Anthropogenic Climate Change: Scientific Uncertainties and Moral Dilemmas

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This paper considers the role of scientific expertise and moral reasoning in the decision making process involved in climate-change issues. It points to an unresolved moral dilemma that lies at the heart of this decision making, namely how to balance duties towards future generations against duties towards our contemporaries. At present, the prevailing moral and political discourses shy away from addressing this dilemma and evade responsibility by falsely drawing normative conclusions from the predictions of climate models alone.

We argue that such moral dilemmas are best addressed in the framework of Expected Utility Theory. A crucial issue is to adequately incorporate into this framework the uncertainties associated with the predicted consequences of climate change on the well-being of future generations. The uncertainties that need to be considered include those usually associated with climate modeling and prediction, but also moral and general epistemic ones. This paper suggests a way to correctly incorporate all the relevant uncertainties into the decision making process.

PACS numbers: 92.60.Ry,92.70.Gt
Keywords: Climate change, Impact models, Precautionary principle, Expected Utility Theory

I. INTRODUCTION

Significant and enduring anthropogenic impact on climate is not a peculiarity of our time. Man is part of the biosphere and as such always did and always will influence the climate system, a system that comprises, apart from the atmosphere and hydrosphere, also the bio-, litho- and cryosphere. Slash-and-burn agriculture, changes in farming practices, building development or regulation of inland waters have modified the backscattering of radiation by Earth's surface and the near-surface atmospheric winds [1, 2]. The shift from nomadism to farming several thousands of years ago resulted in vast clearings and thus had a significant and sustained influence on regional climate.

The converse influence that climate exerts on man, particularly via atmospheric conditions and weather, has been acknowledged for a long time, too. The European revolutions of 1789 and 1848, no doubt a result of long-lasting social, political and economic circumstances, were also affected by continued years of bad weather, bad crops, and high corn prices [3]. Recent research suggests that a possibly worldwide drought in the 10th century was the catalyst for the demise of the Tang Dynasty in China, as well as of the Mayan civilization in Central America [4]

The increased use of fossils fuels, started at the beginning of the industrial revolution, has led to rapid increases in greenhouse emissions since World War II. In particular, atmospheric concentrations of carbon dioxide, the most abundant and hence best-known anthropogenic greenhouse gas, have increased measurably and significantly over the last few decades [5]. The so-called "greenhouse effect" of trapping outgoing thermal radiation in the lower atmosphere yields, in all likelihood, an anthropogenic climate change of global extent and unprecedented consequences, for decades to come.

The present paper does not aim at an overview of the currently available predictions on the future state of the climate system, their relative merit or their shortcomings [5]. We aim instead at describing the role of science within the debate on adaptation and mitigation, and at complementing an understanding of the scientific uncertainties [6] with an introduction to the epistemic, i.e. knowledge-theoretical, uncertainties. By bringing these issues to the attention of the scientific community, we hope to improve communication between this community, the broader public, and decision makers.

We choose to evaluate the state of the climate system only in terms of its value for humans (or other sentient beings). Section II points out that this choice implies one cannot base a normative — i.e. prescriptive rather than purely descriptive or empirical — evaluation of the consequences of climate change on the scientific predictions of the system's future state alone: putting adaptation and mitigation issues into the broader context of competing needs and limited resources raises moral problems that cannot be easily dismissed. Section III suggests addressing the moral dilemmas raised in the previous section within the framework of Expected Utility Theory (EUT)

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[7, 8]. The EUT approach, however, depends sensitively on the predicted impacts of climate change on people's well-being, which are still highly uncertain, and may have to remain so for a long time.

Section IV argues that not all of these uncertainties can be properly quantified. Intrinsic obstacles to communicating certain types of scientific uncertainties to broader audiences might exist. Each scientific community has its own language (or jargon) and translation between these languages, and between either one of them and the common language of educated lay people, poses possibly unsurmountable difficulties. Already the difficulty of communicating between climate dynamicists and welfare economists has been noted by many participants in the emerging dialog between these two communities. Section V draws conclusions about the role of science in the normative evaluation of anthropogenic climate change.

II. JUMPING TO CONCLUSIONS

Large segments of the media, in Europe and elsewhere, presuppose a clear moral obligation to mitigate the socio-economic consequences of climate change. Likewise, most related moral-philosophical considerations focus on questions like how to distribute the costs of mitigation, while considering principles of fairness. The moral obligation to mitigate is rarely discussed; for noteworthy exceptions see [9–11]. At first glance, the sole questions remaining open as regards climate change thus seem to be of a political or scientific nature.

In contrast, we argue here that there are as yet unresolved ethical questions regarding our obligation to mitigate climate change, questions that precede the practical ones discussed in the current literature and media. If there is a moral obligation to preserve the climate in its present state, where does it stem from? Addressing this question seems inevitable in determining what our moral duties as regards climate may reasonably be. Moreover, formulating explicitly the reasons behind what is perceived by many, but not all, as a moral obligation should help in convincing the sceptics.

Let us suppose a moral obligation to take into account the well-being of future generations in the same way as our own and that of our fellow human beings. Obviously this calls for environmentally sound actions in order to not deprive posterity of adequate resources. But, as usual, the devil is in the details: What exactly does this mean in the case of the climate system?

If we value the climate system only because of its value for future generations (or for other sentient beings), a mere rise in global mean temperature is not morally relevant per se, as illustrated in Fig. 1. What matters is the effects of this change in mean temperature and other climatic variables on the living conditions of present and future human beings. These effects are far from straightforward. So-called *impact models* estimate the direct and indirect influences of climate change on the expectancy and quality of human life. The most advanced of these welfare economic models determine the monetary costs arising in a broad range of market sectors, as well as in non-market sectors, such as the costs arising from changes in human mortality or in biodiversity [12–14].

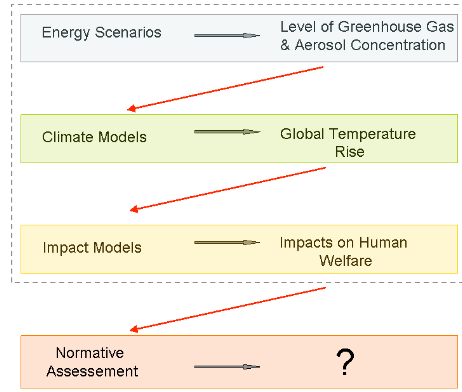

FIG. 1: Estimating the impacts of anthropogenic emissions of greenhouse gases on the living conditions of future generations. The short straight arrows (double arrow, grey) correspond to "yields the output," while long oblique (heavy arrow, red) arrows correspond to "is input for." The dashed rectangle indicates the combination of scientific prognoses that, as a whole, serve as an input for a political or moral evaluation, on the last line.

Still, these models fail to adequately account for many aspects of human suffering possibly caused by climate change, as they evaluate the impact of climate change on human welfare purely in monetary terms [9, 12]. Money can be lent, exchanged, traded or it can carry an interest; many factors which (co-)determine an individual's welfare cannot. Moreover, future losses are discounted at a fairly arbitrary rate. Of course, any realistic analysis has to take into account that future generations might have means and possibilities to adapt to the consequences of climate changes, maybe even of severe ones. The single discount rate currently used is not, however, connected to predictions on the capacity to adapt or mitigate. Furthermore, welfare economic analysis commonly ignores costs stemming from psychological afflictions that are hard or even impossible to monetarize. Finally, almost all impact models in use so far ignore economic variability, e.g. business cycles and major crashes, and the genuine coupling of this variability to climate dynamics [15, 16].

Yet, for the time being, we have to accept these modeling shortcomings — just as we have to deal not only with the various shortcomings of present climate models but also with those of other predictions, e.g. on weather, earthquakes, or stock market prices. These shortcomings introduce uncertainties into the model outputs, which then have to be taken into consideration, along with those of climate-change predictions and of the energy scenarios.

In practice, the distribution of the various tasks in determining the effects of anthropogenic greenhouse gas emissions is not as clear-cut as sketched in Fig. 1. Economic models are frequently mistaken as moral assessments, although they clearly do not constitute evaluations on moral grounds. Basic modeling assumptions — like discounting future losses or evaluating the harm in purely monetary terms, etc. — cannot be morally justified, although they might be reasonable assumptions for estimating the economic impact of climate change. But even if we accept these assumptions as reasonable for the time being, the economic models still do not qualify as a "first-order approximation" to a normative assessment, whether moral or political.

In determining what it means to act rightly or wrongly, in moral terms, a cost-benefit analysis of one action always has to include an evaluation of alternative actions. Climate change and its mitigation cannot be treated as the only issue at hand: epidemics caused by other factors, industrial and agricultural pollution endangering air and water quality, educational opportunities, poverty, discrimination etc., are matters of legitimate concern as well. Existing cost-benefit analyses, even those few that try to avoid the above-mentioned shortcomings of economic models [9], fail to put the analysis of climate change into the requisite broader context.

Societies (or other subjects) are able to part only with a certain amount of money or other resources for predominantly altruistic goals, of which the mitigation of major changes in future climate is only one. Investing in the mitigation of climate-change effects means forgoing other investments, e.g. the reduction of world poverty, towards which we have a moral obligation. For example, on the one hand, the Stern report [12] famously mentions 1 % of global gross domestic product (GDP) as the sum needed to avoid major hazards that may arise from climate change. This amounts to an investment of US $ 450 billion per year, if we base the calculation on the current GDP value. On the other hand, current estimates of the money needed to provide 80 % of rural populations in Africa with access to water and sanitation by 2015 amounts to only US $ 1.3 billion per annum [17].

The trade-off between investment into the mitigation of and adaption to climate-change effects and investment in safe water supply in developing countries, for example, is currently not included in the moral or political evaluation of climate change. Political reasoning seems to shy away from the trade-off. The moral discourse contents itself with an *ex post* justification of established public opinion. As a result, the discussion is cut short and moral obligations are derived already on the level of merely discussing climate model predictions.

This preempting of the moral debate is not only at variance with sound decision making. Putting the cart before the horse, i.e. presupposing a moral obligation before all the steps of the cost-benefit analysis have been carried out, also seems to adversely affect the science itself. As Pielke [18], p. 406, notes in this context: "In many instances science, particularly environmental science, has become little more than a mechanics of marketing competing political agendas, and scientists have become leading members of the advertising campaigns."

The heated debate that followed the publication of Lomborg's book [19], as well as many of the current discussions on various 'scientific' blogs [20], illustrate how scientific reasoning is, mostly implicitly, accused of being but a political instrument for the wrong side [21].

III. BALANCING COSTS AND BENEFITS

Reasoning about morally right or wrong actions becomes significantly more difficult when their consequences affect also future generations. Quite often, various moral duties cannot be honored simultaneously; thus there might arise a conflict between preventing future harm from climate change and fulfilling our duties to currently living humans. Philosophers refer to such situations as *moral dilemmas*. Such dilemmas are not restricted to climate-change issues, but they do become quite critical in this case. Should we invest in educating women in developing countries now or invest in some of the less promising sources of alternative energy? Shall our concerted actions aim at reducing the number of currently ongoing wars or at preventing future flood damages? Such questions are clearly bothersome but still cannot be dismissed easily: has alleviating current suffering priority over mitigating future losses about whose extent legitimate uncertainties might exist?

Having posed the moral dilemma in this way, it seems natural to approach its solution by pursuing a more complete cost-benefit analysis. In such an analysis, costs and benefits have to reflect the impact of alternative courses of action on human well-being, current and future. In this broader setting, the morally correct action is the one that maximizes overall human welfare. This approach can be seen as a variant of utilitarian ethics, dating back to J. Bentham and J. St. Mill [22]. These early thinkers identified well-being boldly with happiness; modern utilitarianists replace the concept of happiness by the general term welfare and refer to the fulfillment of the individual's preferences.

The individual preference function $U_i : X \to \mathbb{R}$, reflects the preference of person i in the distribution X of some goods, with the preference function going from $+\infty$ to $-\infty$, i.e. it can be any real number U_i in $\mathbb{R}$. Note that 'goods' are to be understood here in a very general way, not restricted to material goods but also including mental states, being free from pain, etc. The utilitarian or welfare-ethical principle then amounts to maximizing the welfare function $U = \sum_i \lambda_i U_i$, where the sum is over all individuals which are affected by the action under consideration and λ_i is some arbitrary weighting factor. In this setting, the utilitarian principle of procedural justice, Bentham's famous "Everybody to count for one, nobody for more than one" becomes "$\lambda_i = \lambda_j$ for all i, j."

The utilitarian approach has the advantage that it generalizes in a straightforward manner to actions for which the outcomes are not known with certainty, but only known to occur with some likelihood; e.g. the exact number of class-5 hurricanes at the end of this century that would result from a given greenhouse-gas emission scenario. In this probabilistic generalization, one maximizes the *mean expected welfare*, rather than the deterministic welfare function above. In the welfare-economic and philosophical literature, this approach is referred to as Expected Utility Theory (EUT).

Applying EUT to climate-change issues is not straightforward, since assigning actual likelihood values to expected impacts on human welfare is often difficult or even impossible with the current state of knowledge; see Section IV for a discussion of this issue and [6] and references therein for the underlying uncertainties in climate-change estimates. Another problem with this approach, which has been addressed extensively within the philosophical and economic literature, regards the very existence of an individual welfare function U_i. It seems odd to assign cardinal values to individual harms and benefits in order to make them accessible to interpersonal comparisons [23].

In the context of intergenerational ethics, another problem becomes quite arduous, namely that of assigning preferences to future generations: are theirs going to be necessarily the same as ours? More likely not! J.H. Ausubel [24] gives an amusing example of how the unknown preferences of posterity challenge cost-benefit analysis for climate-change issues: "One hundred years ago icebergs were a major climatic threat impeding travel between North America and Europe. 1,513 lives ended when the British liner Titanic collided with one on 14 April 1912. 50 years later jets overflew liners. Anticipating the solution to the iceberg danger required understanding not only the rates and paths on which icebergs travel but the ways humans travel, too."

In fact, ascribing our own preferences to future generations clearly contradicts the above-mentioned utilitarian principle of procedural justice; see [25] for a possible way of avoiding such problems.

In approaching climate-change issues from a moral point of view, we have chosen here an *anthropocentric consequentialism*: There are no *a priori* obligations, and any action has to be evaluated as to how it promotes overall human welfare. To defend this approach within an intergenerational ethics discourse, we begin with a defense of consequentialism.

Modern normative ethics are frequently classified as either *consequentialist* or *deontological*. The latter focuses on the rightness or wrongness of actions themselves, as opposed to the rightness or wrongness of the consequences of those actions. Kant's categorical imperative is a paradigm of a deontological principle. The utilitarian approach discussed above is rooted in consequentialist ethics, as the actions are evaluated solely on the basis of their impact on human welfare. As previously mentioned, one advantage of the consequentialist approach is that it generalizes to actions with highly uncertain outcomes, while this is not possible for deontological approaches [26]. Moreover, Patzig [27] and others have argued that, in handling moral dilemmas, consequentialist approaches are superior to deontological ones [28, 29].

Various environmentalists have criticized valuing the environment solely as a basic resource for humanity, as done in the present paper. Movements like "deep ecology" [30] or land ethics [31] recently attracted considerable attention in environmental arguments. Their positions are genuinely non-anthropocentric: either nature as a whole or parts of (nonhuman) nature are assigned some moral value. Hence whole ecosystems or even the climate system have to be valued for their own sake, i.e. not merely due to their value for a sentient being. Note that by 'non-anthropocentric', we refer here to approaches that assign actual moral values to plants or inanimate matter; while we do not pursue this avenue in this paper, the welfare-based approach can be generalized to other sentient beings in a straightforward manner.

Most of the proposed non-anthropocentric approaches in the literature have difficulties in dealing with moral dilemmas [32]. This is not a crucial shortcoming of such approaches, though, as a hierarchical value structure could solve this problem.

A key shortcoming of non-anthropocentric approaches, however, is that they contradict Occam's razor: a larger number of premises is needed in arguing for physiocentricism or holism, and these added premises cannot be justified any further [32]. Keeping the number of such metaphysical assumptions as low as possible is particularly important within environmental ethics, for the following reason. In order to become effective, norms that, for example, rule the emissions of greenhouse gases have to be implemented on a global scale and by future generations as well. The metaphysical background shared by different cultures — or, within one culture, over several generations — seems rather limited. The assumptions of a welfare-based approach are the most likely to be shared by people from different cultural backgrounds.

IV. HOW TO COMMUNICATE EPISTEMIC UNCERTAINTIES

Determining the ultimate impacts of present and future greenhouse gas emissions necessitates a multifaceted interplay of various disciplines, as sketched in Fig. 1. The suggested welfare-based approach to climate-change issues — in which the morally correct action is that which maximizes overall human welfare — is seriously called into question by the lack of reliable probability estimates. The requisite estimates range from the various anthropogenic impacts on the climate system to the consequences of these impacts on human welfare. As stressed in [5], even the probability distribution estimates for future mean temperatures or other climatic variables require considerable refinement; this holds true all the more for the estimated probabilities of specific consequences, for example, of the influence of climate change on farming in Africa and its implications on migration [12].

One refers to actions for which there are no reliable probability estimates in terms of objective frequencies of occurrence as "actions under (epistemic) uncertainty." This is opposed to "actions under risk," for which all outcomes of a given action can be assigned some frequency of occurrence. This classification of *risk* and *uncertainty* became popular in discussing the civil use of nuclear power and is now commonly used within technology assessment.

For actions under uncertainty, it has been suggested to fall back on non-probabilistic decision models. The most popular model of this type is the *minimax rule*, i.e. minimizing the maximal harm that can be expected; within environmental ethics or political decision making, this rule is known as the 'precautionary principle'. Note that the use of this phrase is fraught with ambiguity: within a juridical context in general or in European Union legislation in particular, the notion is fairly vague [33]. Hence we prefer to use the term as used within ethics and popularized by H. Jonas [34], namely: if we cannot exclude with certainty that an action, like the release of greenhouse gases, has the potential to cause severe or irreversible harm — to present or future generations — it is to be abandoned.

This principle, however, raises several difficulties [35], the central problem being that, in almost all practical cases, acting as well as not acting might yield unacceptable consequences. Unless a morally relevant distinction between act and omission exists, the precautionary principle therefore is incomplete, and thus is inadequate for actual decision making processes. Hence, despite the lack of probability estimates for the impact of climate change on the well-being of future generations, we have to proceed along the lines of EUT. Applying EUT to decisions under uncertainty requires supplementing the frequencies that are already available for some of the predicted consequences of climate change with subjective probabilities for other consequences. While economists are familiar with such subjective probabilities, natural scientists, including climate dynamicists, are generally quite sceptical about their use.

Note in particular that what is referred to as uncertainties within climate science [6, 36, 37] differs from the epistemic uncertainties as defined above. To be more precise, the uncertainties that climatologists discuss do not involve a need for subjective probabilities. Uncertainties like the range of the predicted temperatures for the end of this century, for example, are only one aspect of the uncertainties that decision making has to deal with. In particular, the uncertainties with which decision making struggles most are those that are not quantified as yet. A very broad or highly skewed probability distribution is awkward, as one needs to discuss issues related to risk-averseness. Such uncertainties, though, do not challenge the foundations of the proposed EUT approach.

Reducing the uncertainties faced by the various IPCC working groups can be associated with the various rectangles in Fig. 1. Each group so far has proceeded within the methodology of a specific field of knowledge [5, 38]. For the climate dynamics addressed within Working Group I, methods for reducing uncertainties in prediction have advanced significantly of late [6, 39]. The same holds true for the economical analyses within Working Group II. Quantitative methods for how to determine not only objective occurrence frequencies, but also reliable subjective probabilities were provided. These methods include, for example, the use of decision markets [40] or the implementation of Delphi methods, in which several experts provide subjective probability estimates that are refined in a multi-level process [41]. Also other quantitative tools for decision making were put forward [42].

Despite this progress, not all epistemic uncertainties can be quantified in a simple figure, like the width of a probability distribution or the area of a Morgan-Keith plot, say. Such plots have been used to yield ostensibly a quantification of the subjective reliability a researcher assigns to a theory, an observation, or the consensus within the field for the model results that underly a specific prediction [43]. Still, in estimating the reliability of a physical or economic model there always remain factors that are hard to communicate. For example, the outputs of a statistical analysis will always depend on the specific experimental paradigm, the accepted practice, and the general research experience within the field; these factors cannot be defined in lay language in a straightforward way, but must be learned by working in the field.

Scientists in a given field tend to assign so-called "higher-order beliefs" to all these factors, i.e. beliefs that express their confidence in the underlying theory, the methodology used, the researcher or group who carried out the work, etc. These higher-order beliefs, however, are only very rarely quantifiable themselves in terms of a subjective probability. Morgan-Keith plots, for example, presuppose that subjective beliefs can be expressed in cardinal numbers.

Hence the communication of uncertainties is, at least in part, limited to a scientific community — physical or economical, say. A scientific community is thus an instance of a Wittgensteinian language community: "the term '*language-game*' is meant to bring into prominence the fact that the *speaking* of a language is part of an activity [...]." As an example of a language-game, Wittgenstein himself refers to "presenting the results of an experiment in tables and diagrams" [44]. Assessing the reliability of climate-change predictions seems, at least to some extent, something that is learnt by the practice of carrying out and verifying such predictions.

V. CONCLUDING REMARKS

The preceding discussion suggests an antithetic conclusion as regards the role of science in political and moral decision making: (i) A partial delegation of responsibility by the decision makers to the scientists, i.e.

mainly climatologists and economists, is absolutely necessary, while (ii) at the same time, the climate-change debate demands a somewhat more restricted role of scientific prognoses than the one they currently play in the public debate.

(i) Non-quantified epistemic uncertainties — whether contingent or necessary — hamper the proper communication of the actual degree of reliability of predicting anthropogenic impacts on the climate system. These uncertainties are wedded to specific model outputs, whether climatic or impact models. The respective modelers thus seem to have the high ground insofar as they can best assess those uncertainties that remain unquantified, at least for the moment.

A cost-benefit analysis depends sensitively on these uncertainties. This sensitivity implies, first, that performing such an analysis rests on the shoulders of the scientists. Second, it calls for more interdisciplinary work: It is the output of impact models that is needed for cost-benefit analysis; in this output, however, the uncertainties from the predicted concentration of greenhouse gases and from climate models, for instance, are compounded, linearly [36] or nonlinearly [6].

The proposed strengthening of the role of the sciences clearly does not imply a blind trust in scientific outcomes. First, it is the decision makers who set the rules for how to perform the cost-benefit analysis; see item (ii) below. Second, taking uncertainties seriously implies scrutinizing closely the scientific methodology. Shifting the actual performance of cost-benefit analysis to the sciences just acknowledges that neither political decision making nor moral evaluation are the place for a critical evaluation of scientific methodology. This is the task of the scientific community itself, together with an exterior watchdog consisting of, for example, the sociology and philosophy of science. Although currently this watchdog seems to lag behind the scientific progress, there already exist some interesting accounts on the "science of climate change," seen from the outside. The practice of welfare economic analysis, however, is still insufficiently elucidated.

(ii) Saying that the cost-benefit analysis has to be performed on the basis of criteria from outside the sciences merely acknowledges the fact that the decision to choose among several ways of reacting to or anticipating climate changes invokes genuine moral values that science shall — and indeed can — be neutral about. As it presumes such a value judgement, the oft-used term "catastrophe" has no place within the scientific debate on climate change.

The decision for or against a reduction or mitigation of predicted climate change impacts is always a decision for or against the promotion of other investments, e.g. in water supply or education for developing countries. In current political decision making, scientific prognoses, however, act as "fig leaves" [45] that hide the actual decision making process and the normative assumptions on which it rests. Scientific, i.e. climatological or economical, prognoses as regards climate change or any other topic, taken on their own, give no sufficient reasons for acting or not acting, this way or the other.

Acknowledgments

It is a pleasure to thank the organizers and participants of the Conference on the "*Euler Equations: 250 Years On*" and, more than all, Uriel Frisch and Andrei Sobolevskii, for a very stimulating experience. We are grateful to our colleagues Peter Taylor and Nick Shackel for constructive input on the issues discussed herein. This study was supported by the U.S. Department of Energy grant DE-FG02-07ER64439 from the Climate Change Prediction Program, and by the European Commission's No. 12975 (NEST) project "Extreme Events: Causes and Consequences (E2-C2)."

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