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 not 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, and 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 in the third section, which discusses 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 that 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 interpretations of scientific knowledge and ethical 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 ecotax 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 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", and "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 that 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-liter-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;
* exclude any answer requiring solutions going beyond existing state of the art technology,
* 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 within a different timeframe. 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 toolbox 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 that 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 unresolved issue. Conclusions may significantly depend 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 that may not have received full attention in climate policy models to date.

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