Climate Change Protection: The Tolerable Windows Approach
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Issue: Comparing the quantifiable costs and benefits of climate protection strategies is an extremely valuable exercise. The considerable scientific uncertainties and unavoidability of normative judgements, however, make it difficult to find a globally optimal climate policy path. A complementary approach, the tolerable windows approach, is therefore proposed, which aims to identify the scope for action compatible with pre-defined climate and socio-economic constraints.

Relevance: Separating facts from value judgements is generally regarded as a prerequisite for reliable science-based policy advice. However, this requirement is often misinterpreted as meaning that value judgements should be excluded from the policy advice process altogether. As this is impossible, decision-support methods should allow an explicit consideration of value judgements in a manner that enables opinions and scientific analysis to be distinguished clearly.

Introduction

Increasing concerns about the potential risks of anthropogenic climate change over the past ten years have led to a series of international conferences intended to combat climate change and its adverse effects. However, the Kyoto Conference of the Parties to the Framework Convention on Climate Change (FCCC) and, more so, the conference in Buenos Aires revealed the tremendous complexity of the climate change issue, which makes consensus about necessary mitigation measures almost impossible. Not surprisingly, scientific advice is highly sought after by the policy makers involved, who are interested in the long-term implications of the short-term decisions they are responsible for.

Different scientific approaches were proposed in order to help climate change decision makers confront the difficult choices involved in implementing FCCC. The policy evaluation approach, for example, projects the physical, ecological, economic, and social consequences of pre-defined climate change scenarios. An additional approach, the method of cost-benefit analysis (CBA), attempts to balance the over-all costs and benefits of climate policies by determining an optimal path for all relevant policy variables, such as carbon taxes.

Unfortunately, both approaches often result in contradictory climate policy recommendations. The policy evaluation approach tends to recommend strong reductions in greenhouse gases in order to avoid severe future impacts even on a regional level. In contrast, CBA focuses on the globally averaged discounted welfare of current and future generations. In this case, impacts are levelled out by regional and temporal aggregation (accompanied by discounting future utilities) thus justifying only slight emission reductions.

Here we will discuss in detail the implications of -these, no doubt unavoidable,- value judgements
together with different attitudes concerning the still large uncertainties surrounding global climate change. Together both aspects are mainly responsible for the discrepancy discussed above - a discrepancy which has caused much confusion and which threatens the credibility of scientific climate policy advice.

Obviously, science-based climate policy recommendations, for instance answers to questions like "By how much, when, and where should emissions be reduced?" cannot be formulated without referring to value judgements (cf. Findeisen and Quade, 1985). Science's own view of itself, and the need for democratic legitimacy, means scientists are not allowed, however, to formulate the necessary normative inputs to the decision process alone (Rat von Sachverständigen für Umweltfragen, 1996). Therefore, an innovative decision-support tool, the tolerable windows approach (also known as the guard-rail approach) has been proposed, in order to allow straightforward consideration of normative settings formulated by policy-makers.

The Scientific-Analytical Complexity of the Climate Change Issue

From a scientific point of view, global climate change is characterized by extremely high regional, sectoral, and temporal complexity (cf. IPCC, 1996). Far-sighted climate change decision makers therefore ask for scientific advice in order to assess the outcomes of the climate protection strategies they are willing to defend, for instance, in FCCC negotiations.

A possible way to proceed in this situation is to specify some test policies and to evaluate the respective physical, ecological, economic, and social consequences by using integrated assessment models. The disadvantage of this 'policy evaluation approach' (IPCC, 1996) is that the respective iterative 'trial and error' process will be very time-consuming.

A promising alternative therefore is to define the goals beforehand and to determine the pertinent policies by applying appropriate optimization models. The basic analytical framework here is cost-benefit (welfare maximizing) analysis (CBA), which firstly seeks to identify all costs and benefits of conceivable climate protection measures, secondly compares the costs and benefits, and finally selects the path that maximizes global welfare.

Figure 1: Example interconnections (solid arrows) between the relevant spaces (shaded rectangles) in investigating global climate change.

The definition of guard-rails (see Sec. 4) results in restricted areas for manoeuvre that are depicted in the various spaces by grey 'windows'. Imposing restrictions on the effects of climate change will restrict the causes of climate change, too. The related forward and backward influences are indicated by the doubled arrows. Note that cost-benefit analysis requires a comparison of outcomes occurring at the extremely uncertain poles of the depicted cause-effect chain.

The corresponding pursuit of completeness doubtless is an advantage of CBA, since a complete identification of conceivable costs and benefits of various climate protection strategies, in so far as this is possible, is obviously extremely valuable (IPCC, 1996). As soon as CBA is used to determine a so-called welfare-optimal path, the pursuit of completeness, however, becomes a
problematic completeness requirement. In order to determine an optimal path reliably, it would be necessary to know all relevant interconnections (see Fig. 1) between socio-economic activities and related climate impacts in a quantitative way - at least in a statistical sense. Currently, however this requirement is beyond the scientific state of the art. Especially with respect to some impacts of climate change, whole parts of the puzzle that may be the crucial ones have still to be investigated and therefore are not known in either a deterministic or statistical sense.

Climate models are built on the laws of physics, which are well known and have been extensively empirically tested. At first sight, climate models should therefore be able to project climate change reliably as long as the underlying emissions are specified with sufficient accuracy. Problems arise, however, as a result of the limited regional resolution of the models, and the non-linearities and uncertain boundary values. It is therefore extremely difficult to decide whether global climate will evolve in the future in a regular way or whether greenhouse gas emissions will trigger some kind of singularity effect, such as a destabilization of atmospheric chemistry; a shut-down of the so-called thermohaline Northeast Atlantic heating "conveyor belt"; the break-up of the West Antarctic ice sheet; or a potential run-away greenhouse effect caused by permafrost melting.

Cost-benefit analyses carried out to date have relied heavily on the results of the often extremely simplified climate models used to describe the ordinary behaviour of climate. 'Optimal' climate protection paths determined in this way run the risk of transgressing the thresholds that correspond to the above mentioned singularity effects, which are critical but not currently understood with any certainty (cf. Schellnhuber, 1997).

Compared with climate system and biophysical climate impact modelling, investigating the future development of the socio-economic system is an even more challenging part of a comprehensive CBA of the climate change issue. Here generally accepted scientific laws describing long-term human behaviour are still lacking. This means socio-economic modelling relies heavily on the extremely idealizing assumption of rationally acting individuals or on extrapolating observed behaviour econometrically far beyond the range of experience.

**The Political-Normative Complexity of the Climate Change Issue**

With respect to the political dimension of climate change, the corresponding requirement inherent to CBA is as two edged as that relating to the completeness of our present knowledge of the science of climate change. Here, the goal of CBA is to replace all normative judgements by one fundamental judgement, namely that the finally selected climate protection strategy should maximize the global welfare of all current and future generations. A detailed analysis of this goal (Helm et al. 1998; Bruckner et al., 1998), however, reveals that in concrete applications various fundamental assumptions of CBA are questionable. For example, already at the stage of defining a global welfare function several normative judgements are involved which affect the intra-personal comparison of different categories of climate impacts, the question of compensating losses by monetary transfers and the relationship between cost-benefit considerations and ethical standards. From a temporal and regional point of view, the normative question is how climate impacts or mitigation costs that affect different generations and different regions should be aggregated. Since the related normative judgements correspond to the definition of often extremely technical aspects of CBA (like appropriately specifying various weight factors used for temporal and regional aggregation), most of these value judgements are not visible to the decision makers who are the ones who should provide the necessary normative inputs.

**The Tolerable Windows Approach**

The huge analytical and political complexity of the climate change issue means the tolerable windows approach (a.k.a. guard-rail approach) does not seek to identify an absolute and generally accepted scientific answer to the climate change decision problem. Instead, the pragmatic and policy-oriented approach provides a suitable platform making it possible to combine the unavoidable normative settings formulated by the decision-makers themselves with our present scientific knowledge without filling still existing scientific gaps by crude and often arbitrary assumptions. We would mention in this context that according to our point of view, the normative settings reflect the will of policy-makers to actively define the climate protection strategy they are prepared to defend in negotiations, instead of simply adopting what should be done according to mainstream economics.
A typical application of the tolerable windows approach starts with an explicitly normative definition of guard-rails that exclude intolerable impacts of climate change on the one hand and unacceptable socio-economic consequences of mitigation measures on the other. A subsequent scientific analysis of the systems involved (see Fig. 1) is then carried out in order to obtain the set of all climate protection strategies that are compatible with the pre-defined constraints. Finally, a single policy path may be selected either by taking into account additional criteria such as cost-effectiveness, by referring to qualitative arguments (like the precautionary principle) or finally during a negotiation process.

The approach deliberately refrains from specifying how the guard-rails should be defined. Therefore, different value judgements can be taken into account in a flexible way. One important advantage of the approach is that the unavoidable normative judgements can be applied to restrict the actual outcomes of climate protection strategies instead of specifying highly technical aggregation factors beforehand (as in the CBA case).

The democratic right of policy-makers to specify the normative settings does not, however, imply that they should do so uninformed. Thresholds concerning potentially catastrophic climate change impacts are suitable candidates for guard-rails that can be defined in an almost systemic way. Since significant impacts may occur well below these thresholds, (almost purely) normatively defined guard-rails can also be used to restrict regular climate change. In the latter case, knowing the results of highly disaggregated simulation models can provide a basis that enhances the policy-makers' ability to specify guard-rails.

With respect to the analytical complexity of the climate change issue, we would mention that the definition of guard-rails is not restricted to the highly uncertain climate impacts or uncertain implications of mitigation measures. Guard-rails can also impose restrictions on intermediate and more reliably computable indicators (such as global temperature change or emission reduction rates). This enhances the applicability of the guard-rail approach to the climate change issue where scientific uncertainties seem to be omnipresent. In addition, some of the guard-rails corresponding to these indicators can be prudently defined without referring to climate impacts at all. For example, global mean temperature may be restricted in order to stay within humanity’s ‘climatological field of experience’ (cf. WBGU, 1995) or within the range of applicability of the simple climate models used in integrated assessments. In this way, aspects of the qualitative precautionary principle can be taken into account by the tolerable windows approach.

The tolerable windows approach was originally proposed by the German Advisory Council on Global Change (WBGU) in a statement on the occasion of the First Conference of the Parties to the FCCC in Berlin (WBGU, 1995) by one of the authors (H.-J. S.) of this article. Subsequently, similar approaches (e.g., "safe-landing analysis") were applied by various research groups (e.g., J. Alcamo, 1996; Y. Matsuoka et al., 1996) world-wide.

Figure 2: Necessary emission corridors derived by taking into account the climate and socio-economic guard-rails formulated by the WBGU (see text).


In what follows we would like to present some illustrative results of the ICLIPS (Integrated Assessment of Climate Protection Strategies) project, which is responsible for the further
development of the tolerable windows approach.

According to the normative judgements in the example below (discussed in detail in WBGU, 1997), global mean temperature change should be less than 2 °C (relative to the pre-industrial level) and the rate of global mean temperature change should not exceed a value of 0.2 °C per decade. The so-defined 'WBGU climate window' is supplemented by a provisional socio-economic constraint requiring that the rate of emission reduction (a proxy for the resilience of the socio-economic system) should be less than 4% per year. In addition, it is assumed that developing countries will have no reduction commitments until equality is reached according to the "equal emission per capita" principle (on the basis of the population of 1992).

By applying appropriate mathematical methods (Toth et al., 1997; Bruckner et al., 1998), necessary emission corridors (Fig. 2) can be determined, which characterize the scope for action that remains if all the pre-defined guard-rails are obeyed simultaneously. Every climate protection strategy that is compatible with these constraints stays within the corridors, i.e. every strategy leaving the corridor is obviously not admissible.

The green area in Fig. 2a depicts the carbon dioxide emission corridor of the industrialized nations (strictly speaking the nations belonging to Annex 1 of the FCCC). According to our model and taking into account the normative inputs, greenhouse gas emissions must be reduced substantially in the long term.

Although the corridor (Fig. 2a) reflects clear short term flexibility, waiting 15 years without implementing emission reduction measures at all would result in a corridor that looks more like a straitjacket than a corridor with ample choice as clearly shown in Fig. 2b. In its statement at the Kyoto Climate Conference (WBGU, 1997), the WBGU therefore recommended a moderate climate protection strategy (black line within the corridor of Fig. 2a). According to this climate protection strategy (corresponding to roughly 1% per year global emission reductions), emissions of industrialized countries should be reduced by about 80% by the year 2050.

Figure 3: WBGU climate window and threshold curves for the thermohaline circulation under different hydrological sensitivity assumptions (see text).

Source: WBGU, 1995; Ganopolski, 1998a. For comparison, the original instability curve which motivated our investigation is also depicted (S&S, Stocker and Schmittner, 1997a and 1997b).

The WBGU climate window can be compared with threshold curves beyond which a complete and permanent shut-down of the North Atlantic thermohaline circulation (THC) cannot be excluded (Fig. 3). In order to emphasize the high degree of uncertainty involved, two different threshold curves were calculated by using the CLIMBER climate model developed at the Potsdam Institute for Climate Impact Research (Ganopolski et al., 1998b). The more restrictive curve (HHS) corresponds to high hydrological sensitivity. The other is related to a low value of this parameter (LHS), which—for a given change in the temperature of the Northern Hemisphere—characterizes the amount of additional freshwater input to the North Atlantic. This freshwater input is ultimately responsible for a weakening of the THC.
Making some simplifying assumptions (discussed in detail in Toth et al., 1998), a first impression of how a necessary global emission corridor for not violating the thermohaline circulation criterion may look like can be obtained from Fig. 4. According to the corridor shown (which is still provisional), we would have to leave the business-as-usual path (IS92e scenario) in about 6 decades at the latest.

Figure 4: Necessary emission corridors for not leaving the WBGU climate window (blue part) and for not transgressing the thermohaline circulation stability threshold (high hydrological sensitivity case; blue and yellow part), respectively.

Source: Toth et al., 1998. The corridors have been computed by assuming a maximum rate of annual emission reduction of 2% and a scenario for SO2 emission reduction at the rate of 2% per year starting in the year 2000. The underlying global greenhouse gas emissions are bounded from above by the IS92e scenario.

From our point of view, it is therefore very important to investigate other possible mechanisms that may lead to climate instabilities, instead of trying to give a more detailed, but potentially misleading picture of regular climate change. At present, however, we have relatively little knowledge concerning other possible instability mechanisms. One sensible approach would therefore be to stay away from the THC instability thresholds and to apply, for instance, the WBGU climate window, which is based mainly on paleoclimatological considerations and which rules out the possibility of global mean temperature exceeding values experienced in the late Quaternary period which shaped our present day environment. This however would imply reducing global emissions substantially, so that the Kyoto outcome can be considered only as a first step in this direction.

Conclusion

A general consensus holds that in the light of the complexity of the climate change issue the best integrated models can offer policy-makers is insights about the nature, basic relationships, and key dynamic features of the problem. We hope to have shown here that, even in its early phase of development, the TWA approach can provide valuable insights for the policy process in its search for appropriate climate protection strategies.

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