INSTITUT D'ECONOMIE ET
DE POLITIQUE DE L'ENERGIE

CAHIER DE RECHERCHE N° 26

Equity and efficiency in climate change negotiations: a scenario for world emission entitlements by 2030

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Juillet 2001

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Abstract

The Kyoto Protocol will establish a distribution of emission permits for the 2008-2012 period ,among the Annex B Parties that will have ratified it. But as emissions expected from the developing countries in the forthcoming decades will considerably increase, it is necessary for the latter to also make some commitment to limit their emissions.

Our paper enhances some methodological aspects both on fair ways of bringing developing countries into a long-term world program for the limitation of emission growth, and on the contribution of emission trading to improving economic efficiency.

We first review the main differentiation proposals and the equity principles they are based on. As no differentiation rule and no single principle of justice have been found that might receive a consensus among all the countries, we then present a simple, pragmatic scenario for stabilizing CO_2 emissions by 2030, that could lead to a reduction in global inequality, a relative convergence of country entitlements and a greater respect for democratic equality.

Furthermore, we show that the implementation of an international emission trading system would re-establish *ex post* the efficiency which *a priori* does not exist in the initial allocation of rights. The utilitarian concept of justice would therefore also be respected.

We wish to thank N. Kouvaritakis (IPTS) for his contribution to the first draft of the Scenario 2030 and O. Godard for helpful comments.

Introduction

The risks associated with global climate change weigh heavily on the future of the international community. However, in the discussion process to determine methods for the joint control of greenhouse gas emissions, all the countries do not have the same interests, do not play the same role and have not proposed the same objectives. The first obstacle to be crossed in the international bargaining process has been - and still is - the problem of the burden sharing, an issue obviously related to the issue of fairness when defining the objectives.

A basis for agreement concerning the industrialized countries was drawn up at the third "Conference of the Parties" in Kyoto at the end of 1997. However, although the objectives were accepted by the Parties, the question of how to regulate the use of the flexibility mechanisms still remains to be settled. Given the global nature of the impact of emissions, to what extent will it be possible for a country to achieve its objectives at a reduced cost by making use of the lower cost reduction potential of another country?

The questions of equity and efficiency become even more acute in a "post-Kyoto" perspective, when examining the conditions in which the developing countries could take part in the effort to reduce world emissions on the basis of quantified emission objectives (or QELROs[1]).

This paper is based on the premise that, because of the divergent interests of the countries involved, it is impossible to find a solution based on a single rule of differentiation applicable to all. It would thus be more appropriate to look at practical solutions and assess *ex post* their validity in relation to different approaches of equity. Since there is no principle of distributive justice that could be globally applied, a multi-criteria approach must be used to determine the international acceptability of a particular solution.

Our analysis is thus divided into two main parts, the first one is devoted to the question of equity, and the second one to the design of a global entitlement scenario that involves all developing countries over the 2010-2030 period. Finally, the scenario is examined through various principles or indicators of distributive justice, in order to evaluate its potential acceptability .

[1] Quantitative Emission Limitation and Reduction Objectives.

1. Differentiation and international equity

The aim of this first section is to identify the criteria and rules which may ultimately enable developing countries to participate in the effort to limit greenhouse gas emissions. We shall start by analyzing the main rules of differentiation either proposed by the countries or put forward in the literature, and then attempt to show, in each case, on which principle(s) of distributive justice they are based.

1.1. Differentiation of emission reduction objectives: rules, criteria and stakes challenge

After the first conference of Heads of State in The Hague in 1989, the heightened concern of the international community clearly emerged in 1992, at the Earth Summit in Rio de Janeiro. Most of the countries represented there signed the United Nations Framework Convention on Climate Change (UNFCCC, 1992). In December 1997, the third Conference of the Parties to the Convention resulted in the Kyoto Protocol (UNFCCC, 1997), but in this case the Parties were not so quick to sign[2]. It is true that the commitments defined in the two documents did not have the same nature. The Convention was composed of general agreements that were not legally binding, while the Kyoto Protocol was specific and binding.

The main new elements included in the Kyoto Protocol were:

- the commitment of the Annex B Parties (*grosso modo*, the industrialized countries) to reduce their overall emissions by at least 5 % below 1990 levels in the period 2008 to 2012. A proper reduction objective is set for each Annex B Party, e.g. - 8 % for the European Union, - 7% for the USA, - 6% for Japan,

- the use of "flexibility mechanisms" such as participation in International Emission Trading, the possibility of Joint Implementation and the Clean Development Mechanism. The emission permits market is accessible only to those countries that have agreed to their emission reduction commitments (the Annex B countries). Consequently, what the Kyoto Protocol has done is to proceed with an initial allocation of emission permits among the Annex B countries.

In 1997, the Kyoto Protocol was seen as a success, as a first stage in the bargaining process concerning the greenhouse effect. However, in addition to current uncertainty as to how quickly the countries will sign and ratify the Protocol, numerous measures in the document still require clarification as to their methods of implementation.

Moreover, the question of including the developing countries in the effort to limit emissions comes up at each Conference of the Parties. Since these countries will see their emissions rise considerably over the next few decades, the actions taken by the

[2] As of 19 March 2001, 84 Parties to the Convention had signed the Protocol and 33 had ratified the agreement, including only one Annex B party (Romania).

more industrialized regions will not be sufficient to achieve the goal of emission stabilization followed by stabilization of concentrations of greenhouse gases in the atmosphere. Consequently, discussions will inevitably focus on ways of including the developing countries in binding commitments.

At the moment, the developing countries clearly cannot follow the example of the Annex B countries by agreeing to reduce or even stabilize their emissions as early as 2008-2012. The energy consumption and emissions of these countries are rising rapidly as a result of population growth and structural changes in their economies. Consequently, it is essential to differentiate between the objectives concerning the emissions of the developed countries and of the developing countries. The same is true within the developing world, which is by no means a homogeneous group of nations.

• Differentiation, a key component of the Framework Convention and the Kyoto Protocol

The term "differentiation" as it is found in numerous articles of the Convention is used in the broad sense of taking into account national characteristics in order to achieve the ultimate goal of the Convention. However, we shall use the term here in the more restrictive sense of "differentiation of the quantified emission limitation and reduction objectives", as our analysis concerns the way in which the limitation objectives can be shared out among the countries.

By using the principle of differentiation, it is possible to take into account, the specific situation of each country, as regards its emissions and its contribution to the greenhouse effect. In the Convention, the emissions reduction objectives are differentiated according to the groups of countries. On the one hand, the Annex I Parties have agreed to stabilize their greenhouse gas emissions at the 1990 level by 2000, while on the other hand the non-Annex I Parties have no obligation of this type. Differentiation is thus based on a "North-South" division, according to the differentiated historical responsibilities of the Parties in creating the problem of the greenhouse effect.

In the Kyoto Protocol, further differentiation - which we call secondary differentiation - is added to the North-South divide. This differentiation applies only to the Annex B Parties, which must reach the objective of reducing overall emissions of greenhouse gases by at least 5 % below 1990 levels between 2008 and 2012. A virtually uniform rate for emission reduction is applied to the triad comprising the European Union (-8 %), USA (-7 %) and Japan (-6%). However, a closer examination of the Protocol reveals a more marked differentiation for other countries: Iceland (+10 %), Australia (+8%), Norway (+1%), New Zealand, the Russian Federation and Ukraine (+0 %).

The question is, on what bases and according to what principles can differentiation be applied in the case of the developing countries? Numerous proposals have been

made by certain countries and in the scientific literature since the end of the 1980s and particularly prior to Kyoto.

• The multiplicity of differentiation rules

Most country proposals that arose in the negotiation process do not use one elementary rule but rather a combination of several elementary rules (UNFCCC, 1996). This same principle can be found in the literature on the subject (Blanchard et al., 1998). But the ways of applying these rules are often poorly defined, and this points to the potential problems that can arise when it comes to practical implementation of certain rules.

However, the rules can be classified according to whether they apply to quantified emission reductions or to emission abatement costs (burden sharing)[3]. Although useful, this distinction is to a certain extent artificial, in the sense that any particular emission reduction target necessarily corresponds to a certain abatement cost level, and *vice versa*. In any case, the proposals of the countries mostly concern differentiation based on the amount by which emissions are reduced: this can be explained by the greater difficulty in observing and estimating abatement costs instead of emission levels. Table 1 sets forth the main rules used and the criteria related to these rules.

- In each category, certain rules are generally described as being more likely to favor the developing countries, and others as being more favorable to industrialized countries. In particular:

- If an *emission ceiling per capita* were ultimately to be set, its value would inevitably be lower than the level already reached by the industrialized countries and higher than that reached by the other countries. The developing countries would then be able to let their per capita emissions increase for a certain length of time[4].

- In the case of *differentiation according to per capita GDP*, it would be possible to take into account the priority in developing countries of meeting basic needs and, in the industrialized countries, their ability to pay. However, since such a rule is not directly related to their emissions or abatement costs, it might not always provide sufficient incentive.

[3] Although the term “emission reduction” is not appropriate for the developing countries, it will be used here to remain faithful to the studies and proposals of the different countries (most of which refer to differentiation within the developed countries only).

[4] The Global Commons Institute refers to this rule as “ contraction and convergence ” (GCI, 1996). Agarwal and Narain, along with the GCI, were the first to have proposed it (Agarwal et al., 1991). Their approach is developed in (Agarwal, 1998) and (Agarwal et al. 1998).

Table 1: Principal rules of differentiation and corresponding criteria

Rules based on emission reduction amounts	**Differentiation criteria**
Per capita emission ceiling not to be exceeded	Per capita emissions
Reduction objective proportional to per capita gross domestic product (GDP)	Per capita GDP
Amount of reduction proportional to the contribution of the country to world emissions or global warming	Current or cumulative emissions, share of responsibility for global warming
Emissions quota assigned on the basis of the current or cumulative emissions of each country *(grandfathering)*	Current or cumulative emissions
Amount of reduction proportional to emissions per unit of GDP	Emissions / GDP
Rules based on abatement costs	**Differentiation criteria**
Total abatement costs proportional to GDP, or cost per unit of GDP proportional to per capita GDP	GDP, per capita GDP
Total abatement costs proportional to contribution of the country to world emissions or global warming	Current or cumulative emissions, share of responsibility for global warming
Abatement cost proportional to emissions per unit of GDP	Emissions / GDP
Equalization of marginal abatement costs	Marginal abatement costs
Total cost to country according to willingness to pay	Benefits of climate change mitigation

- Differentiation defined according to the *contribution of the countries to climate change* would mean that the reduction amounts or total abatement costs would be proportionally lower in the developing countries than in the industrialized countries, if responsibility for climate change was measured simply on the basis of past emissions[5] .

- Allocation of emission quotas *pro rata to current or cumulative emissions* ("inherited" quotas or "grandfathering") would be more beneficial to the industrialized countries since current emissions would be treated as an "acquired right" (Godard, 1997), while the developing countries would be severely penalized in that they would have no room to maneuver to increase their emissions over the next few decades.

[5] The Pew Center on Global Climate Change (Claussen & al, 1998) talks about the possibility of taking into account future emissions (rather than past emissions) when measuring the responsibility of each country. Even discounting the problems of deciding how to measure these emissions, the result in terms of differentiation would be opposite and unacceptable to the developing countries.

- If the effort to reduce emissions (in terms of amounts and cost) was determined according to the *intensity of emissions in relation to GDP*, the countries with energy systems emitting relatively high levels of GHG would have to make the greatest effort to reduce emissions. This differentiation rule is seen as unfavorable to those industrialized and developing countries with energy systems that emit large quantities of greenhouse gases (for example, the USA, India and China).

- *Equalization of marginal abatement costs* is sometimes claimed as a way to set relatively high reduction targets in countries with inefficient energy systems, where there is greater potential for low-cost emission reductions than in the countries where energy use is more efficient. However, this analysis should be qualified by taking into account the structure of each individual energy system and the evolving energy requirements of the countries. This supposedly optimum solution could be implemented through a tax, but it would be more difficult using an approach based on quantified emissions.

- If the abatement cost were related to a country's *"willingness to pay"*, it would be linked to the benefits each country would obtain from climate change mitigation. Since the most negative effects would most likely be felt by the developing countries, the benefits of prevention would *a priori* be greater for these countries. The developing countries should thus be willing to pay the highest mitigation costs. However, such an analysis must take into account the fact that these countries already have very limited financial resources for meeting their own basic development needs.

The rules presented in Table 1 clearly show the potential divergence of interests. But even by applying a rule that is generally favorable to the developing countries, certain countries in the group would be better off than others, depending on their individual characteristics and the particular differentiation rule used. The above analysis shows the importance of the stakes involved in this type of choice. As Müller pointed out (Müller, 1998), it is unlikely that a single rule would appear fair to all the countries: only "mixed" solutions would obtain sufficient consensus and could therefore be adopted. We thus have to go back to the stage preceding the analysis of rules and criteria and examine the principles that could be used for an acceptable approach in terms of international equity.

1.2. From rules of differentiation to principles of justice

In this sub-section, we thus examine the ethical bases of the different rules used to differentiate emission targets. Our analysis will include a discussion of the problems of applying the principles of justice to international relations[6] and to a commodity such as GHG emissions[7]. Our aim will simply be to determine the principles of justice behind the proposed distribution of emission rights on a world scale. Six principal concepts of justice are considered.

[6] On this question, see the summary by P. Hassner in the Dictionnaire d'éthique et de philosophie morale (1996, pp. 1278-85) and the comments of S. Hoffmann on Rawls' The Law of Peoples (Rawls, 1996).
[7] On this point, see especially (Godard , 1992); (Rose, 1992); (Grubb, 1995) and (Paterson, 1996).

• Equality of rights

In the theory of natural rights (Locke, 1690), human beings are considered to be in a natural state of perfect freedom and equality: born equal, having equal access to the benefits of nature and having the same faculties, they must necessarily be equal among themselves.
In the context of climate change, strict application of the principle of equality would mean that each individual would have the same rights where the use of the atmosphere is concerned.

• Utilitarian equality

Utilitarianism teaches that actions can only be judged ethically good or bad in terms of their effects on the happiness of the individuals concerned (Audard, 1996): the greatest happiness for the greatest number is the only desirable universal goal (Bentham, 1789). The utilitarian goal is to maximize not individual utility, but total utility, calculated as a net balance of satisfaction in relation to the disadvantages, each individual counting equally and being treated impartially.

The fair solution in terms of GHG emission reduction on an international scale would thus be to maximize world economic growth, net of adverse effects on the climate, even if such adverse effects were concentrated in a number of "sacrificed" regions. The countries would have the freedom to decide on the reductions they are willing to pay for, depending on their individual preferences.

However, it is difficult to measure the advantages of a preventive strategy (avoiding adverse effects) for the different countries, so that the cost-benefit analysis that in theory would be necessary is often replaced by an analysis in terms of cost-effectiveness, where the overall emission reduction target is determined ex ante. According to the principles of utilitarian equality, sharing the burden to reach the overall objective would involve determining for each country the reduction objective that would make it possible to equalize marginal abatement costs between the countries (and minimize the total cost of abatement). Efforts to reduce emissions would in this case be concentrated in the countries or sectors with the greatest potential for low cost reduction, even though they might not necessarily be the richest countries or the highest emitters of GHGs. This solution could be implemented through the use of the so-called economic instruments of environment policy (tax and / or tradable permits).

• Democratic equality

Democratic equality is the idea of justice as defined by Rawls (1971). It is based in particular on the "difference principle": defending the interests of the least advantaged is of prime importance and it is enough for the position of the most poorly off to improve in order for the final state to be considered more fair than the

initial state. This “maximin” classification criterion involves maximizing the increase in “social primary goods” of those in the lowest (or minimum) position.

Applying the principle of democratic equality to the effort to combat the greenhouse effect comes down to treating the atmosphere as “social primary goods”. Fair distribution of greenhouse gas emission entitlements, according to the difference principle, would mean maximizing the net benefits of the poorest countries. The differentiation rules should take into account the ability of the different States to pay, so that the burden would be shared out to the best advantage of the least advantaged countries. Rules that are designed to allocate a greater proportion of the emission quotas to the poorest countries or make the richest countries pay more of the cost are in line with this Rawlsian concept of justice.

- ***Causal responsibility***

In the “welfare economy”, the principle of causal responsibility stems from the concern to take externalities into account in the economy. Externalities are a group of “uncompensated services” – the result of divergence between marginal social net product and marginal private net product – the cause of sub-optimal allocation of resources in society (Pigou, 1932). The Pigouvian solution involves estimating the monetary value of the costs and the benefits obtained without pecuniary compensation, then putting a price on the externality. Internalization of the externality results in equalization of the marginal social product and the marginal private product. In the case of pollution, the idea is known as the “polluter pays” principle, since it is a question of ascribing responsibility for the externality to those who caused it.

Where the fight against global warming is concerned, application of the principle of causal responsibility would involve implementing the “polluter pays” principle at the international level. Each polluter would be responsible for the cost involved in reducing its own pollution. This solution could be achieved through the use of economic instruments (tax and / or tradable permits) or by applying a GHG emission standard. However, agreement would first have to be reached on the nature and extent of the responsibility (current or cumulative emissions?).

- ***Merit***

Merit is the basis of the principle of justice according to Marx (1875) for the first stage of communism. Marx advocated giving “to each according to his labor”. The endowments of the individual are considered to be rewards for meritorious behavior— the pursuit of virtue, making an effort, and so on — and are distributed in proportion to the meritorious character of the behavior (Van Parijs, 1991). Meritocratic theses thus accept the inequalities in distribution resulting from effort, ability, talent, risk, responsibility or courage (Dupuy, 1992).

Application of this principle to the effort to control global warming could involve taking into account the environmental performance of the different countries in emission reduction management, considering that there is "merit" in having an economy that causes relatively little pollution. A distribution of emission rights that takes into account the intensity of emissions (emissions per unit of GDP) might be in line with such a principle, if it resulted in penalizing carbon-intensive economies and rewarding those that are not carbon-intensive.

• ***Proportional equality***

Proportional equality is the idea of justice as defined by Aristotle, namely that people are unequal and therefore they are treated unequally. Social position is the factor that structures distribution and it is considered to be the only criterion for comparing individuals, since the function occupied by an individual in society is supposed to correspond to the value of his work for that society. The libertarian theories of Nozick (1996) and Gauthier's theory of "rational bargaining" (Gauthier 1986) are in line with this so-called "historic" concept of justice. According to these authors, justice is secured when the benefits that have to be distributed are conceived as entitlements acquired by a purchase, gift, bequest, cooperative effort or discovery (Van Parijs, 1998).

Table 2: Application of principles of equity in efforts to combat the greenhouse effect

Differentiation rules	Principles of justice
Equalization of per capita emissions	Equality of rights
Total cost supported according to willingness to pay Equalization of marginal abatement costs	Utilitarian equality
Emissions reduction objective proportional to per capita GDP Total cost proportional to GDP or cost per unit of GDP proportional to per capita GDP	Democratic equality
Amount of reduction proportional to the country's contribution to world emissions Total abatement costs proportional to the country's contribution to world emissions	Causal responsibility
Amount of emission reduction proportional to emissions per unit of GDP Total emission abatement costs proportional to emissions per unit of GDP	Merit
Emissions quota attributed on the basis of the current or cumulative emissions of each country (grandfathering)	Proportional equality

According to this concept of fairness, existing and / or past emissions could represent an "acquired right" of the States. Distribution according to this principle would mean that future emission quotas would be allocated pro rata to these acquired rights and that the inequalities with respect to use of the atmosphere would be perpetuated ("inherited" rights or "grandfathering"). Few authors have perceived this relationship between the "historic" conceptions of justice and rules for allocating emission entitlements on the basis of the status quo[8]. For want of finding an ethical basis for the criterion of past emissions, most authors refer to common law (Young and Wolf, 1991).

Table 2 provides a summary of the principles of equity mentioned in negotiations. Of all the differentiation rules proposed (Table 1), is there one that reflects a principle of equity (Table 2) that could be used as a fair standard for all countries? Most likely the answer is no, since no principle of distributive justice seems to be acceptable to all societies to solve the problem of burden sharing. As Fishkin (1986) points out, "*the ethics of international relations, more clearly than domestic justice, unveils the necessity of moral conflict, of equilibrium between immeasurable considerations, and thus the impossibility to satisfy absolutist expectations*".

This moral conflict is present in the international efforts to combat climate change, and evidence of this can be found in the Kyoto Protocol: differentiation of the emission reduction objectives of the Annex B countries, decided in Kyoto, is not based on one particular principle of justice. It appears to be more of a compromise negotiated with the different countries, taking into account their different values and interests and what they expect the reduction measures will cost (Viguier, 1999).

It would thus be more appropriate to adopt a pragmatic approach to the question of including the developing countries in the emission reduction process after the year 2010. If it is not possible to agree on a global allocation of emission entitlements that respects a principle of justice, the answer would be to find a solution that would be as simple and robust as possible and would enable the largest possible participation of different States, at an "acceptable" cost, taking into account:

- the collective interest; for example a stabilization objective for GHG world emissions for 2030, combined with an objective of economic efficiency;
- the responsibility of the developed countries with respect to global warming, including, in particular, a continued commitment to reduce emissions after 2010;
- the specific interests of the developing countries, namely concern about future population dynamics, economic growth and energy requirements.

This type of approach is not based on the *ex ante* application of a principle of justice, but rather on an *ex post* validation of the proposed scenario, founded on a series of relevant indicators or criteria in line with different concepts of justice (such as equal rights or democratic equality).

[8] Paterson is an exception, since he establishes a relationship between Nozick's entitlement theory and the status quo position (Paterson, 1996, footnote 68).

2. A scenario for the stabilization of world emissions in 2030

Certain of the rules envisaged for differentiating the reduction objectives have the advantage of not requiring either a projected reference value or an estimation of abatement costs. This is the case when objectives are based on per capita emissions or according to a reduction rate in relation to a base year. The latter solution was considered acceptable by the Annex I countries in the Kyoto negotiations, essentially because it was applied either to industrialized countries where only moderate increases in emissions were expected, or to economies in transition, where emissions have even declined over the last few years.

This rule has not been extended to developing countries, first and foremost because they still refuse to commit themselves to restrictive emission objectives. It is also clear that an emission ceiling calculated on the basis of a past base year cannot be applied to developing countries, since in most cases current population and economic trends will induce a doubling or even tripling of emissions between 1990 and 2010.

The Kyoto Conference thus resulted in a partial allocation of GHG emission entitlements worldwide. The main challenge now is to define post-Kyoto scenarios in order to examine the conditions in which the developing countries may be included in an emission limitation strategy after 2010.

In this second section of the paper, we first attempt to construct such a scenario in the framework of a pragmatic approach, taking into account the constraints imposed by the climate system as well as the economic and energy dynamics in each world region. Our method is based to a large extent on the approach used in Kyoto - differentiation according to groups of countries with consideration of similar variables - our aim being to adapt the scenario to the situation of the developing countries.

Next, we present the preliminary conclusions drawn from the quantitative analysis of this scenario in terms of national marginal abatement costs, then of the "international carbon value" in an emission trading system. We show in particular that emission trading can re-establish *ex post* the efficiency that is *a priori* not found in the initial allocation of entitlements. Finally, we evaluate the proposed scenario in terms of equity and look at the conditions in which it might be acceptable to the different Parties to the negotiations.

2.1. Definition of a pragmatic scenario for the period 2010-2030

The scenario presented here is only a preliminary scenario, to be refined through further research. One of its merits is that it provides a pragmatic answer to the question of integrating the developing countries into the emission reduction process after 2010. It simultaneously considers the emission restrictions aimed at limiting climate change and the economic, energy and demographic constraints of the developing countries.

• The global climate constraint and the Annex B / non Annex B differentiation

There are still numerous open questions concerning climate change and the role of anthropogenic emissions in it. However, the signatories to the Framework Convention on Climate Change adopted the Precautionary Principle in this matter by deciding to stabilize concentrations of greenhouse gases in the atmosphere at a level which would prevent "dangerous anthropogenic interference with the climate system" (Article 2 of the Convention: UNFCCC, 1992).

For its part, the IPCC (Intergovernmental Panel on Climate Change) defined a variety of possible trajectories for changes in CO_2 emissions, from 1990 onwards, leading to stabilization of CO_2 concentrations in the atmosphere at a previously determined level. Regardless of the concentration level chosen (350, 450, 550, 750 or 1000 ppmv[9]) and taking into account the residence time of CO_2 in the atmosphere, the emission trajectories follow a phase of growth, then stabilize at a date between 2020 and 2100, and finally decline at varying rates and speeds (IPCC, 1996).

The scenarios based on a stabilization of concentrations at 550 ppmv are often used as a reference in studies on emission reductions[10], because they respond to the precautionary principle and propose emission trajectories that are *a priori* attainable. The scenario presented here for allocating emission entitlements up to 2030 is based on this hypothesis of stabilization of CO_2 concentrations at 550 ppmv.

To achieve stabilization at a level of 550 ppmv by 2150, the IPCC describes a trajectory in which emissions would reach a maximum of 12 billion tonnes of carbon (GtC) by around 2030 and would subsequently decline. If we take away about 2 GtC of emissions from the agriculture sector, permissible CO_2 emissions from the energy sector in 2030 would be limited to a maximum of 10 GtC.

Hence our goal in terms of world stabilization of CO_2 emissions corresponds to a maximum of 10 GtC shortly after 2030. Next, we continue with the primary differentiation between industrialized countries and developing countries introduced in the Kyoto Protocol, in order to take into account extremely different energy and economic dynamics:

- For the Annex B countries, the targeted rate of emission reduction between 2010 and 2030 is the same as that agreed upon by the countries for the period 1990 to 2010 in the Kyoto Protocol. For example, the reduction objective for the USA in 2030 is 7 % below 2010 and its emissions in 2030 should thus not exceed 0.93*0.93 times its emission levels in 1990. In this "Kyoto exponent two" situation, the secondary differentiation found in the Kyoto Protocol is applied again the same way.

- For the non-Annex B countries, the constraint of stabilization of overall emissions by around 2030 means that, at this date, the increase in their emissions must be at

[9] Ppmv: parts per million by volume
[10] Examples: Chapter 8 (IPCC, 1996); (Gupta et al, 1999)

most equal to the reduction of the Annex B countries. Furthermore, since world emissions should ultimately decline so as to achieve a stabilization of concentrations, the emissions of the non-Annex B countries must, in the longer term, stabilize and then decrease.

• Emission constraints for the developing countries: a "Soft Landing" scenario

For the non-Annex B countries, the proposed entitlement rule involves not *a priori* setting a stabilization level (absolute or per capita) but defining:

- a departure point for determining the initial situation and dynamics of these countries; it is taken as 2010;

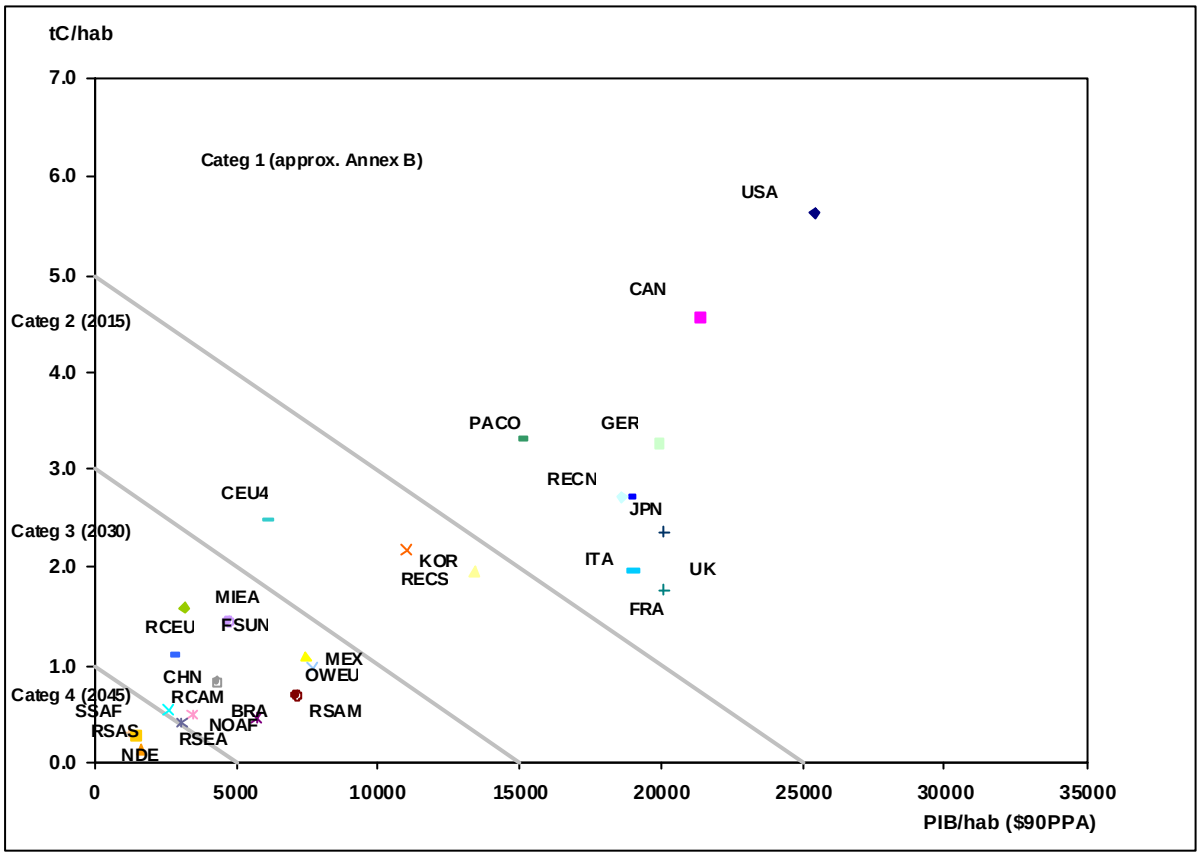
- dates by which emissions must be stabilized, differentiated according to per capita GDP and per capita emissions in 2010;

- an initial growth rate for their emission entitlement paths, differentiated to take into account population growth. It is the gradual reduction in these rates up to the stabilization date that leads to individual and overall stabilization, taking into account the expected reductions in the Annex B countries.

For the non-Annex B countries – a category deriving from the primary differentiation from the Protocol – the exercise thus involves first designing a new secondary differentiation framework that takes into account both per capita income levels and per capita emission levels in 2010. A third and final level of differentiation is then added grounded on population dynamics between 2000 and 2010.

As a result, the countries are divided into four categories, as shown in Figure 1. The first includes only Annex B countries, while the non-Annex B countries are divided into Categories 2 (high income or high emissions), 3 (intermediate income or intermediate emissions) and 4 (low income or low emissions). It shows why the primary Protocol differentiation (Annex B / non-Annex B) may be considered as legitimate and illustrates how the secondary differentiation relating to emission stabilization dates is obtained.

Figure 1: Differentiation of stabilization dates



Notes: The codes for the countries (or regions) are explained in the appendix. Per capita GDP is expressed in constant 1990 dollars, purchasing power parity adjusted.
Source: POLES model data base.

The principle adopted here is that, in order to take into account both the ability of the different countries to pay and their causal responsibility, the higher the income levels and emission levels of a country, the sooner it should be required to stabilize its emissions. Conversely, a poor country with low per capita emissions should not be required to stabilize its emissions until a much later date. It is thus assumed that the countries in Category 2 must stabilize their emissions starting in 2015, those in Category 3 from 2030 on and those in Category 4 from 2045 on (the list of countries and regions in each category is provided in the appendix).

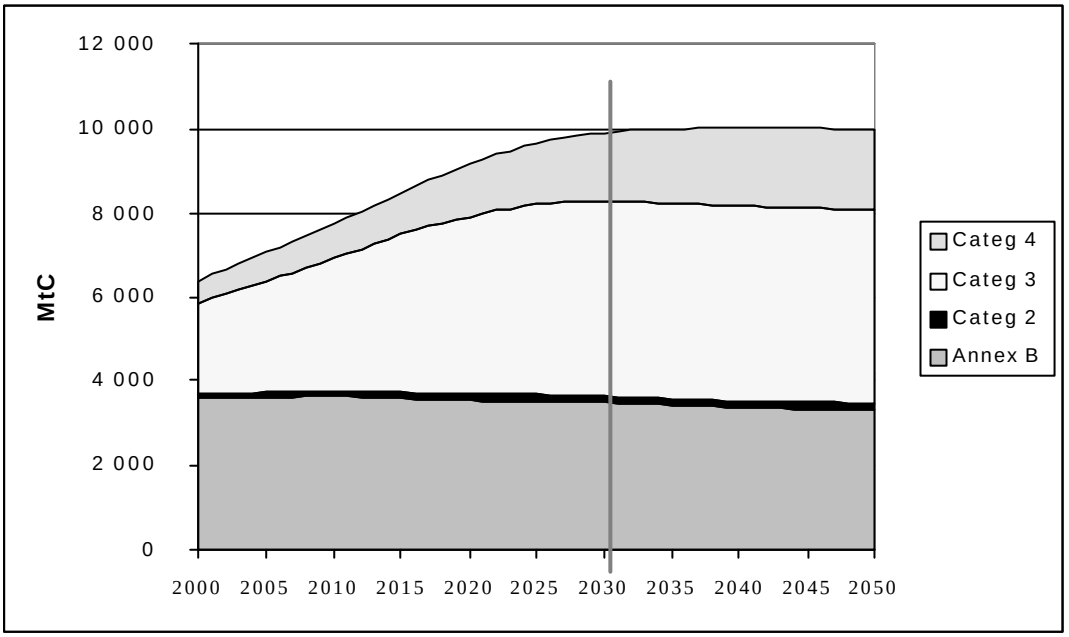
It is then a question of determining the intertemporal profiles of the endowments for the non-Annex B countries, leading from the non-binding situation in 2010, to the country specific stabilization horizon. At this third level of differentiation, the initial growth rate of emissions in 2010 is taken as the sum of an across-the-board annual growth rate of 3 % in per capita emissions for all the developing countries[11], and of the mean annual population growth rate in each country between 2000 and 2010. The rate of increase in emissions then decreases linearly every year until it reaches zero at the stabilization date (2015, 2030, 2045).

[11] Note that a per capita emission growth rate of 3 % is equivalent to 3 % growth in per capita GDP, at a constant intensity of emissions per unit of GDP. In fact, since E/POP = (E/GDP)*(GDP/POP), a first approximation indicates additivity of the growth rates of E/GDP and GDP/POP, with small variations.

To sum up, in the proposed "Soft Landing" scenario, emission entitlements are allocated with the following points in mind: world stabilization of emissions in 2030, "Kyoto-type" continuation of emission reductions in the Annex B countries, and gradual but differentiated slowing of emission growth in the non-Annex B countries, with differentiation based on per capita income and emission levels but also on population growth.

Figure 2 shows the results of the scenario in terms of emissions, with stabilization of overall emissions at 10 GtC shortly after 2030, a decrease in the emissions of the Annex B countries over the entire period, stabilization of emissions in 2015 for the Category 2 countries, in 2030 for those in Category 3 and in 2045 for those in Category 4.

Figure 2: Profile of CO_2 emissions in the Soft Landing scenario



Source: IEPE - POLES model studies

2.2. Economic appraisal : the benefits of flexibility in the Soft Landing scenario

Numerous studies have already demonstrated the economic rationale of setting up a tradable permits market (Criqui, 1999; Energy Journal Special issue 1999). This section of the paper is aimed at showing the global benefit of introducing flexibility mechanisms in the scenario described above.

We first look at the analytical framework for emission trading. This framework is based in particular on an analysis of the marginal abatement costs curves for the different regions, produced by a partial equilibrium model of the world energy

sector, the POLES model. We then go on to present the first elements for the quantitative analysis.

- ***Method for analyzing abatement costs***

As the approach used here is based on a sectoral equilibrium model, it sits between the "top-down" approach of General Computable Equilibrium (GCE) models and the "bottom-up" approach of analytical tools. Abatement costs in the POLES model are estimated by introducing a "shadow carbon tax" – or a "carbon value" – in all of the energy consumption-transformation modules. This shadow carbon tax leads to adjustments in final energy demand, through technological progress or behavioral changes, as well as to substitutions in the energy conversion systems, for which the technologies are explicitly identified. By first projecting a reference case in which the shadow tax is taken as being zero, it is then possible to perform successive simulations to calculate the emission levels associated with a shadow tax that increases step by step, for example from 0 to 600 $/tC. The marginal abatement costs for a particular level of emissions are then deduced (Criqui et al., 1997).

The costs calculated in this way are sectoral costs, or "gross" costs that only relate to the adjustments needed in the energy sector.

- ***Abatement costs of the " Soft Landing " scenario, without flexibility mechanisms***

Table 3 shows the main economic implications of the "Soft Landing " scenario, without the introduction of flexibility mechanisms.

The reduction in world emissions would thus amount to 3600 MtC compared with the reference situation. The contribution of the present Annex B countries would be 1800 MtC, in other words 50 % of the total reduction in emissions, for a total cost equivalent to 60 % of total abatement costs. The gross annual sectoral cost of complying with the commitments for 2030 would represent between 0.005 and 1.7 % of annual GDP for the Annex B countries and between 0 and 1.6% for the non-Annex B countries. In addition, the marginal cost of the projected reductions would vary considerably from one region to the next, and in some extreme cases would exceed 600 $/tC, the high values being found especially in Europe and Japan, as well as in certain developing regions.

Table 3: Abatement costs of the " Soft Landing " scenario, without flexibility mechanisms

STABIL 2030	Emissions 2030 Reference	Emissions 2030 Stabilization Scenario	Emissions reduction	Marginal abatement cost	Total abatement cost	% of GDP
	MtC	MtC	MtC	$ / tC	M$	
USA	2 010	1 153	857	*246.0*	*76 398*	*0.596*
Canada	179	102	76	*325.7*	*6 937*	*0.586*
Mexico	267	235	32	*159.2*	*2 475*	*0.101*
Rest of Centr Am.	130	84	46	*(>600.0)*	*8 163*	*1.628*
Brazil	339	210	129	*338.9*	*15 709*	*0.491*
Rest of South Am.	217	213	4	*10.5*	*20*	*0.001*
France	154	96	58	*465.2*	*9 576*	*0.453*
Germany	303	193	109	*135.3*	*6 086*	*0.227*
Italy	127	94	33	*590.0*	*6 981*	*0.384*
UK	187	130	57	*222.8*	*4 639*	*0.243*
Rest N EU	234	134	100	*(>600.0)*	*18 566*	*1.111*
Rest S EU	172	97	75	*430.0*	*8 124*	*0.530*
Rest W Eur	44	20	24	*(>600.0)*	*3 484*	*1.278*
Turkey	146	120	26	*49.5*	*552*	*0.029*
Egypt	76	52	24	*314.2*	*2 943*	*0.257*
Morocco Tunisia	37	26	11	*490.0*	*2 147*	*0.325*
Alg. Libya	59	48	11	*213.2*	*957*	*0.182*
Gulf	366	386	-20	*0.0*	*0*	*0.000*
Mid. E. Med.	95	74	21	*201.2*	*1 942*	*0.234*
Subsah. Africa	784	651	134	*51.2*	*3 788*	*0.138*
Cent Eur 4	338	156	182	*311.9*	*20 597*	*1.712*
Rest of Cent Eur	129	94	35	*464.8*	*12 570*	*1.766*
Cent Eur. NB	55	41	14	*95.8*	*535*	*0.251*
FSU B	834	799	35	*10.3*	*179*	*0.005*
FSU NB	209	163	45	*152.4*	*2 647*	*0.286*
India	1 044	728	316	*148.8*	*22 161*	*0.362*
Rest S Asia	209	151	58	*298.4*	*6 941*	*0.307*
S Korea	206	149	57	*268.7*	*5 821*	*0.486*
Rest SE Asia	897	562	335	*295.7*	*33 058*	*0.411*
China	2 788	2 226	562	*53.1*	*13 887*	*0.074*
Japan	365	262	103	*340.0*	*13 208*	*0.322*
Rest Pacific	170	89	81	*255.9*	*6 204*	*0.598*
World	13 170	9 540	3 630	*127.5*	*317 297*	*0.347*

Note: Costs are expressed in constant 1990 dollars (1 $1999 = 0.82 $1990)
Source: POLES model and ASPEN software

Finally, the analysis of the "rate of effort" of the different countries (gross abatement cost / GDP) reveals what might appear to be paradoxical situations: the cost could be greater for certain countries that are among the most "virtuous" in terms of emissions, as well as for much less virtuous countries. This paradox can be explained as follows:

- in the virtuous countries, the reductions would be limited in quantity but they could only be achieved at a high marginal cost as the fuel-mix is already poor in carbon, a situation that might be described as the "Norwegian syndrome";

- in the less virtuous countries, on the contrary, reductions may probably be achieved at a low cost but they would also be greater in volume. This may correspond to the "Australian syndrome".

This recalls that, when estimating the costs of mitigation policies it is important to take into account the amount of the reduction – quantity effect – and the marginal cost – the price effect. In fact, the results of the Kyoto negotiations reflected this reality, since countries as different as Norway and Australia ended up with less restrictive commitments than those of the other OECD countries.

• A market for tradable emission permits: impacts in terms of efficiency

Taking this situation as a benchmark, without considering any kind of flexibility mechanisms, it is then possible to analyze the potential gains from introducing an emission permit trading system (Table 4). The gains in economic efficiency stem from the equalization of the marginal abatement costs observed for the different regions.

The quantified objective is still a total reduction of approximately 3 600 MtC below the reference level in 2030 for the world, even though the initial entitlements (2010) of the developing countries are equal to twice their emission levels for 1990. The world marginal cost of compliance – or the price of permits– is thus 127.5 $/tC.

In our framework for allocating world entitlements, only 7 countries (or groups of countries) would be permit sellers, the main ones being China, Russia, sub-Saharan Africa and the Gulf countries. Almost 900 MtC would be traded, which corresponds to 25 % of emission reductions, for a total of about $114 billion. The main permit buyer would be the USA with 235 MtC ($30 billion), but there would also be a number of buyers from the developing countries, for close to 300 MtC (Central America, Brazil, North Africa, Asia excluding China).

The main result of this exercise is undoubtedly that the total annual cost of an emission stabilization program would be reduced from more than $300 billion in the no-flexibility case to about $200 billion. The net gains compared with the no-trading situation are significant for certain regions: $73 billion for the buying countries (including $12 billion for the USA) and $44 billion for the selling countries (including $21.5 billion for China), for a grand total of $117 billion.

Table 4: World market for emission entitlements: an equilibrium price of 127.5 $/tC

	Refer 2030	Stabil 2030	With trading	Domest reduct.	Volume of trade	Value of trade	Domest cost	Total cost	Cost without trading	Gains from trading	Cost after trading
	MtC	MtC	MtC	%	MtC	M$	M$	M$	M$	M$	% GDP
USA	2 010	1 153	1 388	72.6	-235.2	29 990	34 393	64 383	*76 398*	*12 014*	0.502
Canada	179	102	123	73.0	-20.7	2 637	2 538	5 175	*6 937*	*1 762*	0.437
Mexico	267	235	241	81.6	-6.0	761	1 620	2 381	*2 475*	*95*	0.097
RestCen Am	130	84	115	33.1	-30.5	3 884	864	4 748	*8 163*	*3 415*	0.674
Brazil	339	210	263	58.7	-53.4	6 811	4 069	10 880	*15 709*	*4 829*	0.340
RestSth Am	217	213	187		26.2	-3 346	1 390	-1 956	*20*	*1 976*	-0.054
France	154	96	125	49.4	-29.3	3 741	1 476	5 218	*9 576*	*4 358*	0.247
Germany	303	193	196	97.1	-3.2	404	5 670	6 074	*6 086*	*12*	0.227
Italy	127	94	114	41.3	-19.4	2 470	768	3 238	*6 981*	*3 743*	0.178
UK	187	130	143	76.6	-13.4	1 706	2 350	4 056	*4 639*	*583*	0.212
Rest N UE	234	134	193	41.6	-58.5	7 463	2 175	9 637	*18 566*	*8 929*	0.494
Rest S UE	172	97	120	69.9	-22.5	2 866	2 470	5 335	*8 124*	*2 789*	0.348
Rest W Eur	44	20	38	24.0	-18.3	2 327	350	2 677	*3 484*	*807*	0.436
Turkey	146	120	103		16.6	-2 111	1 922	-189	*552*	*741*	-0.010
Egypt	76	52	63	56.9	-10.2	1 294	718	2 012	*2 943*	*931*	0.175
MorocTuni	37	26	33	40.3	-6.5	832	290	1 121	*2 147*	*1 026*	0.170
AlgLibya	59	48	51	73.9	-2.9	373	461	834	*957*	*123*	0.159
Gulf	366	386	315		71.5	-9 112	2 830	-6 283	*0*	*6 283*	-0.303
Mid E Med	95	74	81	67.2	-6.8	872	815	1 687	*1 942*	*254*	0.204
Subsah Afr	784	651	539		112.2	-14 308	13 171	-1 137	*3 788*	*4 925*	-0.041
Cent Eur4	338	156	225	61.8	-69.5	8 860	6 482	15 342	*20 597*	*5 255*	1.275
RestCent Eu	129	94	131	58.8	-37.0	4 714	2 510	7 225	*12 570*	*5 345*	1.015
Cent Eu NB	55	41	39		2.0	-250	753	503	*535*	*33*	0.235
FSU B	834	799	672		127.1	-16 200	7 948	-8 253	*179*	*8 432*	-0.223
FSU NB	209	163	168	89.6	-4.7	602	1 987	2 589	*2 647*	*58*	0.280
India	1 044	728	761	89.4	-33.7	4 291	17 513	21 804	*22 161*	*357*	0.356
Rest S Asia	209	151	175	57.9	-24.3	3 104	1 826	4 930	*6 941*	*2 011*	0.218
S Korea	206	149	169	65.1	-19.8	2 530	2 022	4 551	*5 821*	*1 270*	0.380
Rest SE Asia	897	562	670	67.5	-108.9	13 885	11 047	24 932	*33 058*	*8 127*	0.310
China	2 788	2 226	1 684		542.3	-69 143	61 583	-7 560	*13 887*	*21 447*	-0.041
Japan	365	262	307	56.4	-45.0	5 741	3 238	8 980	*13 208*	*4 229*	0.219
RestPacif	170	89	107	77.5	-18.1	2 314	2 860	5 174	*6 204*	*1 030*	0.499
World	13 170	9 540	9 540	-	(897.9)	(114471)	200 108	200 108	*317 297*	*117 189*	0.212

Note: Monetary values are expressed in constant 1990 dollars
Source: POLES model and ASPEN software program

The solution of a worldwide emission trading market is thus clearly more efficient than the no-trade solution, and all the countries would see a significant drop in their rate of effort. However, one aspect of the new solution is that the shares of domestic reductions would be far from uniform, varying between 24 % (Rest of Western Europe) and 97 % (Germany). The percentage for France would be relatively low at 49 %, since the marginal costs would rise sharply, given the initial low-carbon-intensive profile of that country.

Clearly the case presented here is largely theoretical, as most other assessments of this kind : it supposes, on the one hand, that the full potential for reduction in the developing countries can be achieved and, on the other hand, that the flexibility mechanisms would operate perfectly. In other words, it assumes a situation of a pure, perfect competitive market, without transaction costs. In this context, the value of the tradable permits should be interpreted as a minimum or floor value while the volume traded is a maximum volume.

2.3. Ex post evaluation of the scenario in terms of equity and conditions of acceptability

In the first section of the paper, we drew attention to the difficulty of setting up an *ex ante* agreement according to a single criterion of equity for allocating world emission entitlements. It is for this reason that we proposed a different approach involving first the definition of a pragmatic entitlement scenario, and then an evaluation of the scenario in terms of equity, using a number of different criteria, themselves based on different principles of justice.

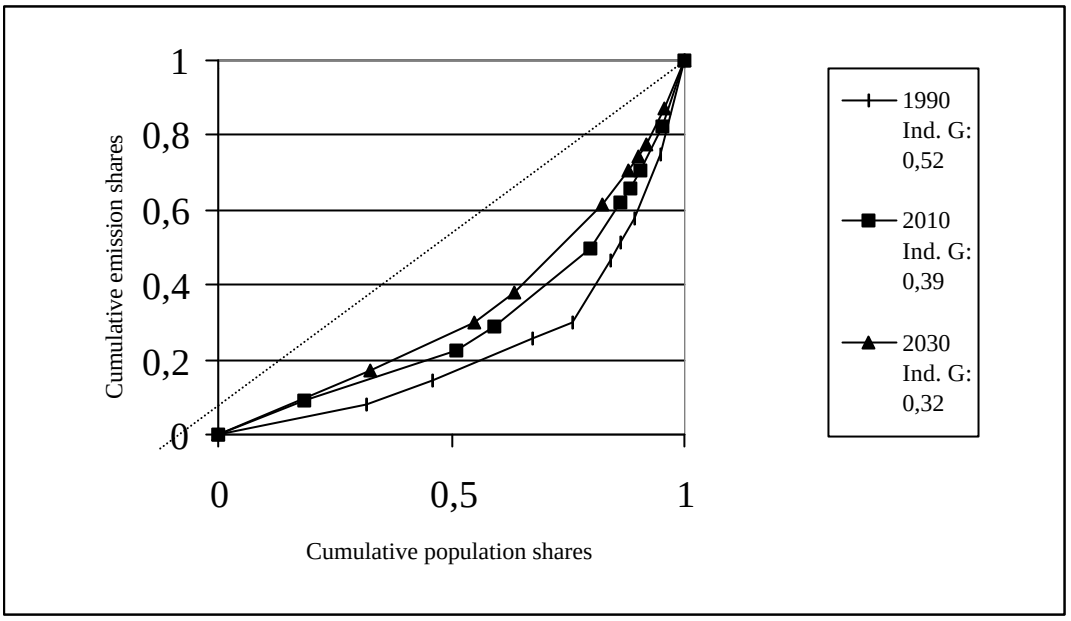
Clearly, the Soft Landing scenario will be acceptable to most of the Parties only if it results in a certain convergence with respect to the criteria used by the Parties as the basis for their discussions on equity. This scenario must therefore be analyzed at least from the point of view of the criterion of per capita emissions (the principle of equality of rights, supported by numerous developing countries) and of rate of effort expressed as abatement costs per unit of GDP (the principle of democratic equality, supported in certain developing countries and usually considered by the Annex B countries).

• Use of a Gini index to measure the convergence of per capita emissions

The Lorenz curve and Gini index were first developed to measure inequality in income distribution of a population. However, these tools can quite easily be used to measure equity with respect to the distribution of the emissions or emission entitlements. Figure 3 shows the Lorenz curves for 1990, 2010 and 2030: the x-axis corresponds to the cumulative population share and the y-axis to the cumulative share of emissions. The 1990 curve represents real CO_2 emissions or "*de facto*" rights for that year, whereas the curve for 2010 shows the distribution of emission rights as accepted in the Kyoto Protocol. The curve for 2030 is based on the allocation of rights described in the "Soft Landing " scenario.

When the Lorenz curve matches the 45° line, distribution is considered perfectly egalitarian. Figure 3 thus shows that the actual situation in 1990 is the most unequal, that the *de jure* situation in 2010 is less unequal and that the hypothetical situation for 2030 succeeds in further reducing the inequalities compared with the situation in 2010. These observations are confirmed by calculation of the Gini index, which goes down from 0.52 in 1990 to 0.39 in 2010 and 0.32 in 2030.

Figure 3: Lorenz curves and Gini indices for world emission entitlements



Source: POLES model

In terms of per capita emissions, Table 5 shows the commitments of the Annex B countries in the Kyoto Protocol (situation in 2010) and those with which they should comply in the stabilization scenario. The emissions of the non-Annex B countries increase without restrictions until 2010 (as simulated with the POLES model), when the entitlements begin to diverge from the reference projections. Table 5 clearly illustrates the convergence in per capita emission endowments of the Annex B and non-Annex B countries: the ratio of the highest to the lowest regional endowment is of 19 in 1990, 9 in 2010, 6 in 2030.

Table 5: Per capita emissions, 1990 and endowments, 2010, 2030

Emissions per capita (tC)	**1990**	**2010**	**2030**
North America	5,23	4,15	3,53
Western Europe	2,19	1,95	1,83
Pacific OECD	2,53	2,24	2,16
Former Soviet Union	3,46	2,81	2,64
Eastern Europe	2,37	2,23	2,27
Latin America	0,62	0,86	1,05
Africa-Middle East	0,48	0,53	0,68
China	0,58	1,13	1,42
Rest of Asia	0,28	0,46	0,60
World average	1,11	1,10	1,14

Source: POLES model

• ***Towards democratic equality***

The rate of effort agreed to by each country to reduce its emissions (total abatement cost / GDP) constitutes one of the criteria for assessing the fairness of the stabilization scenario in terms of democratic equality. Details are shown in Tables 3 and 4. In a no-trade scenario (Table 3), the rate of effort of the Annex B countries would be generally higher than that of the non-Annex B countries. The differentiation rule which recommends a contribution proportional to per capita GDP and which corresponds to Rawls' difference principle is on the whole respected.

However, on a country-by-country basis, Rawls' difference principle is not fully respected. Among the Annex B Parties, the northern European and central European countries, for example, show rates of effort corresponding respectively to 1.1 % and 1.7% of GDP, compared with 0.6% for the USA and 0.3 % for Japan (Table 3). Similarly, among the non-Annex B countries, the rates for the Central American countries and India correspond respectively to 1.6 % and 0.4% of GDP compared with 0.1% for Mexico and 0.07% for China. This is why this stabilization scenario must be considered as a preliminary scenario, which should probably be improved in order to obtain a convergence process that is more satisfactory from a Rawlsian point of view.

The introduction of emission permit trading (Table 4) results in a reduction in the rate of effort for every country, compared with the no-trade situation. This can be explained by the fact that permit trading leads to minimization of the total cost through equalization of marginal abatement costs. Among the Annex-B countries, the costs per country, as a proportion of GDP, become more similar, reflecting a situation of greater democratic equality. Utilitarian equality is assured de facto by the opening of the permit market. Of course, emission permit trading results in a less marked convergence of actual (and not entitled) per capita emissions, compared with the situation without flexibility mechanisms. But this setback - indeed a characteristic of all permit trading systems - is "compensated" from a monetary point of view by financial flows.

It appears that the introduction of flexibility mechanisms need not be called into question by the analysis, a posteriori, of the distribution of benefits that they produce. In fact, if this distribution were considered by the countries to be too unfair, the solution would be rather to look at the entitlement scenario again from the first stages, in a kind of iterative procedure.

This is indeed how this type of exercise opens possible paths for negotiations. The imbalances that it reveals for certain regions will have to be corrected by further modifying the basic hypotheses when preparing future scenarios. For example, the proposed categorization of countries may be modified in order to take into account the specific characteristics of certain developing regions (for instance as concerns their stabilization horizon). In this perspective, any progress in ensuring a satisfactory balance according to different principles of justice, in particular equality of rights, democratic equality and utilitarian equality will enhance the international acceptability of the scenario. This would improve the chances of reaching agreement

on the emission stabilization program for 2030, which is a necessary step in achieving the longer term goal of a stabilization of concentrations.

General conclusion

The Kyoto Protocol - when ratified - will establish a distribution of emission permits among the Annex B Parties for the 2008-2012 period. The use of flexibility mechanisms and tradable emission permits will also be provided for – even though the implementation conditions are yet to be determined – in the case of countries faced with binding reduction commitments. But the question of a future commitment from the developing countries remains open.

In any case, the emission reductions commitments taken on by the Annex B countries represent only a small volume compared with the increases in emissions expected from the developing countries. If the objective of stabilizing the concentration of greenhouse gases in the atmosphere is to be achieved, then it is necessary for these countries to also make some commitment to limiting their emissions. Consequently, questions relating to the quantified objectives and differentiation criteria for the period after 2010 remain open, not only in the context of including the developing countries, but also in relation to the objectives of the present Annex B countries.

In this situation, our paper has developed some methodological aspects which should contribute to fruitful reflection both on fair ways of bringing developing countries into a long-term world program for the limitation of emission growth, and on the contribution of emission trading to improving economic efficiency.

With respect to the first point, it appears that no operational rule for implementing differentiation and no single principle of justice have been found that might receive a consensus among all the countries, in so far as their interests remain structurally divergent. We have therefore constructed a simple, pragmatic scenario for stabilizing CO_2 emissions by 2030, and have then shown that it could lead to a reduction in global inequality, a relative convergence of country entitlements and a greater respect for democratic equality.

As for efficiency, our results underline the advantages of implementing an international emission trading system, since this would make it possible to re-establish *ex post* the efficiency which *a priori* does not exist in the initial allocation of rights. The utilitarian concept of justice would therefore also be respected.

In conclusion it is clear that any solution proposed during future stages of the negotiation process will, in order to be successful, have to take into account at least three requirements : *that of a certain degree of gradual convergence over the long term of per capita emission entitlements - to ensure an equitable distribution of entitlements internationally -, that of the acceptability of the costs imposed on the different regions of the world – for fairness in the effort to be made -, and finally that of the introduction of various flexibility mechanisms - for the overall efficiency of this international undertaking.*

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Appendix: List of countries (or regions) by category

Category 1: Compliance with objectives defined in the Kyoto Protocol

USA: United States of America
CAN: Canada
PACO: rest Pacific OECD
GER: Germany
RECN: rest of Northern European Union
JPN: Japan
UK: United Kingdom
ITA: Italy
FRA: France

Category 2: Compliance with objectives defined in the Kyoto Protocol (Annex B countries), stabilization of emissions in 2015 (non-Annex B countries)

CEU4: 4 countries Central Europe (Hungary, Poland, Czech Republic, Slovakia) (Annex B)
RECS: rest South Union European (Annex B)
KOR: South Korea (non-Annex B)

Category 3: Compliance with objectives defined in the Kyoto Protocol (Annex B countries), stabilization of emissions in 2030 (non-Annex B countries)

MIEA: Middle East
FSUN: former Soviet Union
RCEU: rest Central European countries, non-Annex B
MEX: Mexico
CHN: China
OWEU: other Western European countries
RCAM: rest of Central America
BRA: Brazil
RSAM: rest of South America
NOAF: North Africa
RSEA: rest of South-East Asia

Category 4: stabilization of emissions in 2045

SSAF: Sub-Saharan Africa
RSAS: rest of South Asia
NDE: India