDP)+60*GDP/pop.;
Case 4: 20*(GDP+GDP/pop.)+60*CO_2/GDP.

Figure 6 shows that Sweden reduces between 51% and 64% of its emissions, Norway between 45% and 72%, Austria between 36 and 49%, and France reduces between 34% and 39%. Because of its exceptionally high emissions per GDP and CO_2 emissions per capita, Luxembourg reduces its emissions between 29% and 296%! Italy and Japan reduce their emissions with more than 28%, and Denmark and Finland also make substantial reductions. However, Australia, Canada, and the United States reduce less than 20% of their emissions.

The distribution of emission reductions in Formula III is entirely different from the distribution in Formula I and II. This is also reflected in the resulting national income losses (see Figure 7). Sweden, Switzerland, Norway and Italy experience income losses far above the average. This is basically a result of the large emission reduction commitments for those countries, but it reflects also the large marginal abatement costs in these countries.

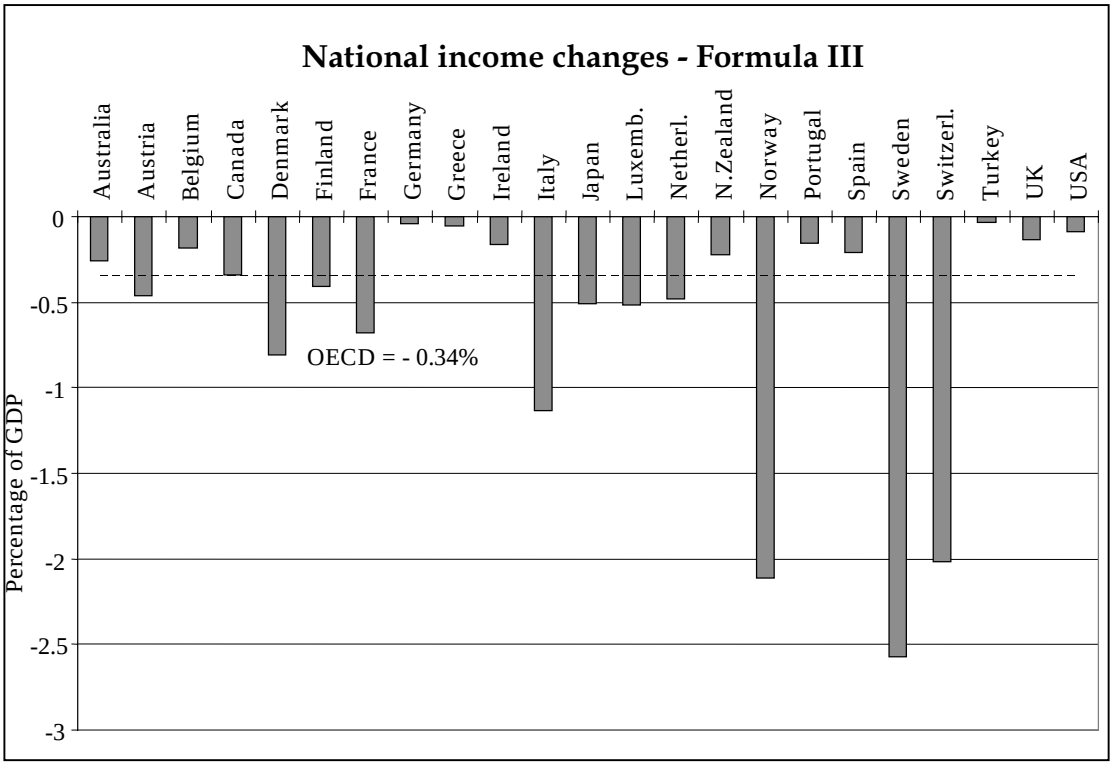

Figure 7: National income changes in percentage of GDP from implementation of Formula III.

With regard to cost-effectiveness Formula III results in a burden sharing arrangement with large total income loss; the total loss is 0.34% of GDP for the OECD area. In comparison, the income losses of Formula I and II were 0.19% and 0.23%, respectively. The high costs follow from the large commitments of some of the Nordic countries, Italy, Japan, Switzerland and France, where abatement costs usually are high, whereas the emission reductions are small in USA, Canada and Australia where the abatement costs are low.

9 Discussion and findings

This article has explored three formulae for distribution of commitments to reduce GHG emissions among OECD countries. These formulae are more complex than simple burden sharing rules, for example per capita targets or equal percentage reductions. Various indicators or criteria corresponding to prominent equity principles were chosen and the overall distribution of national income losses across OECD were compared against the horizontal equity principle.

Their sensitivity was examined by varying the weights given to the indicators in the formulae. The formulae determine how OECD countries would share the burden of emission reduction and how much individual countries would reduce present emissions. A numerical model estimated national income changes for each OECD country. Such formulae could also be used as a basis for the initial distribution of tradable permits within a group of countries, for example the EU.

As should be expected, the article shows that percentage distributions of commitments to reduce emissions inadequately indicate the corresponding distribution of national income losses. The three formulae distribute national income changes very differently. Formula I results in a welfare loss of 0.7% of GDP in Norway, and Canada, Sweden and the United States loose between 0.3% and 0.4% of GDP. Australia and Switzerland experience a loss of about 0.2% of GDP. Importantly, a number of countries will experience net national income gains from the implementation of Formula I, especially Germany. Also important, compared to the reference case in which each OECD country reduces its CO_2 emissions with 20%, Formula I results in smaller national income losses for all countries, except the United States.

As a consequence of Formula II, Norway and Sweden each experience a loss of about 1% of GDP, and Canada, Denmark, Italy and Switzerland loose between 0.4 and 0.6% of GDP. No country receives a net welfare gain under Formula II, and the formula is less cost-effective than the reference case. Compared to Formula I, Formula II is more economically burdensome on all countries except the United States. Under Formula III, the income loss of Norway, Sweden and Switzerland is 2% or more, and a significant number of countries have greater losses than under Formula II. Formula III would also be less cost-effective than the reference case. These cost estimations are of course sensitive to the economic model used.

None of the three formulae produced a burden sharing arrangement that completely equalized the economic costs across the OECD. In other words, Formula I, II and III could not satisfy the principle of horizontal equity among OECD countries implicitly adopted in the Kyoto Protocol and the FCCC. That said, many countries would probably find Formula I to be more economically attractive than the reference case. It is possible, moreover, that these formulae could be adjusted so as to produce more equitable results, or that more equitable formulae could be developed.

The analysis raises, in addition, important issues about how rules and formulae might best facilitate target differentiation. On the one hand, burden sharing rules seem an useful tool in negotiations among countries as they might create new insight into the numerous ways in which it is possible to allocate costs among countries and into underlying economic and social

drivers of global climate change. It also seems plausible that governments by analyzing and negotiating burden sharing rules increase their understanding of the applicability of various concepts of fairness in devising equitable solutions. Raising the issue of burden sharing rules might therefore lead governments toward agreement on particular concepts of fairness and how these could be incorporated into future climate target negotiations.

On the other hand, as the Kyoto negotiations showed, it is unlikely that climate target negotiations will be narrowly focused on any particular rule. In fact, it might be more difficult to obtain agreement on guiding fairness principles than to actually differentiate targets. It will also be important not to focus too narrowly on particular burden sharing rules reducing climate target negotiations to a 'numbers game'. Undoubtedly, economic considerations and other factors, for example domestic political conditions and foreign policy goals, will also influence climate target negotiations, and formulae will not be able to incorporate these systematically.

It will be difficult, although not impossible, to develop politically acceptable formulae and rules. A rule that is able to reflect changes in countries' ability to pay, population changes, and technology and energy efficiency developments would be attractive. On the other hand, a simple and robust burden sharing rule, or at least a burden sharing principle, would be more administratively and politically feasible. It seems clear that equity, opportunities for cost-effectiveness and flexibility are among the main criteria which a burden sharing rule need to satisfy.

The Triptych approach followed by the EU is an interesting framework in this context, since the burden sharing is based on structural characteristics in three main economic sectors and sector-wise differences across the EU member states.[43] At the cost of more data requirements, such a framework provides a higher flexibility to consider important structural characteristics across countries. Again, it must be emphasized that burden sharing rules can be useful conceptual tools and as such might provide some, but not all, of the conceptual framework for climate protocol negotiations. They should be understood as a tool to develop the starting points, rather than end-points, of differentiation processes.

Finally, the larger and more diversified the group of countries, the more complicated it will be to differentiate. Compared to OECD agreements, negotiating differentiated climate agreements among developed and developing countries will be more complex. Developing countries tend to focus on historical GHG emissions and on adverse effects of climate change in developing countries (e.g. flooding of coastal areas or crop losses in agriculture due to reduced precipitation). The first issue raises the question of the responsibility for historical cumulative emissions of GHGs, while the second raises the issue of assistance from developed to developing countries. These issues will create a complex challenge in future negotiations on binding climate commitments for developing countries.

[43] For an analysis, see Ringius (1997).

10 References

Australian Bureau of Agricultural and Resource Economics (ABARE) and Department of Foreign Affairs and Trade (DFAT) (1995). *Global climate change - Economic dimensions of a cooperative international policy response beyond 2000*. Commonwealth of Australia, Canberra.

Barrett, S. (1992) 'Acceptable' Allocations of Tradable Carbon Emission Entitlements in a Global Warming Treaty. In *Combating Global Warming.* UNCTAD, Geneva.

Benedick, R. E. (1991) *Ozone Diplomacy: New Directions in Safeguarding the Planet.* Harvard University Press, Cambridge.

Blok, K., Phylipsen, G.J.M. and Bode, J. W. (1997). The Triptique Approach: Burden Differentiation of CO_2 Emission Reduction Among European Union Member States. Utrecht, the Netherlands. Department of Science, Technology and Society, Utrecht University.

Bruce, J. P., Lee, H. and Haites, E.F. eds. (1996). *Climate Change 1995: Economic and Social Dimensions of Climate Change*. Cambridge University Press, Cambridge.

Bureau of Industry Economics (1995). Greenhouse Gas Abatement and Burden Sharing - An Analysis of Efficiency and Equity Issues for Australia. *Research Report* No. 66, Australian Government Publishing Service, Canberra.

Burtraw, D. and Toman, M. A. (1992). Equity and International Agreements for CO2 Containment. *Journal of Energy Engineering* 118 (2) 122-135.

Chisholm, A. and Moran, A. (1994). Carbon Dioxide Emissions Abatement and Burden Sharing among the OECD Countries. *Tasman Institute Occasional Paper* B26, June.

Earth Negotiations Bulletin (1997). Report of the Third Conference on the Parties to the United Nations Framework Convention on Climate Change: 1-11 December 1997. 13 December, 12 (76).

Energy Technology Systems Analysis Programme (ETSAP) (1997). Multinational Strategies Compared: an ETSAP study. ETSAP Kyoto Statement. December.

Grubb, M. (1995). Seeking Fair Weather: Ethics and the International Debate on Climate Change. *International Affairs* 71 (3).

Grubb, M., Sebenius, J., Magalhaes, A. and Subak, S. (1992). Sharing the Burden. In *Confronting Climate Change: Risks, Implications and Responses*, ed. I. M. Mintzer. Cambridge University Press, Cambridge.

Harris, Paul G. (1996). Considerations of Equity and International Environmental Institutions. *Environmental Politics* 5 (2) 274-301.

Holtsmark, B. (1997). Climate agreements: Optimal taxation of fossil fuels and the distribution of costs and benefits across countries. *CICERO Working Paper* No. 5, Oslo.

Kawashima, Y. (1996). Differentiation of Quantified Emission Limitation and Reduction Objectives (QELROs) according to National Circumstances: Introduction to Equality Criteria and Reduction of Excess Emission. Paper presented at Informal workshop on quantified limitation and reduction emission objectives, Geneva, 28 February.

OECD (1995a). *OECD Environmental Data Compendium*. OECD, Paris.

OECD (1995b). *Energy Policies of IEA Countries; 1994 Review*. OECD/IEA, Paris.

Oxford University Press (1982). *The Concise Oxford Dictionary of Current English.* Oxford.

Parson, E. A. and Zeckhauser, R. J. (1995). Equal Measures or Fair Burdens: Negotiating Environmental Treaties in an Unequal World. In *Shaping National Responses to Climate Change*, ed. H. Lee. Island Press, Washington, D. C.

Ridgley, M. A. (1996). Fair Sharing of Greenhouse Burdens. *Energy Policy* 24 (6) 517-529.

Ringius, L. (1997). Differentiation, Leaders and Fairness: Negotiating Climate Commitments in the European Community. *CICERO Report* No. 8, Oslo.

Ringius, L., Torvanger, A., and Meze, E. (1996). *Climate Policy, Burden Sharing and the Nordic Countries*. TemaNord No. 572, Nordic Council of Ministers, Copenhagen, and *CICERO Report* No. 2, Oslo.

Rose, A. (1992). Equity Considerations of Tradable Carbon Emission Entitlements. In *Combating Global Warming.* UNCTAD, Geneva.

Rose, A., Stevens, B., Edmonds, J. and Wise, M. (1997). International Equity and Differentiation in Global Warming Policy. Mimeo, The Pennsylvania State University, California Energy Commission, and Pacific Northwest Laboratory. 31 July.

Rowlands, I. H. (1997). International Fairness and Justice in Addressing Global Climate Change. *Environmental Politics* 6 (3) 1-30.

Shue, H. (1992). The Unavoidability of Justice. In *The International Politics of the Environment: Actors, Interests and Institutions*, eds. A. Hurrell and Benedict, pp. 373-397. Oxford University Press, Oxford.

Torvanger, A., Berntsen, T., Fuglestvedt, J., Holtsmark, B., Ringius, L. and Aaheim, A. (1996). Exploring Distribution of Commitments - A Follow-up to the Berlin Mandate. *CICERO Report* No. 3, Oslo.

United Nations, Framework Convention on Climate Change (1995). Report of the Conference of the Parties on Its First Session; Held at Berlin from 28 March to 7 April 1995. FCCC/CP/1995/7/Add.1, 4-6.

United Nations, Framework Convention on Climate Change (1996). *Strengthening the Commitments in Article 4.2(a) and (b); Quantified Emission Limitation and Reduction Objectives within Specified Time-Frames; Review of Possible Indicators to Define Criteria for Differentiation among Annex I Parties; Note by the Secretariat.* FCCC/AGBM/1996/7, 8 July.

ANNEX A. Emission reduction from the three burden sharing formulae as percentage of OECD total reduction and percentage of national emissions. Total OECD emissions are reduced by 20% from 1993 level.

FORMULA 1

Emission reduction as a percentage of OECD total reduction

Cases:	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Greece	Ireland	Italy	Japan	Luxemb.	Netherl.	N. Zeal.	Norway	Portugal	Spain	Sweden	Switzerl.	Turkey	UK	USA
1: equal weights	1.4	0.2	0.4	2.3	0.2	0.2	1.6	5.5	0.2	0.1	1.8	8.7	0.1	0.7	0.1	0.1	0.1	0.7	0.2	0.1	0.4	2.6	72.4
2: extra weight on CO2/pop.	1.5	0.3	0.6	2.7	0.4	0.3	2.3	6.6	0.2	0.1	2.4	10.4	0.1	0.9	0.1	0.2	0.1	0.9	0.3	0.3	0.3	3.1	65.9
3: extra weight on CO2/GDP	2.0	0.2	0.6	2.9	0.3	0.2	1.6	5.8	0.5	0.2	1.9	7.8	0.1	0.9	0.1	0.1	0.2	0.9	0.2	0.1	0.8	3.1	69.7
4: extra weight on GDP/pop.	1.6	0.3	0.6	2.7	0.3	0.3	2.1	6.3	0.2	0.1	2.3	9.7	0.1	0.9	0.1	0.2	0.1	0.8	0.3	0.3	0.3	3.0	67.3

Emission reduction as percentage of national emissions

Cases:	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Greece	Ireland	Italy	Japan	Luxemb.	Netherl.	N. Zeal.	Norway	Portugal	Spain	Sweden	Switzerl.	Turkey	UK	USA
1: equal weights	10.1	6.0	7.7	10.5	7.7	7.4	9.1	12.6	6.8	6.5	9.0	16.4	13.6	7.9	5.9	6.3	4.7	6.2	6.0	6.9	4.9	9.5	29.2
2: extra weight on CO2/pop.	11.1	10.5	10.8	12.4	12.9	11.9	13.0	15.1	6.3	8.3	12.4	19.6	15.7	10.9	7.9	12.7	5.3	8.2	12.1	15.2	4.3	11.4	26.7
3: extra weight on CO2/GDP	14.5	7.0	10.1	13.7	9.1	9.0	9.0	13.2	13.3	9.8	9.4	14.7	17.7	10.3	8.9	6.8	8.6	7.9	6.2	6.5	10.4	11.5	28.1
4: extra weight on GDP/pop.	11.8	9.6	10.6	12.7	12.1	11.2	11.9	14.6	6.7	8.3	11.5	18.3	17.3	10.6	7.7	11.2	5.3	7.7	10.6	13.1	4.4	11.2	27.2

FORMULA 2

Emission reduction as a percentage of OECD total reduction

Cases:	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Greece	Ireland	Italy	Japan	Luxemb.	Netherl.	N. Zeal.	Norway	Portugal	Spain	Sweden	Switzerl.	Turkey	UK	USA
1: equal weights	2.2	0.8	1.1	3.7	0.6	0.6	5.7	9.3	0.8	0.3	5.6	14.3	0.1	1.7	0.3	0.5	0.7	3.2	0.9	0.8	3.1	5.9	37.6
2: extra weight on emissions	2.4	0.7	1.1	3.9	0.6	0.6	4.9	9.2	0.6	0.3	5.0	13.4	0.1	1.7	0.3	0.4	0.5	2.5	0.8	0.7	1.6	5.6	43.0
3: even more weight on emiss.	2.6	0.6	1.1	4.1	0.6	0.6	4.2	8.9	0.7	0.3	4.5	11.9	0.1	1.7	0.3	0.4	0.5	2.4	0.6	0.6	1.7	5.5	46.1
4: extra weight on GDP	2.1	0.8	1.1	3.7	0.7	0.6	5.8	9.5	0.6	0.3	5.6	15.3	0.1	1.7	0.3	0.5	0.5	2.7	1.0	1.0	1.5	5.6	39.0

Emission reduction as percentage of national emissions

Cases:	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Greece	Ireland	Italy	Japan	Luxemb.	Netherl.	N. Zeal.	Norway	Portugal	Spain	Sweden	Switzerl.	Turkey	UK	USA
1: equal weights	16.0	29.3	20.6	17.0	22.7	22.5	32.1	21.4	21.3	21.2	28.5	27.0	13.4	20.6	23.0	31.6	29.4	29.4	36.7	39.9	42.3	21.8	15.2
2: extra weight on emissions	17.3	25.9	20.4	18.2	22.6	22.1	27.6	21.1	17.6	19.6	25.1	25.3	16.6	20.3	20.5	28.6	20.8	23.5	31.6	35.6	21.5	20.5	17.4
3: even more weight on emiss.	18.7	22.9	20.2	19.1	21.1	21.0	23.7	20.5	19.3	20.0	22.5	22.5	18.2	20.2	20.5	24.0	21.2	22.1	25.5	27.2	22.7	20.4	18.6
4: extra weight on GDP	15.6	29.6	20.6	17.1	24.4	23.6	32.5	21.9	15.4	19.2	28.2	28.8	14.6	20.5	20.5	34.4	20.3	25.2	39.2	46.1	20.0	20.8	15.8

FORMULA 3

Emission reduction as a percentage of OECD total reduction

Cases:	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Greece	Ireland	Italy	Japan	Luxemb.	Netherl.	N. Zeal.	Norway	Portugal	Spain	Sweden	Switzerl.	Turkey	UK	USA
1: equal weights	2.2	1.2	1.5	3.6	1.1	1.0	6.7	9.5	1.0	0.7	6.2	16.7	0.7	2.0	0.6	0.9	0.8	3.0	1.4	1.5	1.4	5.5	31.1
2: extra weight on GDP	1.9	1.0	1.2	3.4	0.8	0.7	7.0	10.0	0.5	0.3	6.4	17.9	0.2	1.8	0.3	0.7	0.5	2.9	1.3	1.3	1.1	5.7	33.3
3: extra weight on GDP/pop.	2.3	1.3	1.6	3.6	1.3	1.2	6.6	9.3	1.0	0.8	6.1	16.2	1.0	2.1	0.7	1.1	0.8	3.0	1.6	1.7	1.4	5.5	30.0
4:extra weight on emiss./GDP	2.8	1.3	1.8	3.8	1.4	1.3	6.1	8.8	1.8	1.2	5.8	15.0	1.6	2.3	1.1	1.0	1.3	3.0	1.5	1.5	2.0	5.4	28.1

Emission reduction as percentage of national emissions

Cases:	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Greece	Ireland	Italy	Japan	Luxemb.	Netherl.	N. Zeal.	Norway	Portugal	Spain	Sweden	Switzerl.	Turkey	UK	USA
1: equal weights	16.1	42.3	26.4	16.5	37.6	37.4	37.2	21.8	26.9	43.0	31.1	31.5	138.7	23.7	46.8	57.5	33.8	27.3	56.0	69.3	19.1	20.4	12.6
2: extra weight on GDP	13.5	36.0	21.7	15.7	28.7	27.4	39.1	22.8	13.3	21.6	32.4	33.7	29.2	21.1	23.8	45.0	20.2	27.0	51.2	63.1	14.6	20.8	13.5
3: extra weight on GDP/pop.	16.7	48.0	28.9	16.7	45.1	44.5	36.7	21.3	27.6	49.9	30.7	30.6	187.3	25.0	54.8	72.2	35.5	27.2	63.5	81.7	18.6	20.1	12.1
4: extra weight on emiss./GDP	20.3	48.7	32.9	17.8	47.3	49.2	34.3	20.2	51.4	76.0	29.1	28.3	295.8	27.3	81.8	67.3	57.4	27.7	58.0	69.2	27.8	19.9	11.4

Annex B

National income changes as percentage of GDP from the three burden sharing formulae.

Country	Formula I	Formula II	Formula III
Australia	-0,22	-0,33	-0,25
Austria	0,01	-0,15	-0,46
Belgium	0,02	-0,16	-0,19
Canada	-0,31	-0,44	-0,34
Denmark	-0,19	-0,47	-0,81
Finland	-0,01	-0,21	-0,40
France	-0,02	-0,23	-0,68
Germany	0,06	-0,01	-0,04
Greece	0,03	-0,17	-0,06
Ireland	0,04	-0,14	-0,16
Italy	-0,12	-0,58	-1,13
Japan	-0,16	-0,23	-0,51
Luxembourg	-0,05	-0,12	-0,52
Netherlands	-0,03	-0,35	-0,48
New Zealand	-0,05	-0,20	-0,22
Norway	-0,67	-1,03	-2,11
Portugal	0,04	-0,18	-0,16
Spain	0,03	-0,13	-0,21
Sweden	-0,33	-0,96	-2,57
Switzerland	-0,21	-0,54	-2,02
Turkey	0,04	-0,16	-0,04
UK	-0,02	-0,13	-0,14
USA	-0,37	-0,19	-0,09

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