Sharing the burden of adaptation financing - Translating ethical principles into practical policy

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Translating ethical principles into practical policy

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Contents

Abbreviations

AOSIS	Alliance Of Small Island States
CBDR	Common But Differentiated Responsibilities
EIA	Environmental Impact Assessment
GDP	Gross Domestic Product
GHG	Greenhouse gases
ICJ	International Court of Justice
ILC	International Law Commission
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land use and land-use changes and forestry
LDC	Least Developed Countries
MATCH	Ad hoc group for the Modelling and Assessment of Contributions to Climate Change
OECD	Organization for Economic Cooperation and Development
PP	Precautionary Principle
PPP	Polluter Pays Principle
SBSTA	Subsidiary Body for Scientific and Technological Advice (of the UNFCCC)
UNFCCC	United Nations Framework Convention on Climate Change

Executive summary

Projections of the potential impact of climate change across different sectors and in different parts of the world are becoming more serious. Climate change impacts are likely to be felt especially by the weakest and most vulnerable people, who often have contributed least to changing the global atmosphere. As irreversible changes to the climate system have been initiated by past (and future) emissions, the focus of international negotiations is shifting from mitigation to new climate risks and adaptation to them. Financial resources to reduce the impacts of climate change through adaptation are, however, likely to fall considerably short of what is needed.

Burden-sharing of adaptation costs to climate change has received limited attention in the scientific literature, and the principles applicable in sharing the burdens of mitigation efforts are not easily transferable to the problem of adaptation. In this report we establish a conceptual framework that identifies a set of principles that can serve as a basis for choices about how to share the burden of the costs of adaptation to climate change.

Three basic principles are identified: *deontology*, *solidarity* and *consequentialism*. Deontology implies that individuals and countries can be held responsible for their acts. It lies at the heart of principles in economics and law, including the Polluter Pays Principle and the No Harm Principle. The main message in practical terms for policy makers is that these principles imply that those responsible for the problem should also be responsible for dealing with them, practically or financially. However, the inter-temporal effects (emissions now may have effects many decades in the future) and attribution problems (establishing a causal link between a specific greenhouse gas emission and an experienced effect of climate change is scientifically very difficult) associated with climate change impose major difficulties for a direct implementation of a Polluter Pays Principle. Given these problems, we argue that a liability principle may not be appropriate in the short run, and that states could use a less demanding, but also well-established notion of *historical responsibility*. The solidarity and consequentialism principles promote sharing burdens in a fair way, irrespective of the previous actions by different countries. Taking these insights together, the dimensions along which the practical and financial burdens of climate change impacts could be shared are then *equality* and *capacity*. We argue that equality is an unfeasible criterion for sharing adaptation costs, but that capacity is more promising.

The main body of the report is concerned with assessing how these principles might be translated into practice. From a very wide range of possible parameters relevant to responsibility, equality and capacity of states, we choose a more limited set, representing these as scenarios. Quantitative results of applying these criteria and varying parameters are then presented for major world regions. For the *historical responsibility* scenarios it is clear that UNFCCC Annex I countries carry the greatest responsibility under most scenarios, but that the choice of values for key parameters does have a marked affect on outcomes. A number of *common but differentiated responsibilities* scenarios, combining responsibility and capacity criteria, were also evaluated. The analysis shows that outcomes are relatively stable across scenarios, but differ substantially subject to the choice

of a criterion for defining Capacity to Pay. We find that the contribution of The Netherlands to financing adaptation would lie between 0.6% and 1.3% of total global adaptation costs, depending on the policy scenario chosen. Assuming costs of climate adaptation is $100 billion per year (UNDP, 2007), the total financial contribution by The Netherlands could range between $600-1300 million per year, depending on the principles and parameters chosen.

1. Introduction

1.1 Adaptation to climate change

It is more than a century and a half since the first scientific recognition of climate change and only thirty years since the global scientific community first met to discuss its challenges in 1979 at the World Climate Conference. It took another ten years before negotiations to address the problem were initiated in 1990. Yet globally we are still emitting greenhouse gases in increasing amounts (IPCC, 2007: 2).

Meanwhile, the prognosis regarding the potential impact of climate change across different sectors and in different parts of the world is becoming more serious. The fourth assessment report of the IPCC states that "Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases" (IPCC, 2007: 2).

Furthermore, the impacts are likely to be felt most by the weakest and most vulnerable people, who often contributed least to the cause of the problem (Paavola and Adger, 2006). Financial resources to reduce the impacts of climate change through adaptation are likely to fall considerably short of what is needed. Current estimates of the required resources are as high as US $50 billion annually (Oxfam International, 2007) and range up to US $100 billion annually (UNDP, 2007).

At the UN Climate Conference in Bali in 2007 much debate centred on the issues of liability and equity, with many developing countries calling on the developed world – those primarily responsible for most greenhouse gas emissions – to fully engage in the transfer of technologies and funds to help mitigate and adapt to climate change.

1.2 International financing of adaptation as part of a PPP-based policy

The international financing of adaptation efforts raises many relevant questions in terms of burden-sharing, such as who is responsible for causing the climate change problem; who should be held liable for damages that will occur or are already occurring; what would be a fair division of financing obligations, and what is the capacity of different regions to contribute to international financing? It is clear that any meaningful answer to these questions needs to draw on the insights from political, legal, natural science and economic perspectives and needs to pass certain ethical considerations. One major complication in combining these insights is the difference in terminology, which may easily lead to misunderstandings in trans-disciplinary communication. Grasso (2007) points out that the ethical considerations related to burden-sharing of adaptation costs have received limited attention relative to sharing the burdens of mitigation[1].

Thus, it becomes important to establish a conceptual framework for assessing responsibilities for international financing of adaptation related to climate change. A key principle of domestic environmental policy is the Polluter Pays Principle (PPP) adopted by

1 In fact, Ringius et al. (2002a) is one of the few reports that, through their "second fairness framework", treats adaptation, damage and mitigation costs as a basis for burden sharing.

OECD countries. In the words of the OECD (1972): "the polluter should bear the expenses of carrying out the pollution prevention and control measures […] to ensure that the environment is in an acceptable state". This principle assumes that victims of pollution have a right to a certain acceptable state of the environment. Polluters must pay for measures that ensure that the environment returns to (or remains in) this acceptable state. For instance, the emissions of greenhouse gases that cause climate change should be priced at such a level that dangerous climate change is avoided, or differently put, the external cost of emissions should be internalised. In case the environment cannot be returned to an acceptable state, as is the case for climate change impacts, the main idea of the PPP may be expanded, so that the polluter also bears responsibility for damage, knowingly or unknowingly caused.

Climate policy consists of three main pillars: (i) mitigate emissions to reduce future climate impacts; (ii) use carbon sinks and Carbon Capture and Storage to avoid climate impacts from emissions that do take place; and (iii) invest in adaptation to minimize (or in extreme cases even eliminate) the unavoidable negative impacts of climate change. The PPP justifies such a climate policy in an international context, as it implies that polluters should undertake action on each of these three pillars and should bear the financial consequences. The focus of this report is on the third pillar of climate policy: investing in adaptation. In particular, we investigate how to design an international framework for financing adaptation that is in line with the PPP.

Establishing 'environmental liability' and designing compensation principles and mechanisms for climate change is a complex task that will need to draw on legal and ethical precedents in other fields, such as international law and consumer protection. These mechanisms may not directly draw on the Polluter Pays Principle, it is clear that they are intrinsically linked to each other. For example, one of the fundamental principles in international law is sovereignty, subject to the principle of not causing harm to others, and where such harm is caused – to provide compensation and redress the harm through injunctive relief.

While the basic assumptions of PPP and liability are clear, it is not straightforward how these principles can be used to assess the responsibilities of specific regions for international financing of adaptation. This study addresses this issue by making such general principles applicable in the context of climate change. We start by analysing the literature from different disciplinary perspectives for the most important basic ethical (or philosophical) principles that can be used to determine the responsibilities of countries. Then we investigate how these principles can be used to specify some practical policy guidelines, offering practical considerations and suggestions for policy makers. The main aim of the study is to provide a limited set of "images" that can be used by the Dutch government to establish a position on the financing of international adaptation to climate change. Finally, we investigate how these discussions may evolve and what these guidelines may mean to specific countries and regions, including the Netherlands.

1.3 Responsibilities and contributions to climate change

The contribution of different countries to climate change is one of the key aspects of establishing responsibilities of countries for adaptation funding as part of a PPP-based policy. It is, however, difficult to disentangle historical and current contributions, because historical emissions may have long lasting effects on climate conditions in the future for two main reasons.

First, the atmospheric lifetime of most greenhouse gases is (very) long (Montenegro et al., 2007). Climate simulations by Matthews and Caldeira (2008) suggest that "any future anthropogenic emissions will commit the climate system to warming that is essentially irreversible on centennial timescales". Second, lags in the climate system imply that past emissions continue to change the climate in the future as a result of effects not directly related to the long lifetime of greenhouse gases (IPCC, 2007). For example, heat transports slowly into the deep ocean so that thermal expansion causes sea levels to rise for a long time in response to an increase in surface temperature.

Figure 1.1 illustrates these issues by showing how the cumulative stock of anthropogenic CO_2 emissions from various historical time periods contributes to the components of the cause-effect chain of climate change, i.e. the enhancement in total CO_2 concentration (compared to pre-industrial levels), radiative forcing and temperature increase. It should be noted here that there remains considerable scientific uncertainty concerning the exact relations in this cause-effect chain, for instance in the relationship between atmospheric concentrations of greenhouse gases and long-term changes in mean global surface temperatures (see Section 3.2 and Appendix I).

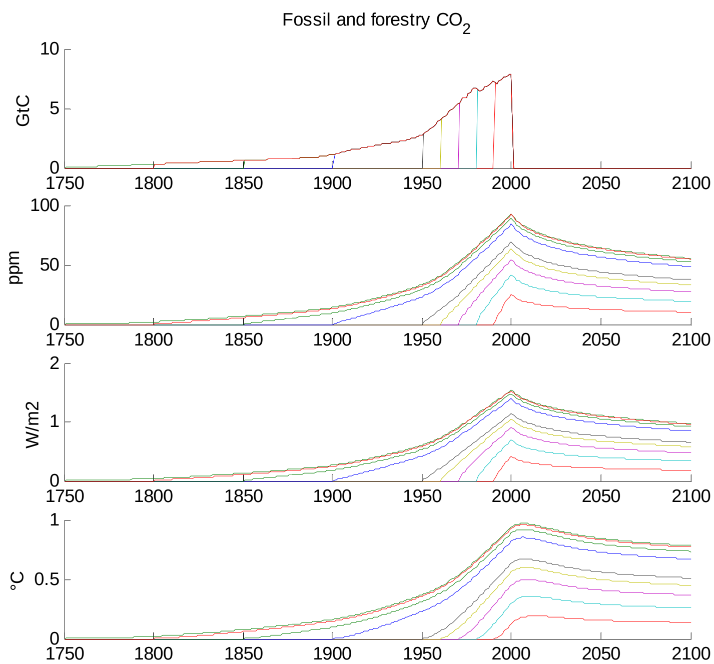


Figure 1.1 Historical emissions of CO_2 only and its impacts on concentrations, radiative forcing and temperature change using the MATCH climate model (see Appendix I). Individual curves represent contributions of emissions from different start dates (1750 to 2000). Source: den Elzen et al. (2005a).

Due to these intertemporal effects of emissions and the changes they cause in the Earth System, it is unlikely that studies of the historical contribution to climate change capture all future impacts of emissions, unless evaluation dates extend very far into the future. A related issue is that several studies indicate that abrupt changes in climate may occur once greenhouse gas concentrations cross certain thresholds (Alley et al., 2003).

This difficulty of identifying and disentangling historical and current contributions could be an important complicating factor in the allocation of responsibilities between countries and regions. At this moment the industrialized countries, notably Europe, USA, Japan and Russia, carry the main responsibility for past human contributions to atmospheric greenhouse gas concentrations (den Elzen et al., 2005b; Srinivasan et al., 2008). For this reason, many developing countries have argued that they should not be penalized for historical emissions by the rich countries (Najam et al., 2003). However, it should be noted that relative contributions to the climate problem are changing, notably due to the rapid industrialization of China and to a lesser extent India and other developing countries. Therefore, in the future the responsibility for the climate problem will be shared by the historically large emitters, as well as rapidly developing countries (Botzen et al., 2008). The next section will look closer at these changing emission patterns.

Another issue open for debate is the extent to which countries are still responsible for climate impacts that are caused by emissions that occurred before there was scientific consensus about anthropogenic causes of climate change, or which occurred during a period after the creation of an international climate regime (say the coming into force of the Kyoto Protocol). Höhne et al. (2008) conclude that it is very likely that the element of historical responsibility will play a role in the design of a future agreement. It is, however, unlikely that it will be the only parameter used for sharing emission reductions between countries.

1.4 Changing emission patterns and responsibilities

In 2007 China surpassed the USA in total annual CO_2 emissions (please see http://www.mnp.nl/en/dossiers/Climatechange/moreinfo/Chinanowno1inCO2emissions USAinsecondposition.html). Economic development and growth in industrializing countries will increase their demand for energy and result in higher growth of greenhouse gas emissions. Therefore, the responsibility for the climate problem will shift gradually to these large rapidly developing countries in the future. Botzen et al. (2008) examine this issue and project cumulative CO_2 emissions from fossil fuels for Western Europe, the USA, Japan, China and India. Cumulative CO_2 emissions were taken as an approximation of the degree of responsibility for human-induced climate change. Botzen et al. show that the rapid industrialization of countries, such as China and India, is expected to change relative contributions of countries to climate change in the coming decades. This shows that computations of the contributions of countries to global warming will need continuous revision over time, as will an assessment of their responsibility. Botzen et al. also conclude that international arrangements for financing adaptation need to be flexible so agreements can adjust to changes in the relative contribution to climate change by different countries.

1.5 The Brazilian proposal on countries' contributions to climate change

Although difficult, some attempts have been made to use historical responsibility for assessing the contributions of countries to international climate change financing mechanisms. The "Brazilian proposal" was the first and most influential of these attempts. In 1997, Brazil proposed a method to calculate contributions of emission sources to climate change (FCCC/AGBM/1997/MISC.1/Add.3) (UNFCCC, 1997). Although the original application to emissions reduction targets was not pursued, continued interest in the scientific and methodological aspects of the proposal by Brazil led to a series of expert meetings (reported in FCCC/SBSTA/2001/INF.2), followed by a model inter-comparison exercise on the "Attribution of Contributions to Climate Change" (from which some results were reported in FCCC/SBSTA/2002/INF.14). The conclusions of this analysis are described in UNFCCC (2002), and some institutes have reported their analysis in more detail (e.g., den Elzen et al., 2002a; Andronova and Schlesinger, 2004; Höhne and Blok, 2005; den Elzen et al., 2005b; Trudinger and Enting, 2005).

The SBSTA, at its seventeenth session, agreed that work on the scientific and methodological aspects of the proposal by Brazil should be continued by the scientific community, in particular to improve the robustness of the preliminary results and to explore the uncertainty and sensitivity of the results to different assumptions.
(FCCC/SBSTA/2002/13, paragraphs 28-30). Subsequent to this agreement the governments of UK, Brazil and Germany took the initiative to organize an expert meeting in September 2003 that formed the Ad Hoc Group on Modelling and Assessment of Contributions to Climate Change (MATCH).

Encouraged by the mandate of the SBSTA, the aim of MATCH has been "...to evaluate and improve the robustness of calculations of contributions to climate change due to specific emissions sources, building on the proposal by Brazil, and to explore the uncertainty and sensitivity of the results to different assumptions." The aim is to provide guidance on the implications of the use of the different scientific methods, models, and methodological choices. Where scientific consensus allowed, the group would recommend one method/model/choice or several possible methods/models/choices for each step of the calculation of contributions to climate change, taking into account scientific robustness, practicality and data availability. Outputs of the group are primarily articles for the peer-reviewed scientific literature (see http://www.match-info.net/ for all papers and meeting reports).

1.6 Existing compensation schemes for damage and adaptation costs

Several international bodies have developed funds to assist developing countries in paying for the costs of adaptation related to the negative (or positive) impacts of climate change. The main aim of these funds is to transfer wealth from developed to developing countries in order to compensate for the heavy burden climate change puts on developing countries. None of the existing funds rely on the notion of historical responsibility in determining the level of national contributions to these funds. Instead all funds, except the international Adaptation Fund established under the Kyoto protocol, are based on 'conventional' funding methods that underpin assessments of financial contributions to the United Nations and overseas development assistance, including related grants and loans (Müller, 2008). Hence, a clear relationship with the PPP has not yet been established. We will set out briefly the main existing funding mechanisms.

Under the Kyoto protocol the signatory countries decided to form an international *Adaptation Fund*, such that signatory developing countries can finance concrete adaptation projects and programmes. Funds are raised partly through 2% proceeds from certified emission reductions under the clean development mechanism. However, other sources of funding are required and the linkage to trade in certified emission reductions puts great uncertainty on the size of funds available. At the UNFCCC conference in Bali (December 2007), it was decided that the adaptation fund will be managed by the Global Environmental Facility and the World Bank will act as banker.

The Global Environmental Facility is also the entity managing two other UNFCCC funds, (i) the *Least Developed Countries Fund* supports LDCs in preparing and implementing National Adaptation Programmes of Action; and (ii) the *Special Climate Change Fund* was established to finance projects targeted mainly at studies, as well as demonstration and pilot projects, on adaptation planning and assessment. In fact, the Global Environmental Facility also adopted the *Strategic Priority on Adaptation* providing funds to implement adaptation pilots. Funding relies on voluntary contributions, with additional funds needing to be raised through overseas development assistance and loans.

The World Bank is also active in financing adaptation in other forms than through the international Adaptation Fund. The *Strategic Climate Fund* aims at increasing climate resilience in developing countries to climate change and is supposed to be aligned with the international *Adaptation Fund*. Funds are provided in the form of loans to developing countries.

Müller (2008) highlights that the main critique on 'conventional' funding methods originates from the fact that the donating countries decide what happens with the money, while it is the developing countries that experience the damage caused by polluting countries, often the major donors. In fact, by providing loans, developing countries create new debts to donor-polluter countries. Furthermore, the voluntary nature of the contributions contradicts the essence of the Polluter Pays Principle.

Other, more innovative mechanisms to generate international funds for adaptation are currently being proposed; an analysis of these proposals is, however, beyond the scope of the current report.

1.7 Research question

Against this background, this report aims to address the question:

What are the issues of relevance in using the polluter pays principle, in conjunction with liability and compensation principles, to develop a fair position on the responsibility of specific (groups of) countries, and especially the Netherlands, for adaptation to human-induced climate impacts?

Specifically:

1. What does the literature say about how the polluter pays principle, and liability and compensation principles, should be interpreted in relation to the climate change problem and in relation to allocating responsibility to individual countries?
2. How can we translate these arguments and positions into a practical set of approaches, focusing, inter alia, on a possible cut-off date for assessing responsibility for past emissions, ethical principles for determining responsibility (e.g. per capita; gross emissions), and responsibilities for the future?
3. What does this imply for the Netherlands' position in international negotiations?
4. Can the international division of responsibilities, as laid out in the practical set of approaches addressed in research questions 2 and 3, be quantified through an (approximate) assessment of historical emissions and the associated contributions to climate change?

1.8 Focus and limits

It should be stressed that this assessment is a preliminary review of the responsibilities for climate change in relation to the PPP for the Netherlands. It does not focus on: (a) the liability of individuals and companies; (b) to whom compensation should be paid and how; and (c) the mechanisms by which international payments can be made (funding, insurance and compensation schemes).

The review is anchored in the international law and economics literatures, not in the study of ethics per se. Rather, the current project limits itself to providing a conceptual (but practical) framework that may form the basis for designing a position in international climate policy on the international financing of adaptation efforts, as part of a broader PPP-based policy. It further briefly sketches international responsibilities, focusing on the role of the Netherlands, and on some quantitative insights into the international division of these responsibilities.

1.9 This report

This report is structured as follows. Chapter 2 establishes the ethical and other principles that can be used to consistently assess countries' contributions to climate change. It develops three main principles that can be used to develop a policy that is fair. These three ethical and legal principles are translated in Chapter 3 into three principles (responsibility, equality and capacity) that could underpin policy. It further highlights the main policy choices that need to be addressed in order to establish contributions of countries. Chapter 4 provides a quantitative analysis of applying alternative choices in allocating responsibility for global climate change and its impacts. In particular, we are interested in the international division of contributions to climate change. Chapter 5 concludes.

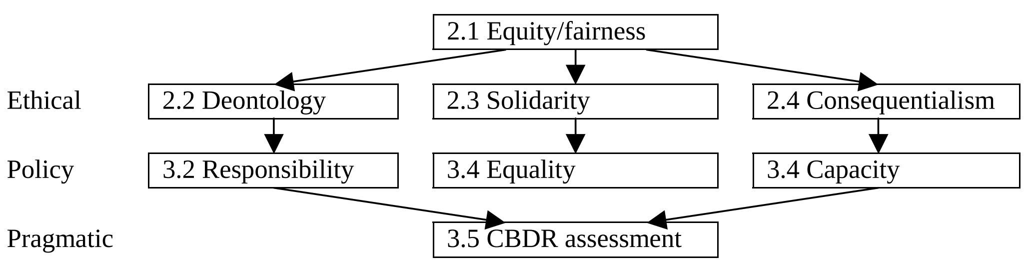
2. Ethical and other principles

2.1 Introduction

It is widely accepted that the distribution of adaptation costs among individual countries should be based on an underlying principle of fairness. Several such principles have been suggested from disciplines ranging from philosophy and ethics to international relations, law and economics. As a result of partial overlaps in terminology and meaning this is a potentially confusing area. Therefore, this chapter tries to structure the discussion by providing an overview of relevant concepts identified in the literature, while making the boundaries of their validity and origins explicit.

Using equity ("fairness" in the economic sense) as the starting point, several guiding principles are at hand to distribute the costs among countries. Ikeme (2003) presents an important distinction between deontological and consequential justifications. Bouwer and Vellinga (2005) further point to the role of solidarity as a guiding principle. These are labelled in Table 2.1 as ethical principles. Table 2.1 shows that these ethical principles can be translated into principles that form the basis of policy choices. Each of these so-called 'policy principles', which are based on the classification by Heyward (2007), in turn implies a set of specific policy choices that should be made. These specific policy choices will be described in the next chapter. The combination of all three policy principles results in an assessment of 'Common But Differentiated Responsibilities' (CBDR), which can function as a pragmatic basis for developing proposals. Before going into this in Chapter 3, we will first explain the foundations of the ethical principles in this chapter.

Table 2.1 Structure of the approach with corresponding section numbers.



2.2 Deontology

The deontological principle has some old and respectable philosophical and ethical roots. Ikeme (2003), Low and Gleeson (1998) and others trace the principle back to the philosopher Emanuel Kant. Kant combined three arguments in his moral philosophy. His first premise is that all humans are equal in the sense that they experience happiness and suffering alike. His second premise holds that people are rational in the sense that they can take account of the consequences of their own actions for others. After all, those consequences are experienced equally. And his third premise is that people are free to choose their actions. From these arguments, Kant reasons that people can and should be held responsible for the consequences of their actions.

Several recent approaches to justify a distribution of costs of negative environmental consequences, have adopted the foundations of the deontological principle (see for example Cullet, 2007; Faure and Nollkaemper, 2007). The No Harm principle uses it in an international and legal context, the Polluter Pays Principle starts from an economic point of view and the Precautionary Principle looks mainly at the duties of states.

2.2.1 No Harm Principle

In international law the No Harm Principle has been adopted to signify that sovereign states can use their territory in whatever manner they want to, but they cannot cause harm to other states. When transboundary environmental problems became evident, the restricted territorial sovereignty principle led to the development of the principle of sovereignty becoming subject to duty towards other states. This implied that states had complete control over their natural resources, but had the responsibility to ensure that they did not cause environmental harm to other states. As Tol and Verheyen (2004) explain, the principle further implies that when harm is done, causing states are obliged to redress or compensate the damage.

This principle is deeply rooted. At Stockholm in 1972, the Declaration on the Human Environment stated that:

> “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 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.”
>
> Stockholm Declaration 1972: Principle 21

In several principles of the Rio Declaration (1992), the environment is represented as a global resource, for which all states have a common responsibility to protect. With this, according to Birnie and Boyle (2002), the declaration broke with earlier tradition in international law where only state responsibilities for the national and transboundary environment are set. “For the first time, the Rio instruments set out a framework of global environmental responsibilities” (Birnie and Boyle, 2002: 97). In 1992 in Rio, during the United Nations Conference on Environment and Development, the No Harm Principle was once again emphasised in Principle 2. Since then, this principle has been included in many international environmental treaties, including the UNFCCC. In the convention text it is stated that states have 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” (UNFCCC 1992).

In the literature, attention has been paid to the difficulties and drawbacks of the No Harm Principle. The difficulty of linking damage at one place to polluting activities in another place, especially in the case of climate change where polluters are spread all over the world, is raised by several authors (Birnie and Boyle, 2002; Faure et al., 2007; Voigt, 2008). Drumbl (2008: 10) furthermore points out that for harm that is “too indirect, remote, and uncertain” causation cannot be established and therefore “falls outside the scope of the reparative obligation”. This is a result of the jurisprudence on the Trail Smelter case, where the judges ruled that part of the alleged harm that the Canadian trail smelter had caused to some areas in the U.S. fell into the 'indirect and uncertain' category and thus fell outside Canada's duty to repair. Tol and Verheyen (2004) on the other hand argue that in the past it was possible to bring in a claim against only one state while several states were at the cause. Another complexity that is frequently pointed to is the question what actor can be held responsible: states, operators or consumers? States as such are not emitters of greenhouse gases, even if they may have the powers to regulate such emissions (see for example Faure et al., 2007; Cullet, 2007). It is important to note that the No Harm Principle as a *legal liability* principle has been proposed as the basis to sue countries for damages. This does not address their *moral responsibility* to limit damages or to provide compensation for damages unavoidably caused. The feasibility of this approach with respect to climate change has been the subject of much debate in the literature, see for example Allen (2003).

2.2.2 Polluter Pays Principle

The Rio Declaration also called on states to adopt the Polluter Pays Principle in domestic law. This principle can be traced back to OECD (1972), as noted in section 1.2, and can be used as a starting point for establishing international responsibility, c.q. liability and compensation rules. As past and current emitters together contribute to increasing environmental risks caused by climate change, the emissions of greenhouse gases should be priced such that they can compensate affected countries to reduce their environmental risks and related impacts to an acceptable level. The PPP is incorporated in The Treaty Establishing the European Community (July 1st 1987, Article 174(2)) as one of the four leading principles that environmental policy should be based on, and it was introduced in the Single European Act (1987).

Multiple problems complicate a direct application of the PPP to climate change. Stern (2007) labels climate change as an intergenerational and international externality, which is far more complex to deal with than other forms of pollution. Defining the polluter and the victim will be difficult enough in the present day. But establishing these for the past, as well as in the future, let alone developing a context in which there can be something meaningfully recognised as bargaining between polluters and victims across the space of decades and centuries, also raises obvious conceptual and practical problems.

The primary concern of the PPP, from an economic perspective, is that the negative side effects of emissions are internalized by the polluters in such a way that the expected damages are included in profit and utility functions. Taxes, (tradable) property rights, quota and technological requirements are at hand for policy makers to achieve this internalization of damages (Perman et al., 2003). In particular the Coasian approach through private bargaining (between polluters) suggests emissions abatements should be achieved in places with lowest abatement and transaction costs. Hence, applications and discussions on the PPP are most often focused on efficiency discussions (Shukla, 1999).

Knox (2002) highlights that relevant international laws and central authorities are lacking to identify the polluter and secure the enforcement of burden-sharing schemes. Furthermore, states disagree on which state has the right to pollute and which is entitled to clean resources (Barrett, 1996). Scientific uncertainties regarding the causes and impacts of climate change would even further complicate an application of PPP for climate change in making specific polluters liable by proving causality (Franck, 1995; Seymour et al., 1992).

We may conclude that PPP under certain conditions may lead to an (economically) efficient solution to the externality; however, many obstacles prevent an application of the principle to climate change. Recent attempts to apply PPP and liability schemes to climate change have only been restricted to assigning property rights to reductions in emissions (such as in emissions trading) and neglect the historical responsibility issue(Tol and Verheyen, 2004; Tol, 2006). Even if an application of PPP can be designed that takes into account the intergenerational and international aspect of climate change, then it also needs to be flexible. Efficiency[2] considerations do, however, not take into account fairness of changes in wealth distribution. To come to an international agreement all players need to consider the burden-sharing and mitigation scheme as fair. Hence, equity issues play a more important role in international negotiations (Fischhendler, 2007; Rose et al., 1998).

2.2.3 Precautionary Principle

Trouwborst (2007) describes three main characteristics of the precautionary principle. First, there must be a "threat of environmental harm" (Trouwborst, 2007: 187). Second, because the environmental system is complex, there is always a degree of uncertainty connected to the threat of harm: the exact impacts cannot be calculated. According to the Precautionary Principle, however, this uncertainty is no excuse for non-action. The third characteristic holds that action must be taken "at a moment which is early enough to prevent unacceptable environmental damage" (Trouwborst, 2007: 187), and that when there is uncertainty relating to the impacts, the environment should get the benefit of the doubt. The Precautionary Principle is included in principle 15 of the Rio Declaration. Furthermore, the Precautionary Principle is incorporated in The Treaty Establishing the European Community (Article 174(2)), where it was introduced in the Treaty of Maastricht (1992) as a leading principle. Its background and a dozen case studies have been described in detail by the European Environment Agency (Gee and Vaz, 2001). The UNFCCC also adopted the principle. Article 3.3 of the convention states that "The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures" (UNFCCC 1992).

Due diligence is a central theme in the Precautionary Principle. As Rao (2002) explains, due diligence means a state should do everything within its capabilities to take measures that are "appropriate and proportional to the degree of risk of transboundary harm" (p. 27). This implies that to determine whether a state has acted with due diligence, two factors should be taken into account: First, its capabilities to act – i.e. its economic level; and second, the degree to which the harm could or should have been foreseen by the state (Voigt, 2008). The first factor thus adds to CBDR by making a distinction between the responsibilities of states. The second factor holds that the state is no "absolute guarantor of the prevention of harm" (Birnie and Boyle, 2002: 112). In the UNFCCC, the due

[2] Please note this is *economic* terminology meaning: no resources should be wasted.

diligence principle is connected to the Precautionary Principle. States should act according to the Precautionary Principle, but “policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost. To achieve this, such policies and measures should take into account different socio-economic contexts” (UNFCCC 1992).

The duty to act with due diligence and in accordance to the precautionary approach is laid down in different parts of international treaties, declarations and law. As a result, states can be called to account for not living up to these obligations. This has happened in several international court cases. In the 1995 ‘Request for an Examination of the situation’ (New Zealand v. France) for example, judges used the precautionary principle when stating that France is obliged to perform an Environmental Impact Assessment (EIA) to show that there are no detrimental consequences resulting from their underground nuclear testing in the Pacific (Birnie and Boyle, 2002). Although in such cases non-compliance with due diligence or the precautionary principle was established, a number of difficulties with applying the principle in international law are identified in the literature. Voigt (2008) and Birnie and Boyle (2002) both argue that due diligence and the precautionary principle are ill-defined in international law and their interpretation can differ from court to court. In fact, the US and EU interpretations of the precautionary principle contrasts markedly, as can be seen from their attitudes towards genetically modified food (Gaskell et al., 1999). In fact, these basic differences in legal approaches have been established in detail for liability for damage to public natural resources (Von Meijenfeldt and Schippers, 1990; Brans, 2001).

2.3 Solidarity

Bouwer and Vellinga (2005) point to solidarity as a guiding principle. There are many social and international public goods for which the solidarity principle holds. For instance, it is the duty of all citizens equally to uphold the law, or to refrain from contravening the law. Likewise, in international law, every state equally has a duty to uphold certain human rights or rules of war, without exception. Ringius et al. (2002b) argue that the most common starting point in (international) negotiations is that all parties have equal responsibilities to address the problem at hand. From a moral point of view, as Shue (1999) explains, the most just division of costs thinkable would be to share all costs equally among all parties. “What could possibly be fairer… than absolutely equal treatment for everyone?” (Shue, 1999: 537).

2.4 Consequentialism

(Shue, 1999: 537) criticises the egalitarian approach. According to him, the problem is that the principle does not consider outcomes in terms of the relative consequences for different actors. For instance, if all states had to contribute equally to a global adaptation fund this could give rise to a situation in which some parties contribute such a large share of their national incomes that it compromises other necessary developmental expenditures. Another ethical principle underlying equity is therefore invoked – consequentialism (Ikeme, 2003).

In practice, the consequentialist principle is often invoked. Consider the progressive taxation systems, for example. The rich pay a larger share of their income in taxes than the poor and therefore contribute relatively more to public funds. Rather than a flat rate in absolute terms, an equivalent degree of effort is assumed, with everybody contributing according to their capacity, i.e. the system is outcome-based.

In the context of climate change and adaptation, consequentialism may also be a useful principle to apply if there are problems in identifying the polluter and the victim – as we have argued above. If there is an agreement on burden-sharing according to Capacity to Pay, then there is less need to go through the complex technical and political process of establishing responsibility for greenhouse gas emissions and for the damages that might result. Instead, the older and independent principle of Capacity to Pay would be invoked.

2.5 Liability versus responsibility

The distribution of adaptation costs among individual countries should be based on an underlying principle of *fairness*. Several fairness principles, deriving from disciplines ranging from philosophy and ethics to international relations, law and economics were reviewed in this chapter. Although legal principles are invariably based on underlying ethical and moral principles, this is potentially an extremely confusing area as a result of overlap in terminology and ambiguity of meanings. While some authors are of the opinion that historical GHG emitting countries can successfully be subject to liability claims in an international context (Allen, 2003), a majority argue that the legal principles are ill-defined and, therefore, the interpretation will differ from court to court (Birnie and Boyle, 2002; Brans, 2001; Voigt, 2008).

With respect to the latter, three issues are important. First, the approach of liability in domestic law differs from country to country. For example, successfully suing the tobacco industry for health damage to smokers as has been done in the USA has failed elsewhere (e.g. in a Dutch court in December 2008). Second, domestic law and international law are worlds apart. Many domestic liability issues do not have an equivalent under international law and *vice versa*. Third, neither in domestic law, nor in international law, liability for climate change is a settled issue. For instance, establishing liability for climate risks associated with historic emissions would be difficult, as illustrated for industrial soil pollution in the Netherlands. Many industrial soil polluters were taken to court on charges of general liability (Von Meijenfeldt and Schippers, 1990). Very few were convicted, however, primarily because the law covering soil pollution was not established until many years after the soil pollution took place. Furthermore, there was often a lack of consensus on the precise date when the polluters should have been aware of the impacts.

Although GHG emitting countries or companies may yet be taken to international or domestic courts on liability charges, the outcome is considered highly unpredictable (Farber, 2007; Faure et al., 2007). Furthermore, there are scientific uncertainties in establishing the causal chain from emissions of greenhouse gases to climate change damages. The IPCC's Fourth Assessment Report (IPCC, 2007), for example, labels the chance that anthropogenic emissions lead to *global* climate change as "very likely". The *local* and *regional* impacts of climate change are far more difficult to establish, because there are substantial problems in distinguishing between man-induced climate change and natural climatic variability at these scales. This does not imply that a liability track should not be pursued. Rather, the currently proposed methodology can be considered an intermediary step that ensures that accountability is implemented as soon as possible, until a liability-based approach becomes viable.

Taking these aspects into account, we draw the conclusion that establishing international liability by suing for damages caused by climate change in domestic or international courts is currently very difficult and the outcomes would be highly uncertain. In our view, it may therefore be risky to employ a strict liability principle as the basis for an argument about the sharing of burdens of climate change impacts.

Notwithstanding, the legal scope for liability compensation has been evolving for some time in the area of marine oil pollution (Mason, 2003) and legal progress in the area of climate change seems pending (Verheyen, 2005). The scientific uncertainties may also become smaller over time as research is able to build evidence for the causal chain between an emission and an impact and climate models become more reliable. These two developments may make the possibilities for international liability claims – or an international liability protocol – more promising *in the longer run*. Therefore, it is essential that in the meanwhile better insight is gained into the major scientific and legal bottlenecks in establishing an international liability context.

We believe that the most reliable way to pursue compensation for climate change *in the short run* will be by establishing an international protocol. Evidently, the time required for international ratification would be considerable and the political feasibility of a global agreement may be limited (cf. the outcomes of the COP14 in Poznan, December 2008). Such a protocol may be based on *liability* principles, but the related concept of *historical responsibility* can also be used as a basis. The two notions share the same ethical basis, and the outcomes of using the principles in terms of regional contributions to the international financing of adaptation are the same. Therefore, using the legal concept of liability may not even be necessary in the international political negotiations, especially given that policy makers want to make substantial progress *in the short run*. Therefore, throughout the remainder of this report, rather than using the narrower concept of *liability*, we will use the broader notion of state *historical responsibility*.

3. From principles to a pragmatic policy

3.1 Introduction

The three underlying principles discussed in Chapter 2 can be transformed into three policy perspectives (pragmatic guiding principles), using the classification of Heyward (2007) as a starting point. First, an ethical and legal interpretation of what we have termed in Chapter 2 as the *Deontontology Principle* indicates that historical contributions to climate change can be used to assign *Responsibility* to individual countries. Second, the *Solidarity Principle* states that responsibilities should be divided equally, i.e. the approach should be based on *Equality*. Third, the *Consequentialism Principle* suggests that responsibilities should be based on the *Capacity* of countries to share the burdens of climate change. These three perspectives provide a legal and ethical framework through which contributions of countries to international financing of adaptation can be established. For each perspective, a set of policy choices needs to be made in order to translate the perspective into an operational framework. This chapter builds up towards this framework by identifying the set of policy choices that needs to be made and by evaluating the justifications and consequences of particular choices based on the three perspectives in Sections 3.2 through 3.4, respectively. Finally, we set out an assessment of CBDRs that follows from an approach drawing on all three perspectives in Section 3.5.

3.2 Responsibility

The Treaty Establishing the European Community says the following on environmental policy (Article 174(2)):

> "...Community policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Community. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay."

In other words, the EU emphasizes an application of the polluter pays principle and the precautionary principle with respect to environmental problems and highlights the responsibility of individual countries by rectifying the problem at the source. As past and current GHG emissions will irreversibly change environmental conditions these rectifications are best captured by a division of responsibilities based on historical contributions to the problem. Hence, this seems an excellent point of departure for a practical approach to establish historical responsibility for climate change. At this moment, taking historical responsibility into account means that OECD countries pay more because they have emitted more.

Given the complexity of the problem of allocating historical responsibility for greenhouse gases and their associated damage, and of estimating the costs of adaptation, we need to begin by clearly identifying the scientific and political options under discussion. This analysis build on Den Elzen et al. (2005a), with respect to both a set of primarily *technical / scientific* options (discussed further in Appendix I) and a set of primarily *policy* options (presented in Table 3.1). Other important reference points in this discussion are Den Elzen and Schaeffer (2002b), Trudinger and Enting (2005), Rive et al. (2006) and Müller (2008).

In relating the effects of the two choice sets on the assessment of historical responsibilities Den Elzen and Schaeffer (2002b) conclude that the “results for relative contributions to climate are found to be quite robust across a range of various simple models and scientific choices. Policy-related choices, such as time period of emissions, climate change indicator and gas mix, generally have larger influence on the results than scientific choices”. Hence, the policy choices as described in Table 3.1 deserve a more elaborate discussion.

First, it is sometimes argued that a distinction should be made between emissions that serve a basic need, such as emissions for cooking and heating, and emissions that can be regarded as “luxury” (Müller et al., 2007). Accounting emissions on the basis of “full responsibility” attributes all emissions to individual countries, whereas limited responsibility deducts a given amount of “basic allowances” and / or “subsistence allowances”. The latter refer to the set of needed emissions to survive and achieve some form of growth by developing countries, whereas the former represent a set of emissions which are harmless to the climate (Müller et al., 2007).

Secondly, there is the question of whether emissions (and consequently climate impacts) should be attributed to the source of the emission or to the destination of the good or service responsible for the emission, i.e. whether *causal attribution* should be to producers or consumers. It is customary to attribute emissions to the source; the UN Handbook on environmental accounting also adopts this custom. From an ethical perspective it may, however, make sense to attribute emissions to the final destination, i.e. to consumers. For instance, a large proportion of Chinese emissions are related to the production of goods consumed in OECD countries. Should these emissions be allocated to China or to the country where the good is consumed? Attributing emissions to consumers relies heavily on information on international trade flows, in order to link the sources and destinations of emissions that are embedded in produced goods. This makes it extremely hard to approximate emissions of specific regions and countries on a consumer-basis.

Thirdly, concerning the *gas mix* taken into consideration, alternative choices can have major impacts on responsibility for individual countries. Since the pattern of industrial production differed across countries the share of individual countries in the emission of particular gases varies widely across gases. Furthermore, the inclusion of different sets of GHGs has other impacts on climate change across different climate models – an uncertainty represented in the range of ‘climate sensitivity’ still found in the literature (IPCC, 2007). Specific combinations of the choice of the start, end and evaluation dates may put a somewhat larger weight on short-lived greenhouse gases, for instance.

Table 3.1 Policy choices for establishing responsibilities.

Issues	Options	Considerations/remarks
Basic needs:	• Full responsibility • Limited responsibility	Limited responsibility assumes that harmless emission levels should not be included to determine responsibility
Causal attribution:	• Producer-based • Consumer-based	Producer-based matches official emissions registration conventions. Difficulties in tracing back emissions to consumers.
Greenhouse gas mix:	• Fossil CO_2 • Total CO2 • All Kyoto GHGs	Different historical gas mixes across regions. Different GHGs have different residence times and effects on temperature increases. Kyoto GHGs are part of climate policies.
Land-use change:	• Include • Exclude	Affects concentrations and absorptive capacities of the climate system.
Indicator:	• Radiative forcing • Cumulative emissions • Weighted concentrations • Temperature increase • Integrated temperature • Sea level rise • Damages	Brazilian proposal suggests the use of temperature increase. Note that indicators that are more closely related to climate impacts/damages have a higher degree of uncertainty due to attribution issues. Damages could include indirect effects on economy but are very hard to estimate.
Start date:	• 1750 • 1900 • 1950 • 1990 • 2005 (“now”)	There are shifts in emission concentrations over time between regions. Larger uncertainty in emission levels prior to 1950. Before 1900 even more uncertain 1750 – start emission measuring; 1900 – start EDGAR database; 1950 – post World War II; 1990 – climate change in negotiations (Kyoto Protocol) and first publication of IPCC Assessment report; 2005 – the model used in our analysis includes emissions until 2005.
End date:	• 1990 • 2000 • 2005 (“now”) • 2050 • 2100	Shift in responsibilities between countries (expected growth in non-Annex I countries due to increasing emission levels). After 2005 combination of historical contribution and mitigation efforts, also requires the use of scenarios
Evaluation date:	• 2000 • 2005 (“now”) • 2100 • 2500	Later evaluation date shifts attention to longer living gases in the atmosphere.

Fourth, concerning the *climate change indicator* selection, it should be noted that – like with any type of indicator – there is an obvious trade-off in accuracy in measurement (early in the cause-effect chain) versus accuracy in impact (late in the cause-effect chain), i.e. choosing temperature increase as indicator may be more accurate in terms of impact (although even then it is a proxy measure), but very uncertain in terms of measurement; while for cumulative emissions as indicator the opposite holds. For those indicators that are not “forward-looking” (radiative forcing, temperature increase and sea-level rise), a time gap between attribution end and evaluation dates enables delayed, but inevitable, effects of the attributed emissions to be taken into account. It therefore shifts the weight toward long-lived gases and towards more recent emissions (den Elzen et al., 1999). An extreme choice as climate change indicator is the use of climate damages. The major advantage of using damages as climate change indicator is that it is the only indicator that can potentially assess the indirect economic impacts of a climate change. Estimation of damages brings, however, further uncertainties that are an order of magnitude higher than for the other indicators due to the requirement that impacts due to anthropogenically-caused climatic changes are estimated and valued. Furthermore, the choice of the discount rate becomes relevant, which brings its own problems.

Fifth, the most significant choice related to the choice of a greenhouse gas mix is the inclusion or exclusion of CO_2 emissions from land use changes in addition to CO_2 from fossil fuel emissions. In fact, the geographical spread of historic land use change emissions differs substantially from the geographical spread of emissions from burning of fossil fuels. Including total (fossil and land-use change) CO_2, N_2O and CH_4 emissions decreases the OECD share by 21 percentage points and increases the Asia share by 14% when compared with fossil fuel CO_2 emissions alone. The effect of the remaining Kyoto greenhouse gases is in most cases negligible with respect to the chosen gas mix (den Elzen et al., 1999). There are fundamental differences between emissions from the combustion of fossil fuels and emissions from *land use and land-use changes and forestry (LULUCF)*. Thus, it becomes a policy choice whether or not to include land use change emissions with substantial reductions in emissions allocated to OECD countries. Significant measurement problems may arise when land use change emissions are included in the analysis. One especially sensitive issue could be the question of how to treat deforestation and land use change during periods of colonialism in parts of Asia, Africa and Latin America. Should these emissions be allocated to the modern independent state, or to the colonising state?

Finally, with respect to the time period of analysis, there are three choices to be made. The first two choices are the *start date* and *end date*, which define the time interval for the emissions that will be attributed to regions (hereafter referred to as the attribution period, i.e. start date – end date). Emissions that occurred before or after the attribution period are included in the climate model but not attributed (see Figure 3.1). The third choice is the *evaluation date*, which is the time for which attribution is performed. Usually the indicator is assessed at the end of the attribution period. The evaluation date may, however, be any later date (see Figure 3.1). This would allow consideration of the long-term effects of emissions, but would only be relevant for indicators that have time-dependent effects i.e. in the cause-effect chain from concentrations onwards, due to the inertia of the climate system. It is important to note that the contribution calculations can be applied to any period of time; Table 3.1 provides a set of considerations.

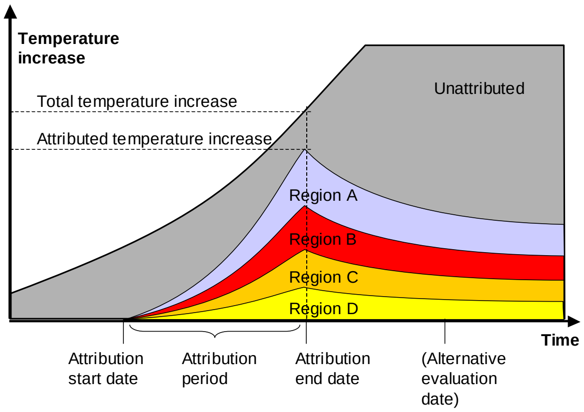


Figure 3.1 Schematisation of the impact of time period choices on attributed temperature changes. Source: Den Elzen et al. (2005a).

3.3 Equality

When using Equality as the guiding principle, the considerations above may be foregone and practical choices may be made based on an evaluation of e.g. the size of the country. These considerations are presented in Table 3.2. The most practical application of equal treatment of all individuals proposed in the mitigation framework is equal emissions per capita (Baer et al., 2000). The latter would shift most rights to emit from developed countries to developing countries and induce a large transfer of wealth from rich to poor countries at the same time. Panayotou et al. (2002), however, argue that equal per capita emissions provide an imperfect solution to the equity dilemma, because not all individuals experience the same damages from climate change. The latter in combination with the large wealth transfers would not generate support for this proposal by the developed countries in climate policy negotiations.

Limited views exist regarding burden sharing of adaptation costs based on equality considerations. Obvious choices are attributing adaptation costs to individual countries on the basis of their share in the world population, or by setting an amount of adaptation costs per square kilometre. Both measures involve a size effect for individual countries, but if the costs would be shared equally one can or should also incorporate the residual damages. As such all burdens would be shared equally, however, ex ante determination of residual damages seems deeply problematic.

Table 3.2 Policy choices for Equality.

Issues	Options	Considerations/remarks
Indicator:	• Population number • Land area	The unit of choice may be an individual or a country

3.4 Capacity

Capacity to Pay approaches that take the economic capacity of a country as a starting point: countries should not bear unacceptably high costs. Müller et al. (2007) provide an excellent overview of different indicators that can be used to assess the Capacity perspective. In this assessment we limit ourselves to two straightforward interpretations of Capacity by looking at absolute GDP levels and the UN Scale of Assessment.

The system of financial contributions of individual member states to the UN is commonly agreed, through the General Assembly, to be based on the principle of Capacity to Pay. The level of these contributions is determined by the Committee on Contributions for a three year period and recorded in the UN Scale of Assessment (UN, 2007). This consensus among member states on the principle used to apportion the cost burden makes the UN Scale of Assessment a fair indicator of Capacity to Pay. In broad terms, countries' share in the cost burden is determined by their recent level of GNI, with some correctional factors. The exact procedure and the level of assessment can be retrieved from the resolution. Noteworthy is that special arrangements have been made for LDCs by setting a maximum assessment rate of 0,01%. For the developed countries this maximum rate is set at 22% is set. On the other hand, as all member states need to share in financing the UN a minimum rate of 0,001% has been set.

Burden sharing schemes based on Capacity to Pay can be implemented in two forms, e.g. flat rates and progressive rates. Flat rates distribute the total costs climate change such that all countries pay an equal share of their wealth. A problem with applying flat rates is that the outcomes are not fully dealt with (Shue, 1999). With flat rates, people or countries can fall below a minimum income level required for survival. Baer et al. (2007) defines Capacity to Pay in a different way and analyzes how much countries are capable of paying above a certain threshold level. The latter implies that high-income countries should contribute about 80% to the costs of climate change. Progressive rates display a growing share of wealth with increasing incomes. So those who are wealthier also pay relatively more. This is another way to overcome the above-explained difficulty. Criticism on progressive rates holds that it takes away incentives for becoming wealthy in the first place.

Table 3.3 Policy choices for Capacity.

Issues	Options	Considerations/remarks
Indicator:	• Gross Domestic Product (GDP)	country total vs. per capita
	• UN Scale of Assessment	flat rate vs. progressive rate

3.5 CBDR assessment: A set of concrete choices

The described policy options in combination with the technical/scientific options outlined in Appendix I produce an extremely complex set of choices for policymakers. There are many different combinations of options, each leading to specific outcomes. In the following chapter we work towards a restricted set of concrete (feasible) choices in the form of so-called images, or scenarios. However, to illustrate the impact of specific choices on the historical responsibility of countries, we first determine a "default case" in the numerical assessment in Chapter 4 along which individual variants of policy choices related to historical responsibility are explored. As Equality and Capacity are outcome-based, separate cases are presented for these perspectives. Justification of the specific values used in these variants is deferred to Chapter 4.

Apart from the cases that resemble each of the different policy perspectives described in Sections 3.2 through 3.4, it can be argued that a full evaluation of an equitable (or fair) distribution of responsibility for adaptation financing internationally should be based on an integration of the underlying perspectives. Only an integrated approach can really lead to a full CBDR assessment (cf. Table 2.1). Integration of the different perspectives can be implemented in several ways; we explore a wide range of alternative scenarios. The specification of these scenarios tries to attain a balance between all fairness considerations, such that the scenarios may serve as a credible basis in negotiations.

Summarising, the following set of scenarios will be explored in the numerical assessment in Chapter 4:

Image	Label	Variants
I	Responsibility	a) Default case (cf. Chapter 4)
		b) Single variation of policy options
II	Equality	a) Contribution on basis of population
III	Capacity	a) Contribution on basis of GDP
		b) Contribution on basis of UN Scale of Assessment 2007-2009
IV	CBDR	1. Full historical contribution to warming – 1750
		2. Historical contribution to warming – 1900
		3. Historical contribution to emissions – 1900
		4. Protocol contribution to warming – 1990
		5. Protocol contribution to emissions – 1990
		6. Limited responsibility protocol contribution to emissions – 1990
		7. Present emissions – 2005
		Each scenario is integrated with two Capacity indicators (leading to 14 CBDR scenarios in total):
		1. GDP
		2. UN scale of assessment 2007-2009

4. Consequences for specific groups of countries

4.1 Introduction

This chapter aims at providing insights into the implications of different policy choices on the attribution of adaptation costs to specific groups of countries, based on the three principles outlined in Chapter 2. Besides analysing the dynamics of these choices a set of scenarios is discussed, using a CBDR, which may serve as a useful starting point or reference case in the negotiation process. The quantitative analysis in this report primarily builds upon the work of den Elzen et al. (2005a), which uses the general MATCH climate model (see Appendix I) to analyse the influence of different policy-related and scientific choices on the calculated regional contributions to global climate change (the "Brazilian Proposal" as discussed in Chapter 1) [3.] We further extend the analysis to a country-level, using the general MATCH climate model combined with a historical emissions dataset at the level of 192 UN countries, as described in Höhne et al. (2008) and briefly explained in the Appendix I.

4.2 Historical responsibility – the default case

In identifying the extent to which regions and individual countries have a historical responsibility for the climate change problem, we concentrate on two indicators of climate change, (i) global warming potential (GWP) weighted cumulative emissions and (ii) their effect on global-mean surface air temperature. These two indicators are most commonly used and most intuitive. The Brazilian proposal suggested that the global-mean surface air temperature increase should be used, but other indicators would be possible as well (UNFCCC, 2002).

The default case (see choices underlined in Table 4.1) serves as a starting point in the analysis of impacts of underlying policy choices on historical responsibility. Following the Brazilian proposal, we calculate the contributions to the temperature increase in 2005 from the emission from 1900 to 2005 for all GHGs and sectors. We assume full responsibility, as this is the most common used and does not require the difficulty of estimating the emission level associated with harmless climate impacts. In fact, the latter issue has only been introduced recently by Müller et al. (2007). Furthermore, the historical emissions are based on producer-based estimates, because the consumer-based estimates in the literature are not available for all regions and highly uncertain. A limited set of gases is included as historical emission levels on F-gases, i.e. HFCs, PFCs and SF_6, are also surrounded by uncertainty. It seems natural to include all anthropogenic emissions as a starting point for historical responsibility. Data limitations in the period 1750-1900 justify the choice for 1900 as the start date in the default case, because for non-CO_2 gases emission data is non-existent before 1900. Furthermore, LULUCF related CO_2 emission levels are available only from 1850 onwards[4]. The attribution and evaluation date are set in 2005 for two reasons. First, the most recent emission data available date from that year. Second and in line with the first argument, future attribution and evaluation dates

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3 The calculations are at the level of 13 world regions.

4 Extrapolation was used (see Appendix I) in the other scenarios to cover the complete period.

are based on hypothetical emission levels. Hereby, they send out the wrong message, as climate policy is aimed at reducing these emission levels. The attribution period does not end in 1990, because we are interested in establishing historical responsibility covering past and more recent periods.

Table 4.1 Specifications of policy choices, with the default case (underlined).

Alternative policy choices evaluated numerically		
Basic needs	<u>Full responsibility,</u> limited responsibility	
Causal attribution	<u>Producer-based</u>	
GHG mix	CO_2, <u>[CO_2, CH_4, N_2O]*</u>	
Indicator	GWP-weighted cumulative GHG emissions, <u>temperature increase</u>	
Land-use change	<u>all anthropogenic GHG emissions</u>, Energy and Industry CO_2 only	
Timeframes	Attribution start date	1750, <u>1900</u>, 1950 and 1990
	Attribution end date	1990, <u>2005</u>, 2050 and 2100
	Evaluation date	<u>2005</u>, 2050, 2100, 2500
	* henceforth labelled as all gases	

Table 4.2 The contributions (%) to the increase in global-mean surface temperature in 2005 according to the default policy choices.

	Country	%		Country	%
Annex I		53	Non-Annex I		47
	Australia	1.5	Rest-OECD		2.6
	Canada	2.2		Mexico*	1.3
	Japan	2.8		Turkey	0.7
	New Zealand	0.3	Brazil, China, India		19
	Russia	7.0		Brazil	4.7
	Ukraine	1.8		China*	10.8
	USA*	18.7		India	3.7
EU-25		18	OPEC		8
EU-15		14		Indonesia*	3.6
	France	2.1		Nigeria	0.8
	Germany*	3.8		Venezuela	0.9
	Italy	1.2	AOSIS		1
	Netherlands	0.6		Cuba*	0.2
	Spain	0.7		Maldives	0.00
	UK	3.2	LDC		5
				Afghanistan	0.07
				Congo*	0.6
			Rest World		13
				Argentina	0.9
				South Africa*	0.9

* Representing the country within the group with the highest contribution
Source: MATCH climate model.

According to these reference calculations, of which the results are presented in Table 4.2, just over half of the historical contributions is attributed to the Annex I countries. At the country level, the two major current emitters of CO_2, USA and China, also have the largest historical contribution. When the European Union (EU25) is regarded as an entity, it accounts for 18 percent of global contributions; with Germany and the UK as the major countries within the EU-total; The Netherlands has a contribution of 0.6 percent. Large developing countries have contributions that are of the same order of magnitude, or are even larger, than those of OECD countries (apart from the USA); the main source of these contributions is however, different: they stem to a much larger extent from emissions due to land-use change and deforestation, whereas for the OECD countries emissions from energy-use play a bigger role.

4.3 Historical responsibility – sensitivity of the default case

The end of the previous section already noted that the choices made to form the default case may affect the attribution of responsibilities. This section investigates the degree to which each of these particular choices individually affects the historical responsibility by varying a single choice at a time, using the default case as a reference.

Varying the indicator

Switching between increases in temperature to cumulative emissions as an indicator of climate change only affects responsibilities to a minimum extent in most cases. The effect is largest for countries that have a time path of emissions different to the world average, like Russia (in relative terms, compare column 1 with column 2). E.g. emissions in Russia were high in the 1980's and are much lower today. Since the high emissions of the 1980's have a full effect on temperature increase and the recent emissions yet have to develop their full effect, the relative contribution of Russia to temperature increase is larger than to cumulative emissions.

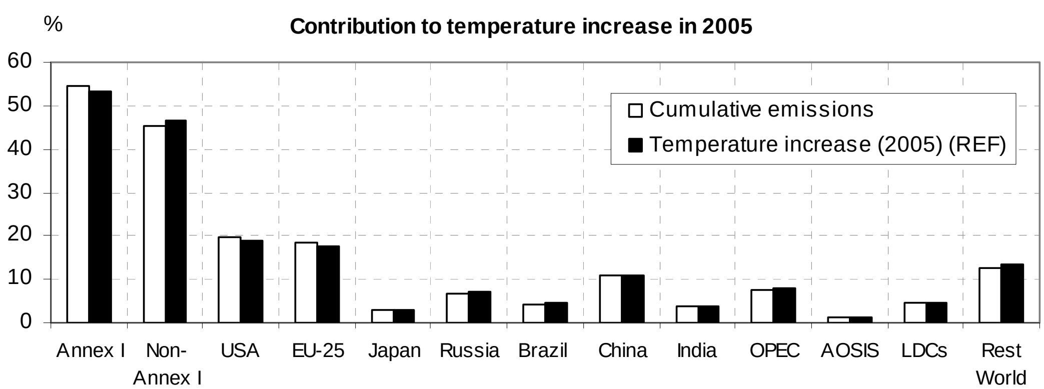

Figure 4.1 Relative contribution to cumulative emissions (first bar), to temperature increase in 2005 (second bar) based on emissions from 1900 to 2005 of all gases including LULUCF for selected countries and country-groups. Source: MATCH climate model.

Full versus limited responsibility

As a second variation we show the influence of limited versus full responsibility. In the full responsibility case responsibilities were determined by the level of aggregate historic emissions – representing causal contributions. Limited responsibility reduces these aggregate emission levels for each country by an annual basic level of harmless emissions per capita[5]. We adopt for the total level of harmless emissions (globally) a value of 7 Gt CO_2eq, the current sink of CO_2 by the oceans (Müller et al., 2007), which is allocated on a per capita basis. For ease of comparison we directly compare responsibilities in the full and limited scenarios based on cumulative emission levels, as the impact of the indicator was only marginal. Results are presented in Figure 4.2 and it is not surprising that the contribution of the LDCs is substantially reduced. It also decreases the contribution of non-Annex I, in particular for India and China due to their large population, and increases the contribution of most Annex I countries. The results are qualitatively in line with those presented by Müller et al. (2007).

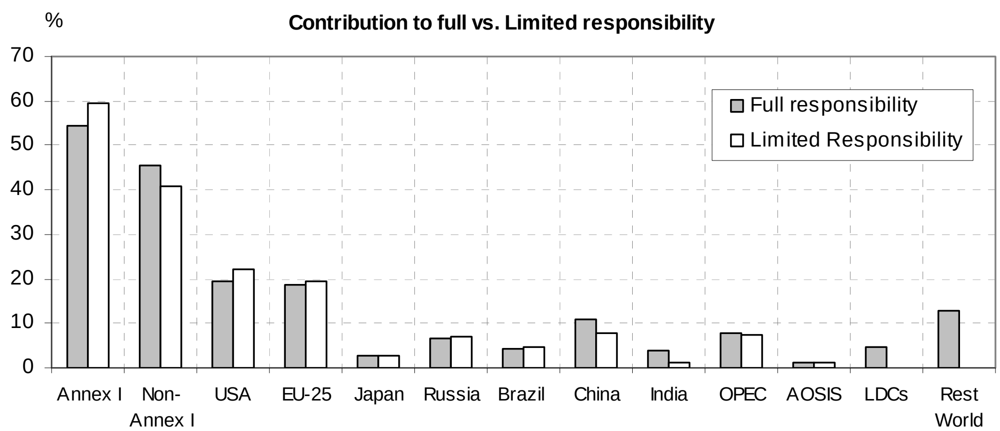

Figure 4.2 Relative contribution to cumulative emissions for full vs. limited responsibility in 2005 based on emissions from 1900 to 2005 of all gases including LULUCF for selected countries and country-groups. Source: MATCH climate model.

Varying the start date

As a next case we show the influence of choosing a different year as of which to start accounting for emissions. Figure 4.3 shows the relative contribution to temperature increase in 2005 due to emissions from 1750, 1900, 1950 and 1990 to 2005 of all gases including LULUCF. The results of the climate model show the start date to have a strong impact on the regional contributions. Choosing a later attribution start date (e.g. 1950 or 1990 instead of 1900) minimises the relative contributions of the industrialised countries ('early emitters') to temperature increase in 2005, emphasizing the shift in heavily emitting countries over time. An exception is Russia, for which the relative contribution increases for start date 1950, since their rate of emission growth is low compared to the OECD90 over the 1900-1950 period. The rapid increase in emissions recently in China and India is also well reflected in the figure, highlighting again that fluctuation in emission profiles in combination with specific start dates affects the attribution of responsibilities.

5 Calculated as the sum over all countries of the product population number in a country multiplied by countries' per capita emissions corrected for per capita harmless emissions

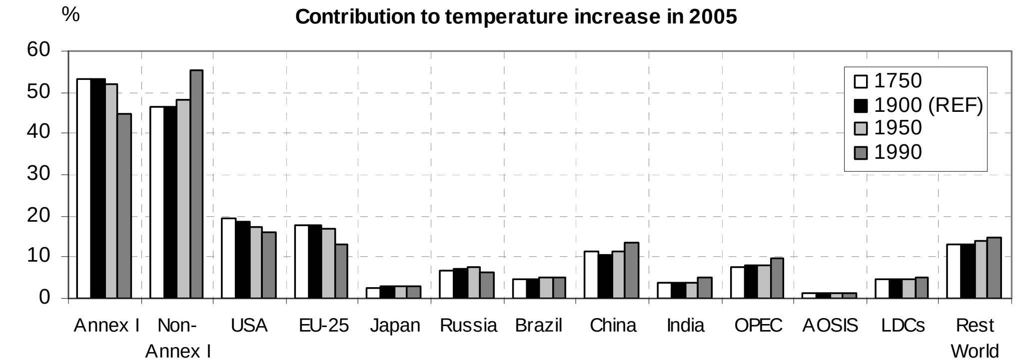

Figure 4.3 *Relative contribution to temperature increase in 2005 based on emissions using various start dates of all gases including LULUCF for selected countries and country-groups. Source: MATCH climate model.*

Varying the end date

Figure 4.4 illustrates the regional contribution to global temperature increase for different attribution end dates in 2005, 2020, 2050 and 2100. The emission start date is set back to the default case of 1900. By extending the attribution (and evaluation) period predicted future levels of emissions and their affect on climate change are also taken into account, having a strong impact on the relative contribution of most regions to increases in temperature.

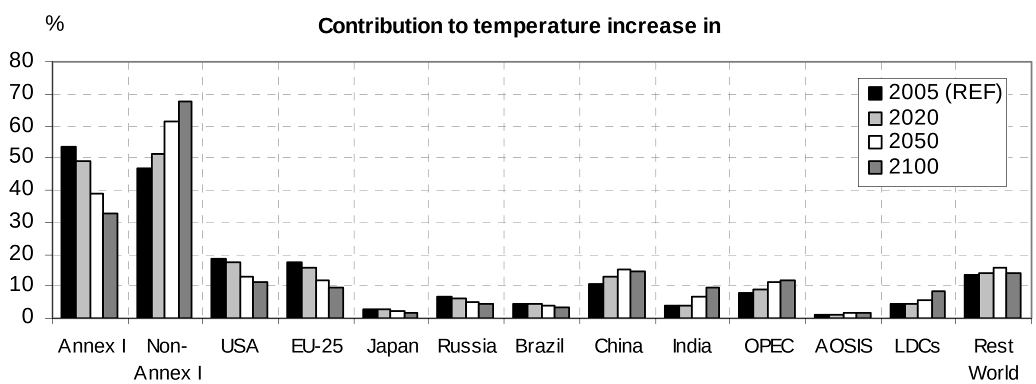

Figure 4.4 *Relative contribution to temperature change at four different end years from emissions from 1900 of all gases of all gases including LULUCF for selected countries and country-groups. The future emission scenario used is A1B. Source: MATCH climate model.*

Choosing a point further into the future lowers the relative contributions of Annex I regions like USA and Russian Federation and raises those of non-Annex I regions, especially those with expected fast-growing emission levels after 2005, like India and China. The responsibility of developing regions for the rise in temperature will increase when high economic growth is combined with a diminishing economical gap between Annex I and non-Annex I regions. Note that future attribution end dates attribute the effect of emissions from a future emissions trajectory, not just historical emissions. Using a different IPCC-SRES emission scenario, as analysed in den Elzen et al. (2005a), has a strong influence on a region's relative contribution to temperature change in 2100 (not shown here).

Varying the evaluation date

The third time-frame choice is the evaluation date, the year in which the attribution calculations are performed; see Figure 3.1. Using an evaluation date after the attribution end date, captures the delayed effects in the climate system and accounts for delayed, but inevitable, global warming, and also discounts early effects. It therefore shifts the weight towards the effect of long-lived gases and towards most recent emissions. Figure 4.5 depicts the impact of two evaluation dates, using the default values for the attribution start date (1900) and end date (2005). For a fixed attribution end date (2005) and an evaluation date far beyond 2005 (here 2100), the relative contribution for Annex I rises, while contributions for the other regions drop. The major reason is related to the relatively small share for the Annex I regions in CH_4 emissions compared to other regions. Since CH_4 has a relatively short lifetime in the atmosphere, the large amount of forcing resulting from CH_4 emissions for non-Annex I regions will dissipate quickly. Thus non-Annex I contributions are lowered compared to the Annex I contributions as the evaluation time is shifted further into the future. Another reason explaining this is the larger Annex I share in historical CO_2 emissions. Historical emissions form a large part of the contribution to CO_2 concentration, due to the slow responses of some components of the carbon cycle. Thus, the fraction of total contribution caused by historical emissions remaining in the atmosphere will fade away more slowly than the contribution from e.g. methane.

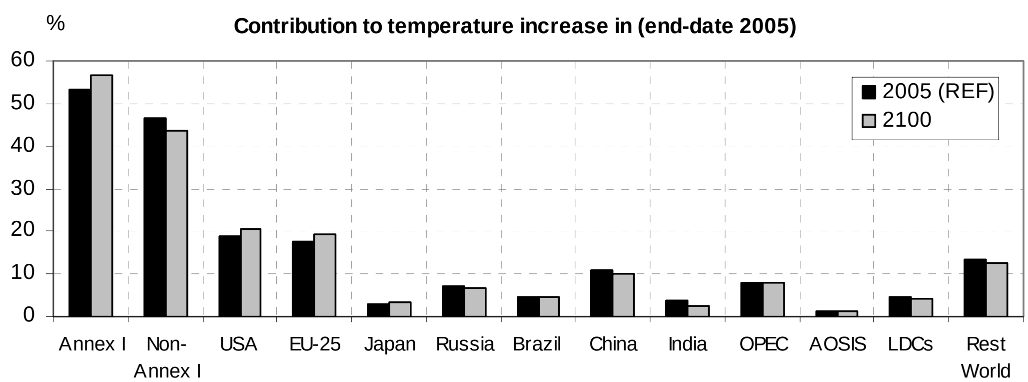

Figure 4.5 Relative contribution to temperature change in 2005 and 2100 based on emissions from 1900 to 2005 of all gases including LULUCF for selected countries and country-groups. Source: MATCH climate model.

Varying the gas mix and land-use change

As a final case we study the influence of including or excluding emissions from land-use change and forestry as well as the non-CO_2 gases CH_4 and N_2O. These emissions are significant for some countries, but are also surrounded by more uncertain compared to CO_2 from energy and industry with respect to reliability of historical emission data. Figure 4.6 shows the relative contribution to temperature increase in 2005 from emissions from 1900 to 2005 of all gases including and excluding LULUCF, for CO_2 only (including LULUCF) and for CO_2 from energy and industry only.

The difference with the default case is largest for countries with high emissions from deforestation and/or from CH_4 and N_2O in particular to Brazil, China and India. Annex I countries usually have lower relative contributions when all gases and sectors are considered, which is most apparent for Japan. The most sensitive countries are those with a low state of industrial development, but large emissions from agriculture and deforestation.

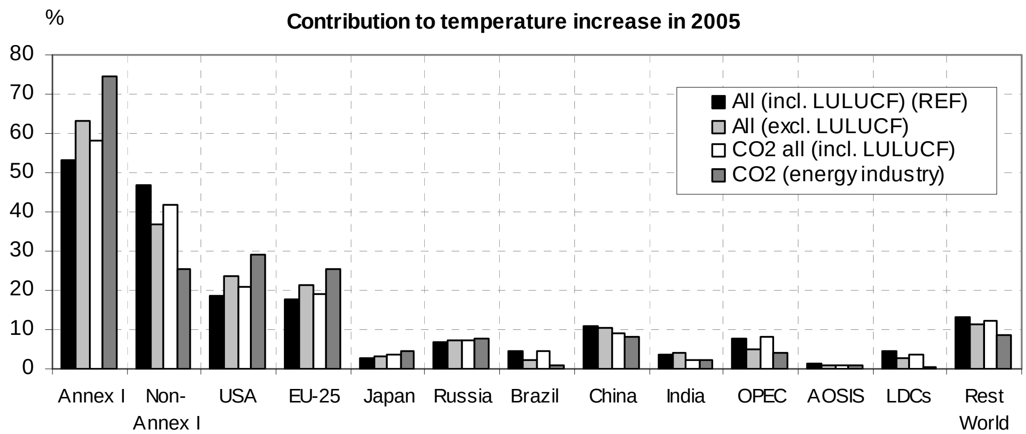

Figure 4.6 Relative contribution to temperature increase in 2005 based on emissions from 1900 to 2005 of all gases including and excluding LULUCF and non CO_2 gases for selected countries and country-groups. Source: MATCH climate model.

4.4 Equality and capacity

The previous analysis focused on responsibilities in the international financing of adaptation from a PPP perspective, by calculating the contribution of specific regions and countries to the climate change problem. In the previous chapters two additional principles were analysed that paid more attention to the distribution of adaptation costs. Both the Equality and Capacity perspective provided indicators that can be used to divide these costs among countries. For these indicators separate scenarios are presented below.

We have included a single indicator for Equality, i.e. equal contribution per country based on population size. The calculation for the contribution of countries is then calculated as the share in world population, as shown in Figure 4.7. Financing adaptation on the basis of share in population evidently leads to a large burden for the developing countries, and may lead to the situation that the developing countries are financing the adaptation costs of the Annex I countries. This option is therefore not very realistic from a policy perspective, especially since this option would imply imposing an equal lump sum tax on everybody.

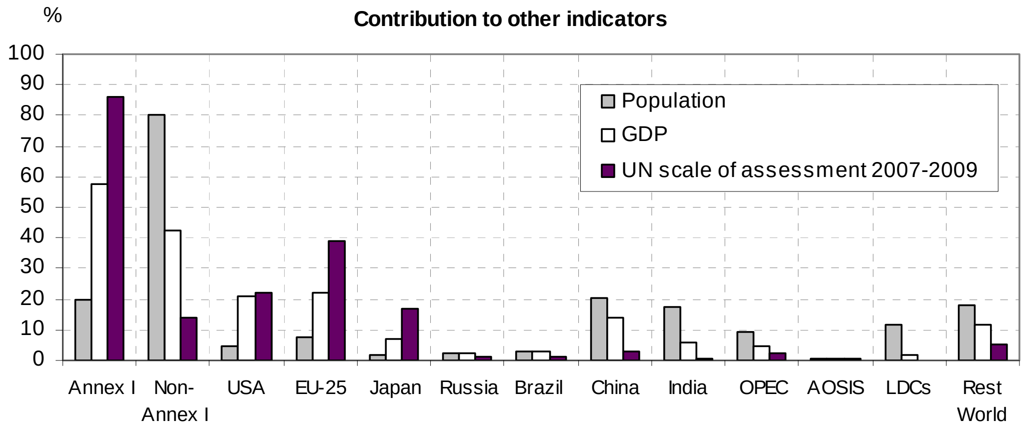

Figure 4.7 Relative contribution to indicators of Equality (population) and Capacity (GDP and UN scale of assessment). Source: WRI-CAIT tool (population, GDP, http://cait.wri.org/) and UN (2007).

Capacity to Pay is, however, likely to offer more feasible indicators for the division of costs. Section 3.4 described two attractive and common used indicators of Capacity to Pay, i.e. GDP and the UN Scale of Assessment. The contribution based on income leads evidently to the highest contribution for the Annex I countries. The burden is even further shifted towards Annex I countries due to the maximum limit of contributions set for LDCs in the UN Scale of Assessment 2007-2009 (UN, 2007)[6]. Interesting in this perspective are the low responsibilities of China and India in the UN scenario. Table 4.3 presents more detailed numbers on the results for these different indicators.

6 We also calculated a scenario based on GDP excluding LDCs, which increases the shares of all other countries by a factor of 1.017, thereby hardly affecting responsibilities; these results are not presented in Figure 4.7.

Table 4.3 The contributions (%) of the equality and capacity indicators.

	Country	%-population	%-GDP	%-UN scale of assessment		Country	%-population	%-GDP	%-UN scale of assessment
Annex I		**20**	**57**	**86**	**Non-Annex I**		**80**	**43**	**14**
	Australia	0.3	1.1	1.8	**Rest-OECD**		**3.5**	**4.6**	**4.8**
	Canada	0.5	1.8	3.0		Mexico*	1.6	1.8	2.3
	Japan	2.0	6.7	16.6		Turkey	1.1	1.0	0.4
	New Zealand	0.1	0.2	0.3	**Brazil, China, India**		41	22	3.9
	Russia	2.2	2.5	1.2		Brazil	2.9	2.6	0.9
	Ukraine	0.7	0.5	0.0		China*	20.3	13.7	2.7
	USA*	4.6	20.7	22		India	17.4	5.9	0.5
EU-25		**8**	**22**	**39**	**OPEC**		**9.0**	**4.4**	**2.1**
EU-15		**6**	**20**	**37**		Indonesia*	3.5	1.4	0.2
	France	0.9	3.1	6.3		Nigeria	2.1	0.2	0.0
	Germany*	1.3	4.1	8.6		Venezuela	0.4	0.3	0.2
	Italy	0.9	2.9	5.1	**AOSIS**		**0.8**	**0.6**	**0.6**
	Netherlands	0.3	0.9	1.9		Cuba*	0.1	0.005	0.1
	Spain	0.7	2.0	3.0		Maldives	0.02	0.03	0.0
	UK	0.9	3.4	6.6	**LDC**		**11.5**	**1.7**	**0.1**
						Afghanistan	0.37	0.04	0.0
						Congo*	0.88	0.07	0.0
					Rest World		**17.9**	**11.6**	**5.0**
						Argentina	0.6	0.9	0.3
						South Africa*	0.7	0.9	0.3

* Representing the country within the group with the highest contribution
Source: WRI-CAIT tool (population, GDP, http://cait.wri.org/) and UN (2007).

4.5 CBDR

4.5.1 CBDR scenarios

Obviously not any of these individual cases would survive on itself in the negotiations process on coping with the burdens of climate change. A more realistic approach is to combine elements of Responsibility and Capacity in order to have a more feasible set of scenarios. Essential for this approach is to determine a target level of required adaptation (and mitigation) funds that can be divided along CBDR. The way in which these funds should be divided is highly dependent on the balance between Responsibility and Capacity and the set of policy choices as discussed in Table 3.1. For this purpose, we explore a whole range of scenarios that may provide an image of potential cost distributions under a new climate policy.

Within these scenarios we strive to include as many GHGs as possible, LULUCF and the most recent set emissions, because all contribute to the problem of climate change and hence should be considered in a *fair* distribution of its burden based on Responsibility. This implies that we maintain part of the settings from our default case, i.e. including all gases, LULUCF and set the attribution and evaluation date up to 2005. Note that we do not include projected future emission levels as they conflict with the goal of climate policy to reduce them, and we prefer to use data of historical observed data, and not based on uncertain future emission projections. Furthermore, we assume an equal balance between Responsibility and Capacity by giving both an equal weight in the calculations.

Variations are brought in by (i) the extent to which countries can be held responsible for their past emissions, (ii) the indicator of climate change and (iii) full or limited responsibility, i.e. without or with correction for “harmless” emissions. With respect to Capacity to Pay, both the GDP and the UN Scale of Assessment 2007-2009 are used to illustrate these various responsibility scenarios. Below we discuss in total 7 CBDR scenarios and illustrate them for each indicator for Capacity in Figure 4.8 and Figure 4.9.

CBDR scenario #1: Full historical contribution to warming

(including all GHG emissions from 1750 to 2005 including LULUCF; indicator: temperature change)

From a PPP perspective countries are responsible for the effects all their past emissions had and still have on the climate system. This is illustrated for the Responsibility part of the CBDR scenario by including all gases and by setting the start date at 1750, the date from which emission data is available, such that all known emission levels are attributed to individual countries and form the basis for a full responsibility to global warming.

CBDR scenario #2: Historical contribution to warming (default case)

(including all GHG emissions from 1900 to 2005 including LULUCF; indicator: temperature change)

The Responsibility part of this CBDR scenario is equivalent to our default case presented in section 4.2. Compared to CBDR scenario 1 this scenario has the same goal of compensating for climate change damages caused by individual countries. The reliability of the underlying emission data has, however, improved by setting the start date to 1900. As noted in Section 4.3 the impacts of changing the start date from 1750 to 1900 can be expected to be marginal.

CBDR scenario #3: Historical contribution to emissions

(including all GHG emissions from 1900 to 2005 including LULUCF; indicator: cumulative emissions)

As not all impacts of past emissions have revealed themselves through increases in temperature it can be argued that it is fairer to distribute the adaptation cost based on cumulative emission levels, as this indicator does not have a time lag.

CBDR scenario #4: Protocol contribution to warming

(including all GHG emissions from 1990 to 2005 including LULUCF; indicator: temperature change)

Knowing about climate change might not be sufficient to establish state responsibility. A more convincing argument is that countries could (and maybe should) have acted from the moment they started to negotiate on how to address the problem. In the case of climate change negotiations started around 1990. Therefore, countries are assumed to be responsible from 1990 onwards for the effect their emissions caused on global average temperature up to now.

CBDR scenario #5: Protocol contribution to emissions

(including all GHG emissions from 1990 to 2005 including LULUCF; indicator: cumulative emissions)

In the same vein CBDR scenario 5 uses 1990 as a starting date, but determines historical responsibility on the basis of cumulative emission levels over the 1990-2005 period.

CBDR scenario #6: Limited responsibility protocol contribution to emissions

(including all GHG emissions from 1990 to 2005 including LULUCF; indicator: cumulative emissions; correcting for basic harmless per capita emissions)

As a variation to CDBR scenario 5 this scenario also takes into account that not all emission levels cause damages. Hence, countries can not be held responsible for their "harmless" emissions during the attribution period.

CBDR scenario #7: Present contributions to emission levels

(*including all GHG emissions for 2005 including LULUCF; indicator: cumulative emissions)*

Alternatively, it can be argued that a PPP based policy can only make countries responsible from the moment that the policy gets into force. Hence, the adaptation regime should only look at recent contributions to climate change. By adopting this approach of sharing the total burden over new emissions level the attention is shifted more towards prevention of new emissions. If the regime only looks at the previous year, new emitters need to cover all the adaptation costs. As these new emissions had limited time to affect the climate system, emission levels are taken as an indicator of climate change.

4.5.2 CBDR implications

Many of the individual variations between scenarios have already been discussed in Section 4.3 and are therefore not discussed here. It is more interesting to look at the overall difference between the CBDR scenarios, especially because they also take into account the capacity aspect. As noted in section 4.4 using the UN Scale of Assessment as an indicator of capacity heavily increases the burden on Annex I countries from around 57% to 86% compared to using GDP levels. However, it becomes apparent from Figure 4.8 that the choice for a particular CBDR scenario in general affects the responsibility of countries in the margin. Of course, several scenarios are extremely beneficial or costly for particular regions and countries. The USA, Europe and Russia, for example, profit from CDBR scenario 7, as the concentration in emission levels moved to other countries during the past decade. Most important to note is that a large transfer of wealth will be directed towards the AOSIS countries and LDCs in each of the CBDR scenarios, which also experience the largest impacts of climate change. This is even achieved more by using the UN Scale of Assessment, which on the other hand also is very beneficial for China. Overall we may conclude that negotiation possibilities exist, which can have major implications for particular countries, especially through the choice of capacity indicator. However, in general impacts vary to a smaller extent for the separate responsibility scenarios. Further details on these implications are provided in Tables 4.4 and 4.5.

Assuming costs of climate adaptation is $100 billion per year (UNDP, 2007), the total financial contribution by The Netherlands could range between $600-1300 million per year, depending on the principles and parameters chosen. For instance, if contributions to global surface mean temperature increases in 2005 are taken as a measure, the contribution of The Netherlands would be 0.6% of total global adaptation costs. However, if we include Capacity to Pay as a criterion and use the UN Scale of Assessment measure, the contribution of The Netherlands would rise to up to 1.3%.

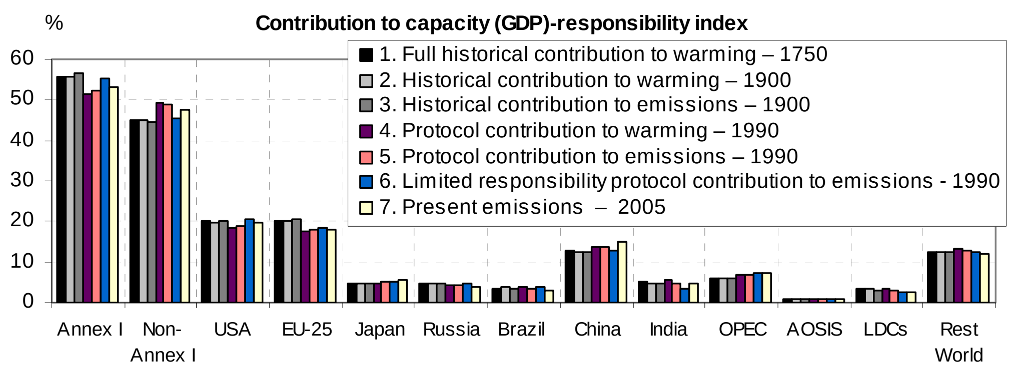

Figure 4.8 The contribution to capacity (GDP)-responsibility index.

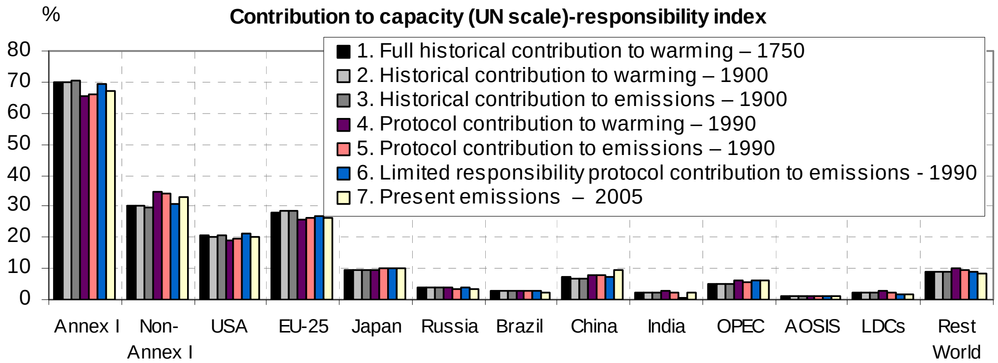

Figure 4.9 The contribution to capacity (UN scale)-responsibility index.

Table 4.4 The contributions (%) based on CBDR scenarios, using GDP for capacity.

	Country	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Annex I		**56**	**53**	**56**	**56**	**51**	**52**	**55**
	Australia	1.3	1.5	1.3	1.3	1.4	1.4	1.5
	Canada	2.0	2.0	2.0	2.0	1.9	1.9	2.1
	Japan	4.7	5.4	4.8	4.8	4.8	5.1	5.2
	New Zealand	0.2	0.1	0.2	0.2	0.2	0.2	0.2
	Russia	4.7	4.0	4.8	4.6	4.4	4.1	4.5
	Ukraine	1.1	0.8	1.2	1.1	1.0	0.9	1.0
	USA*	20.2	19.5	19.9	20.3	18.5	19.0	20.5
EU-25		**20**	**18**	**20**	**20**	**18**	**18**	**19**
EU-15		**17**	**16**	**17**	**17**	**15**	**15**	**16**
	France	2.7	2.2	2.6	2.7	2.3	2.3	2.4
	Germany*	3.9	3.5	4.0	4.1	3.4	3.5	3.7
	Italy	2.0	2.2	2.1	2.1	2.1	2.2	2.2
	Netherlands	0.8	0.8	0.8	0.8	0.8	0.8	0.9
	Spain	1.3	1.6	1.4	1.4	1.4	1.4	1.5
	UK	3.5	2.6	3.3	3.5	2.6	2.6	2.7
Non-Annex I		**45**	**48**	**45**	**44**	**49**	**49**	**46**
Rest-OECD		**3.6**	**4.3**	**3.6**	**3.6**	**4.0**	**4.0**	**4.0**
	Mexico*	1.6	1.7	1.6	1.6	1.7	1.7	1.7
	Turkey	0.8	0.9	0.8	0.8	0.9	0.9	0.8
Brazil, China, India		**21**	**23**	**21**	**21**	**23**	**22**	**20**
	Brazil	3.6	3.1	3.7	3.5	3.8	3.6	3.8
	China*	12.8	15.1	12.4	12.4	13.7	13.7	12.8
	India	5.0	4.8	4.9	4.9	5.5	4.9	3.3
OPEC		**6.1**	**7.2**	**6.2**	**6.0**	**7.1**	**7.0**	**7.2**
	Indonesia*	2.6	2.7	2.5	2.5	2.8	2.9	3.0
	Nigeria	0.5	0.5	0.5	0.5	0.7	0.6	0.4
	Venezuela	0.6	0.5	0.6	0.6	0.6	0.6	0.6
AOSIS		**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**1.0**	**1.1**
	Cuba*	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Maldives	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LDC		**3.3**	**2.6**	**3.2**	**3.2**	**3.5**	**3.0**	**2.5**
	Afghanistan	0.1	0.0	0.1	0.0	0.1	0.0	0.0
	Congo*	0.3	0.3	0.3	0.3	0.4	0.0	0.0
Rest World		**12.3**	**11.8**	**12.5**	**12.2**	**13.4**	**12.7**	**12.2**
	Argentina	0.8	0.7	0.9	0.8	0.9	0.9	0.9
	South Africa*	0.8	1.0	0.9	0.8	0.9	0.9	1.0

Table 4.5 The contributions (%) based on CBDR scenarios, using UN scale of assessment for capacity.

	Country	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Annex I		**70**	**67**	**70**	**70**	**65**	**66**	**69**
	Australia	1.6	1.9	1.6	1.6	1.8	1.7	1.9
	Canada	2.5	2.6	2.6	2.6	2.5	2.5	2.7
	Japan	9.6	10.3	9.7	9.8	9.7	10.0	10.2
	New Zealand	0.3	0.2	0.3	0.3	0.2	0.2	0.2
	Russia	4.1	3.3	4.1	3.9	3.7	3.5	3.9
	Ukraine	0.9	0.5	0.9	0.9	0.8	0.7	0.7
	USA*	20.7	20.0	20.4	20.8	19.0	19.5	21.0
EU-25		**28**	**26**	**28**	**29**	**26**	**26**	**27**
EU-15		**26**	**24**	**26**	**26**	**24**	**24**	**25**
	France	4.2	3.8	4.2	4.3	3.8	3.9	3.9
	Germany*	6.1	5.7	6.2	6.3	5.6	5.7	5.9
	Italy	3.1	3.3	3.2	3.2	3.2	3.2	3.3
	Netherlands	1.2	1.3	1.3	1.3	1.3	1.3	1.3
	Spain	1.8	2.1	1.8	1.9	1.9	1.9	2.0
	UK	5.1	4.2	4.9	5.1	4.2	4.2	4.3
Non-Annex I		**30**	**33**	**30**	**30**	**35**	**34**	**31**
Rest-OECD		**3.7**	**4.4**	**3.7**	**3.7**	**4.0**	**4.1**	**4.1**
	Mexico*	1.8	1.9	1.8	1.7	1.9	1.9	1.9
	Turkey	0.5	0.6	0.5	0.5	0.6	0.6	0.5
Brazil, China, India		**12**	**14**	**12**	**11**	**14**	**13**	**10**
	Brazil	2.7	2.2	2.8	2.6	2.9	2.7	2.9
	China*	7.1	9.5	6.7	6.7	8.1	8.0	7.1
	India	2.2	2.0	2.1	2.1	2.7	2.1	0.5
OPEC		**4.9**	**6.0**	**5.0**	**4.9**	**5.9**	**5.9**	**6.0**
	Indonesia*	2.0	2.1	1.9	1.9	2.1	2.3	2.4
	Nigeria	0.4	0.4	0.4	0.4	0.6	0.5	0.4
	Venezuela	0.5	0.4	0.6	0.5	0.6	0.5	0.6
AOSIS		**0.8**	**0.9**	**0.9**	**0.9**	**0.9**	**1.0**	**1.0**
	Cuba*	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Maldives	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LDC		**2.4**	**1.8**	**2.4**	**2.3**	**2.6**	**2.2**	**1.7**
	Afghanistan	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Congo*	0.3	0.3	0.3	0.3	0.4	0.0	0.0
Rest World		**9.0**	**8.4**	**9.1**	**8.9**	**10.0**	**9.3**	**8.9**
	Argentina	0.6	0.4	0.6	0.5	0.7	0.6	0.6
	South Africa*	0.5	0.7	0.6	0.6	0.6	0.6	0.7

5. Conclusions

As global impacts of climate change become more evident and serious, and given that a large part of the impacts will be felt in less developed countries and regions, the issue of international financing of adaptation to climate change impacts has become more urgent. This report aims to establish a conceptual framework for assessing responsibilities for international financing of adaptation related to climate change, in line with ethical principles established in philosophy, jurisprudence and economics. Using equity as the starting point, several guiding principles are at hand to distribute the costs of global adaptation efforts among countries: no harm; polluter pays; precaution; solidarity; and consequentialism. These principles have been translated into policy principles that we term *responsibility, equality and capacity*. Although it is possible to adopt each one of these principles separately, with divergent results, we believe that a politically legitimate and therefore feasible approach would be to find a balance between them in what we term *common but differentiated responsibility*. We have conducted a quantitative analysis of a variety of policy scenarios to show what consequences they would have for the allocation of responsibility for the international financing of adaptation.

There are many policy choices to be made when establishing the contributions of different countries to climate change. Many alternatives exist; all have their merits. One rule of thumb that arises from these alternatives is that there is a trade-off between being *complete*, in the sense of including as many aspects that contribute to climate change impacts as possible, and being *reliable*, in the sense of being able to provide estimates with reasonable confidence intervals. For example, including greenhouse gases besides CO_2 may be important from a theoretical perspective, but difficulties in estimating past emission levels of these gases, in combination with the limited contribution of these gases to the division of contributions across countries, may argue for a less complete but more reliable approach. From a legal perspective reliability may also be a desirable characteristic of the choices to be made. Precedent suggests that technical uncertainty will undermine claims of responsibility as a basis for establishing a global climate adaptation compensation fund.

The quantitative analysis shows that both the principles themselves, and the values of key parameters that are chosen in expressing them, have a marked influence on results. For instance, if contributions to global surface mean temperature increases in 2005 are taken as a measure, the contribution of The Netherlands would be 0.6% of total global adaptation costs. However, if we include Capacity to Pay as a criterion and use the UN Scale of Assessment measure, the contribution of The Netherlands would rise to up to 1.3%. Assuming costs of climate adaptation is $100 billion per year (UNDP, 2007), the total financial contribution by The Netherlands could range between $600-1300 million per year, depending on the principles and parameters chosen.

References

Allen, M. (2003). Liability for climate change. *Nature, 421*, 891-892.

Alley, R.B., Marotzke, J., Nordhaus, W.D., Overpeck, J.T., Peteet, D.M., Pielke, R.A., Jr., Pierrehumbert, R.T., Rhines, P.B., Stocker, T.F., Talley, L.D. & Wallace, J.M. (2003). Abrupt climate change. *Science, 299*(*5615)*, 2005-2010.

Andronova, N. & Schlesinger, M. (2004). Importance of sulfate aerosol in evaluating the relative contributions of regional emissions to the historical global temperature change. *Mitigation and Adaptation Strategies for Global Change, 9*(*4)*, 383-390.

Baer, P., Athanasiou, T. & Kartha, S. (2007). *The right to development in a climate constrained world: The greenhouse development rights framework*. Berlin, Germany: Heinrich Böll Foundation.

Baer, P., Harte, J., Herzog, A., Hultman, N. & Raymond, L. (2000). *Equal per capita emission rights: The key to a viable climate change policy*. Berkeley: RAEL, University of California.

Barrett, S. (1996). Building property rights for transboundary resources. In Hanna, S.S., Folke, C. & Maler, K.G. (eds.), *Rights to nature*. (pp. 265-285). Washington D.C.: Island Press.

Birnie, P.W. & Boyle, A.E. (2002). *International law and the environment*. 2nd Edition, New York: Oxford University Press.

Botzen, W.J.W., Gowdy, J.M. & van den Bergh, J.C.J.M. (2008). Cumulative CO2 emissions: Shifting international responsibilities for climate debt. *Climate Policy, 8*, 569-576.

Bouwer, L.M. & Vellinga, P. (2005). Some rationales for risk sharing and financing adaptation. *Water Science & Technology, 51*(*5)*, 89-95.

Brans, E.H.P. (2001). *Liability for damage to public natural resources: Standing, damage and damage assessment*. International environmental law and policy series, ISSN 1383-861X, vol. 61. Rotterdam, The Netherlands: Erasmus University.

Cullet, P. (2007). Liability and redress for human-induced global warming: Towards an international regime. *Stanford Journal of International Law, 43*(*1)*, 99-121.

de Campos, C.P. (2007). *Historical land use change CO2 emissions from land use change to agriculture and pasture and the climate change contributions by country – The Proposal by Brazil to the Climate Convention*. PhD Thesis. Rio de Janeiro, Brazil: University of Rio de Janeiro.

de Campos, C.P., Muylaert, M.S. & Rosa, L.P. (2005). Historical CO2 emission and concentrations due to land use change of croplands and pastures by country. *Science of The Total Environment, 346*(*1-3)*, 149-155.

den Elzen, M.G.J., Berk, M.M., Schaeffer, M., Olivier, O.J., Hendriks, C. & Metz, B. (1999). *The Brazilian proposal and other options for international burden sharing: An evaluation of methodological and policy aspects using the FAIR model*. MNP Report (728001011). Bilthoven, The Netherlands: Netherlands Environmental Assessment Agency (MNP).

den Elzen, M.G.J., Fuglestvedt, J., Höhne, N., Trudinger, C., Lowe, J., Matthews, B., Romstad, B., Pires de Campos, C. & Andronova, N. (2005a). Analysing countries' contribution to climate change: Scientific and policy-related choices. *Environmental Science & Policy, 8*(*6)*, 614-636.

den Elzen, M.G.J., Schaeffer, M. & Eickhout, B. (2002a). *Responsibility for past and future global warming: Time horizon and non-linearities in the climate system*. MNP Report (728001022). Bilthoven, The Netherlands: Netherlands Environmental Assessment Agency (MNP).

den Elzen, M.G.J. & Schaeffer, M. (2002b). Responsibility for past and future global warming: Uncertainties in attributing anthropogenic climate change. *Climatic Change, 54*(*1)*, 29-73.

den Elzen, M.G.J., Schaeffer, M. & Lucas, P.L. (2005b). Differentiating future commitments on the basis of countries' relative historical responsibility for climate change: Uncertainties in the 'Brazilian Proposal' in the context of a policy implementation. *Climatic Change, 71*(*3)*, 277-301.

Drumbl, M.A. (2008). *Trail smelter and the International Law Commission's work on state responsibility for internationally wrongful acts and state liability*. Working Paper (No. 03-06). Available at http://ssrn.com/abstract=411764.

Farber, D.A. (2007). Basic compensation for victims of climate change. *University of Pennsylvania Law Review, 155*(*6)*, 1605-1656.

Faure, M.G. & Nollkaemper, A. (2007). International liability as an instrument to prevent and compensate for climate change. *Stanford Journal of International Law, 43*, 123-179.

Fischhendler, I. (2007). Escaping the "polluter pays" trap: Financing wastewater treatment on the Tijuana-San Diego border. *Ecological Economics, 63*(*2-3)*, 485-498.

Franck, T. (1995). *Fairness in international law and institutions*. Oxford: Oxford University Press.

Gaskell, G., Bauer, M.W., Durant, J. & Allum, N.C. (1999). Worlds apart? The reception of genetically modified foods in Europe and the U.S. *Science, 285*, 384-387.

Gee, D. & Vaz, S.F. (2001). *Late lessons from early warnings: The precautionary principle 1896-2000*. ISBN 9291673234. Luxembourg: Office for Official Publications of the European Communities.

Grasso, M. (2007). A normative ethical framework in climate change. *Climatic Change*, *81*(*3)*, 223-246.

Heyward, M. (2007). Equity and international climate change negotiations: A matter of perspective. *Climate Policy, 7*, 519-534.

Höhne, N. & Blok, K. (2005). Calculating historical contributions to climate change – Discussing the 'Brazilian Proposal'. *Climatic Change, 71*(*1)*, 141-173.

Höhne, N., Blum, H., Matthews, B., Fuglestvedt, J., Skeie, R.B., Kurosawa, A., Hu, G., Lowe, J., Gohar, L., Nioac de Salles, A.C. & Ellermann, C. (2008). Contributions of individual countries' emissions to climate change and their uncertainty. *Climatic Change (submitted)*.

Houghton, R.A. (2003). *Emissions (and sinks) of carbon from land-use change (Estimates of national sources and sinks of carbon resulting from changes in land use, 1950 to 2000)*. Report to the World Resources Institute from the Woods Hole Research Center. Available at: http://cait.wri.org.

IEA (2006). *CO2 emissions from fuel combustion (2006 edition)*. International Energy Agency.

Ikeme, J. (2003). Equity, environmental justice and sustainability: Incomplete approaches in climate change politics. *Global Environmental Change*, *13*(*3)*, 195-206.

IMAGE team (2001). *The IMAGE 2.2 implementation of the SRES scenarios: A comprehensive analysis of emissions, climate change and impacts in the 21st century*. Bilthoven, The Netherlands: National Institute of Public Health and the Environment (RIVM).

IPCC (2007). *IPCC Fourth Assessment Report: Summary for policymakers of the Synthesis Report*. Available at http://www1.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf.

Joos, F., Bruno, M., Fink, R., Siegenthaler, U., Stocker, T.F., Le Quere, C. & Sarmiento, J.L. (1996). An efficient and accurate representation of complex oceanic and biospheric models of anthropogenic carbon uptake. *Tellus B*, *48*, 397-417.

Joos, F., Plattner, G.K., Stocker, T.F., Marchal, O. & Schmittner, A. (1999). Global warming and marine carbon cycle feedbacks on future atmospheric CO2. *Science, 284*(*5413)*, 464.

Klein Goldewijk, C.G.M. & Battjes, J.J. (1995). *The IMAGE 2 hundred year (1890-1900) data base of the global environment (HYDE)*. RIVM Report (481507008). Bilthoven, The Netherlands: National Institute of Public Health and the Environment (RIVM).

Knox, J.H. (2002). The myth and reality of transboundary environmental impact assessment. *The American Journal of International Law, 96*(*2)*, 291-319.

Low, N. & Gleeson, B. (1998). *Justice, society and nature: An exploration of political ecology*. London and New York: Routledge.

Marland, G., Boden, T.A. & Andres, R.J. (2003). Global, regional, and national fossil fuel CO2 emissions. In ORNL Carbon Dioxide Information Analysis Center (DoE) (ed.), *Trends: A Compendium of Data on Global Change*. Oak Ridge, Tennessee, U.S.A.: Available online at: http://cdiac.esd.ornl.gov/trends/emis/meth_reg.htm.

Mason, M. (2003). Civil liability for oil pollution damage: examining the evolving scope for environmental compensation in the international regime. *Marine Policy, 27*(*1)*, 1-12.

Matthews, H.D. & Caldeira, K. (2008). Stabilizing climate requires near-zero emissions. *Geophysical Research Letters, 35*, 1-5.

Montenegro, A., Brovkin, V., Eby, M., Archer, D. & Weaver, A.J. (2007). Long-term fate of anthropogenic carbon. *Geophysical Research Letters, 34*, 1-5.

Müller, B. (2008). *International adaptation finance: The need for an innovative and strategic approach*. OIES Report (EV 42). Oxford, UK: Oxford Institute for Energy Studies.

Müller, B., Höhne, N. & Ellermann, C. (2007). *Differentiating (historic) responsibilities for climate change*. Oxford, UK: Oxford Institute for Energy Studies.

Najam, A., Huq, S. & Sokona, Y. (2003). Climate negotiations beyond Kyoto: developing countries concerns and interests. *Climate Policy, 3*(*3)*, 221-231.

OECD (1972). *Recommendation of the council on guiding principles concerning international economic aspects of environmental policies*. Report reprinted in OECD (1975), The Polluter Pays Principle: Definition, Analysis, Implementation (No. C(72)128). Paris: OECD.

Oxfam International (2007). *Adapting to climate change: What's needed in poor countries, and who should pay*. Available at http://www.oxfam.org/en/policy/briefingpapers/bp104_climate_change_0705.

Paavola, J. & Adger, W.N. (2006). Fair adaptation to climate change. *Ecological Economics, 56*(*4)*, 594-609.

Panayotou, T., Sachs, J.D. & Zwane, A.P. (2002). Compensation for "meaningful participation" in climate change control: A modest proposal and empirical analysis. *Journal of Environmental Economics and Management, 43*(*3)*, 437-454.

Perman, R., Ma, Y., McGilvray, J. & Common, M. (2003). *Natural resource and environmental economics*. 3rd Edition, Essex: Pearson.

Ramaswamy, V., Boucher, O. & Haigh, J. (2001). Atmospheric chemistry and greenhouse gases. In Houghton, J.T. (ed.), *IPCC Third Assessment – Climate Change 2001, The Scientific Basis*. Cambridge, UK: Cambridge University Press.

Rao, P.S. (2002). Prevention of transboundary harm from hazardous activities: A subtopic of international liability. *Environmental policy and Law, 32*(*1)*, 22-27.

Ringius, L., Frederiksen, P. & Birr-Pedersen, K. (2002a). *Burden sharing in the context of global climate change*. NERI Technical Report (No. 424). Denmark: National Environmental Research Institute, Ministry of the Environment.

Ringius, L., Torvanger, A. & Underdal, A. (2002b). Burden sharing and fairness principles in international climate policy. *International Environmental Agreements: Politics, Law and Economics, 2*(*1*), 1-22.

Rive, N., Torvanger, A. & Fuglestvedt, J.S. (2006). Climate agreements based on responsibility for global warming: Periodic updating, policy choices, and regional costs. *Global Environmental Change, 16*(*2*), 182-194.

Rose, A., Stevens, B., Edmonds, J. & Wise, M. (1998). International equity and differentiation in global warming policy. *Environmental and Resource Economics, 12*(*1*), 25-51.

Seymour, S., Lowe, P. & Cox, G. (1992). Nitrates in water: The politics of the polluter pays principle. *Social Ruralis, 32*(*1*), 82-103.

Shue, H. (1999). Global environment and international inequality. *International Affairs, 75*, 531-545.

Shukla, P.R. (1999). Justice, equity and efficiency in climate change: A developing country perspective. In Toth, F. (ed.), *Fairness concerns in climate change*. London: Earthscan Publications.

Srinivasan, U.T., Carey, S.P., Hallstein, E., Higgins, P.A.T., Kerr, A.C., Koteen, L.E., Smith, A.B., Watson, R., Harte, J. & Norgaard, R.B. (2008). The debt of nations and the distribution of ecological impacts from human activities. *Proceedings of the National Academy of Sciences, 105*(*5*), 1768-1773.

Stern, N. (2007). *The economics of climate change: The Stern review*. Cambridge: Cambridge University Press.

Stott, P.A. (2000). External control of 20th century temperature by natural and anthropogenic forcings. *Science, 290*(*5499*), 2133.

Tol, R.S.J. (2006). *The polluter pays principle and cost-benefit analysis of climate change: An application of Fund*. FEEM Working Paper (No. 88.2006). Available at http://ssrn.com/abstract=907456.

Tol, R.S.J. & Verheyen, R. (2004). State responsibility and compensation for climate change damages: A legal and economic assessment. *Energy Policy, 32*(*9*), 1109-1130.

Trouwborst, A. (2007). The precautionary principle in general international law: Combating the Babylonian confusion. *RECIEL, 16*(*2*), 185-195.

Trudinger, C. & Enting, I. (2005). Comparison of formalisms for attributing responsibility for climate change: Non-linearities in the Brazilian Proposal approach. *Climatic Change, 68*(*1*), 67-99.

UN (2007). *Scale of assessments for the apportionment of the expenses of the United Nations*. Resolution adopted by the General Assembly (A/RES/61/237). New York, USA.

UNDP (2007). *World development report 2007/2008 – Fighting climate change: Human solidarity in a divided world*. New York: UNDP.

UNFCCC (1997). *Paper no. 1: Brazil; Proposed elements of a protocol to the United Nations Framework Convention on Climate Change*. UNFCCC Report (UNFCCC/AGBM/1997/MISC.1/Add.3 GE.97). Bonn, Germany.

UNFCCC (2002). *Methodological issues, scientific and methodological assessment of contributions to climate change*. Report of the expert meeting, Note by the secretariat (UNFCCC/SBSTA/2002/INF.14,). Bonn, Germany: Available at http://www.unfccc.int.

UNFCCC (2005). *2005 Annex I Party GHG inventory submissions (1990 – 2003)*. Common reporting format from Finland to the UNFCCC.

USEPA (2006). *Global anthropogenic non-CO2 greenhouse gas emissions: 1990-2020*. Washington, D.C., USA: US Environmental Protection Agency.

van Vuuren, D.P., Lucas, P.L. & Hilderink, H. (2007). Downscaling drivers of global environmental change: Enabling use of global SRES scenarios at the national and grid levels. *Global Environmental Change, 17*(*1)*, 114-130.

Verheyen, R. (2005). *Climate change damage and international law: Prevention duties and state responsibility*. ISBN 9789004146501. Leiden, The Netherlands: Martinus Nijhoff.

Voigt, C. (2008). State responsibility for climate change damages. *Nordic Journal of International Law*, *77*, 1-22.

Von Meijenfeldt, H.G. & Schippers, E.C.M. (1990). The bill is presented: Motives behind the recovery of soil clean-up costs in the Netherlands. In Arendt, F., Hinsenveld, M. & van den Brink, W.J. (eds.), *Contaminated Soil '90, Vol. 1*. (pp. 11-16). Dordrecht: Kluwer Academic Publishers.

Appendix I. Modelling assumptions and data choices

MATCH climate model

For this analysis we use the simple default model as used in the earlier MATCH exercise (also MATCH climate model), as described in detail in (den Elzen et al., 2005a). This model is based on Impulse Response Functions (IRFs) for the calculations of concentrations, temperature change and sea level rise, and based on functional dependencies from the IPCC-TAR (Ramaswamy et al., 2001) for the radiative forcing (e.g., logarithmic function for CO_2). For the CO_2 concentration, the IRF is based on the parameterisations of the Bern carbon cycle model of Joos et al. (1996; 1999), as applied in the IPCC Third Assessment Report. For the concentrations of the non-CO_2 GHGs, single-fixed lifetimes are used. The total radiative forcing considered here consists of the radiative forcing from CO_2, CH_4 and N_2O plus direct and indirect radiative forcing from aerosols derived by the coupled ocean-atmosphere General Circulation Model HADCM3 (Stott, 2000). Surface temperature change is modelled using two-term IRFs also derived from the HADCM3 model. The contributions of individual emissions to concentrations, temperature change and sea level rise are calculated by separately applying all equations defined at global level to the emissions of the individual emitting regions. The assumption of linearity of these steps in the MATCH climate model ensures that the sum of the regional contributions is equal to the contribution of the global total. The relationship between concentration and radiative forcing is non-linear ('saturation effect'). Here, the normalised "marginal method" is used as default (taking the effect of small additional emissions normalized so that the sum of all contributions is the total effect, see also (den Elzen et al., 2005a). Here, we use the ECOFYS implementation of the MATCH climate model (see: Höhne et al., 2005; Höhne et al., 2008). This model calculates the contribution to climate impact indicators, including global temperature increase at the levels of countries, using an historical emissions data set based on the UNFCCC, IEA, EPA and PBL, as described below.

Emissions data

A new emission datasets has been compiled with results for 192 countries or regions for three sectors: energy and industry (CO_2, CH_4, N_2O), agriculture/waste (non-CO_2) and land use change and forestry (CO_2) from1750 to 2100. Hydrofluorocarbons (HFCs and HCFCs), Perfluorocarbons (PFCs) and Sulphurhexafluoride (SF_6) were not included as historical emission estimates were not available on a gas-by-gas level. Total cumulative GWP-weighted historical emissions of these omitted gases (as collected in: Höhne et al., 2005) amount to about 0.5% of total cumulative historical emissions of CO_2, CH_4 and N_2O collected here.

The emissions database was compiled by first collecting historical and future emission estimates by country or region, by gas and by sector from the following sources and ordered them in the following hierarchy (see also Höhne et al., 2008) based on expert judgement. The datasets vary in their completeness and sectoral split:

1. National submissions to the UNFCCC as collected by the UNFCCC secretariat and published in the GHG emission database available at their web site. For Annex I countries the latest available year is usually from 1990 to 2004. Most non-Annex I countries report only or until 1994 (UNFCCC, 2005).
2. CO_2 emissions from fuel combustion as published by the International Energy Agency. It covers usually the year 1970 to 2004 (IEA, 2006)[7] This dataset was supplemented by process emissions from cement production from (Marland et al., 2003) to be cover all industrial CO_2 emissions.
3. Emissions from CH_4 and N_2O as estimated by the US Environmental Protection Agency. It covers the years 1990 to 2005 (USEPA, 2006).
4. CO_2 emissions from fuel combustion and cement production as published by Marland (2003) as retrieved in 2006. It includes emissions from 246 countries (existing and no longer present today) from earliest 1750 (only OECD countries) or 1950 to 2003.
5. Regional past data: Edgar/Hyde available for all sectors, 17 regions from 1890 to 1990 (Klein Goldewijk and Battjes, 1995).
6. Regional future regional emission data: PBL/RIVM IMAGE 2.2 implementation of the SRES scenarios (IMAGE team, 2001), available for all gases and sectors from 1970 to 2100 for 17 regions.

The new database was then completed by applying an algorithm to the hierarchy. For each country, gas and the sectors "energy & industry" and "waste & agriculture", the algorithm comprises the following steps:

1. For all data sets, missing years in-between available years within a data set are linearly interpolated and the growth rate is calculated for each year step.
2. The data source is selected, which is highest in hierarchy and for which emission data are available. All available data points are chosen as the basis for absolute emissions.
3. Still missing years are filled by applying the growth rates from the highest data set in the hierarchy for which a growth rate is available.

Some past and future emissions are only available on a regional basis and not country-by-country. In these cases we applied regional growth rates to country level emission estimates. This essentially back casts the current territory of a county into the past; territorial changes are not taken into account. Other methods for downscaling regional growth to individual countries within a region are available (van Vuuren et al., 2007).

For LULUCF, we used a different approach (de Campos, 2007). The use of growth rates is not possible here as the estimates can be negative (removals). Hence we used the simple approach of taking the average between the two datasets that for the global total represent the two extremes: Houghton (2003) and IVIG (de Campos et al., 2005). Both

[7] The IEA calculation is less detailed than national calculations and may be treating distribution losses and feedstock differently.

datasets were extended to 2100 using SRES scenarios. To downscale from SRES regions to nations, a concept of “potential LULUCF sink” is used, simply assuming that the more a country has emitted from LULUCF in the past, the more potential it has to create a sink by reverting to the original biomes. As potential LULUCF depends on past emissions, this also prolongs the difference between Houghton and IVIG. A more sophisticated model should take into account climate feedbacks and changing demand for agriculture etc., this is just a first approximation for reasonable downscaling.

Evidently the emissions data are surrounded with uncertainties, which are larger for the emissions in the past than present, and also larger for the non-CO_2 greenhouse gases than CO_2. Therefore this dataset also includes a low and high estimate, as described in Höhne et al. (2008). For the analysis in this study, we will however not present the impact of uncertainties on the countries’ contributions, and refer to Höhne et al. (2008).

Table I.1 The contributions (%) to the climate indicator (global-mean surface temperature change (default) or cumulative GHG emissions or other indicator) in end-date (default: 2005).

		Indicator		Start date				End date			
Cases		Cumulative Emissions	Temperature (REF)	1750	1900 (REF)	1950	1990	2005 (REF)	2020	2050	2100
	Country	%	%	%	%	%	%	%	%	%	%
Annex I		**55**	**53**	**53**	**53**	**52**	**45**	**53**	**49**	**39**	**32**
Non-Annex I		**45**	**47**	**47**	**47**	**48**	**55**	**47**	**51**	**61**	**68**
Annex I		**55**	**53**	**53**	**53**	**52**	**45**	**53**	**49**	**39**	**32**
	Australia	1.5	1.5	1.5	1.5	1.6	1.8	1.5	1.5	1.3	1.2
	Canada	2.2	2.2	2.1	2.2	2.1	2.0	2.2	2.1	1.7	1.5
	Japan	2.9	2.8	2.6	2.8	3.0	2.8	2.8	2.8	2.3	1.8
	New Zealand	0.3	0.3	0.2	0.3	0.3	0.2	0.3	0.2	0.2	0.1
	Russia	6.6	7.0	6.9	7.0	7.4	6.2	7.0	6.3	5.3	4.6
	Ukraine	1.7	1.8	1.7	1.8	2.0	1.5	1.8	1.5	1.2	1.0
	USA	19.6	18.7	19.5	18.7	17.5	15.9	18.7	17.4	13.2	11.0
	EU-25	**19**	**18**	**18**	**18**	**17**	**13**	**18**	**16**	**12**	**10**
	EU-15	**15**	**14**	**14**	**14**	**13**	**10**	**14**	**12**	**9**	**7**
	France	2.2	2.1	2.1	2.1	1.9	1.4	2.1	1.8	1.3	1.0
	Germany	4.0	3.8	3.6	3.8	3.6	2.6	3.8	3.2	2.3	1.8
	Italy	1.3	1.2	1.2	1.2	1.3	1.3	1.2	1.2	1.0	0.9
	Netherlands	0.7	0.6	0.6	0.6	0.7	0.6	0.6	0.6	0.5	0.4
	Country	%	%	%	%	%	%	%	%	%	%
	Spain	0.8	0.7	0.7	0.7	0.7	0.8	0.7	0.8	0.8	0.7
	UK	3.5	3.2	3.5	3.2	2.6	1.8	3.2	2.6	1.8	1.3
Rest-OECD		2.5	2.6	2.5	2.6	2.6	3.3	2.6	3.0	3.8	3.9
	Mexico	1.2	1.3	1.3	1.3	1.3	1.5	1.3	1.4	1.6	1.5
	Turkey	0.7	0.7	0.7	0.7	0.7	0.8	0.7	0.8	1.1	1.2
BRIC		19	19	20	19	20	23	19	21	26	27
	Brazil	4.4	4.7	4.4	4.7	4.9	4.9	4.7	4.6	3.8	3.2
	China	10.8	10.8	11.6	10.8	11.2	13.5	10.8	12.7	15.1	14.8
	India	3.8	3.7	3.9	3.7	3.8	4.9	3.7	4.2	7.0	9.4
OPEC		7.6	7.9	7.8	7.9	8.2	9.7	7.9	8.9	11.5	11.9
	Indonesia	3.7	3.6	3.8	3.6	3.6	4.1	3.6	3.5	2.9	2.4
	Nigeria	0.7	0.8	0.8	0.8	0.9	1.1	0.8	1.0	2.0	2.8
	Venezuela	0.8	0.9	0.9	0.9	1.0	0.9	0.9	1.0	1.1	0.8
AOSIS		1.2	1.2	1.1	1.2	1.2	1.2	1.2	1.3	1.5	1.6
LDCs		4.6	4.7	4.8	4.7	4.5	5.1	4.7	4.8	5.6	8.2
Rest World		12.7	13.3	12.9	13.3	14.0	14.9	13.3	13.9	15.6	13.9
	Argentina	0.8	0.9	0.8	0.9	0.9	1.0	0.9	0.9	1.0	0.9
	South Africa	0.8	0.9	0.8	0.9	0.9	1.0	0.9	1.0	1.4	2.1

Table I.1. Cont'd.

		Sectors				Full vs. limited responsibility		Indicator			
Cases		All incl. LULU-CF (REF)	All excl. LULU-CF	CO_2 all incl. LULU-CF	CO_2 energy indus-try	Full respon-sibility	Limited respon-sibility	Emis-sions	Popula-tion	GDP	UN scale of as-sess-ment 2007-2009
	Country	%	%	%	%	%	%	%	%	%	%
Annex I		**53**	**63**	**58**	**74**	**55**	**59**	**48**	**20**	**57**	**86**
Non-Annex I		**47**	**37**	**42**	**26**	**45**	**41**	**52**	**80**	**43**	**14**
Annex I		**53**	**63**	**58**	**74**	**55**	**59**	**48**	**20**	**57**	**86**
	Australia	1.5	1.4	1.3	1.2	1.5	1.7	1.9	0.3	1.1	1.8
	Canada	2.2	2.1	2.4	2.3	2.2	2.5	2.2	0.5	1.8	3.0
	Japan	2.8	3.2	3.6	4.5	2.9	2.9	4.0	2.0	6.7	16.6
	New Zea-land	0.3	0.2	0.2	0.1	0.3	0.3	0.1	0.1	0.2	0.3
	Russia	7.0	7.4	7.1	7.7	6.6	7.1	5.5	2.2	2.5	1.2
	Ukraine	1.8	2.2	1.7	2.3	1.7	1.7	1.0	0.7	0.5	0.0
	USA	18.7	23.7	20.9	29.2	19.6	22.3	18.0	4.6	20.7	22
	EU-25	**18**	**21**	**19**	**26**	**19**	**20**	**14**	**8**	**22**	**39**
	EU-15	**14**	**17**	**15**	**20**	**15**	**16**	**11**	**6**	**20**	**37**
	France	2.1	2.5	2.1	2.8	2.2	2.4	1.3	0.9	3.1	6.3
	Germany	3.8	4.6	4.3	5.8	4.0	4.3	2.8	1.3	4.1	8.6
	Italy	1.2	1.5	1.3	1.8	1.3	1.2	1.5	0.9	2.9	5.1
	Netherlands	0.6	0.8	0.7	0.9	0.7	0.7	0.7	0.3	0.9	1.9
	Spain	0.7	0.9	0.7	1.0	0.8	0.7	1.2	0.7	2.0	3.0
	UK	3.2	4.0	3.7	5.0	3.5	3.9	1.8	0.9	3.4	6.6
Rest-OECD		**2.6**	**2.2**	**2.8**	**2.3**	**2.5**	**2.4**	**3.9**	**3.5**	**4.6**	**4.8**
	Mexico	1.3	1.0	1.4	1.0	1.2	1.2	1.5	1.6	1.8	2.3
	Turkey	0.7	0.5	0.8	0.5	0.7	0.6	0.9	1.1	1.0	0.4
BRIC		**19**	**17**	**16**	**11**	**19**	**14**	**23**	**41**	**22**	**23**
	Brazil	4.7	2.5	4.3	0.8	4.4	4.7	3.6	2.9	2.6	0.9
	China	10.8	10.4	9.3	8.1	10.8	7.9	16.3	20.3	13.7	2.7
	India	3.7	4.0	2.3	2.3	3.8	1.1	3.6	17.4	5.9	0.5
OPEC		**7.9**	**5.0**	**8.4**	**4.2**	**7.6**	**7.5**	**10.0**	**9.0**	**4.4**	**2.1**
	Indonesia	3.6	0.9	4.4	0.5	3.7	3.7	4.1	3.5	1.4	0.2
	Nigeria	0.8	0.7	0.5	0.2	0.7	0.5	0.8	2.1	0.2	0.0
	Venezuela	0.9	0.7	0.9	0.6	0.8	1.0	0.7	0.4	0.3	0.2
AOSIS		**1.2**	**1.0**	**1.1**	**0.9**	**1.2**	**1.3**	**1.2**	**0.8**	**0.6**	**0.6**
LDCs		**4.7**	**2.7**	**3.7**	**0.3**	**4.6**	**3.7**	**3.5**	**11.5**	**1.7**	**0.1**
Rest World		**13.3**	**11.5**	**12.3**	**8.8**	**12.7**	**12.1**	**11.9**	**17.9**	**11.6**	**5.0**
	Argentina	0.9	0.9	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.3
	South Africa	0.9	2.2	2.3	2.4	0.8	0.8	0.8	0.9	0.9	0.3