Epistemic Uncertainties in Climate Predictions: A Challenge for Practical Decision Making

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Epistemic Uncertainties in Climate Predictions. A Challenge for Practical Decision Making

by Prof. Dr. Dr. Rafaela Hillerbrand[1]

Abstract: Most scientists agree that, at least for the time being, unquantified uncertainties are inevitably connected to predictions of climate models. Uncertainties, however, do not justify political inaction. This paper addresses the question of how epistemic uncertainties are of relevance for practical decision making. It is shown how common decision approaches based on the precautionary principle fail to adequately deal with uncertainties as they arise in climate modeling. I argue that with regards to climate change, unquantified uncertainties can neither be ignored in decision making nor be reduced to quantified ones by assigning subjective probabilities. This distinguishes the ethical problems associated with climate change from other problems regarding energy supply and demand like, for example, those associated with nuclear power.

Introduction

The uncertainty of climate predictions is discussed intensively within the scientific community – not only among climate sceptics. However, uncertainties are often kept under wraps when scientific findings are communicated to the public.[2] It is not the scientists who are to blame here. Rather the practical debate seems incapable of adequately reflecting uncertainties in modeling predictions. If these uncertainties were communicated, sound scientific research runs the risk of being discredited as unscientific; the public seems to prefer black and white instead of the scientists' shades of grey. Often predictions are taken either as correct and unquestionably reliable or simply as wrong. However, most scientific models are neither true, in the sense that they exactly predict future events, nor simply wrong and useless.[3] It is argued in this paper that in order to incorporate aspects of inter- and intragenerational justice, practical decision making has to carefully consider the shades of grey

that affect the reliability of climate models in practical decision making.[4]

The focus here is not on the question of how much, if any, reduction of greenhouse gases is ethically legitimate,[5] but rather on what kind of decision making criteria should guide our reasoning about this very question. The aim of the paper is twofold: Firstly, I contend that some of the uncertainties that practical decision making has to consider cannot be quantified. Secondly, it is argued that common decision making approaches based on the precautionary principle and expected utility maximisation fail to adequately deal with unquantified uncertainties and therefore are unable to incorporate issues of intergenerational or international justice.

> This is the first age that's ever paid much attention to the future, which is a little ironic since we may not have one.
> / Arthur C. Clarke /

The second section shows that any ethical evaluation of greenhouse gas emissions has to deal with epistemic uncertainties that comprise, but go well beyond, what climatologists refer to as *uncertainty*. Most pressing for practical evaluations is the fact that this auxiliar uncertainty is not quantified. I argue in the third section that discerning quantified and unquantified uncertainties is relevant for practical decision making. The fourth section contends that the precautionary principle is not capable of adequately implementing questions of fairness between different nations or generations. The fifth section sketches briefly why, for the climate debate, expected utility maximization does not provide a more rational decision criteria than the precautionary principle. As an outlook, a way to modify expected utility maximization in view of unquantified uncertainties is adumbrated.

What is uncertain about climate predictions?

Climate change raises serious problems regarding considerations of inter- and intragenerational justice. This paper focuses on the former and restricts itself to the ethical issues associated with climate change insofar as they are related to the distribution of welfare across different generations. Presupposing that our interest in the ethical aspects of climate change arises mainly from considerations of intergenerational justice, we may assume that we value a certain 'state of the climate system' only because of its value for future generations. Then a mere rise in global mean temperature is not morally relevant per se. What actually matters is how changes in mean temperature or other climatic variables influence the living conditions of present and future human beings.[6] Quite often, however, the discussion is cut short and moral conclusions are derived directly from climate-model predictions, which merely determine the state of the climate system. Unless one assigns an absolute value to the climate system, there is, however, no a priori obligation to maintain the climate system in a particular state. This preempting of the moral debate is not only at variance with sound decision making, it also adversely affects the science itself as scientific reasoning is, mostly implicitly, accused of being but a political instrument for the wrong side.[7]

The direct and indirect influences of climate change on the expectancy and quality of human life cannot be determined straightforwardly; hence so-called impact models are used by (welfare) economists. The threefold distinction between a scenario, an earth-scientific, and an economic level introduced in figure 1 helps to clarify where and how epistemic uncertainties arise and how they enter the practical discourse.[8] Only some of the uncertainties in climate modeling (level two) may be quantified in a meaningful way, e.g. in terms of the width of the probability distribution of, say, a change in global mean temperature. These quantifiable uncertainties mainly correspond to unknown parameter ranges, while unquantified uncertainties remain. This is particularly (but not exclusively) because on the first and third level in figure 1 it is not known how adequately the models used represent the relevant causal mechanisms of the modeled system. This uncertainty in the model conceptualization may be due to finite computational power or due to our insufficient understanding of the modeled processes.

Note that in practice, the distribution of the various tasks in determining the effects of anthropogenic greenhouse gas emissions is not as clear-cut as suggested by figure 1, particularly when impact models mix with normative assessment. This is, on the one hand, unavoidable and even necessary: Only a normative evaluation can determine which aspects of human life are worth modeling. Some modeling assumptions, like the discounting rate of non-monetary losses, have to be considered (also) on moral grounds.[9] On the other hand, merging normative and descriptive assessments blurs many (normative) assumptions and makes the evaluation rather opaque.

The immediacy and practical relevance of uncertainties

Why worry about epistemic problems when reasoning about issues of inter- and intragenerational justice? If uncertainty is a serious problem, why not simply wait until climate models and global and long-term economic predictions have overcome their teething troubles? The climate system only reacts very slowly to changes in its parameters, such as changes in carbon dioxide contraction. Hence the atmospheric concentration of persistent greenhouse gases like carbon dioxide can only be stabilized by reducing emissions.[10] The large inertia of the climate system necessitates timely countermeasures. Once particular effects occur, it may well be too late for a systematic response. Note again that this paper deals with a sound discourse about how to react to climate change, not with the issue of correct reduction or

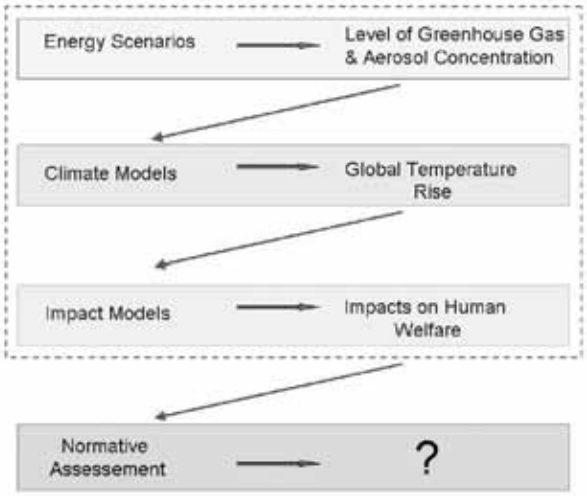

Figure 1: 'Estimating the impacts of greenhouse gas emissions on human wellbeing.' Short straight double arrows correspond to 'yields the output', long oblique thick arrows correspond to 'is input for'. The dotted rectangle indicates the combination of scientific prognoses that, as a whole, serve as the empirical input for a political or moral evaluation on the last line.

mitigation strategies. The practical discourse may or may not come to the conclusion that instead of mitigating now, we should wait and adapt later. However this decision cannot wait for better and less uncertain predictions: it has to be taken now.

A need to address epistemic uncertainties in practical debates can be deduced from three (fairly weak) assumptions: Firstly, practical decision making has to be based on the best (empirical) knowledge available. Secondly, practical problems related to environmental issues can be formulated as scientific problems. Thirdly, science gives us the most reliable understanding of the natural world. I do not want to justify these suppositions, as all three seem to be both weak and rather intuitive. From these epistemic and practical assumptions it follows that we have to consider epistemic uncertainties in practical decision making: The best available information that we have today is our scientific forecasts *plus* information on their reliability. Though the latter may not be expressed or even be able to be expressed in numeric terms, information on the quality of various climate predictions is available.

If, for example, quantified uncertainties that arise from insufficient knowledge on the input parameters were the only uncertainties we had to deal with, common probabilistic decision criteria like utility maximization could be applied in a straightforward way. Unquantified uncertainties, however, that arise from insufficient understanding of the model conceptualization pose a severe problem. Quantitative figures may be misleading, but they can be communicated easily to people outside one's own discipline. This is not the same for errors and shortcomings that are not quantified. Nonetheless, in estimating the reliability of a physical or economic model there always remain unquantified factors that are hard to communicate. For example, the outputs of statistical analysis will always depend on the specific experimental paradigm in use, accepted practices, and the general research experience within the field; these factors cannot be defined explicitly, but must be learned by working in the field. In this way the scientific community establishes a Wittgensteinian language community.[11] Even if scientists in a given field tend to assign 'higher order beliefs' that express their confidence in an underlying theory, the methodology used, the researcher or the group who carried out the work, etc, these higher-order beliefs are only very rarely quantifiable themselves in terms of, say, subjective probabilities.

The precautionary principle and justice as fairness

When outcomes are highly uncertain, it is often suggested that we fall back on the precautionary principle. The phrase *precautionary principle* is fraught with ambiguity, so let us briefly explicate the term and its use within ethical, juridical, and political contexts. The Rio Declaration on Environment and Development, for example, formulates the precautionary principle (rather vaguely) as follows: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."[12]

In this weak formulation, the precautionary principle provides no distinct directive for practical decision making. Instead it constitutes a meta-criterion stating that uncertainties in scientific forecasts have to be taken seriously. Strong formulations of the precautionary principle constitute a genuine decision criterion. The following is an example of the *precautionary principle* in a strong formulation: "Where an activity raises threats of harm to the environment or human health, precautionary measures *should be taken* if some cause and effect relationships are not fully established scientifically [my italics]."[13]

Proponents of the precautionary principle like C. Raffensberger and J. Tickner suggest the following core idea behind all formulations of the *precautionary principle*: "In its simplest formulation, the precautionary principle has a dual trigger: If there is a potential for harm from an activity and if there is uncertainty about the magnitude of impacts or causality, then anticipatory action should be taken to avoid harm."[14]

In this paper, I want to understand the precautionary principle as a genuine decision making criterion, that, loosely following Gardiner,[15] interprets the strong formulation as a variant of the minimax rule in decision theory: Minimize the maximally bad outcome. Given certain assumptions about how to quantify harm and wellbeing, this may be reformulated as a maximin rule and reads (for climate change): Maximize wellbeing in those scenarios in which the involved humans are worst off (minimally benefited), regardless of how uncertain these scenarios are. At first glance, a precautionary approach seems well suited to avoiding an ethically unjustifiable discounting of future damage caused by our present greenhouse gas emissions: We cannot exclude with certainty the possibility that the release of greenhouse gases has the potential to cause severe harm to future generations, hence emissions of greenhouse gases ought to be abandoned. A precautionary approach seems adequate when the stakes are high – the living conditions of all future humans may be endangered by severe climatic changes. Furthermore, some economic assessments suggest that reducing anthropogenic greenhouse gas emissions is not very costly.[16] Following Stern,[17] a commitment of only 1 percent of global gross domestic product (GDP) is needed to avoid the major hazards that may arise from climate change. At first blush, this appears very affordable; but if we base our calculation on current GDP value, it amounts to an investment of US $ 450 billion per year. For comparison: the current estimates of the money needed to provide 80 percent of rural populations in Africa with access to water and sanitation by 2015 amounts to US $ 1.3 billion per annum.[18] Clearly, societies (or other organisations) are able to part with only a certain amount of money or other resources for altruistic endeavours, and the mitigation of major changes in future climate is only one such endeavour.[19] Investing in the mitigation of climate-change effects means forgoing other investments which we have a moral obligation to make. One central requirement of the practical debate is a decision about which investment has priority over others. Presupposing an answer to this question from the very beginning of the debate – for example by assuming that climate change is currently humanity's most pressing problem – pre-empts the moral debate, as discussed in section 2. Applying the precautionary principle to global warming as a singular problem thus does not allow us to adequately deal with the valid claims of groups that are adversely affected by natural or societal 'disasters' other than climate change. This approach is clearly incapable of adequately incorporating considerations of inter- or intragenerational justice as it does not address the question of why suffering arising from climate change has priority over suffering caused by other sources. The critique raised here, however, is not a charge

> Our greatest responsibility is to be good ancestors.
> / Jonas Salk /

against the precautionary principle itself; it only disqualifies common applications of the precautionary principle.

Suppose that one can show that – given certain ethical standards, which are not under debate here – the worst-case scenario regarding the effects of climate change is that these effects are worse than any other type of human suffering, present and future. This means that if our (possibly very unrealistic) assumptions are indeed correct, then following the precautionary principle, we have to mitigate climate change at any cost. We are trading the certain suffering of people living presently against a possibly more severe, but yet uncertain suffering of people living in the future. If the worst-case scenario is as uncertain as currently estimated for global warming, and is balanced against certain other scenarios whose bad effects are certain (like the actual suffering of many people in third word countries, for example), it is unreasonable to completely mask all other scenarios and focus on mitigation of the uncertain, but worst outcome.[20] As noted above, the available information on the effects of anthropogenic global warming includes information about the 'likelihood' of the worst-case and other scenarios. This information is not quantified and may not be fully quantifiable at all. However, we do have information that suggests that, while present suffering is certain, future suffering caused by global warming is uncertain. Good arguments for neglecting this information should be given. But to the best of the author's knowledge, no such arguments have been presented tin the literature.

Problems with a precautionary approach as an action guiding principle have been discussed extensively in the literature.[21] This paper only addresses one central issue of importance in any intergenerational ethics, namely how to balance obligations towards future generations against obligations towards people living presently. Even if one argues for the ethical legitimacy of trade-offs between losses and gains experienced by different people one cannot deny that presently living people have a right to safe water and sufficient nutrition. One needs to argue at least that uncertain future losses are worse than current suffering. But a mere precautionary approach to global warming is incapable of simultaneously incorporating considerations of inter- and intragenerational justice.

A modified expected utility approach for a greener future

The precautionary principle is often perceived as the opposite e of maximizing expected utility: Instead of focusing on the worst case scenario, the latter considers all possible outcomes and the associated utilities u_i, weighted by their occurrence probability $\sum_i u_i p$, or, to put it in more technical terms: We are to maximize and sum over all possible scenarios. The extreme scenarios of run-away climate change or very little temperature change, for example, are thus taken into account, as is the scenario in which the temperature change exactly equals the estimated mean value. The latter scenario being the most probable, is given the greatest weight.

Maximizing the expected utility is an adaptation of the utilitarian maxim of the *greatest good for the greatest number* to decisions under uncertainty: It is not the overall utility (or 'good') that is to be maximized, but the expected utility, i.e. the sum of different utilities weighted by their probability of occurrence. The assignment of utilities to possible climate-change effects raises many difficult problems, but I do not want to dwell on these problems here. These problems are not specific to decision making under uncertainty and related problems of welfare-based ethics. Note, in particular, that problems about determining the utility of an event, or deciding what utility actually amounts to, parallel to some extend a problem of the precautionary approach, i.e. to decide as to how to actually determine the worst-case scenario.[22] As this paper's focus is on uncertainties (of expected utility and of the worst-case scenario), the problems associated with measuring human welfare and how to equate it with utilities are not discussed here. For the purposes of this paper it suffices to assume that the impact on human welfare estimated in economic models on level three in figure 1 can be associated with (intersubjective) utilities in a meaningful way.[23]

In order to apply the principle that tells us to maximize expected utility to global warming, all (morally) relevant effects of greenhouse gas emissions have to be assigned some probability p_i. As there are no frequency estimates for most of these effects, one may fall back on a Bayesian account, i.e. via subjective probabilities, the reliability of scientific outcomes is quantified. The distinction between quantified and unquantified uncertainties thus becomes obsolete. That is rather brief, so let us dilate somewhat on the problem here: Our most successful method for tackling uncertainty has been to regiment situations of uncertainty by the use of probabilistic propositions. But unless one is a certain kind of subjectivist about probability, one wishes that one's probabilistic beliefs are constrained by objective facts, so that they approximate to objective variables, whether one takes the latter to be frequencies, propensities, or some other concept.

As argued above and elsewhere,[24] there is no reliable basis for assigning probabilities to the empirical inputs needed for practical assessment. Unquantified uncertainties are of central relevance when we are discussing climate-change issues. This distinguishes the threat of global warming from other ethical problems related to energy supply and demand, such as safety issues of nuclear power plants, or final disposal site, where there is a reliable basis of assigning probabilities. Not only is it impossible to choose meaningful prior probabilities, but due to the large time scales in which the climate system reacts to changes, there is also insufficient data for updating these probabilities. The Bayesian method of assigning subjective probabilities via prior guesses therefore fails in the case of climate change.

Another way to assign subjective probabilities is to use Laplace's principle of insufficient reason: All possible effects are taken as equally probable. This approach, which was employed, for example, by Harsanyi,[25] is at fault for neglecting available empirical information (as is the precautionary approach). There is no logical superiority of Harsanyi's assumption of equiprobability over Rawls' focus on the worst outcome as, per se, there is no logical need to assign subjective probabilities to uncertain decision outcomes on the basis of Harsanyi's equiprobability assumption. We do have information – albeit not fully quantified – about the likelihood of certain effects of climate change. Hence, even when we leave problems associated with assigning meaningful utilities to the impacts of various energy sce-

Today, more than ever befor, life must be characterized by a sense of universal responsibility, not only nation to nation and human to human, but also human to other forms of life.
/ Dalai Lama /

narios aside, climate change cannot be treated by expected utility maximization. This is unfortunate as maximizing expected utility has one clear advantage over a precautionary approach: By incorporating an inter-temporal as well as an international perspective, maximizing expected utility is, by its very nature, able to trade-off the costs and benefits of different people living at different places and times.

The lack of (subjective) probabilities in the sense defined above does not imply, however, that one has to fall back on to non-probabilistic decision criteria such as the precautionary approach. This paper's proposition should not be misunderstood as a kind of reformulation of the precautionary principle in its weak form, i.e. 'Take uncertainties seriously and therefore address also the uncertain outcomes'. If anything, the paper aimed to argue that uncertain effects are not to be (mis)taken as certain ones, which seriously undermines the use of the precautionary principle.

In the literature decision methods are suggested, which parallel expected utility maximization, to cope with the lack of reliable prior probabilities and information about how to update these priors on the basis of the conditional probability calculus.[26] An adequate decision procedure for global warming would assign meaningful utilities to various outcomes in a first step by political decision makers, moral philosophers and others. As to the occurrence of unquantified uncertainties, however, the second step, the actual cost-benefit analysis (understood in a broad sense), should be conducted by experts on the empirical forecasts. Such a blue print can only work when, though philosophical ethics may not aim at a detailed casuistic, it does not shy away from context-variant information on the very decision. The 1970s debate on the 'rationality' of expected utility maximization or maximin, whose main protagonists were Harsanyi and Rawls, was only able to show that answering the question of whether the precautionary principle or expected utility maximization is adequate has to, willy-nilly, implement context-variant features of the decision situation. Note that this paper argues against the precautionary principle only when applied to global warming. The given arguments do not discredit this principle as a decision-making criteria in itself.

Concerning an adequate decision-making approach to global warming, this paper has, so far, turned a blind eye to factors that actually precede the debate on whether the precautionary approach or expected utility measures seem most adequate. So, concluding this paper, let me briefly discuss this problem: Before being able to actually talk about uncertain outcomes of the decision whether to try to reduce greenhouse gases, we have to decide what this decision is actually about – is it about the welfare of future humans?; do we need to discuss the pros and cons of alternative energy supplies that do not emit greenhouse gases as well?, etc. Any analysis of a specific decision must start with some delimitation of the decision itself. It is not always well established how to determine the 'decision horizon'.[27] The scope of the decision, or even which problem the decision is supposed to solve might be unclear. The further in time the consequences of our decisions lie, the more difficult it is to determine the decision horizon. For example, on moral grounds different people are not to be treated in a different way, but we cannot simply be all treated in the same way. Currently, the decision horizon is set by pragmatic considerations, though, particularly in intergenerational ethics, it is of central relevance. As for how to determine the scope of a decision, whether it be about climate change issues or other issues, this should be a topic for the empirical sciences, only insofar as these determine limits to our knowledge. It remains a genuine task for ethics that philosophers should not shy away from, because this task requires dwelling in detail, on the context of the decision-making situation.

Notes:

1. I would like to thank Steve Clarke, Martin Peterson, Andreas Pfennig, Nicholas Shackel, and Hartmut Westermann for helpful discussions on the topic of this paper as well as criticism and comments on earlier versions. I thank Till Spieker for help in finalizing the paper.
2. Compare, for example, the full IPCC report and its summary for policy makers: Solomon et al. 2007.
3. Giere 2004.
4. Though moral uncertainties are indisputably a big concern in an intergenerational ethics, this paper focus on epistemic uncertainties only.
5. Therefore compare, for example, Gardiner 2006a, Hanson/Johannesson 1997, Lumer 2002.
6. Note in this context that the anthropocentric approach pursued in this paper can be extended straightforwardly to incorporate other sentient beings as well.
7. Compare Oreskes 2004 and Pielke 2004 on the heated debate that followed the publication of B. Lomborg's book *The Sceptical Environmentalist* in 2001.
8. Hillerbrand/Ghil 2008.
9. Stern 2007.
10. Solomon et al. 2007.
11. Wittgenstein 2001, 10.
12. UNEP 1992; UNFCC 1998.
13. Apart from the two versions discussed in this paper, various other formulations of the precautionary principle exist: Sandin et al. 2002, O'Riordan/Jordan.
14. Raffensberger/Tickner 1999, 1. 15. Gardiner 2006b.
16. Note that there is considerable disagreement within the economic community on the costs of reducing greenhouse gases,see the response of Weitzmann 2009 and Nordhaus 2008 to Stern 2007.
17. Stern 2007.
18. Martinez Austria/van Hofwegen (eds.) 2006.
19. Note that the assumption of one well-defined decision maker that underlies the debates on climate change and is adopted here is unrealistic.
20. Note that this argumentation needs refinement when the worst-case outcome is a singular event like the end of human life on Earth (c.p. Ord/Hillerbrand/Sandberg 2009). The current empirical knowledge, however, seems to exclude that climate change is of this very nature.
21. Peterson 2006, Clarke 2005, and references therein.
22.The problem of the precautionary approach is somehow easier, as it needs only an ordinal concept of wellbeing, while EUT presupposes a cardinal welfare measure. Cardinal and ordinal measures can only identical when the welfare function already fulfills certain restraints Neuman/Morgenstern 1967.23. How to actually assign meaningful utilities has been discussed extensively in the literature. For an intergenerational ethics it raises rampant problems, see Lumer 2002 for a discussion as to how assign utilities in the context of climate change.
24. Frame et al. 2007.
25. Harsanyi 1975, 1982.
26. For example Shafer 1990.
27. Hansson 1996, 371.

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