Policy framework and systems management of global climate change

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Summary

Climate change is representative of a general class of environmental issues where decisions have to be taken under controversies. The policy framework for these kinds of decisions is defined by three important traits: scientific ignorance, mediatization and the need for innovation. Scientific ignorance is an issue here because decisions must be taken before the end of scientific controversies about the predictability of future climate. Mediatization is key because agents can't have a sensible experience of the global climate change, and some interest-holders (future generations, distant countries) cannot participate directly in the decision. Third, the need for innovation is crucial because today's technology offers the only alternative between fossil fuels and nuclear power as a main primary energy source.

In the case of climate change, the institutional context is the United Nations Framework Convention on Climate Change. The making of global environmental policy is framed not upon a hypothetical code of international law (there is no such a thing), but upon a body of doctrine arising from consistent reference to a given set of principles. The key principles are sustainability (satisfying the

need of present generations without preventing future generations to satisfy theirs), precaution (ignorance is not an excuse for inaction), the common but differentiated responsibility (developed countries take the lead in action against climate change), and economic efficiency (which lead to prefer flexible instruments over blind regulation).

Given the scientific controversies and the fuzziness of guiding principles, no clear-cut demonstration could justify the choice of a theoretically optimum course of action, even in the short term. Historically, climate negotiations can be seen as an oscillation between two regulation modes. On one side is coordinated policies and measures, where countries adopt an uniform international rate of carbon tax. On the other side is emission trading, where a defined emission reduction target is allocated to each country.

1. Introduction

The outlook of the international agenda has changed fundamentally over the past two decades. Global issues, such as nuclear hazards, acid rains, ozone hole and the greenhouse effect are now in the limelight, and the intrinsic characteristics of these invading issues create the conditions for increasing implementation difficulties: threshold effects, high degree of irreversibility, all pervasiveness, but essentially the radical uncertainty about the ecological mechanisms actually at work and even the reality of dangers.

At the same time, the economic and industrial stakes associated with ecological issues have become more and more obvious. The environment is no longer only an externality that the welfare-state forces agents to integrate in the name of collective interest, and has become more a part and parcel of technological, industrial and economic strategies. Let us only mention here the demise of civil nuclear programs in several countries, the global ban on ozone-depleting substances, the use of environmental norms as protectionist tools, the comparative advantages between competing energy sources triggered by the greenhouse effect debate.

This topic paper examines system management and policy framework for the climate change issue using three different points of view. We first start from a general picture of the way environmental policies happen when they have to be framed before scientific controversies can be resolved. In the second section, we examine the normative principles of intergenerational equity, precaution, international solidarity and efficiency. We finally go back to a descriptive stance with the third section on the history of climate negotiations.

2. Controversial environmental issues and public decision

2.1. Uncertainties and sequential policymaking

The specifics of global environment issues stem from the fact that policy-making "runs ahead" of the scientific knowledge needed to inform that policy making because of both the inertia of "natural machine" and the economic and technological dynamics. Waiting for uncertainty to resolve (the policy of doing nothing) is also a choice.

However, the view that scientific uncertainties alone are important and that they will resolve naturally with time would be naive, as we will discuss in this section. In the debates about the magnitude of global environment change and about the costs of coping with it, uncertainties about innovation trends, consumption patterns, land use and economic structural change are everywhere.

The problem of decision-making under uncertainty is usually framed in terms of expected utility maximization given a set of possible but unknown "states of nature", a set of feasible acts and a set of impacts (see Decision Making and Policy Frameworks for Addressing Climate Change). That classical model meets its limits when it comes to emphasize the formation of bifurcations (irreversible or quasi-irreversible trends) in technology because of lock-in effects, in consumption patterns (connection between urban planning and transportation patterns), and in land-use patterns. Moreover, alternative possible baselines in development patterns are ex-ante available, with very contrasted long term impacts and the switch between the one or other of these baselines being made for reasons unrelated to environmental policies.

An example of this uncertainty feature arises when debating the nuclear versus fossil fuel ecological controversy. This relates strongly to such issues as the dangers of the enhanced greenhouse effect, the overall limits to thermal pollution, and the possibility of another large nuclear accident. Besides the lack of scientific certainty that characterizes each of these matters, risks which are immeasurable by nature now have to be taken into account.

After the limitations of the expected utility concept, there is the issue of the multiplicity of actors. Concerns about global environment issues do not result from a learning process where agents have a direct experience of a nuisance; the risk perception is determined by the way the warnings from scientific community are conveyed to public opinion and policy-makers by mass media. This is complicated by the earth sciences not being able to provide definitive answers about the incurred risks, by engineering sciences being uncertain about the potential of competing technologies and by ethical debates about the burden sharing.

The result of any negotiation process depends, consequently, on the power of conviction of the defender of each technical (nuclear energy, biofuels) or institutional project (taxes, tradable permit system, standards) and of its capacity to mobilize controversies in technical fields, economics or ethics. Uncertainty becomes a strategic space for actors. Then, because of the fear of some forms of a dictatorship over the short term, in the name of the long term, resulting from arbitrary technological or economic policies, the trap to be avoided is to be paralyzed by never-ending controversies impeding a minimum consensus for action.

In this context, the evaluation of environment policies, which requires the use of complicated Integrated Assessment models, aims not only at conveying information to policy-makers about the actual feedbacks between economy, environment and human welfare. It also aims at coordinating the expectations of agents having various worldviews grounded in various interpretation of scientific knowledge and ethic judgments.

These Integrated Assessment models are, or should, be both knowledge tools and a negotiation language for actors (see Economics of Potential Climate Change and Integrated Assessment of Policy Instruments to Combat Climate Change): clarification of what is really at stake, coherence analysis of the implicit assumptions behind arguments, description of unexpected consequences of a given policy. The methodological issue is then to define such a language when the looseness of parameters is too high and when some of them are too influential on the results.

Related to this objective, the difficulties of carrying out an agreed cost-benefit balance of climate policies (or any multi-criteria analysis) are easy to point out. Both the avoided costs of environmental change and the greenhouse gases abatement costs are uncertain. To cite a few critical parameters: energy prices and demand in baseline scenarios, timing of penetration of backstop technologies, transaction costs for removing the barriers to negative costs potentials, side-effects of recycling ecotaxes revenues.

Fortunately, the precautionary principle recognizes the necessity to act without waiting for an agreement about controversial long-term parameters. For both scientific and political reasons, it is necessary to launch a sequential decision process instead of searching for a once and for all optimized policy. From a normative point of view, this framing points out the economic value of short term quantitatively limited actions in terms of option value (preventing the bifurcation risks) and information value: to curb down GHGs emissions today provides, for example, more time for getting a better scientific knowledge and drawing benefits from technical innovation. From the decision-making point of view, the aim is no longer to search for optimal decisions, but decisions taken "on time": in many cases, the real trade-off is between the costs of premature action and the risks of postponed action.

In terms of procedural efficiency, a sequential decision-making process focuses on the search for first step agreements between actors who do not share the same vision of the long term and value judgments on the burden sharing. This is the context in which concepts such as "no-regret", "double-dividend", "joint-product" of global environment policies make sense. In practice, an efficient integrated assessment should help in reconciling the kinetics of ecological hazards, of scientific knowledge, of technical change, of environmental concerns and of political cycles.

2.2. Public decision from policy optimization to controversies management

In the context of controversial environmental issues, political stakes may create the need for a decision to be made under emergency conditions. When it takes too much time for science to explain phenomena, the only means to solve a crisis lies in a socio-technical solution based on existing technologies, that is capable of reconciling political and economic interests involved in the debate on the environment. The emergency which necessitates taking decisions in the context of environmental and political crisis constrains both the rhythm and contents of choices.

The European acid rain pollution illustrates that aspect of the public policy decision process under controversies. In this case, regulations (engine emissions norms implying the use of catalytic exhaust pipes and fuel injection) were decided hurriedly in order to solve an environmental issue (declining forests health) without the background of any scientific well-established knowledge. Long after the decisions, the scientific community is not yet really able to provide a satisfactory model of the phenomenon to the economic and political decision-makers.

As a matter of fact, most scientists have given up all unilateral explanations and consider multi-factorial approaches. The causes currently studied include permanent sources such as soil acidity due to atmospheric pollutants (usually called acid rain even if it includes dry deposits), acid fog (for its direct action on leaves and needles), photo-oxidation (PAN and ozone due to the anthropogenic emissions of NOx and volatile organic compounds), and some exceptional climatic events, such as the delayed effects of the 1976 drought, or the high temperatures of the 1983 summer. Finally some scientists put into question the consequences of some forestry practices (especially spruce monoculture).

The short decision time-scale prevents a following of the classic "positivist" way that goes from fundamental knowledge to applied research and implementation of the innovation. Technical solutions to environmental crises have always to be found in the available existing technologies inevitably related to the "trumps" prepared long beforehand.

Moreover, "clean technologies" considered here are not part of the classic categories of innovation: innovations significantly lowering the costs of an existing service or inventing a new service disclosing a new demand. Actually, production costs are increased *a priori* by ecologically sound innovations, which do not bring any new real benefit to the private consumer. Consequently, the producer cannot reasonably expect to find self-maintained markets for getting rid of pollution or ecologically-sound technologies without betting on national or international regulations likely to occur.

Therefore, from the standpoint of the industry, the problem is not ecological but the inverted, economic risk. The inverted risk can be defined as a situation in which the industrial risk generated by the controversial solution to the environmental crisis surpasses the ecological danger. In other words, the producer has to take into account a new environmental cost category; it is neither the ecological costs nor the costs of getting rid of pollution that are usually discussed in literature, but more fundamentally a strategic revision cost, i.e., the cost of redefining part or the entire industrial strategy: re-orienting the "three-liters-car" innovation strategy and adjusting to the catalytic exhaust pipe constraint, converting quickly to unleaded gasoline and setting up of a double oil-distribution network, totally freezing the nuclear program in case of another accident, etc.

Since the innovation policy of industrial groups is generally led by criteria, which are quite different from environmental efficiency, their "normal" behavior will be:
* to try negotiating a framework of new rules which minimizes the adjustment costs;
* to exclude any answer requiring solutions going beyond existing state of the art technology,
* to build, on the basis of the present state of knowledge, an argument capable of scientifically legitimating this position; with the risk that the implicit prophecy supporting this argumentation turns to be defeated either because of the eruption of real environment problems, or because of politically more convincing images produced by competitors.

This suggests that there may be no rational process that would allow the ending of a negotiation to be ecologically efficient. It also suggests that the worse case to be avoided may be the generalization of out-of-control disputes on the inverted risk, disregarding the environmental issue.

On the whole, in a context of scientific uncertainty, the environmental issue is apparently becoming used as an argument for quite independent industrial or energy strategies. This instrumentalization is, in fact, linked to the "mediatization" of the environmental crisis that leads decision-makers to be argumentative towards both public opinion and the political sphere, and to the necessity for each actor to rely, in the short term, on the existing available technologies.

To be brief, the sequence can be interpreted as follows:

1. The environmental issue is highlighted by scientists. Scientific uncertainty leads to controversy.
2. Mediatization: the environmental crisis is a communication issue related to major social stakes. Mediatization of the incomplete information relative to major ecological risk results both in a mobilization of public opinion on these topics and, consequently, in alerting the political sphere.
3. Instrumentalization: the environment is integrated as a marketing argument in industrial strategies.
4. Then, there is an environment-specific innovation process.

Each phase of this sequence is played with a different tempo. Actually, as long as an environmental problem may be considered as securing a certain amount of time to prepare answers, this delay may favor self-comforting attitudes, which will lead to hasty reactions when a crisis draws near. The mediatization process dictates its own political rhythm, driven by short-term considerations.

The attempt at avoiding this mediatization-instrumentalization process would, probably, be irrelevant because this would imply the possibility of a legitimate substantive rationality, the absence of which is actually highlighted by the crisis itself. But it may be interesting to try to escape from the crisis temporality dictated by this process in order to avoid too hasty choices that would leave no time for developing alternative technological projects. The stake here is the one of the regulation of contradictory anticipations of what is the common good and to avoid a too hasty closing of the controversies.

2.3. Summarizing the Policy Framework

In environmental issues, such as the acid rain issue or climate change, the structure of relationships between economy, ecology and society share three important defining characteristics, namely controversies, mediatization and the need for innovation.

* Controversies: The present and future "states of the world" are not only largely random and uncertain, but also controversial. Randomness and uncertainty are linked to the idea of a learning process bringing additional information and have been dealt with through the concept of option value. In the configuration of "decision under controversy", several scientific theories are competing for describing the possible states of the world and the assessment of the probability distribution. The key point of this group process is that decisions must be taken before the scientific closing of these controversies.

* Mediatization: the agents preferences for environment are no more linked to a direct perception of a state of nature, but rather are the result of a mediatization process in which experts from the scientific community are involved. For example, the level of concern about acid rain was very low in Western Germany and the mediatization model better explains the timing of the reactions than does the real evolution of the phenomena, which is very slow. The history of the acid rain concern is in fact an archetype of a new range of problems: people living near a motorway often protest against the noise and impose protection walls, but nobody would complain about ozone layer depletion or greenhouse effect, without the warning of some scientists and the activity of journalists and politicians.

* Need for innovation: The problem at stake is less about internalizing the external costs with a given technical tool-box by addition of de-pollution units, than about playing on the innovation process.

As no industrial commitment can be taken without a certain stabilization of the decision context (norms, laws, economic instruments), and because this stabilization cannot be achieved without a minimum collective agreement on the controversies, there is a collective pressure to reduce this instability and to converge on a subset of theories able to legitimate a minimum agreement.

The competition between scientific theories is then part and parcel of the strategy of each economic actor. Actors look forward to a situation in which the agreement is made on the theory, which maximizes their strategic advantages. The environment becomes a parameter of the industrial strategy with no guarantee that the common agreement be ecologically founded.

Based on these reasons, the reflection on the optimum institutional process for dealing with the economy/ecology interface cannot only be focused downstream, assuming a well-shaped distribution of costs and benefits and a straightforward determination of the cause/effect relationships. Cost-benefit analysis has difficulty in founding collective action when the costs and benefits remain unknown and controversial throughout the decision process.

The institutional context partly determines the cognitive process, and at least the state of suspension of controversies within a scientifically non-achieved cognitive process, which will permit the beginning of the collective action.

3. Principles for managing global commons

In the case of climate change, the institutional context is the United Nations. Formally, this is the United Nations Framework Convention on Climate Change (FCCC) and Conference of Parties. From a more general point of view, the global environmental policy is framed not upon a hypothetical code of international law (there is no such a thing), but upon a body of doctrine arising from consistent reference to a given set of principles.

In this section, we examine four key principles explicitly recognized in the UN FCCC, namely: sustainability, precaution, the common but differentiated responsibility, and economic efficiency.

3.1. Intergenerational solidarity and timely action

Sustainability, broadly defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs, has many interpretations. Developing countries stress the right for sustainable development goes much beyond the preservation of natural resources. In this section, we will focus on an important aspect of the sustainability debate: the question of inertia and climate policy timing.

Let us temporarily adopt the usual deterministic decision-making framework. This is equivalent to assuming that we are certain of what constitutes the stabilization level of a greenhouse gas that prevents dangerous anthropogenic interference with the climate system. In a deterministic setting, discounting, inertia of economic systems and technical change justify that early abatement may be proved less cost effective than abatements postponed to further time periods, at least for targets above 550 parts per million in volume (ppmv).

Climate policies will have consequences for both the present and future generations, and any decision comes practically to a form of implicit or explicit weighting of the value of events occurring at different points in time. Economic analyzes try and make this weighting explicit by using a discounted utility function for comparing different inter-temporal welfare distributions. This makes the welfare losses of given abatement costs lower in the future, and, consequently, a higher discount rate makes postponing action more attractive. This raises the question of the appropriate level of the discount rate (see Equity, Economic Discounting, and Cost-Benefit Assessments).

Socio-economic systems are clearly characterized by important inertia in the sense that rapid changes of their evolution require far larger amount of efforts than smooth adaptations. Recent debates on economic and social inertia have extended beyond the question of physical capital stock turnover, which spans from 5 to 50 years, depending upon the type of equipment considered. They led to the idea that part of the emissions dynamics is determined by parameters beyond the energy sector and whose inertia may be far higher. Mark Jaccard portrays the great diversity of the sources of inertia using a three level hierarchy of the decisions governing the dynamics of emissions and energy demand:

* The end use equipment: For the selection of equipment using energy in a more or less efficient way, decisions are made by private agents and the turnover of capital stock ranges from a few years to two decades. At this level, the relative cost of delivering a given energy service is the key criteria within informational constraints and market imperfections inhibiting the access to the best available technologies.
* The infrastructure and industrial equipments: This level is largely governed by centralized public and/or private decision-makers. It encompasses the buildings, the major transit modes, and industrial infrastructure. The turnover of capital stocks is measured in decades and every decision involves an amount of capital whose magnitude is far higher than that at the end-use level. Except in some energy intensive activities, energy costs are a minor decision parameter compared with, for example, strategic criteria in the industry or cost/speed ratio in the transportation sector.
* Land-use and urban planning: This level is driven by infrastructure decisions and by public policies which can either be explicit, i.e., urban planning, incentives to an even distribution of the human settlements, or implicit, i.e., subsidies to mobility, or rules governing tenants and landlords relationships. It greatly determines the growth of transportation needs and the related demand for fuels.

Beyond the turnover of capital stocks, inertia in the economic system results from the interactions between these three levels. Final energy demand is driven not only by the efficiency of the end-use equipment but also by structural changes in the production sectors (share of energy intensive industries or as just-in-time production processes) and by evolutions in life styles and in the geographic distribution of human settlements.

For example, the very architecture of the buildings determines the air conditioning requirements; urban forms determine not only the transportation needs but also the relative proportion of travel made on foot, on bicycles, by rail or by private car. The attraction of activities around the proximity of infrastructures, the induced investment, the nature of skills and the amount of embedded interests generate dynamics that are hard to curve overnight.

Most economic analysts pointed out the fact that accelerating the turnover of capital stocks would imply higher costs of climate policies because the costs of premature retirement of existing capital stocks are to be covered, in addition to the costs of abatement techniques.

Inertia also has an opposite effect: the more important is the inertia (it is reasonable to anticipate that reforming the energy systems will take at least 50 years), the sooner one has to start. This is why the Intergovernmental Panel on Climate Change (IPCC) states that: "The choice of abatement paths involves balancing the economic risks of rapid abatement now (that premature capital stock retirement will later be proven unnecessary), against the corresponding risks of delay (that more rapid reduction will then be required, necessitating premature retirement of future capital)".

The balance between both these effects is a matter of empirical evaluation, but in a certainty case it could be argued that, given a 550 ppmv target for atmospheric CO_2 concentration, the balance might not be that biased in favor of early abatement.

3.2. The precautionary principle

Reasoning in a certainty case ignores the fact that we are not likely to know in the near future at what concentration level dangerous interferences with the climate system would occur, which is the FCCC objective adopted at Rio in 1992. The precautionary principle states that, when there is a danger of large or irreversible damage, ignorance is not a motive for inaction. In this section, we will first examine some potentially large damages, before discussing more in detail the effects of irreversibilities.

Beyond scientific uncertainties on climate dynamics, uncertainties endogenous to human behavior may also influence the timing of action. Sudden changes in public concern should be anticipated for many reasons. Past experience demonstrates that political life cycles of environmental issues is not only driven by scientific discoveries or symptomatic events, but also by the necessary maturation of the public acceptance of new risks, by possible mismanagement of information, (e.g., the``mad cow'' crisis) or by the combination of political parameters as illustrated by the European acid rain/forest dieback crisis example.

This is why IPCC also states that\ “the challenge is not to find the best policy today for the next 100 years, but to select a prudent strategy and to adjust it over time in the light of new information". To fully recognize this statement's meaning, however, one has to consider that uncertainty is not only limited to the impacts of climate change, but also pertains to the economics of reducing emissions.

Uncertainties about the baseline socio-economic future are as large as uncertainties about the climate system, and this is all the more dangerous as the underlying technical systems are rigid. In the transportation sector, the loop between demand and supply patterns is so high that inertia may lead to a lock in carbon intensive development patterns. Experience demonstrates that progress in the efficiency of oil-based motors has been largely offset by rebound effects such as higher driven distances; bigger cars and increased competitiveness of road compared to rail and waterways transportation. This can significantly delay the market penetration of low- and zero-carbon transport technologies (see CO_2 mitigation and adaptation measures).

Evolutions in energy demand and technology are intrinsically uncertain. Most of the baselines retained in recent forecasting studies incorporate expectations of stable or steadily increasing energy prices over the following decades. These are not, however, fully supported by recent analysis of structural determinants of oil prices, which underlines in particular the drastic decrease of the cost of new discoveries. Moreover, they do not capture possible bifurcations in trends in the transportation sector over the long run, which are conditional upon today's infrastructure decisions.

To some extent, technical change on carbon saving techniques supports the idea of belated GHG abatements. If, thanks to invention and adoption of technical innovation, costs of these techniques decrease along with time, then technical progress concurs with discounting: it decreases the relative cost of future efforts.

The fact that most available modeling tools capture this process through an autonomous technical change coefficient may, however, reinforce the common misperception that carbon saving technical change is a “Manna from Heaven” whose quantity steadily grows over time. Considering more realistically the fact that technical progress is yielded by investments in research and development leads to a different view because it focuses on the timing of required policy signals.

This is why the logical distinction between the timing of abatement and the timing of action must be emphasized. Abatement implies investments within a given technical endowment. Policy action, such as a carbon tax aiming primarily to induce low-cost alternatives in the future, is much more comprehensive.

The combination of the irreversibility of CO_2 build-up with unexpected bad news from climate science could lead to a sudden acceleration of adaptation and mitigation policies to compensate a delay in abatement efforts. Stabilization of CO_2 concentration at 400 ppmv has already become a goal difficult to defend in a full cost-benefit analysis (although it can be noted that there exist several consistent global energy scenarios to this target). It will be the same for 450 ppmv in a couple of decades if present emissions trends continue.

The precautionary policy approach explicitly balances the environmental irreversibility: that increasing the stock of pollutant today implies more effort tomorrow, and the investment irreversibility, i.e., the opportunity cost of over-cautious policies. The first and most robust insight of the analysis is that the critical factor is adjustment costs under the worst-case hypothesis. If the target is 550 ppmv, then differing action until 2010 has only a modest effect upon the optimal cost profile, but if the target is 450 ppmv there is a very high supplementary cost to waiting.

There is a “window of opportunity” for any concentration target. Out of this window of opportunity, we would then face the dilemma of choosing between economically disruptive policy measures or facing climatic changes which are today viewed as unacceptable. An earlier mitigation action may increase the flexibility in moving toward stabilization of atmospheric concentrations of greenhouse gases.

The reverse is also true. It is still arguable that, ultimately, damages due to climate change will be proven negligible even for an average temperature increase well over 2^{o}C. Then, symmetrically to the environmental irreversibility effect, an investment and technical irreversibility effect has to be considered which sets a brake to climate change mitigation policies. It implies that waiting for more information will avoid the risk of over-protecting the environment.

The balance of these two opposed irreversibility effects is still an unsettled issue. Conclusions may depend significantly on ideas about technical change. If indeed, instead of being viewed as autonomous or induced in a very flexible manner by public policies, technical change is treated as an autocatalytic process of learning-by-doing, economies of scale, informational increasing returns and positive network externalities, then it can induce bifurcations and lock-in processes.

Beyond a critical point, market forces indeed tend to reinforce the first choice in a self-fulfilling process instead of correcting it. Seen from 1998, there are several possible market equilibria in 2020, and several possible states of the world characterized by different technical contents. The bifurcation towards one or another depends upon the early decisions made today and on the present expectations.

For example, we can easily distinguish two very different equilibria in the transportation sector with relatively similar total costs, but very different carbon contents: they can't be discriminated today, but the costs of shifting from the adopted one to the other in the future might be all the more important when the transition period is short. In such a setting, the technical irreversibility effect may be higher than generally expected in literature.

Another important component of the option value in the context of global environmental risks has been named ‘dependent-learning’ by economists A. C. Fisher and W. M. Hanemann. To quote them, it surely requires no algebra to show that, if the information about the consequences of an irreversible development action can be obtained only by undertaking development, this strengthens the case for some development. In other words, at the beach one can't taste the water without wetting one's feet.

Here again one has to consider symmetrically this effect on the environmental side and on the technological side. Less CO_2 emissions would slow the rise of the climate change ‘signal’ over the climatic natural variability ‘noise’. This effect, which supports the idea of more emissions over the short run, may actually be very small. According to Prof. B. Bolin, former chairman of the IPCC, implementing the Kyoto Protocol would only make a difference of 1 or 1.5 ppmv for the CO_2 concentration in 2010. That is to be compared with the about 120 ppmv increase over the pre-industrial level.

Conversely, emission control policies are likely to bring significant scientific, technical and institutional learning. This is why, in the case of climate change, we argue that the dependent learning effect is far higher on the technology-side. This is an argument for earlier decisions which may not have received full attention in climate policy models to date.

3.3. The common but differentiated responsibility

The common but differentiated responsibility states that developing countries should take the lead in action. One of the likely deadlocks of climate policies is that, under the dominant interpretation of the Kyoto framework, the rules governing the quota allocation beyond 2012 have to be clarified for embarking developing countries in climate policies. "Until the question of emission rights and entitlements is addressed equitably, it [will] not be possible to have emission trading". This request by the G77 expresses both the concern of developing countries to be excluded from the new technological markets provisioned in the Kyoto protocol and the impossibility for them to commit to binding emission limits without prior clarification of the rules of the game. In this section, we discuss the burden sharing issue.

Those who expect that the Clean Development Mechanism (CDM) will get round the allocation problem should remember this blunt statement by the "father" of the concept Estrada-Oyuela, in 1998: "Though I facilitated approval of this proposal, I did not like it. My reservation was that the CDM is considered as a form of joint implementation but I do not understand how commitments can be implemented jointly if only one Party involved is committed to limit or reduce emissions and the other Party is free from the quantitative point of view". This problem can become serious if baselines from individual CDM projects are set without regard to the total emissions of greenhouse gas in the country where the project is located.

Beyond this North-South divide, the entitlement problem also underpins the "supplementary condition to the use of flexibility mechanisms" requested by the EU. This condition expresses, indeed, the concern that countries using these mechanisms to escape domestic efforts may be embarked on carbon intensive pathways and will not accept ambitious targets for the next budget period. This dynamic inconsistency problem can be resolved only through target setting rules, which preserves the environmental integrity of the framework.

In such a context, the recommendation by the IPCC Second Assessment Report that "equity and efficiency should be separated", however wise it is, is hardly operational. Indeed, allocating emissions quotas amongst countries inevitably leads to questioning the linkages between equity and efficiency.

Negotiating burden sharing rules in the real world confronts evidently with the non- observability and the uncertainty of some critical parameters. Hence, the operational necessity of simple rules relying on observable parameters: population, wealth, or energy use. Many of these rules have been proposed in literature. None of them has an economic legitimacy *per se* and none even pretend to be a proxy of the first best economic rules. They translate a mix of political judgments, but they will not be apt to support an agreement over the long run if they lead to an outcome that will be viewed as too costly and unfair by some parties.

The obvious start is to examine per-capita figures using the present situation.

Table 1 presents the allocation of a total 10 billion dollars bill among countries on the basis of the per capita Gross Domestic Product (GDP) allocation rule. This rule is that the burden is shared proportionally to wealth. The reference year is 1997. We come to the fact that both individual expenses and total national expenses are strongly differentiated among countries. Following this rule, each North American should pay $10.3 for climate against only 15 cents for each Indian (a 71 to 1 ratio), each European should pay $7.6 (a 52 to 1 ratio with India), and each Chinese only 26 cents (a 1.8 to 1 ratio). Globally, OECD countries do contribute to nearly four fifths of the overall effort.

Table 1. International allocation of a 10 billion dollar climate burden proportionally to per capita GDP.

Even if climate expenses are built on the basis of purchasing power parity GDP (figures not shown in this paper), the discrepancies between countries remain wide. With this new basis, each American pays $8.2 (17 times more than each Indian), and each European $5.7 (a 12 against 1 ratio). OECD still contributes to three fifths of the overall effort.

It is important to note here that, although it is based on an allocation of weights in the inter-temporal utility function proportional to wealth, the allocation rule we obtain here is a good translation of the common but differentiated responsibility of the UN Framework Convention on Climate Change. Had we used a more equitable weight distribution, for instance by giving each agent the same weight, we would have obtained a costs distribution in which the richest region would finance the integrality of the public good, which might not be the most efficient.

Beyond today's per-capita figures, it is critical to consider trends and expectations when it comes to regulating the growth of CO_2 emissions.

Some empirical results lead to the idea that in the richest countries, demographic increase is more critical than the increase in per capita GNP. The intuition behind this result is that per capita growth consists mostly of dematerialized services that embed little greenhouse gas emissions. The idea is also supported by the fact that only population increase can explain the emission growth in the poorest countries, which had negative growth per capita over the period from 1985 to 1995.

The link is less appealing for other areas of the world that are industrializing. Figure 1 shows that population growth and emission growth are positively correlated, although countries which are experiencing large structural change in the economy are well away from stabilization per capita - in both directions.

Figure 1. Emissions trends vs. population trends, 1990-1996. Average population growth rate (source World Bank) versus fossil fuel CO_2 emissions variation rate (source WEC). In 1996, fossil CO_2 emissions were: World: 6.51, USA: 1.75, EU 15: 0.96, China: 0.83, India: 0.22 GtC.

Demographics helps to explain part of the divergence between Europe and US initial propositions for Kyoto. The US Bureau of the Census foresees one hundred million new inhabitants in the United States between 1996 and 2038, with a 32 million increase by 2010. To date, the debate has mainly focused on per country rather than per capita emissions, hiding the consequences of this particular population effect.

At current per capita emission levels, these 32 million US inhabitants correspond CO_2-wise to 271 million Chinese, 770 million Indians or 75 million Europeans. Even assuming annual variation rates of per capita emissions of -1% in the US and +4% in developing countries, these figures remain impressive: the additional population in the US emits as much as 142 million Chinese or 406 million Indians.

It helps to explains why -15% seems unrealistic and unachievable in America while technically feasible and economically manageable in Europe, even if static economic reasoning would suggest the opposite: given the higher per capita emissions levels, many low cost reduction opportunities that have been already exploited in Europe may still be available in America.

After per-capita figures, we will explore a convergence scheme.

The hot issue of the climate negotiations is the entry of non-annex I countries within a binding agreement. Per capita convergence is possibly one way to involve non annex I countries in an eventual emission market without constraining them. We consider here short-term implications of convergence. A convergence goal is defined by the date at which per capita emissions are supposed to converge, and the level of the common target. We explored targets in 2100 or 2050, at levels going from 0.5 to 1.5 tC per person per year.

Table 2 uses the projected population and the prescribed quota per head to derive the 2010 global and regional emission quotas. Results are in the same units as targets defined in Kyoto: CO_2 reductions relative to the base year 1990.

Table 2. Implications for 2010 of a normative per capita linear convergence of fossil CO_2 emissions.

Looking first at the global level, it is noticeable that in 2010, the goal 1.5 tC in 2050 is broadly consistent with the central no action IPCC scenario IS92a: +42% emissions. This would make it difficult afterwards to stabilize the atmospheric CO_2 concentration at a level of 550 ppmv (a level corresponding to the doubling of pre-industrial concentration, and over which the temperature increase could be judged dangerous).

Due to its softer slope of decreasing emissions per head, Western Europe has a prescribed target of -10%, while the USA are pressed to -15%. However, the USA are protected in the sense that future population increases grants this country more emission rights and compensates the higher rate of per capita decrease implied by convergence. All other Annex I countries stand in between. The short horizon puts the USA under a stronger pressure, and the longer run horizon favors the USA much more than countries with lower population dynamics (Central and Eastern Europe). The Western Europe quota in 2010 is more dependent on the target range at both horizons.

Keeping the 1tC convergence target at both horizons (2050, 2100) we now turn to non Annex 1 countries: is the per capita convergence principle consistent with their growth needs? Possible quotas have to be compared with how much emissions are expected under different business as usual hypotheses. Such a criterion favors low 1990 emitters per head: South Asia and Sub Saharan Africa. Others might be neutral (Middle East and North Africa) or slightly favorable to the 2050 horizon.

However in the case of (1tC, 2050) the 2010 index of +58% for China and +64% for Latin America is not up to their economic growth expectations. Chinese emissions in 1996 were already 30% above these in 1990. Paradoxically, the relatively slower demography of China up to 2010 (+27%) is putting at risk its favor to such a purely per capita criterion which would not take account of past ecological debts of Annex I countries.

3.4. Efficiency

In modern economics, global environmental risk is often considered as a classic problem of the "public good". This means that a private activity (the legal ownership does not matter here) is implicitly allowed to "use" the environment, i.e., to take the risk of affecting the quality of public goods; this can be expressed in theoretical terms as the attribution of "primary property rights". Market economy operates when these rights are defined and ascertained; when new standards are enacted for the environment or other fields, these rights are really redistributed. This redistribution results in an institutional process including the administrative, juridicial and political spheres at various levels from local to international authorities. Firms, local and national authorities, as well as groups of citizens can be affected.

Theoretically, the allocative dimension and the distribution of both costs and benefits should be considered. Appendix 1 discusses the fundamental difference between cost-benefit versus cost-efficiency analysis in more detail (see *Equity, Economic Discounting and Cost Benefit Assessment*). However, during the following decade, the focus might remain on how to minimize the costs of meeting the Kyoto targets. This is why in practice, the dominant negotiation language will probably remain only in terms of cost.

However, the word "cost" is not without confusion in itself (see *Generic Assessment and Costs of Response Strategies*). This is because the concept of cost applies to four scales in the social system:
1. At the scale of the plant or the household good, technical costs for alternative energy saving technologies can be known with confidence, in an engineering perspective. This corresponds, for example, to the difference in cost between an electric vehicle and a conventional gasoline-powered one.
2. At the scale of a given industry in a given region, sectoral costs associated with alternative regulation programs can be computed. An example of this would be the costs to the electricity industry as a whole to cap CO_2 emissions at its 1990 levels.
3. Economy-wide, costs have to account for inter-sectoral and general equilibrium effects. For example, when analyzing stricter thermal insulation norms in commercial buildings, one has to account not only for the cost to the landowners, but also for the extra activity in the building sector.
4. Finally, social costs go beyond the economy to encompass other welfare objectives, such as employment or health. These are very difficult to define and measure precisely. However, these kind of costs cannot be ignored.

This distinction in scales allows the clarification of policy debates on the no-regret policies. These are defined as the measures that will not be regretted if, ultimately, anthropogenic climate change is proved to be harmless. There is no rigorous definition of the no-regret concept and it will suffice, for the following discussion, to note that a "no-regret" strategy is possible only if the current state of economy is assumed to be located somewhere below the theoretical production frontier between conventional goods and the quality of environment.

First centered on the efficiency gap due to market imperfections in the energy sector (the so-called bottom-up and top-down debate), discussions about no-regret were extended to the environmental double-dividend expected from the side-effects of GHGs reductions on other environmental issues and from the economic double-dividend from carbon taxes.

Environmental double dividends are also known as "ancillary benefits" of climate policy. The issue with naming reflects the complexity of the underlying question: policymakers target several objectives at the same time and each choice has implications for all of those. In other words, everything depends on everything.

Still, research to date finds, rather consistently, that the result that reducing global pollution tends also to bring local air quality benefits, but the opposite is not true: local air quality improvement measures may use more energy, and therefore may lead to an increase in global CO_2 emissions.

The above discussion about the meaning of 'cost' should not be taken as a tree hiding the forest. Even if there can be only very crude estimates of the costs, an order of magnitude estimate is basically all what policymaking needs. An assessment of short-term economic consequences of various long-term CO_2 concentration ceilings is possible:

Setting such a ceiling at 650 ppmv is consistent with global CO_2 emissions averaging around 10 Gigatons of Carbon (GtC) per year during the next century. Given that current emission level is around 7 GtC (more or less 1GtC), there is no sense of urgency for this target.

Achieving 450 ppmv is consistent with an average carbon budget of about 6.5 GtC per year during the next century. This is less than the actual emissions for the year 2000. Given the previous discussion of inertia, little additional explanation is needed to understand that immediate action is required to ensure compatibility between this target and future demographic and economic growth.

The numbers above suggest that an ultimate objective for atmospheric CO_2 concentration in the range of 450 to 650 ppmv makes economic sense. To set a more precise objective seems difficult. For example, the target of two times the pre-industrial CO_2 concentration level retained by the EU before Kyoto to support its position, and which is governed at least implicitly many thought-experiments, refers to a CO_2-equivalent level of 550 ppmv. Experts generally agree that the target 550 ppmv does not adequately qualify the ultimate UNFCCC policy objective for various reasons:
* Ambiguity: accounting for other greenhouse gases, the target could be interpreted as referring to about 450 ppmv for the level of CO_2 alone. It is also unclear whether 550 is more related to radiative forcing, which matters for climate dynamics, or to a two degree warming, temperature being a proxy for damages.
* Atemporality: there are no serious policy targets without timetables. This is all the more important that the speed of climate change commands the variability of climate, and that increased intra-annual and regional climatic instability is directly related to the occurrence of extreme events in local ecosystems and economies.
* Uncertainty: surprises are still possible regarding the concentration level and the pace at which global climatic non-linearities occur, leading to a revision of the ultimate objective.

Modeling exercises suggest that the idea of a long run GHG concentration target apt to prevent dangerous interference with the climate system, as phrased by the Climate Convention, should be taken with caution. This is the reason why the IPCC Second Assessment Report strongly advocated that climate policies must be framed as a sequential process: one should not look forward to optimize the response over the long run, but one should try to find a flexible strategy apt to be modified in the light of new information regarding climate and technology.

From a price point of view, models show that a carbon tax of about 50 to 100 dollars per ton could have a significant effect of the 10-20 years horizon. Existing carbon sequestration technologies are in the range of 100-200 dollars per ton. As we have seen above, the order of magnitude of carbon emissions per capita in a developed country is a few tons per year. Given the existing energy prices, such a tax would increase household energy bills significantly, but not to the point of doubling it.

Theoretically, in an ideal economic world perspective, a carbon-tax should be set at an uniform rate across all countries, since it aims at giving to every agent the same "signal" about the potential costs of climate change (see *What Do We Know about Carbon Taxes*). In practice, one has to account for many pre-existing distortions in energy markets.

Side-effects of an internally recycled ecotax were analyzed in great detail, some empirical macro-economic studies mainly in the European context concluding to a positive double-dividend. Works from a theoretical perspective shed some doubts about the likeliness of such a double-dividend being apt to offset the gross costs of climate policies if all the general equilibrium effects of such a fiscal reform are accounted for. It is not the place here to enter into the details of this discussion, but it is uncontroversial that a double-dividend occurs when the marginal distortion of a carbon tax is lower that the distortion of taxes to which it is substituted.

This introduces a second element of heterogeneity between countries' cost functions. Many European countries, for example, finance not only their public administration but also their health system, social security and teaching system by raising funds from taxes levied directly or indirectly on wages, which is suspected to be a cause of structural unemployment; the fiscal system is very different in the US and in Japan as a practical translation of different views of social organization. In the same way, the measurement of the distortionary effects of pre-existing energy taxes cannot be directly derived from their observed level: many oil importing countries indeed levy energy taxes to achieve public objectives, such as security, minimization of shocks of trade balance, funding of road infrastructure.

The consequence is that the recycling of a carbon tax creates a wedge between the gross cost of GHGs abatement (the sum of the costs of abatement technologies) and the net cost for the economy; determinants of this wedge are country specific and are not apt to be homogenized through foreign trade.

The Kyoto Protocol recognizes the limitations of tax-based mechanisms. Together with quantitative targets, the Protocol contains several provisions for the use of ‘flexibility mechanisms'. The most important facility is emissions trading (see *Using Emissions Trading to Regulate Global GHG Emissions*). A second flexibility mechanism is the banking-borrowing of emissions allowances. Third, compensations between pollutants is possible, since the target is on a basket of six gases. For example, methane emission cuts beyond the target levels could partially offset insufficient reductions in carbon dioxide emissions.

To facilitate each country to keep within its emissions assignment, the Protocol also allows: emissions trading amongst developed countries, the joint implementation projects in developed countries and the Clean Development Mechanisms in developing countries.

In addition, the existence of the so-called European Bubble leads to the possibility for other Annex B countries to create new `bubbles' within which they can renegotiate their assignments through a political deal between GHG emissions and other economical and political objectives.

The risk of too high economic costs of a trading system can be limited by introducing an upper cap to the price of permits, also known as a safety valve. This can be done by ensuring an infinite supply of permits is available at the given cap price, for example $150/tC.

The safety valve may facilitate the commitment to action. But the environmental efficiency of the system is not guaranteed under this system. There are two answers to that concern. First, a cap price will exist in practice even without an explicit safety valve. It will be the expected penalty for noncompliance. This is because an economically rational agent would always choose to pay a fine of \$150/tC instead of buying permits at \$250/tC. Second, the policy objective should not consider only the environmental efficiency, but the total social cost that also includes the effects of abatement measures upon the economy.

On the other hand, it is also possible to implement in the trading system a lower floor for the carbon price. This recent proposition may contribute to addressing concerns about effectiveness of a flexible emissions control system. In effect, doing both confines the market in a tunnel between the floor price and the ceiling price. Such a system would combine features of both price-based and quantity-based instruments.

Given the scientific controversies and the fuzziness of the guiding principles, no clear-cut demonstration could justify the choice of a theoretically optimum course of action, even in the short term. In the next section, we turn to a historical perspective to understand todays situation of the policy framework.

4. Historical perspective on climate negotiations

The history of climate negotiations can be seen as an oscillation between two regulation modes. On one side are coordinated policies and measures, where countries adopt a uniform international rate of carbon tax. On the other side is emission trading, where a defined emission reduction target is allocated to each country. In this section, we describe how negotiations arrived to the emissions trading system, and discuss its potential for the future.

4.1. Before Rio: a quick start, then a failed EU initiative

Let us come back to the emergence of the global warming issue on the international policy arena and the respective role of the US and the European countries in this affair. There is, indeed, no simple explanation of the reasons why the US administration put it on the table of the G7 meeting in 1988.

Many parameters have played a role within the US political system: the pressure from ecologists movements, the public sensitivity to climate risks after the dramatic consequences of the 1987 and 1988 summers in the middle-west, the activism of the epistemological community in favor of the energy efficiency who wanted to transform this emerging challenge into a new opportunity. This would probably never have resulted so quickly in such a consideration by top level officials without some more general concerns over the stability of oil markets and its geopolitical implications. Climate change was viewed by a part of the US administration as a possible tool for convincing the US public opinion to accept some form of internal policy in the energy field.

Obviously, the geopolitical interest in the global warming issue changed drastically after the gulf crisis and the war against Iraq, and to a lesser extent after the fall in the costs of the discovery of new reserves.

On the European side, the dominant reflex was to frame the response in terms of internationally coordinated tax. It appeared later that the governments of some big European countries, officially supportive of this proposal, were not really ready to confront the political difficulties of implementing it. North European countries (Sweden, Norway, Finland, Netherlands) adopted small carbon or carbon energy taxes before Rio de Janeiro for domestic reasons, but also to have a demonstration effect and facilitate the adoption of a harmonized tax within the European Union.

It is also certain that some of the departments of the European Commission, such as DG XI but also in part DG II, developed a strong argumentation in favor of a mixed carbon-energy tax. France, having officially rejected any form of quota approach, proposed a very high carbon tax (around 166 European currency units) and Germany having claimed its will to support an increase of the fiscal burden of energy uses, the road was open for the so-called Rippa di Menea initiative.

This initiative is to be understood in the context of the formation of the Single Market and in the perspective of a unique currency. The context created a need for harmonizing the policies of the European countries. Contrary to the energy field, the environment was one of the recognized areas for common policies. Symptomatically, the European White Book on Growth and Employment advocated the importance of a synergy between growth, the environment and employment.

The internal consistency of the Rippa di Mennea proposal was strong and articulated several levels of argumentation typically representative of the linkages between climate policies and other strategic objectives:
* the prolongation of energy policies and disciplines adopted during the two oil shocks: the inverted oil shock in the middle of the eighties could, indeed, discourage any new progress in direction to energy efficiency and to carbon free energy supply; would the period of low oil prices last too long, the European countries might be incited to come back to the pre-1973 situation, namely a high fragility of their economy in case of a new oil shock,
* strategic interests *vis-a-vis* the US: climate change is an issue on which the US cannot be anything but in a defensive position, because of a very high level of per capita emissions which is, probably, non replicable all over the planet; to put a credible proposal on a world scene would have two positive outcomes: either this proposal would be withdrawn in the exchange of concession on the hard discussions for the building of the World Trade Organization, or the proposal would be accepted and Europe would benefit from this first US effort towards an internal discipline in terms of fossil fuel consumption
* the possibility of taking advantage of this international tax to swap energy taxes for some other taxation and to yield a so-called double-dividend of environmental policies, in order to protect the welfare society in an opened and competitive economy.

But, the formal European proposal was withdrawn a few weeks before the Rio Earth Summit without any attempt to impose it to the US and even without any attempt to use it diplomatically as a symbol of a will to act. This withdrawal highlights one of the constant difficulties in building a European leadership in environmental affairs, i.e., the gap between the discourses at the elaboration stage in the European formal arena, and the reality of wills and interests of European economic actors and political representatives when the time for effective decision approaches.

This cannot but raise the question of to what extent the internal elaboration mechanisms of EU policy are undermined by an unbalanced representation of interests and visions of the world which is revealed at the last minute, at the moment of truth when the apparent consensus about generous ideas breaks down.

Some economic rhetoric was voiced against the ecotax approach: distorsions in international competitiveness; non-effectiveness of price signals, and theoretical inconsistency of the double-dividend. This set of counter-arguments against an ecotax would not have sufficed in undermining the support of the tax approach in the EU without the specific intellectual and political conditions inhibiting the emergence of pro-active alliances in any EU country and between some key countries.

To sketch the major determinants of an EU leadership over that time period, we have to reduce a complex multidimensional game into a set of key players. In principle, given the lessons of economic analysis, the game is rather simple. On one side, the ministries of the environment and the ecological movements and the labor-intensive industries should be in favor of an ecotax. On the other side, high energy intensive industries should be against the tax. The finance ministries should be in a rather neutral wait-and-see position.

In terms of countries, the positions were *a priori* clear: France, Germany, Italy and the Netherlands were in favor of some form of tax approach, while the Southern Countries were reluctant. Even if this may be contradicted by a general equilibrium analysis of the feedbacks of such measures, the perception by these countries of their own interest was that to place the same level of taxation on each country irrespective of their development level and of the emissions per capita would be inequitable unless compensatory measures are accepted; the level of the common ecotax is indeed a tangible metric of the marginal cost, while the general equilibrium feed-backs, however real they may be, are intangible and appear only in the artefacts of economic models. As to the position of the UK, it was to repeatedly reject any compulsory harmonization of taxation.

In fact, the outcome of this game was greatly determined by the contrast between the looseness of the official advocates of the ecotax approach and the constancy of its contradictors. This contrast can be explained by the following parameters:
* In many member countries, finance administrations supported only mildly the idea of ecological taxes for two sets of reasons. The first is the vanishing fiscal basis hypothesis. A carbon tax is indeed meant to cut down its own basis. In fiscal theory, a good tax has to be levied on very inelastic activities, both for reasons of minimizing welfare losses and for reasons of predictability of the government revenues. This posture can be criticized on the grounds that energy consumption is rather easily foreseeable from one year to the next. Also, any tax basis vanishes beyond a certain point: for example, payroll taxes may create a disincentive for employment, may trigger a labor saving technical change, and capital taxation may provide incentive for relocation of activities. The second reason explaining the lack of support for the ecotax was that finance departments have cultivated the idea that taxes and charges do not and should not have an incentive effect, with few exceptions such as taxes on tobacco or alcohol. At the root, this position comes from the political necessity to block, from the outset, the multiplication of proposals of fiscal basis under the pretext that on this basis, taxes may have an incentive effect and a positive economic outcome over the long run. Would any tax be justified on such grounds, this would make it more difficult to impose a minimum discipline on public expenditures.
* Model and analysts suggest that a swap between an ecotax and a labor tax would affect adversely only 10 to 15% of firms in the industry, depending on the country and the level of transfers to non wage revenues. While most of the industry benefits from modest reductions, those hit face significant costs increases. This raises a negotiation problem. It becomes impossible to give credit to the representatives of the whole of the industrial interest in every country. The winners of reform may be far less concerned, informed and organized than the potential losers. This imbalance in the representation issue was all the more acute that no provision was made in the first versions of the EU

proposal to take some guarantees against ecological dumping.
* Moreover, the fiscal neutrality of the reform, which conditions the occurrence of a double-dividend, was not guaranteed in the eyes of business representatives. This lack of credibility, which was grounded on concerns about the mismanagement of money by public administration, was legitimated by two contextual features. First, the Ripa de Menea proposal and the following discussions raise a fundamental problem of competence and subsidiaries. If higher energy taxes were adopted under the pressure of a European process, there would be no certainty that the revenues of such taxes would be recycled to achieve a tax neutrality, because such a recycling has to be under the authority of national governments, not Europe. In other words, the fact that no agreement, and hence no commitment, could be made on the type of recycling, facilitated the caricature of the ecotax into an additional fiscal burden legitimated by environmental pretexts. Second, this argument was reinforced in 1994 by the occurrence of the Maastricht convergence criteria which determined the eligibility to the Euro monetary sphere. These criteria comprised the limitation of public deficits to 3% of the GDP and the concern of the industry was that this new source of revenues would be used by the governments to meet these criteria, instead of decreasing public expenditures.
* Politically, with a low-profile UK position, the success of the ecotax proposal was conditional upon a common pro-active position of France and Germany. At this point, the differences in the perception of nuclear risks in France and Germany represented one of the big obstacles towards a common approach. France suggested a progressive carbon tax in 1991. Contrary to the French approach in favor of a pure carbon tax, the European proposal consisted of a mixed tax, based both on the energy content and on the carbon content. The purpose of this balance was to account for a widely shared concern in European countries (and especially in Germany) about the short and long term risks of the nuclear power. This central point was continuously criticized by French officials. On one side, some pro-nuclear advocates were unprepared to accept the idea of a mixed tax, claiming that the problem at stake was global warming, and nothing else. Technically, a compromise was possible since the mixed carbon-energy tax, far from weakening the competitiveness of the nuclear energy, resulted in a higher burden for the electricity produced by fossil fuels; moreover, a compromise was possible around a share above 50% for the carbon content. But ideologically this would have come to recognize that nuclear energy is not environmentally friendly and is the only response over the long run. On the other side, the anti-nuclear and ecologists movements in France did not support the government official position, as they suspected an implicit encouragement to nuclear power everywhere in the world.

These conflicts created a situation in which the French government suddenly stopped any support to the EU proposal one month before the Rio Conference. Other member countries did not support the text further. This dropping of the Rippa de Menea proposal paved the way to a specific solution in Germany and in the Netherlands where the basic tool of climate policies in the industry would be the voluntary agreements.

4.2. From Rio 1992 to Berlin: the diplomatic timing and the adoption of binding targets

In the absence of articulated economic proposals to mitigate climate change, the EU could not pretend to exert a leadership through a demonstrative effect apt to force the USA to take its responsibility and to provide some guarantees to developing countries that the challenge was taken seriously into account. From the perspective of a developing country, there was no real difference in the concrete proposals of the three key players in the North (the USA, the EU and Japan). This resulted in the unbinding commitments by countries of the Annex 1 of the Climate Convention to stabilize their emission in 2000 at their level of 1990.

Note that these non-differentiated targets are neither economically efficient nor equitable, given the huge discrepancies in the emissions levels per capita or per Gross National Product in the Annex I countries. The unbinding character of these claimed targets facilitated their adoption, even by countries that were very reluctant to act, and it was felt politically useless and dangerous to launch a quarrel about targets without real consequences over the short term. This form of commitment was the only way to save face in the absence of alternative proposals about price signals. This diplomatic fait accompli, in fact, framed the future Kyoto protocol.

Just after 1992, the possibility of an approach in terms of coordinated policies and measures (including carbon taxes) were not ruled out. But it was undermined by contradictory political agendas in the US and in the EU.

In the USA, the new democratic administration tried to impose an energy tax. Its implementation was blocked because of a wave of demands for exemptions by the industry; this wave being triggered when the administration accepted such exemptions for a very few sectors and had little ground to refuse other exemptions. This type of perspective remained on the agenda despite the political risks specific for the American reflex against taxation, and could have benefited from a diplomatic push by the European countries in the context of the follow up of the FCCC. In other words the coordinated policies and measures remained on stand-by.

The alternative solution, the use of emissions trading systems, was increasingly analyzed in the US economic and business circles, but with some ambiguities: for many apparent supporters in the industry, this was to escape a tax system and it was unclear that industry was really ready to accept emissions cap. Moreover, the need for flexibility (see above, end of subsection 3.4 on Efficiency) was increasingly argued, but it was unclear whether the US industry was really ready to support the setting up of international trading systems and was really convinced by the potentials for joint implementation projects in countries in transition and in the developing countries. In other words, the balance between the two options remained very unstable.

During the same period, however, the perspective of coordinated policies and measures (including price signals) remained in a paradoxical situation in the EU. Formally combating climate change through this approach remained the sole strategy discussed within the European Community in the delegations of the European Commission in charge of climate policies and in the meetings of the Ministries of the Environment. Beyond the strict climate policy elaboration, discussions about the harmonization of the excise taxes as a good substitute to the ecotax were actively carried out up to the Essen meeting in 1994.

At the Berlin conference in 1995, the importance of the wording of the Rio unbinding commitments appeared. This Conference of Parties could not check that the Annex 1 countries were on track to meet their claimed unbinding objectives. From a purely economic viewpoint, the logical outcome of such a diagnosis might have been that quantitative targets are ineffective in the absence of coordinated policies and measures, and that the Berlin Mandate should be to set up the rules for such an approach. The US delegation was apparently prepared to negotiate on this ground, but no real proposal about how to co-ordinate policies and measures was made by the EU countries, because of the very absence of any progress in that direction at the Community level.

Then, under the pressure of very active Non-Governmental Organizations and under the control of developing countries, the logical reflex was to ask the Annex 1 countries to transform their emissions targets into binding commitments and to update them as a function of the emissions trends after 1990, and also of the new scientific evidence of the anthropogenic nature of global warming. As the organizing country, Germany was at ease with such a perspective, since it claimed that the objectives put it on a stance of moral and intellectual leadership.

The US resistance to such an outcome could not lead to a diplomatic failure and the US delegation decided to derive the better profit of the circumstances by accepting the inscription of binding targets into the Berlin Mandate towards Kyoto with the idea that such targets would open the way to generalized trading systems and joint implementation mechanisms, the so-called flexibility mechanisms discussed above. Part of the US administration indeed perceived that it would be politically easiest to make the climate policy adopted in the US under the rhetoric of trading systems, that under this coordinated policies and measures would, in whatever form, have incorporated a carbon taxation.

4.3. Tentative assessment of Kyoto quantitative targets

Kyoto targets, broadly recalled in Table 3, are interpreted in very opposite ways by various stakeholders: in the US, opponents to any mitigation policy argue that they result from a pure political bargain and will entail dramatic costs for society. Symmetrically, many environmental non-governmental organizations express the concern that the adopted targets may not be ambitious enough to enforce a real precautionary principle with respect to climate risks.

Table 3. Contemporary fossil CO_2 emissions (Mt C per year), after Bolin (1998).

Figure 2. Global CO_2 emission pathways consistent with long-term stabilization of CO_2 concentration at 550 ppmv. The S550 and W550 trajectories illustrate two extreme attitudes with respect to early action. The U550 curve illustrates a sequential decision-making strategy. It assumes that the 550 ppmv target is only an expected value, to be revised in 2020 at 450, 550 or 650 ppmv ; and it minimizes the present value of reduction cost using the DIAM model.

Figure 2 compares the CO_2 emissions trajectory corresponding to the Kyoto targets (curve labelled K) to different strategies proposed in the timing debate.

First, one can see that the emission Kyoto profile is well below the reference emission profile R following the IPCC scenario IS92a. Note that this reference profile does not match the observed evolution for 1990-1995 in Table 3: actual emission growth has been less than that described in the IS92a scenario. But, ongoing revisions of the IPCC scenarios suggest that the 1990-1995 time period may be very specific (among other reasons, the economic collapse of ex-centrally planned economies) and that business as usual emissions for Annex I may be steadily increasing over the IS92 scenario. Thus, Kyoto targets do represent a significant departure from likely trends.

Second, the K curve is also well below the W curve, defined by following the R path until 2010 and stabilizing CO_2 concentrations at the 550 ppmv level. Admittedly, that W path is closer to an economically rational emission path towards a 550 ppmv target than the S trajectory. The latter is defined by using an inverse carbon cycle model to find the smooth emission path consistent with a given concentration profile leading to stabilization at 550 ppmv.

Third, the K curve is also below the U curves, which represent an optimal precautionary strategy given that the ultimate concentration ceiling is determined only in 2020 between 450, 550 and 650 ppmv. This U curve corresponds to a subjective probability distribution, equally weighing the three ceilings.

This gives a first interpretation of the Kyoto targets: the position of the K curve below the U curve suggests that more weight was implicitly given to 450 ppmv than to 650 ppmv, as if policy-makers had retained an option value for preserving the environment and accounted for environmental irreversibility, technological dependent learning and risk aversion. In this sense, Kyoto targets can be seen as rather ambitious and revealing a real attempt to translate a precautionary approach in the face of unknown risks.

The concern emerges from many quarters that globally, the Kyoto targets may not be ambitious enough to significantly mitigate climate change. Quantitatively, model simulations illustrated in Figure 2 tend to demonstrate the contrary. Kyoto targets are consistent with the option of staying below a 2°C rise in global warming, and do not preclude the possibility of shifting from an intermediate 550 ppmv target towards a more ambitious 450 ppmv target with reasonable costs if future scientific information demonstrates that such a shift is required.

5. Concluding remarks

In conclusion, the distinction between action and abatement is critical to clarify policy debates. Abatement corresponds to quantitative emission reduction targets over a given time period, but a quantitative target is not a good indicator of the relevance of policies over the long run. Immediate action corresponds to enhanced research and development, and infra-structural efforts. They contribute little to the abatement of greenhouse gases emissions over the short to medium term, but these efforts are required in order to be able to abate more, faster and cheaper in the future.

At the aggregate level, the Kyoto targets are compatible with precautionary strategies against a 2°C rise in global warming. They would trigger a shift towards lower levels of greenhouse gases emissions, which is apt to avoid passing a too heavy burden to future generations. The problem is not that the Protocol is not strict enough, rather that the Protocol may not be enforced at all.

Quantitative targets over the short and medium run are not a good indicator of the sustainability over the long run: the short-term Kyoto targets do not assure any long-term climate stabilization. Even if, technically, Kyoto targets could then be met without investments into low- and zero-carbon technology research and development and in sustainable transportation infrastructure development, these actions could be unacceptable from the point of view of future generations', as it narrows their future response options by increasing technological and infra-structural inertia.

If one looks at the dynamics behind the aggregate figures, there is no certainty that, while respecting their emissions assignment, developed countries will not be trapped in emission paths, which will make it difficult to adopt tighter abatement targets beyond 2012. Behind what appears technically to be a dynamic consistency problem due to the dynamics in rigid sectors, such as transportation or housing, lies the sensitive issue of long-term innovation and the evolution of life styles. If domestic policies and measures are not adopted in due time in developed countries, the emergence of GHG trading systems may then create a masking effect which will end in a failure of climate policies.

This risk is all the more important because the entry of developing countries within Annex B will be necessary after 2012. Due to the non-observability of emission baselines, any such entry may generate a new wave of excess assigned amounts, resulting in low carbon prices over the long run and in the absence of any incentive to curb down real emissions trends.

There were at the outset of the nineties two competing approaches to climate negotiation. The first was to try and coordinate policies and measures without pretending to set up quantitative targets; the second was to set up targets. The latter was finally adopted because it provided an apparent level of guarantee of action to environmental Non-Governmental Organizations, while avoiding in practice the difficult debate about the coordinated policies and measures. The mix of medium term targets and flexibility mechanisms adopted at Kyoto in turn does not guarantee that the ultimate objective will be fulfilled.

This consideration, plus the difficulty of encouraging developing countries to adopt quantitative targets without assigning them emission amounts above their baseline, should lead to a reconsideration. For the period beyond 2012, an approach in terms of coordinated policies and measures (including higher energy prices) may be the only real guarantee of achieving the objective of the FCCC. Could this be done within the framework of the Convention and the Protocol, since to re-negotiate it would certainly be politically impractical? Our opinion is that the phrasing of the Protocol is flexible enough for this.

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Glossary

Annex I Parties: Annex I parties are committed to adopt national policies and take measures to mitigate climate change. Annex I of the United Nations FCCC comprises countries who were members of the OECD in 1992, countries undergoing the process of transition to a market economy, and the European Economic Community.

Capital stocks: The accumulation of machines and structures that are available to an economy at any point in time to produce goods or render services. These activities usually require a quantity of energy that is determined largely by the rate at which that machine or structure is used.

Climate: Climate is usually defined as the "average weather", or more rigorously, as the statistical description of the weather in terms of the mean and variability of relevant quantities over periods of several decades (typically three decades as defined by WMO). These quantities are most often surface variables such as temperature, precipitation, and wind, but in a wider sense the "climate" is the description of the state of the climate system.

Climate change: (UNFCCC usage) A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

Damage function: The relation between changes in the climate and reductions in economic activity relative to the rate that would be possible in an unaltered climate.

Discount rate: The annual rate at which the effect of future events are reduced, so as to be comparable to the effect of present events.

Emission Permit: A non-transferable or tradable allocation of entitlements by a government to an individual firm to emit a specified amount of a substance.

Emission Quota: The portion or share of total allowable emissions assigned to a country or group of countries within a framework of maximum total emissions and mandatory allocations of resources or assessments.

Energy Intensity: Ratio of energy consumption and economic or physical output. At the national level, energy intensity is the ratio of total domestic primary energy consumption or final energy con sumption to gross domestic product or physical output.

Equivalent CO_2: The concentration of CO_2 that would cause the same amount of radiative forcing as the given mixture of CO_2 and other greenhouse gases.

Fossil CO_2 emissions: This includes all anthropogenic contributions to the net atmospheric carbon budget, except for those classified as associated with land-use change. In practice, the contributions are those from fossil fuel combustion (including gas flaring) and cement production.

GHGs: Greenhouse gases

GDP: Gross Domestic Product, the value of all goods and services produced (or consumed) within a nation's borders.

GNP: Gross National Product, the value of all goods and services produced (or consumed) by all members of a nation.

GtC: Gigatonnes of carbon (1 GtC = 3.7 Gt carbon dioxide)

IIASA: International Institute for Applied Systems Analysis

Integrated assessment: A method of analysis that combines results and models from the physical, biological, economic and social sciences, and the interactions between these components, in a consistent framework, to project the consequences of climate change and the policy responses to it.

IPCC: Intergovernmental Panel on Climate Change

Marginal cost: The cost of one additional unit of effort. In terms of reducing emissions, it represents the cost of reducing emissions by one more unit.

Market-based incentives: Measures intended to directly change relative prices of energy services and overcome market barriers.

Measures: Actions that can be taken by a government or a group of governments, often in conjunction with the private sector, to accelerate the use of technologies or other practices that reduce GHG emissions.

Non-market damages: Damages generated by climate change (or some other environmental change) and that cannot be evaluated by a competitive market because of a lack of information and/or the inability to act on that information.

OECD: Organization for Economic Cooperation and Development

Opportunity Cost: The cost of an economic activity foregone by the choice of another activity.

Optimal control rate: The rate of intervention at which the net present value of the marginal costs of the intervention, equals the net present value of the marginal benefits of the intervention.

Policies: Procedures developed and implemented by government(s) regarding the goal of mitigating climate change through the use of technologies and measures.

ppmv: Parts per million (10^6) by volume

Precautionary principle: When there is a large or irreversible risk, the precautionary principle implies that a lack of scientific certainty should not be used as a pretext for doing nothing.

Regulatory Measures: Rules or codes enacted by governments that mandate product specifications or process performance characteristics.

Research, Development and Demonstration: Scientific/technical research and development of new production processes or products, coupled with analysis and measures that provide information to potential users regarding the application of the new product or process; demonstration tests the feasibility of applying these products or processes via pilot plants and other pre-commercial applications.

Scenario: A plausible description of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces (e.g., rate of technology changes, prices). Note that scenarios are neither predictions nor forecasts.

Structural Changes: Changes, for example, in the relative share of GDP produced by the industrial, agricultural or services sectors of an economy; or, more generally, systems transformations whereby some components are either replaced or partially substituted by other ones.

Sustainable development: Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

tC: Tonnes of carbon

UNFCCC: United Nations Framework Convention on Climate Change

WEC: World Energy Council

"When" and "where" flexibility: The ability to choose the time (when) or location (where) of a mitigation option or adaptation scheme in order to reduce the costs associated with climate change.

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