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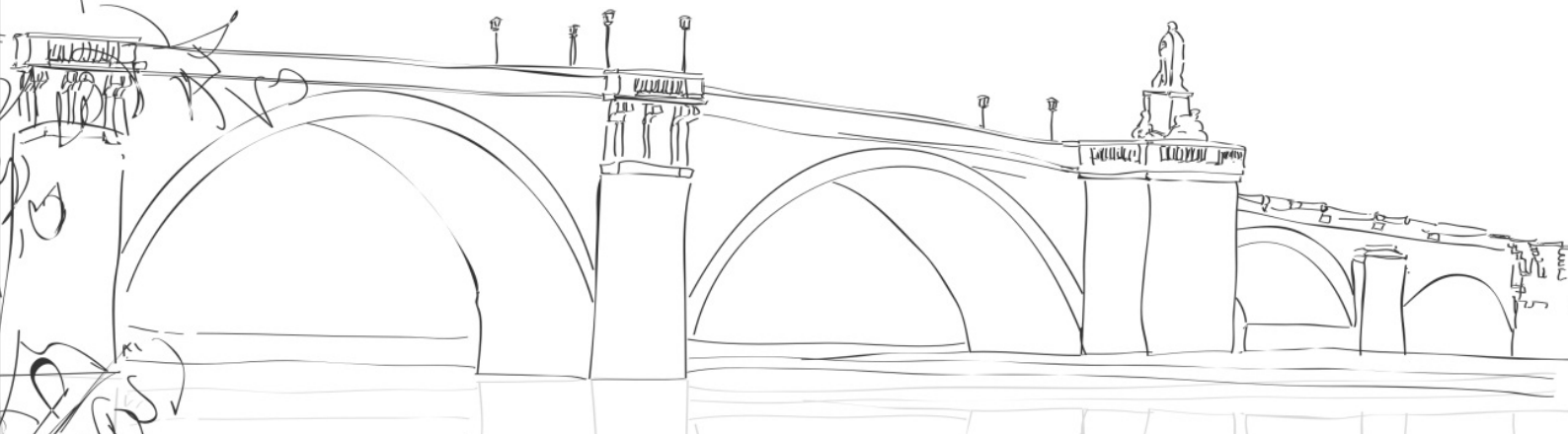
Beyond calculation

Climate Engineering risks from a social sciences perspective

Dorothee Amelung, Wolfgang Dietz, Hannes Fernow, Daniel Heyen, David Reichwein, and Thilo Wiertz

Abstract

Decisions in the context of Climate Engineering (CE), the deliberate large-scale manipulation of the Earth's climate, are decisions made under uncertainty. CE options are associated with a broad range of environmental and societal risks that raise complex questions: How can the risks be assessed and evaluated when balanced against the risks of alternative strategies to counteract climate change? What are the strategic implications for climate politics against the background of insufficient scientific knowledge? Can we estimate the ethical implications of the risks involved for society? Uncertainties and risks represent a central aspect of the issue but cannot be reduced to the traditional technical orientation of risk terminologies. The article elaborates on the specific characteristics of the risks and uncertainties associated with CE technology from six different disciplinary viewpoints. It thereby seeks to reveal chances for a mutual enrichment of these individual viewpoints since each discipline experiences boundaries while examining the complex risks of CE. In this way, the article redefines disciplinary boundaries without entirely dissolving them and without disregarding the valuable contribution every individual viewpoint can make. This aim is realized by means of the identification of new approaches to central questions regarding the risks and uncertainties involved in CE that can only be addressed from an interdisciplinary perspective.



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Preface

Sebastian Harnisch and Joachim Funke

In December 2010, the Marsilius Kolleg project "The Global Governance of Climate Engineering" convened an internal workshop on "Risk and Climate Engineering". This workshop was undertaken as an exercise of interdisciplinarity in a multidisciplinary research project funded by the Marsilius-Kolleg (MK)[1] on the feasibility, efficiency and legitimacy of various climate intervention techniques. The workshop offered the opportunity to take a fresh look at the state of disciplinary approaches towards risk and uncertainty in general and recent developments in the scientific discourse on risks of specific climate intervention techniques in particular.

The issue: risk and Climate Engineering

Issues of risk and uncertainty have played a key and arguably growing role in the development of humanity. According to Ulrich Beck's influential "risk society" thesis, risks always occur as side effects of modern industrial societies and they are responsible for modern societal transformation over time.[2] From this risk-sociological perspective, complex technological development cannot be addressed by statistical-probabilistic risk assessments alone because they involve large scale societal effects. Risks, thus, call for an interdisciplinary research approach which addresses the variation in the nature and construction of risk by a wide spectrum of societal actors and scientific disciplines.[3]

Global warming and climate change as long-term risks have been an issue in public and political discussions for more than 20 years now. Despite mounting concerns about the impact of CO_2 emissions, there is no substantial behavioral change observable – especially in industrialized societies. As a consequence, the ecological footprint is growing constantly.

Against this background, some scientists have started to argue that there may be an alternative strategy to deep emission cuts and adaptive measures. These technologies are broadly called "Climate Engineering" (CE) or "geoengineering".

[1] The Marsilius Kolleg was established in 2007 as a "Centre for Advanced Studies" to support interdisciplinary research projects across disciplinary cultures. It is a central part of Heidelberg's proposal within the Excellence Initiative launched by the federal and state governments in Germany (for more information: http://www.marsilius-kolleg.uni-heidelberg.de/).
[2] Cf. Ulrich Beck: *Weltrisikogesellschaft – Auf der Suche nach der verloren Sicherheit*, Frankfurt a. M.: Suhrkamp 2008.
[3] Ortwin Renn: *Risk* Governance – *Coping with Uncertainty in a Complex World*, London: Earthscan 2008; Peter Taylor-Gooby, and Jens O. Zenn: *Risk as an Interdisciplinary Research Area*, in: *Risk in social science*, ed. by Peter Taylor-Gooby and Jens O. Zinn, Oxford: Oxford University Press 2007, pp. 20-54.

They involve the intentional technical intervention in the global climate system on a planetary scale and they are commonly understood to be a (plausible) response to the failure of international abatement efforts.[4]

Is this an acceptable solution to the problem of climate change? Do "the weather makers"[5] deliver us a "climate fix"[6], a quick and dirty workaround for a very complex problem? In this brief introduction we offer two brief disciplinary perspectives as a frame of reference for the comparative and transdisciplinary views of the following chapters. In the first section, Joachim Funke outlines some of the key aspects of a psychological approach to risk and decision making. In the second section, Sebastian Harnisch presents a first cut of risk, uncertainty and threats from a political science perspective. We conclude by calling for further and stronger multidisciplinary engagement when dealing with long-term high-risk policy problems.

The psychological perspective: CE as a complex problem

From a psychologist's point of view, the CE situation can be described as a complex problem. First, we will show that this view is a fair description of the CE situation. As a consequence of this description (CE as a complex problem), we are able to show some of the implications of this framing for a problem solver.

First, a complex problem is said to occur when finding a solution demands a series of operations which can be characterized as follows[7]: (a) The number of elements relevant to the solution process is large (complexity), highly interconnected (connectivity), and (b) the system is dynamically changing over time (dynamics). In addition, (c) neither the decision structure nor (d) its dynamics are disclosed to the actor (intransparency). Finally, (e) the set of goals is not as straightforward: in dealing with a complex problem, a decision-maker is confronted with a number of different goal facets that have to be weighted and coordinated (polytelic situation).

All of these attributes can be found in the context of Climate Engineering: (a) concerning complexity, the number of considerations relevant to the solution seems

[4] David W. Keith et al.: *Research on global sun block needed now*, in: *Nature* 463 (2010), pp. 426-427; Wilfried Rickels, Gernot Klepper, Jonas Dovern (eds.) et al.: *Gezielte Eingriffe in das Klima? Eine Bestandsaufnahme der Debatte zu Climate Engineering*, Sonderstudie für das Bundesministerium für Bildung und Forschung 111, Kiel Earth Institute 2011.

[5] Cf. Tim Flannery: *The Weather Makers: The History and Future Impact of Climate Change*, Melbourne, Australia: Text Publishing Co. 2005.

[6] Cf. Roger A. Pielke: *The Climate Fix: What Scientists and Politicians Won't Tell You About Global Warming*, New York, NY: Basic Books 2010.

[7] Cf. Dietrich Dörner et al.: *Lohhausen – Vom Umgang mit Unbestimmtheit und Komplexität*, Bern: Huber, 1983; Joachim Funke: *Complex Problem Solving: A Case for Complex Cognition?*, in: *Cognitive Processing* 11 (2010), pp. 133-142.

extremely large if one does not only include the physical variables but also the psychological, social, economical, and political aspects; (b) concerning connectivity, CE relates to an intensively connected network of variables; (c) with regard to decision dynamics, CE does intend to influence the climate dynamics; (d) concerning intransparency, there are many open questions, for example, about unintended consequences of some technologies; (e) concerning polytely: as the intervention has winners and losers, the different regional interests seem to be one of the major sources of missing consensus.

Consequences from the complex problem view

What are the situational consequences for the problem solver, be it a scientist, a politician, or a normal citizen? Complex problems require dealing with uncertainty[8]. Thus, research on complex problems in human decision making reveals some interesting insights:

(1) The complexity and connectivity of the situation transcends the capacity of human working memory. Therefore, humans have to reduce complexity by using simplified causal models. This simplification is helpful but bears the danger of incomplete representation of reality. Reduction of complexity can also lead to an erroneous understanding of scientific proposals.

(2) The dynamics of the situation require making predictions about future events. This prediction is often done through simplified linear models which face difficulties when dealing with nonlinearities and cyclic processes. Because models are not reality, computations often accumulate errors (especially over longer time periods) and produce incorrect predictions.

(3) The intransparency of the situation produces fear (and other negative emotions) which may have two extreme consequences: either fear leads to a more intensive information search which in turn requires decision-making that uses cues (proxies), or fear leads to an information aversive strategy, metaphorically speaking putting a paper bag over one's head. Intransparency explains the reluctance of the public opinion to go further into CE techniques. In order to gain broader acceptance, much more transparency about CE techniques and about long-term consequences (including side effects) is needed.

[8] Magda Osman: *Controlling uncertainty: A Review of Human Behavior in Complex Dynamic Environments*, in: *Psychological Bulletin* 136(1) (2010), pp. 65-86.

(4) The polytelic nature of a risky situation necessitates setting up priorities and balancing conflicting values and goals. Since different players with different stakes are involved and no central decision-making body is readily available, a difficult mediation process between the various stakeholders will have to take place in order to reach a legitimate consensus.

CE seen as a complex problem makes it better understandable why we should not expect a quick decision in one or another direction. It might be a good strategy to sell CE research in the public as a necessary step in reducing uncertainty.

Engaging multiple perspectives

Perspectivity is a central feature of human thinking:[9] We all have our own individual perspective and see the world around us from different angles and different backgrounds. This may be seen as a disadvantage: a common ground is not reached easily. However, perspectivity may also be viewed as an advantage because different perspectives give a more realistic, broader picture of reality which takes the interests and values of various individuals into account. In this sense, the interdisciplinarity of the following papers is actually a result of such a multi-perspectivity. It helps us to better understand the complex risks and uncertainties of research and development of CE technologies. In addition, multi-perspectivity offers a window to creative solutions because the perspective from another discipline might lead to new ideas and new solutions.

Risk and uncertainty: a political science perspective

From a political science point of view, Climate Engineering poses several long-term policy challenges to both national and global governance institutions. Such challenges will occupy at least one human generation, include substantial uncertainty over time and engender strong public good production problems.[10] In this sense, CE technologies can be viewed as uncertainty about involved agents, potential unintended consequences and potential losses. As such, CE technologies are but one of numerous other significant risk issues (e.g., genetically modified crops, disposal and storage of radioactive waste or technical catastrophes) modern

[9] Carl F. Graumann and Werner Kallmeyer: *Perspective and Perspectivation in Discourse: An Introduction*, in: *Perspective and Perspectivation in Discourse*, ed. by Carl F. Graumann and Werner Kallmeyer, Amsterdam: John Benjamins 2002, pp. 1-11.

[10] Jon Hovi et al.: *Implementing Long-Term Climate Policy: Time Inconsistency, Domestic Politics, International Anarchy*, in: *Global Environmental Politics* 9(3) (2009), p. 20.

industrial societies face. In addition, these long-term policy problems raise a host of questions about the roles scientists play in rationalizing the cost/benefit considerations in modern societies.[11]

Conceptualizing risk

Following Christopher Daase,[12] risk may be defined as "the probability of a future loss or damage that can be influenced by current action". In contrast, a threat appears when states perceive an actor (agent), which holds an adversarial intention (intention) and possesses the means to inflict considerable damage (capability). In the absence of one or more of these three elements – actorness, intention or capability – a threat should not be considered a threat, but a risk.[13]

Drawing on these three elements of a risk-threat distinction, a first-cut set of analytical questions can be identified to ascertain when and under what circumstances a risk may turn into a threat: First, we may ask which actors and institutions hold a dominant role in the CE-debate? How are their strategies and proposals judged by other actors (trust)? Secondly, we may locate intention within the wider context of respective climate change policies, asking how the negative impacts of global warming are perceived (e.g. the severity of current and future impacts of global climate change). How are the results of climate negotiations perceived and interpreted? Thirdly, considering capabilities, we may examine how the probability of potential losses in the future is perceived and how the risks of CE-technologies are assessed (likelihood of losses). How do actors decide if a risk is acceptable or not (acceptability)?

Contribution to an interdisciplinary CE research field

As a long-term policy problem CE poses a critical challenge to scientific theories that are based only on causal rather than causal and constitutive reasoning. Risks, defined as the probability of a future loss or damage that can be influenced by current action, are inherently generical. As such, they include, by definition, the impos-

[11] Cf.Gili S. Drori et al., eds.: *Science in the Modern World Polity – Institutionalization and Globalization*, Stanford, CA: Stanford University Press 2003; Roger A. Pielke: *The Honest Broker – Making Sense of Science in Policy and Politics*, Cambridge: Cambridge University Press 2007.

[12] Cf. Christopher Daase: *International Risks and the Perils of Proactive Security Policy*. Paper prepared for the Sixth Pan-European International Relations Conference Turin, 12-15 September 2007.

[13] Christopher Daase: *Internationale Risikopolitik. Ein Forschungsprogramm für den sicherheitspolitischen Paradigmenwechsel*, in: *Internationale Risikopolitik. Der Umgang mit neuen Herausforderungen in den internationalen Beziehungen*, ed. by Christopher Daase et al., Baden-Baden: Nomos Verlag 2002, pp. 9-35.

sibility to assign reliable quantitative values to the various "probable states of the world in the future".[14]

At this time, we simply do not know enough about the risks of CE because we simply do not know what it means to live in a climate that is "artificially cooled down". By imagining or experimenting, however, scientists, both natural and social, "create these risks" in the sense that their scientific risk assessments often do become "accepted knowledge through scientific discourse". In this sense, the impact of the roles scientists play in public discourse and the evolution of distinct discourse patterns on the risks of a yet unproven technology will have to be "conceived" rather than "detected".

Conclusion

The complexity of CE cannot be dealt with in terms of a single scientific discipline. The multi-perspectivity of our group gives a chance for a deeper and broader view of the complex situation. This might lead to more appropriate solution proposals in the end. Because of their inherent multiple perspectives, these solutions might also be more acceptable to a broader community than single-perspective solutions.

Young researchers and principal investigators from several projects brought a variety of different disciplinary perspectives to the workshop's topic, ranging from Human Geography, Philosophy, Environmental Economics, Political Science and Political Economy to Psychology and International Environmental Law. Reflections on the commonalities and differences of the disciplinary approaches and the role of interdisciplinary dialogue completed this first broad overview of risk and climate intervention mechanisms.[15]

Although there were no formal conclusions derived and adopted by all workshop participants, certain trends in interpretation of disciplinary perspectives and a consensus on the theoretical applicability of the terms "risk" and "uncertainty" were evident. The following brief summaries of the disciplinary enquiries and follow-on discussions during several workshops are our own,[16] but they reflect both the thrust

[14] Ibid., pp. 9-35.

[15] A list of further publications and activities may be found on the project's website: http://www.climate-engineering.uni-hd.de/.

[16] We would like to thank the participants of the 2nd Transdisciplinary Climate Engineering Summer School, a collaborative endeavor of the University of Calgary, Carnegie Mellon University, Pittsburgh and the Marsilius Kolleg, Heidelberg University.

of the workshop papers presented in this volume as the findings of the research done at Heidelberg University, Karlsruhe (KIT) and elsewhere under the interdisciplinary perspective.

Thus, this volume reports some of the results of the project on “The Global Governance of Climate Engineering” under the auspices of the MK and some of the findings from individual research projects. The workshop and subsequent reviews and presentations were deliberately designed to present the results of the research team in Heidelberg to a critical review by leading experts in the field. Hence, this volume represents to some extent the state of the art in the disciplinary analysis of risk with regard to Climate Engineering.

As the findings have been reviewed critically several times but other theoretically informed studies on the risks and uncertainties remain still in short supply, the volume tries both to present a disciplinary rich interpretation of the risks and uncertainties involved in Climate Engineering and to reflect on the strength and weaknesses of the respective disciplinary frameworks.

The workshop and this report on its findings could not have been carried out without the generous support of the Marsilius Kolleg (MK), the critical input of its two Directors, Hans-Georg Kräusslich and Wolfgang Schluchter, and its Executive Officer, Tobias Just. We would also like to thank David Keith and Juan Moreno-Cruz of Calgary University and their staff for the 2nd summer school which was another critical test for our ideas.

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Introduction

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The consequences of climate change are increasingly being recognized and experienced as a threat to the lives of millions of people around the world. Although there is no doubt that the recent increase in the earth's mean surface temperature has primarily been caused by contemporary industrial production and consumption patterns and the concomitant release of greenhouse gases into the atmosphere, international negotiations under the auspices of the United Nations have yet to demonstrate that changes to the global economic growth paradigm based on fossil fuel consumption are attainable. Growing concerns about the dramatic consequences of anthropogenic global warming and disillusion about the political will to radically reduce emissions has led some scientists to propose technological interventions into the global climate. Climate Engineering, i.e. the large-scale manipulation of the global climate to alleviate the impacts of global warming, comprises technologies that either aim at increasing the planetary albedo or at sequestering large quantities of carbon dioxide from the atmosphere. The latter is termed Carbon Dioxide Removal or CDR. The former techniques, subsumed under the acronym SRM (Solar Radiation Management), are especially linked to large risks regarding their regional impacts on climate and weather and hence are the focus of this discussion paper.

Potential SRM methods comprise the injection of reflective particles (e. g. sulphur) into the stratosphere, or whitening marine clouds by means of sea-salt aerosols. When compared to 'classic' mitigation approaches or CDR, SRM appears potentially both cheap and fast. However, since it does not deal with the problem of higher GHG levels, SRM only addresses one of the symptoms of global warming: the increase in global mean surface temperature. Any deployment of SRM would thus entail the interplay of significantly high levels of GHG concentrations together with the need for continuous technical intervention to preserve moderate temperatures – an unprecedented climatic state with uncertain consequences for circulation patterns and hence local weather and regional climate conditions. Additionally, there might be side effects which research cannot reveal.[1] The complexity of such an undertaking raises the question as to how individuals, societies or states can address the risks implied by SRM; apart from the technological problems, Climate Engineering entails manifold social, political and ethical challenges. The focuses of our social sciences perspective are the social and political questions arising from the risks and uncertainties associated with SRM.

[1] Cf. Alan Robock: *20 reasons why geoengineering may be a bad idea*, in: *Bulletin of Atomic Scientists* (64) (2008), pp. 14-18.

Before tackling these questions, the establishment of a common starting point and a clarification of the terms ‘risk’ and ‘uncertainty’ appear necessary. Most definitions of risk and uncertainty share two aspects: first, there is uncertainty regarding the occurrence of several possible outcomes or consequences due to activities, and second, these different outcomes or consequences differ in terms of how individuals or groups value them. Therefore, risk can be understood as “an uncertain consequence of an event or an activity with respect to something that humans value”.[2] Within some contributions to this paper, the distinction between ‘uncertainty’ and ‘risk’ is made in order to refer to the ‘incalculability’ and ‘calculability’ of these uncertain losses or gains, respectively. Due to their disciplinary viewpoints, the subsequent contributions might highlight some aspects of this definition while being silent on others, but every author will explicitly state upon which understanding his or her terminology is based.

Our starting point is the assumption that climate change and SRM are both complex risks. *Hannes Fernow* discusses the concept of ‘world risks’ (BECK) with regards to climate change and SRM. *Fernow* supports *Ulrich Beck*’s argumentation that classical approaches to risk evaluation fail to cope with the complexity of new technological risks. This line of thought is particularly relevant for SRM and culminates in arguing for cross-border communication and transnational cooperation, a proposition that is prevalent and underscored within following contributions. Taking up the idea of transnational cooperation, the subsequent section addresses the question as to under which conditions this cooperation among states might emerge when states are confronted with complexity and high uncertainties. According to *Wolfgang Dietz,* a game theoretical approach is only partly useful since states face more than simply the problem of deciding upon the right amount of deployment: States are additionally confronted with a high degree of uncertainty with regards to real-life causalities. Therefore, he proposes a cognitivist approach to international relations and examines a case-study on Arctic haze, which could provide similarities with regards to future SRM cooperation.

Since no cooperation with regard to the deployment of SRM currently exists, it is essential to look at the status quo of International Environmental Law. By getting an idea of how related treaties and customary international law generally deals with risks and uncertainties, we can draw some conclusions as to whether international law prohibits, limits or even supports research and deployment of SRM technologies. Here, as *David Reichwein* proposes, the Precautionary Principle may be read as a call for further research on SRM and could be taken as an initial guideline for

[2] Terje Aven, and Ortwin Renn: *On risk defined as an event where the outcome is uncertain*, in: *Journal of Risk Research* 12 (2009), pp. 1-11.

international risk management strategies. This is a notion also shared by *Daniel Heyen*, who focuses on the economic dimension of risk evaluation, the limits of traditional economic modeling and the potential of formalizing the Precautionary Principle in order to avoid the drawbacks of classic approaches.

In order to adequately address the social challenges posed by complex risks, it is equally important to look at the individual level. Therefore, *Dorothee Amelung* calls for the integration of individual psychological risk evaluation criteria and social processes of risk communication and governance. This resonates with the reasoning in other sections which demonstrate that classical risk evaluation approaches are inadequate with regards to SRM. Finally, from a post-structuralist viewpoint, *Thilo Wiertz* challenges the notion that social outcomes of SRM are predictable. Using the 'moral hazard' debate as an example, he reflects on the role social sciences play in the debate and criticizes purely technical conceptions of 'governance'.

Since the contributions are written from different social sciences perspectives, it is important to clarify the relevant methodology. The aim of this particular discussion paper, rather than narrowing down the diverging perspectives to one coherent viewpoint, is to outline the different directions from which Climate Engineering may be approached. While the contributions take a disciplinary perspective, the issues raised and the perspectives taken are the results of repeated (and on-going) interaction and discussion between the authors. The complementarity of the approaches employed reveals two points central for the debate: Firstly, it shows that any disciplinary approach by itself is insufficient to address the problems posed by Climate Engineering in isolation. Secondly, the objective is not only to clarify but rather to raise questions and highlight blind spots that may indicate directions for further inquiry.

Complex Risks and the Limits of Cost-Benefit Analysis

Hannes Fernow

Introduction

The debate on Solar Radiation Management technologies largely focuses on uncertainties about the unintended consequences of research and deployment of SRM. The fundamental challenge is derived from the fact that steering mechanisms in sensitive and dynamic systems are risky *per se*. Firstly, in the climate system as well in societies, the consequences of complex interaction are at least partly uncertain, and secondly, these interferences always refer to something that humans value. The latter means that physical (side-) effects can be perceived as more or less 'unfavorable' in a social and political respect. Taking no risks, however, is not an option, since not only SRM but also climate change itself poses various 'threats'. This indicates the need to assess the risks and weigh the benefits and costs exactly.

But who will and who is entitled to decide what is riskier, and for whom? In this respect, we have to reflect on the notion that anthropogenic climate transformations are not only a scientific problem, nor simply a threat to the global economy waiting for 'the best' technical solution, but also an opportunity to rethink epistemological conditions and ethical measures of values. The latter is reflected, for example, in the problem that a transfer of risks to future generations would raise questions of inequity:[1] If we do not cut emissions and rather decide to deploy SRM technologies, these methods would make the Earth's natural system vulnerable to technological failure for several thousand years.[2] If CO_2 emissions are not reduced in conjunction with the implementation of SRM, the deployment of the technologies may have to be maintained indefinitely once it is started. Therefore, two questions arise: Should we really launch SRM if we do not have an exit strategy? To which extent do we want to determine the actions of subsequent generations and trust in their capabilities to control the climate system? But, research into SRM techniques can alternatively be considered as our moral duty, since arming the future might present us with an opportunity to pay off our CO_2-'debt'.

I propose that these sorts of questions cannot be answered unambiguously from a scientific perspective and by the means of 'technical' risk analyses. Therefore, I

[1] Cf. Stephen M. Gardiner: *A Perfect Moral Storm: Climate Change, Intergenerational Ethics and the Problem of Moral Corruption*, in: *Environmental Values* 15 (2006), pp. 397-413.

[2] Cf. Victor Brovkin et al.: *Geoengineering climate by stratospheric sulfur injections: Earth system vulnerability to technological failure*, in: *Climatic Change* 92 (2009), pp. 243–259.

argue in favor of a change in perspective and would like to emphasize that a philosophical discussion of the spatial and temporal 'globalization' of risks may enhance our understanding of the challenges posed by the governance of SRM. Especially the theoretical approach of Ulrich Beck's 'World Risk Society' can help us to understand these challenges, because it reconsiders the characteristics of planetary risks posed by large-scale technologies and environmental change. This particular interpretation of complex risks leads to the question as to which consequences arise from this situation for society as a whole. This contribution suggests that at least one consequence is the need to foster civil debates and ethical considerations to complement standard approaches to risk calculation.

A critical theory of the calculability paradigm

The classic differentiation between 'calculable' risks and fundamental uncertainties is based on Frank Knight's concept. This approach to calculating risks has developed out of both the rationalistic and the utilitarian traditions. Within this theoretical framework it is clear: On the one hand, we like to avoid damages effectively. On the other hand, risks not only offer costs, but also opportunities to enhance common welfare. Therefore, taking the risk of a loss is rational if we can stochastically 'exclude' the occurrence of these losses by calculating the incidence rate. For that reason, one can postulate that all decision making should be left to the caring management of economic cost-benefit analysts.

But, in the case of global warming and SRM, are the expected numeric values reliable enough to serve as criteria for a 'mathematical ethic'? Referring to the work done by Ulrich Beck and many others, we can see the problem that the traditional acute differentiation between risks and uncertainties is not applicable. The concept of calculable risks has developed cracks, since modern, global 'risks' themselves are characterized by fundamental uncertainties. These uncertainties already begin with the calculus of probability distributions (cf. *Heyen*). Consequently, it is difficult to *predict* local and precisely timed effects of climate changes caused by global warming as well as by SRM. And it is also difficult to *predict* the development of people's attitudes regarding risky situations (cf. *Wiertz*). However, if we want to know which decision is 'good' and which is 'bad', we have to know the *consequences* of our decisions; at least from a utilitarian/economic perspective.

In the case of most of the SRM-measures, it seems advisable to specify this skeptical glance at 'classic' risk assessment methods. Therefore, it is worthwhile referring to Ulrich Beck's 'World Risk Society', since this theory is sensitive to the

high degree of uncertainty associated with the consequences of large-scale interventions.

Global environmental risks

Beck states three core aspects which characterize global risks. Current risks to civilization – for example climate change or financial crisis – are, firstly, *manufactured uncertainties*. They are not external threats, but rather are produced by western civilization itself.[3] Global risks are, in this sense, the result of current and past decisions and refer to both self-inflicted chances and self-inflicted future damages. However, the ratio between benefits and losses is socially and spatially unequally distributed. Therefore, risk communication implies dissent and doubt. When we think of risk, we cannot have definite and objective phenomena in mind, but threats or opportunities (!), which are differently defined: Some are talking about unlikely residual risks and others about unacceptable dangers – depending on, for example, the way one is affected. In accordance with Beck we have to state: A risk is not a substance but a 'construction' in a twofold sense: Global risks are the result of action and not the consequence of an external force. Furthermore, risks are perceived differently in specific cultural contexts.

Secondly, current global risks are not perceptible in everyday life. They are, in this regard, non-existent, but rather constitute the *anticipation* of an upcoming chance or catastrophe in the present.[4] The expected disasters do not exist in a material sense and we can hardly resort to comparable experiences. Instead, neither will these catastrophes inevitably occur, nor must they take place in the expected manner. Hence, in dealing with such risks, a speculative relation to the future is created. In other words: The reality of risk is always a projected one. "As a result, risk leads a dubious, insidious, would-be, fictitious, allusive existence: it is existent *and* non-existent, present *and* absent, doubtful *and* real".[5]

Last of all, world risks can hardly be *confined* in space, in time or socially.[6] For example, the consequences of a nuclear catastrophe would not only affect the responsible 'actors', the impacts would tend to transgress geographical and temporal boundaries. As a result, people with different backgrounds and from different generations who pursue diverging interests and perhaps do not intend to interact with

[3] Cf. Ulrich Beck: *Critical Theory of World Risk Society – A Cosmopolitan Vision*, in: *Constellations* 16, 1 (2009), p. 7.
[4] Cf. ibid., p. 3.
[5] Ibid.
[6] Ibid., p. 11.

each other, become 'close neighbors' in a globalized world. Ulrich Beck calls this the "cosmopolitan moment" in the age of mass media mediated risks.[7]

Both global warming and global cooling fulfill these three criteria because (1) their risks are engineered and they are assessed differently, (2) they are associated with different schemes of anticipation and forecasting and (3) the secondary effects and unintended consequences will unfold belatedly and in a globally heterogeneous way. What does this mean? Why is it actually so very tricky to calculate these consequences? To shed light on these prediction difficulties, it is helpful to clarify the epistemological problems of technological interferences in complex systems in more detail.

The limits of prediction of unintended consequences from large-scale technologies

High-tech and large-scale technologies imply more extensive spatial and temporal effects than less complex techniques, and not only in the event of their failure.[8] The acknowledged impacts of *global* technologies can be neither fully reversible nor spatially containable. Especially the latter aspect applies to the method of sulphur injections into the stratosphere, since the location of implementation does not coincide with the location of the effects, and the consequences not only affect global temperature, but also precipitation patterns and perhaps even the color of the sky.[9]

On a fundamental level, this 'risk'-globalization is based on the fact that SRM technologies interfere in complex dynamic systems which are characterized by uncertainty and partial unpredictability.[10] These dynamic complex systems are also referred to as non-linear systems, where the relationship of cause and effect is not proportional. To put it in another way, local changes can cause significant, global effects and vice versa; large changes in certain parameters need not necessarily have large effects. Furthermore, those 'causes' are not sufficient or monocausal prerequisites, since feedback processes modify the results from *interactions* among the components. That is to say, the network character of complex systems is re-

[7] Ibid., p. 6.

[8] Cf. Ortwin Renn und Michael M. Zwick: *Risiko- und Technikakzeptanz*, ed. by Die Enquete-Kommission „Schutz des Menschen und der Umwelt" des 13. Deutschen Bundestages, Berlin/Heidelberg/New York: Springer, 1997, pp. 2 f.; Beck: *Weltrisikogesellschaft*, fn. 2, pp. 61 ff.

[9] Cf. Robock: *20 reasons why geoengineering may be a bad idea*, in: *Bulletin of Atomic Scientists* (64) (2008), pp. 14-18.

[10] Sandra Mitchell: *Komplexitäten – Warum wir erst anfangen, die Welt zu verstehen*, Frankfurt a. M.: Suhrkamp 2008, pp. 48/113.

flected in the fact that each part of the system affects every other part and therefore, at the same time, the whole is changed when only a part is modified. As a result, a critical feature of complex systems is the sensitivity that results from the *connectivity* of the system. Consequently, the classical security category of 'containment' in terms of control and enclosure of consequences has partly been dissolved.[11]

Hence, it is crucial for the comprehensive regulation of complex and sensitive processes to bear in mind that possible adverse, irreversible consequences of planetary-scale manipulations could emerge exactly from the unforeseeable and non-linear dynamics of ecological and social systems. For that reason, different modeling outcomes not only result from empirical deficiencies, but are also the results of a more fundamental, epistemological uncertainty.

Since both the climate system and societies can be referred to as such complex dynamic systems, engaging in SRM will always have effects upon both these entire systems. The uncertainties involved in this respect are the starting point for the hypothesis that, in the case of SRM, scientific risk evaluation is remarkably limited because we cannot forecast the physical impacts and social effects in a precise and unequivocal way. Furthermore, classic risk calculations cannot provide evidence on the actual intensity, time of occurrence, course duration and on the question as to who will be affected. As a result, classic risk assessments have limited capacities to inform political decisions.

Prospects: We should engage in a dialogue

In conclusion, it seems that the principles of industrial modernity, such as the conception of a linear, technical-economic rationality and control, are hard to apply to this situation: With respect to global risks, we cannot merely talk about '*residual* risks' and '*almost certain'* probabilities, since, with this scientific approach, one is not able to grasp the fundamental spatial, temporal and qualitative range of the implicit uncertainties and ambiguities of technological responses to global warming. In the common concept of risk, Niklas Luhmann recognized that a society tries to normalize its functioning by making accidents and surprises expectable.[12] In this sense, the way we deal with risks is a typical feature of modern times, an aspiration to get rid of the unexplainable by (scientifically) 'explaining' it.

[11] Cf. Charles Perrow: *Normal Accidents, Living with High-Risk Technologies*, Princeton, NJ: Princeton University Press 1999.
[12] Niklas Luhmann: *Soziologie des Risikos*, Berlin, New York: Walter de Gruyter 1991, p. 2.

This contribution has argued that different means to cool the planet affect the Earth as a whole and that they are associated with many uncertainties and fundamental difficulties. Hence, for scientific computation it is difficult to calculate the incidence rate of adverse side effects of SRM, just as it cannot definitely know what we ethically *should* do and which risk is *tolerable* for everybody. But if weighing the benefits and costs exactly is insufficient in view of global risks, the question is what the alternatives are if we do not want to remain in a paralyzing abeyance – like Buridan's ass.[13]

Based on the notion that sciences cannot sufficiently answer questions concerning a comprehensive risk evaluation, I would like to highlight that not knowing objectively how the future will and should be offers a chance for everyone to fundamentally reconsider which future options he prefers and which he rejects. Furthermore, it is a question of justice to claim that tackling global operations requires cross-border communication and transnational cooperation.[14] [15] Justified research and deployment of SRM means taking into account what people all over the world, both 'experts' and 'laymen', think about SRM. That implies the need to integrate critical voices as well as to create an informed dialogue between different subsystems of societies. The objective is to find out where the golden mean between unreasonable risks and crippling securities lies. Of course, these ideas of communication and participation are very demanding because the topic is considerably complex and democratic institutions of self-determination do not exist in all countries. But we must aspire to implement these approaches because the call for the transparent provision of information, civic participation, transnational institutions, and a review of history addresses an import discourse about the future and how 'humanity' wants to live in the coming years, decades and centuries.

Conclusion

As we have seen, successfully predicting the local, i.e. the crucial, consequences of large-scale manipulation is problematic and, furthermore, computing the consequences does not imply knowing how they are perceived. Thus, the question of what is *'valuable'* cannot be answered on the basis of cost-benefit analysis. There-

[13] The parable from Johannes Buridan (originally from Aristotle) refers to a donkey standing between a heap of hay and a bucket of water, each an equivalent distance away. The donkey dies of hunger and thirst because it cannot make a logical decision.

[14] Cf. Steve Rayner et al.: *Memorandum on Draft Principles for the Conduct of Geoengineering Research*, House of Commons Science and Technology Committee inquiry into The Regulation of Geoengineering, 2009, p. 4.

[15] From a pragmatic perspective one can in addition argue that governance of SRM can, in the long run, only be 'efficiently' realized if accepted by the international public. An 'efficient' governance of SRM refers, in this formal respect, to *operability in the long run*. Unilateral proceedings may provoke 'expensive' social resistance and uncooperative approaches may aggravate or countervail the effects of SRM (cf. *Dietz*).

fore, CBA cannot exclusively ethically legitimize technological designing of the future. In line with Jürgen Habermas, I argue that comprehensive legitimization of the deployment of SRM cannot exist without a systematic, worldwide exchange of arguments.

Cooperation behind the Veil of Ambiguity

Wolfgang Dietz

Introduction

The preceding contribution indicated the unintended consequences of SRM as being a major challenge to societies. It stated that SRM involves global risk, meaning that the effects transcend state borders. This fact deserves attention from a political science perspective, since states are still the most important players in the international arena. The contribution argues that states have incentives to become involved in SRM and they depend on cooperation to avoid undesired outcomes from SRM. But in addition to common collective-action problems that impede multilateral, rule-based cooperation, the aforementioned uncertainties add new challenges to cooperation.

I proceed in the following steps: First, I will outline why we have to consider international conflict and cooperation with respect to SRM. I will show that SRM presents two different challenges to the international system. Secondly, I will demonstrate that pure game-theoretic analysis is only partly useful when assessing the issue of SRM. The critique serves as a starting point to suggest an alternative: Turning towards cognitive heuristics, scientific knowledge and mental models of policymakers are expected to give a more detailed picture about how actors form their interests and eventually achieve multilateral rule-based cooperation. I will suggest an empirical case for the purpose of exemplification.

Classically, risk is defined as the combination of the probability of an (undesired) event happening and the expected loss that accompanies this event. To account for the complexity and partial incalculability of risks as they occur in complex systems, I will not distinguish between risk and uncertainty in this contribution, but only speak of uncertainty.

SRM, the Need for Coordination and Information Ambiguity

Since climate is a complex, interdependent system, manipulation of the climate is hardly ever limited locally. The transboundary dimension of SRM is therefore the overarching source of potential political conflict. Domestic action has international consequences, meaning that one state's deployment of SRM has effects on the climate of other states. If we imagined a world where we had perfect knowledge

about climate sensitivity and perfect knowledge about the indented consequences of SRM, states would still be expected to have different interests regarding the climate in their territory. More precisely, they would stand to gain differently from lower or higher temperatures. Therefore, they might disagree on the preferable temperature, and the right amount of SRM to be deployed, respectively. If we continued this scenario and imagined states came to an agreement and compromised about one desired temperature, states would have to coordinate on who will deploy how much SRM. Once such an agreement was struck, states with diverging interests would have an incentive to defect and either “free-ride” on other states’ SRM efforts or deploy an amount of SRM that moved temperatures from the compromised point towards their own desired one. Policymakers would be unsure about the interests and motives of their counterparts and would fear commitments that might leave them worse off if their counterparts decided to defect.

But in addition to the question of how different states could come to an agreement on the right amount of SRM – meaning the optimal amount serving everybody’s best interests – the issue of safety also arises. Since the technique is still at an early stage of exploration, the unintended side effects of SRM-deployment are far from being clear. Effects on the ozone layer and precipitation patterns are unknown. On top of that, it is unclear how a climate will behave that is in fact cooler, yet contains CO2 concentrations that rise at an unprecedented pace. Statements on these effects have so far been merely speculative. The unequal distribution of negative side effects seems to be uncontroversial. This aspect of SRM turns it into an international issue again since both the side effects as well as the intended effects are transboundary in their nature. It seems plausible that states would aspire to regulate SRM and again depend on cooperation.

Regarding unintended side effects, policymakers are confronted with a high degree of uncertainty about the real-world consequences of their actions. They do not know whether the positive effects of SRM outweigh the negative side effects on their territory. Therefore, they have trouble clearly defining their own interests on the deployment of SRM.

Information and Uncertainty in Rational Approaches to International Cooperation

I argue that the two aspects described above need to be treated separately. The first set of problems illustrates cooperation dilemmas. States have an incentive to cooperate since uncoordinated action would lead to undesired outcomes in the form of “unideal” deployment of SRM. The obstacles to cooperation are (a) the diffi-

culty of compromising on an amount of SRM that serves everybody's interests at least partially and (b) uncertainty regarding compliance with the bargained terms of agreement. I argue that this resembles a situation that is characterized by strategic uncertainty.[1]

The second set of problems of unintended side effects is characterized by a high degree of uncertainty about real-world causalities. The uncertainty stems not from the interaction of actors with unknown motives, but from a lack of knowledge about the real-world implications of the issue at hand. The level of knowledge is still at the research frontier and different, even contradicting, models and hypothesis exist to explain the issue at hand.[2] I argue that this resembles analytic uncertainty as opposed to strategic uncertainty.[3]

How can this be assessed from a political science point of view? One – and perhaps the most prominent – branch in literature on international cooperation typically explains the occurrence or failure of international cooperation using rational approaches that employ game-theoretic assumptions. In a very simple application of these assumptions to the two different aspects of SRM, I argue that, concerning the first aspect of SRM, which is marked by strategic uncertainty, policymakers face a coordination game in which they have to coordinate their action to avoid the undesired outcomes of too much or too little SRM. This can be solved simply by means of the exchange of information. On top of that, they face a prisoners' dilemma where they have to insure compliance with a bargained target. This could be solved by means of power by a dominant actor (hegemon) or by an institution that serves the function of guaranteeing compliance. Political science literature is extensive on this issue and will not be addressed further in this article.

Since analytic uncertainty is a main characteristic of SRM, it seems much more interesting to consider the aspect of unintended consequences and their implications for international cooperation. A game-theoretic approach assumes that if actors are confronted with analytic uncertainty, they attribute probability distributions to certain outcomes and maximize their utility accordingly. But as *Heyen* shows, uncertainties are much wilder than we assume. The distribution of outcomes is far from clear and an evaluation of SRM appears to differ from the probability distribution that is attributed to the unintended consequences of the technique.

[1] Keisuke Iida: *Analytic uncertainty and international cooperation: Theory and application to international economic policy coordination*, in: *International Studies Quarterly* (1993), pp. 431-457.

[2] Cf. Arild Underdal: *Science and politics: the anatomy of an uneasy partnership*, in: *Science and Politics in International Environmental Regimes: Between Integrity and Involvement*, ed. by Steinar Andresen, et al. Manchester: Manchester University Press 2000.

[3] Iida: *Analytic uncertainty and international cooperation*, fn. 1, pp. 431-457.

In addition, not only the probability distribution is uncertain, but the outcome itself is also not known. As noted above, the complexities of climate interaction are unclear. This means that actors are not only unsure if they will be struck by unintended consequences, but they are also uncertain *what exactly* might strike them.

In conclusion, the image of reality remains quite blurry to policy makers. If knowledge about a policy issue like SRM is still at the research frontier, actors only have ambiguous information to base their decisions on.

Models and Heuristics as Tools to Reduce real-world Complexity

If actors cannot attribute probability distributions to certain outcomes accurately, does an assumption of rational, utility-maximizing actors make sense to analyze international cooperation on SRM? Yes, but only to a certain extent. Actors can still be regarded as rational utility maximizers, but their decisions can be assumed to be biased by cognitive limitations. To assess the potential for cooperation on a highly complex policy issue such as SRM, research on the formation of rule-based international cooperation has turned to incorporating the *perception* of actors about the policy issue. If means-ends-relations are unclear, perception of reality is highly dependent on the models actors rely on to assess the issue at stake.

To come to a decision about the regulation of SRM, actors have to rely on scientific knowledge, models and cognitive heuristics as ‘shortcuts’ to form an understanding of the reality they have to decide upon. The former is provided by scientific networks, the latter can be described as “…tools all humans use to reduce confusion”.[4] They are mental models that bias perception,[5] policy paradigms that are used as guidelines and provide decision-makers with a subjective lens through which real-world complexity can be reduced.

In terms of international cooperation, this implies that rule-based cooperation is facilitated if states share similar mental models of real world means-ends-relations and if their perception of reality encompasses possibilities of achieving gains from cooperation.[6] It has been outlined that, in the case of SRM, there are two areas of possible conflict and/or cooperation – the amount of SRM to be deployed and dealing with unintended consequences. Presuming that cause-effect relations are

[4] Brian Christopher Rathbun: *Uncertain about uncertainty: understanding the multiple meanings of a crucial concept in international relations theory*, in: *International Studies Quarterly* 51(3) (2007), p. 546; James M. Goldgeiger, and Philip E. Tetlock: *Psychology and international Relations Theory*, in: *Annual Review of Political Science* 4 (2001), S. 67-92.

[5] Cf. Rathbun: *Uncertain about uncertainty*, fn. 4, p. 546.

[6] Andreas Hasenclever, Peter Mayer, and Volker Rittberger: *Theories of International Regimes*. Cambridge: Cambridge University Press 2000, p. 139.

known concerning the intended effects of SRM, states have only to be concerned about how to get what in strategic negotiation settings. With regard to unintended consequences of SRM, international regulation is facilitated if actors share a similar perception of how the climate will react to the deployment of SRM.

Arctic Haze as possible analogy?

So far, the discussion in this contribution has been hypothetical. Since SRM does not exist yet, the way states will come to an agreement on regulation cannot be assessed yet. But to shed light on how models and heuristics influence policy choices on international cooperation, it is helpful to take a look at issues that share the same features of uncertain scientific knowledge from the research frontier. The phenomenon of Arctic haze serves as a good example of how uncertainty about real-world cause-effects-relations might impede international cooperation.

The phenomenon of arctic haze was discovered in the 1950s by pilots who crossed the Arctic at an altitude of the lower troposphere (4-5 km)[7] and noticed a widespread brownish fog that occurred during winter and spring[8]. But it was not until the 1970s that scientists traced it back to pollution from the middle latitudes.[9] It proved to be caused by emissions from Russia, Europe, North America and East Asia and was identified as a transnational environmental problem with numerous effects for the Arctic ecosystem. Two scientific contributions have developed model-based hypotheses about the possible effect of the haze;[10] both have suggested that it has caused changes in the solar radiation budget. But while one model suggests that these changes have actually led to lower radiative forcing and cooler temperatures in the Arctic, the other model suggests the opposite. Even though the issue experienced considerable political recognition between 1977 and 2000, it has not been regulated yet.[11]

The example is just an illustrative case of where the suggested nexus between diverging models and policy decision might be at work. To draw sound conclusions, the case has to be studied more in detail.

[7] Ken Wilkening: *Science and International Environmental Nonregimes – The Case of Arctic Haze*, in: *Review of Policy Research* 28 (2011), p. 129.

[8] Kathy S. Law, and Andreas Stohl: *Arctic Air Pollution: Origins and Impacts*, in: *Science* 315(5818) (2007), pp. 1537-1540.

[9] Cf. Leonard A. Barrie: *Arctic air pollution: An overview of current knowledge*, in: *Atmospheric Environment* 20 (1967, 1986), pp. 643-663.

[10] Cf. Law, and Stohl: *Arctic Air Pollution*, fn. 8.

[11] Cf. Wilkening: *Science and International Environmental Nonregimes*, fn. 7, pp. 125-148; Marvin S. Soroos: *The Odyssey of Arctic Haze toward a Global Atmospheric Regime*, in*: Environment: Science and Policy for Sustainable Development* 34(10) (1992), pp. 6-27.

Conclusion

I have argued that SRM comprises two issues that need to be treated separately from a political science perspective. *Deployment* poses a different challenge to the international system than the *unintended consequences* of SRM. While actors can define their interests on the temperature levels manipulated through SRM based on past experiences, they have trouble doing this with respect to the unintended side effects. I have argued that an analysis of international cooperation in fields that are marked by high uncertainty has to account for the models that actors use to reduce uncertainty. Furthermore, I indicated an empirical case where international cooperation has frequently failed and suggested that this failure might be due to different models that actors use to reduce complexity.

Basic Instruments to Tackle Risks and Uncertainties in International Environmental Law

David Reichwein

Introduction

International cooperation for the deployment of SRM faces various obstacles as shown vividly by *Dietz.* This is due to various reasons, inter alia the abovementioned political difficulties with regard to deployment as well as the risks and uncertainties associated with SRM in general. Yet, since these obstacles might complicate international cooperation and no specific governance schemes or cooperation tools with regard to SRM have been developed so far, it is necessary to analyze how to deal with risks and uncertainties[1] in international environmental law in general based on the status quo. Which rules in international environmental law are applicable if we do not achieve any kind of governance scheme for SRM? I will concentrate on some of the most important principles in international environmental law. Starting with the rules on state responsibility and the obligation not to cause significant transboundary harm, I will elaborate in more detail on the importance of the Preventative Principle with regard to SRM technologies. I conclude that the Precautionary Principle is currently the most promising approach to SRM, although clarification on the specific applicability and the legal impacts of the principle is necessary.

State Responsibility and the Obligation not to cause Significant Transboundary Harm

At first glance, there are several instruments in international law for dealing with risks and uncertainties, the rules on state responsibility being one of them. According to Article 1 of the International Law Commission (ILC) Articles on the Responsibility of States for Internationally Wrongful Acts, every internationally wrongful act of a state entails the international responsibility of that state. An international act is qualified as wrongful, according to Article 2 of the ILC Articles, when an action – or omission of action – is attributable to a state under international law and constitutes a breach of an international obligation of that same state. As to the deployment of SRM technologies, a breach of the obligation not to cause significant transbounda-

[1] In the following, I will understand risk and uncertainty as risk equaling the probability of an adverse outcome, as opposed to uncertainty where the probability is non-quantifiable; cf. Terje Aven, and Ortwin Renn: *On risk defined as an event where the outcome is uncertain*, in: *Journal of Risk Research* 12 (2009), p. 2.

ry harm could constitute such an internationally wrongful act . According to Principle 2 of the Rio Declaration on environment and development,

> *"states have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction".*

According to the International Court of Justice's (ICJ) Advisory Opinion on the Legality of the Threat or Use of Nuclear Weapons, the principle of the responsibility not to cause transboundary environmental damage has been established as a norm of customary international law.[2] However, in order for it to be classified as having been breached, a causal link between a state's behavior and the effect in question on the environment within another state's territory must be established.[3]

This necessity of establishing a causal link between a state's activity and a significant threat to the environment is probably difficult to fulfill with regard to SRM technologies. Whether, for example, regionally varying changes in precipitation can be traced back to the deployment of aerosols in the stratosphere[4] is questionable. The same applies to the assumption that the ozone layer will be seriously depleted in the event of sulfur deployment.[5] Providing proof in a situation in which damages to the environment are caused by SRM technologies is, at this moment, difficult to achieve. Therefore, this norm is rather ineligible with regard to climatic effects of SRM. The rules on state responsibility, therefore, appear to be a strong instrument – also in international environmental law – in cases where a conclusive judgment on the precise attribution of responsibilities and an establishment of clear causal links is possible.[6] This is problematic with regards to global warming[7] and SRM.

Preventative Principle and Procedural Obligations

The law of state responsibility is "backward looking [since it …] may provide answers as regards the settlement of wrongful activities that occurred in the past",[8]

[2] International Court of Justice (ICJ), *Legality of the Threat or Use of Nuclear Weapons*, Advisory Opinion, I.C.J. Reports 1996, pp. 226, 242.

[3] Wolfgang Vitzthum (ed.), Michael Bothe et al.: *Völkerrecht*. Berlin: De Gruyter 2010, p. 455.

[4] Katherine L. Ricke, M. Granger Morgan, and Myles R. Allen: *Regional climate response to solar-radiation management*, in: *Nature Geoscience* 3 (2010), pp. 537-541.

[5] Patricia Heckendorn et al.: *The impact of geoengineering aerosols on stratospheric temperature and ozone*, in: *Environmental Research Letters*, 4 045108 (2009).

[6] Christian Tomuschat: *Global Warming and State Responsibility*, in: *Law of the Sea in Dialogue*, ed. by Holger Horstemeyer et al., Heidelberg: Springer 2011, p. 25.

[7] Ibid., p. 11.

[8] Ibid., p. 4.

while dealing with risks and uncertainties requires a forward-looking, preventive or precautionary approach. Therefore, another important instrument in the field of global environmental risk management is the Preventative Principle. Compared to the obligation not to cause significant transboundary harm, the Preventative Principle has a different objective. While the former derives from the idea of sovereignty, the latter aims more generally at minimizing environmental damage.[9] The principle, "as a customary rule, has its origins in the due diligence that is required of a State in its territory. […] A State is thus obliged to use all the means at its disposal in order to avoid activities which take place in its territory, or in any area under its jurisdiction, causing significant damage to the environment of another State".[10] The principle is accompanied by various procedural obligations. These obligations to inform, to notify and to conduct an environmental impact assessment are all binding norms of customary international law.[11] They play an important role in establishing procedures when dealing with risks and uncertainties on the international level and strengthening international cooperation.[12]

Compared to the Precautionary Principle, which enforces a state's activity without requiring scientific certainty,[13] the Preventative Principle is applicable in cases when the effects of a specific activity are known.[14] This differentiation between risks and uncertainty – being understood as the presence or absence of scientifically established and well-understood causal relationships[15] – is rather soft and often difficult to establish. Because of this difficulty, several authors argue that the Precautionary Principle has effectively absorbed the Preventative Principle or constitutes its most developed form.[16] In addition scientific proof of causal effects and side effects of SRM techniques is hard to establish.[17] Uncertainties are prevailing and clouding the understanding of the complex climate system or interference with it, as pointed out earlier by *Fernow*.

[9] Philippe Sands: *Principles of International Environmental Law*, Cambridge: Cambridge University Press 2003, p. 246. Furthermore, the obligation not to cause significant transboundary harm primarily deals with harm to other states, whereas states are also required to protect global common areas under the obligation of the Preventative Principle; Patricia W. Birnie, Alan Boyle, and Catherine Redgwell: *International Law and the Environment*, Oxford: Oxford University Press 2009, p. 145.

[10] International Court of Justice (ICJ), *Case Concerning Pulp Mills on the River Uruguay, (Argentina v. Uruguay)*, Judgment, 20/04/2010, par. 101.

[11] Cf. ibid., par. 101, 204.

[12] Malcolm N. Shaw: *International Law*, Cambridge: Cambridge University Press 2008, p. 862.

[13] Cf. Sands: *Principles of International Environmental Law*, fn. 9, pp. 272 f.

[14] Astrid Epiney, and Martin Scheyli: *Strukturprinzipien des Umweltvölkerrechts*, Baden-Baden: Nomos Verlag 1998, pp. 114 f.

[15] Arie Trouwborst: *Prevention, Precaution, Logic and Law – The Relationship between the Precautionary Principle and the Preventative Principle in International Law and Associated Questions*, in: *Erasmus Law Review* 2(2) (2009), p. 117.

[16] Ibid., p. 126.

[17] See also Wilfried Rickels, Gernot Klepper, Jonas Dovern (eds.) et al.: *Gezielte Eingriffe in das Klima? Eine Bestandsaufnahme der Debatte zu Climate Engineering*, Sonderstudie für das Bundesministerium für Bildung und Forschung 111, Kiel Earth Institute 2011.

Precautionary Principle

Therefore, the Precautionary Principle, being the most developed form of the Preventative Principle, currently appears to be the most viable international law instrument for structuring research and deployment of SRM technologies. This is due to the lack of comprehensive scientific knowledge of the effects and side effects of SRM technologies and holds true as long as no more specific governance schemes are developed. Apart from the scientific uncertainty that predominates the application of this principle; legal uncertainty concerning the normative status, the content and the legal effects further complicates its application.

The Precautionary Principle has found its way into various treaties and declarations. Yet, the question as to whether the Precautionary Principle is a norm of customary international law and therefore binding upon states remains controversial. Customary international law consists of the consistent actual behavior of States (*state practice*) and the belief that such behavior is law *(opinion iuris)*.[18] Due to the various interpretations and applications of the principle there seems to be neither sufficient common state practice nor *opinio iuris* to establish such a norm of customary international law. Therefore, the principle lacks binding force according to widespread opinion in legal literature.[19] Supporters of the binding force of the Principle argue that uncertainties about its content do not affect its binding force.[20] The Seabed Disputes Chamber of the International Tribunal for the Law of the Sea has lately ruled in its advisory opinion on "responsibilities and obligations of states sponsoring persons and entities with respect to activities in the area" that the incorporation of the principle into various treaties "has initiated a trend towards making the [… precautionary approach] part of customary international law".[21] The chamber confirmed the view of the International Court of Justice that "a precautionary approach may be relevant in the interpretation and application" of a treaty.[22] The Seabed Disputes Chamber concluded that "this statement may be read in light of article 31, paragraph 3(c), of the Vienna Convention [on the Law of Treaties] according to which the interpretation of a treaty should take into account not only the context, but 'any relevant rules of international law applicable in the relations between the parties'".[23] The consideration of these international decisions indicates

[18] Cf. Malcolm N. Shaw: *International Law*, Cambridge: Cambridge University Press 2008, p. 74.

[19] Cf. Epiney, and Scheyli: *Strukturprinzipien des Umweltvölkerrechts*, fn. 14, p. 108.

[20] Ibid., p. 108.

[21] International Tribunal for the Law of the Sea, Seabed Disputes Chamber of the International Tribunal for the Law of the Sea: *Responsibilities and obligations of States sponsoring persons and entities with respect to activities in the Area*, Case No. 17, Advisory Opinion, 01/02/2011, par. 135.

[22] International Court of Justice (ICJ): *Argentina v. Uruguay*, fn. 10, par. 164.

[23] International Tribunal for the Law of the Sea: *Responsibilities and obligations of States*, fn. 21, par. 135.

that the Precautionary Principle has meanwhile indeed become a binding norm of customary international law.

This leads to the question as to which content and legal effects result from the binding nature of the principle. One can broadly distinguish between a weak and a strong version of the Precautionary Principle.[24] The former and most basic version[25] is exemplified in Article 15 of the Rio Declaration on Environment and Development:

> *"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. 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."*[26]

Two requirements have to be met: the potential damage has to be serious or irreversible and the measures must be cost-effective. Scientific uncertainty and the threat of serious or irreversible harm to the environment appear to be the core elements of all variations of the Precautionary Principle.[27] Yet, since the decision – e.g. to do or refrain from doing research in SRM technologies – is based upon uncertainty, a *prima facie* finding that shows that an activity may lead to environmental damage is still necessary. Additionally, a regular review of the decision has to take place.[28] To sum up, this version proclaims "action in spite of uncertainty".[29] States have the right to act in advance of actual harm despite of scientific uncertainty. The action taken by the state to counteract the potential damage to the environment has to be effective and proportionate.[30] Due to the broad scope of application of this norm and the vast variety of possible countermeasures[31]a *specific* action, however, cannot be inferred[32]. In this context, it is noteworthy that, at present, due to the scientific uncertainty concerning the possible serious or irreversible threats posed to the environment by climate change as well as Climate Engineer-

[24] Malgosia Fitzmaurice: *Contemporary Issues in International Environmental Law*, Cheltenham: Edward Elgar Publishing 2009, p. 8.

[25] Cf. Daniel Bodansky, Jutta Brunée, and Ellen Hey (eds.): *The Oxford Handbook of International Environmental Law*, Oxford: Oxford University Press 2007, p. 604.

[26] Art. 3 III of the United Nations Framework Convention on Climate Change aims in the same direction: "The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost. To achieve this, such policies and measures should take into account different socio-economic contexts, be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors."

[27] Cf. Epiney, and Scheyli: *Strukturprinzipien des Umweltvölkerrechts*, fn. 14, p. 109.

[28] Fred L. Morrison and Rüdiger Wolfrum (eds.): *International, Regional and National Environmental Law*, The Hague: Kluwer Law International 2000, p. 13.

[29] Cf. Trouwborst: *Prevention, Precaution, Logic and Law*, fn. 15, p. 121.

[30] A. Trouwborst, *Precautionary Rights and Duties of States* (2006), pp. 147 ff.

[31] Epiney, and Scheyli: *Strukturprinzipien des Umweltvölkerrechts*, fn. 14, p. 123.

[32] Bodansky et al.: *The Oxford Handbook of International Environmental Law*, fn. 25, p. 604.

ing, the application of this principle with regard to the deployment of SRM technologies can argue for or against deployment, regardless of the technique's potential to slow global warming. In such risk vs. risk situations one has to bear in mind the ultimate goal to reduce "the overall impact on ecosystems to a minimum."[33]

Yet, it can be maintained that the Precautionary Principle - at least in this weak version - argues for further research in SRM techniques.[34] Since the threat of negative implications and irreversible effects of Climate Change is very serious , research of CE technologies is an effective and proportionate measure in order to find means to counteract Climate Change. Hence, further research is an "indispensable tool to […] overcome or reduce uncertainties"[35] in SRM technologies and can be regarded as a right of a state inclined in even the basic version of the Precautionary Principle.

Stronger versions of the Precautionary Principle lead to a shift of the burden of proof. According to the 1982 United Nations World Charter for Nature, activities should not proceed when potential adverse effects are not fully understood.[36] This interpretation would require the person who wishes to carry out the activity to prove that it will not cause harm to the environment.[37] Applying this interpretation with regards to SRM, proponents of the techniques might have to prove their safety.[38] Besides the fact that this interpretation leads to a technological deadlock, the ICJ ruled that the Precautionary Principle does not include such a shift of the burden of proof.[39] Combining this view with the existing uncertainties regarding the legal nature of the principle, only the weaker version, as found in Article 15 of the Rio Declaration, can be regarded as *customary international law*[40].

Criticism and the Road ahead of the Precautionary Principle

Apart from these uncertainties concerning the content and the effects, the concept of the Precautionary Principle itself has often been questioned. According to *Sunstein*, weak forms of the Principle, as found in Article 15 of the Rio Declaration,

[33] Trouwborst, *Precautionary Rights and Duties of States*, p. 186.

[34] Cf. Kerstin Güssow et al.: *Ocean iron fertilization – Why further research is needed*, in: *Marine Policy* 34 (2010), pp. 911-918, who reason that the Principle argues for further research in ocean fertilization.

[35] Trouwborst, *Precautionary Rights and Duties of States*, p. 174.

[36] Cf. Fitzmaurice: *Contemporary Issues in International Environmental Law*,fn. 24, p. 9.

[37] Cf. Sands: *Principles of International Environmental Law*, fn. 9, p. 273.

[38] Cf. Daniel Bodansky: *May we engineer the climate?*, in: *Climatic Change* 33 (1996), p. 312.

[39] International Court of Justice (ICJ): *Argentina v. Uruguay*, fn. 10, par. 164.

[40] This does not, however, mean that a stronger version cannot be included in a treaty. Yet, only the weak version is binding to all actors in the international arena.

lack utility since they just "state a truism".[41] The Principle fails to offer any practical guidance for policy makers.[42] Strong versions of the Precautionary Principle, understood by *Sunstein* as versions that require regulation whenever there is a possible risk to the environment,[43] would prevent consideration of any policy, e.g. on new technologies because a risk of one kind or another can hardly ever be excluded.[44] This is the dilemma with SRM. The intention is to save the environment and mankind from severe harm resulting from climate change. Yet, the technology itself poses various threats to the environment which are not yet fully understood. With regard to the deployment of SRM technologies, one cannot draw a clear-cut direction from the Precautionary Principle. Therefore, *Sunstein* proposes the balancing of all costs of a policy against its benefits, not without incorporating concerns of precaution.[45] While claiming that economic efficiency "is relevant, but is hardly the only goal of regulation"[46] *Sunstein* favors "to endorse cost-benefit analysis (CBA) while noting that precautions, especially against possible catastrophes, should play a role in its application"[47]. The main advantage of CBA over the Precautionary Principle is its wider "viewscreen".[48]

Yet, the applicability and utility of a CBA itself can be questioned with regard to uncertainties and SRM. A practical application of such an analysis requires a huge amount of data and information. With regard to global warming the collection of these data "presents a likely impossible task"[49]. This also holds true for SRM. More fundamentally, in a first step we need to have reliable data at hand. As elaborated in the next contribution by *Heyen*, the uncertainty with regard to SRM prevents meaningful results. Therefore, the application of the Precautionary Principle still appears to be the better approach. This does not entail that such an application cannot include a CBA, as shown on the European level. Next to other factors such as the proportionality of the envisaged measures and its non-discrimination, the application of the Precautionary Principle should include a cost-benefit analysis, if appropriate and possible.[50] Again, this possibility is hardly given in the case of

[41] Gregory N. Mandel, and James Thuo Gathii: *Cost-Benefit Analysis Versus the Precautionary Principle – Beyond Cass Sunstein's Laws of Fear*, in: *University of Illinois Law Review* (2006), p. 1039.

[42] Ibid.

[43] Cf. Cass R. Sunstein: *Laws of Fear – Beyond the Precautionary Principle*, Cambridge: Cambridge University Press 2005.

[44] Robert W. Hahn, and Cass R. Sunstein: *The Precautionary Principles as a Basis for Decision Making*, in: *The Economists' Voice* 2(2005), Article 8, p. 2.

[45] Ibid., p. 6.

[46] Sunstein: *Laws of Fear*, fn. 43, p. 129.

[47] Ibid., p. 130.

[48] Ibid.

[49] Mandel, and Gathii: *Cost-Benefit Analysis*, fn. 41, p. 1045.

[50] Cf. European Commission: *Communication from the Commission on the Precautionary Principle*, COM (2000)1, http://ec.europa.eu/environment/docum/20001_en.htm, 25.07.2011.

global warming or interference with it using SRM, due to the huge uncertainties involved in both cases.

A first step[51] in overcoming one of the main critiques of the principle – its lack of guidance for policy makers – might be seen in the integration of the principle as an "integral part of the obligation of due diligence. The due diligence obligation […] requires […states] to take all appropriate measures to prevent damage […]. This obligation applies in situations where scientific evidence concerning the scope and potential negative impact of the activity in question is insufficient but where there are plausible indications of risk"[52]. The Seabed Disputes Chamber concludes that the obligation of due diligence is not met if a state disregards those risks.[53] The obligation arising from the abovementioned Preventative Principle is one of due diligence. The standard of this due diligence obligation is twofold: The conduct of a state has to be appropriate and proportional to the degree of risk of transboundary harm[54] and it "entails an evolving standard of technology and regulation", usually referred to as "best available techniques"[55]. Integrating the Precautionary Principle into this standard – or in other words applying this standard within the Precautionary Principle - is logical for various reasons. The necessity for proportionate and appropriate measures when dealing not only with risks, but also "with plausible indications of risks" is in line with the idea of the Precautionary Principle being the most developed form of the Preventative Principle. The differentiation between risk and uncertainty is, as has already been mentioned, hard to establish. Hence, a consistent standard is reasonable and necessary in order to establish a comprehensive protection from significant threats to the environment.

Conclusion

Since traditional schemes like the rules on state responsibility are not appropriate for complex processes like climate change or SRM, states are obliged to notify, consult and cooperate when facing the threat of serious harm to the environment. Due to the huge uncertainties associated with SRM, the Precautionary Principle is

[51] For further development of the Precautionary Principle as a procedural balancing mechanism, cf. Alexander Proelss: *International Environmental Law and the Challenge of Climate Change*, in: *German Yearbook of International Law* 53 (2010), pp. 81 ff. According to *Proelss* the principle could be institutionalized to balance the "environmental risks resulting from specific activities which are potentially contrary to the objectives of a particular environmental treaty [… with] the environmental protection potential of such activities regarding the fulfillment of the aims of the other treaty". With regards to CE this risk-balancing procedure could help to overcome the above mentioned dilemma that the isolated interpretation of the Precautionary Principle might argue for or against SRM deployment.

[52] International Tribunal for the Law of the Sea: *Responsibilities and obligations of States*, fn. 21, par. 131.

[53] Ibid.

[54] Cf. Unites Nations General Assembly (UNGA): *Report of the International Law Commission*, UNGA Res. A/56/10, New York, NY 2001, pp. 391 ff.

[55] Birnie et al.: *International Law and the Environment*, fn. 9, p. 148.

currently the most suitable substantive norm, besides the procedural requirements, to deal with SRM. Due to its broad applicability, the weak implementation of the legal effects is only natural. The newest approach of integrating the Precautionary Principle within the standard of due diligence and thereby requiring proportionate and appropriate measures as well as the best possible environmental practices is an important step towards further clarification of the content and legal effects of the principle, and might be of huge importance with regard to SRM. Leaving the international arena and turning towards the micro-level, as has been attempted to some extent in this contribution already, economics, too, might help to further clarify this important principle of environmental regulation.

An Economic Perspective on Risks of Climate Change and SRM – Limitations of Methodology, New Concepts and the Precautionary Principle

Daniel Heyen

Introduction

The previous article (*Reichwein*) raised two issues that can be addressed from an economic perspective. The first, *Cost-Benefit Analysis,* originates from economic theory and offers a very clear methodology for dealing with risk. Though an indispensable and helpful tool in many situations, I nevertheless challenge its applicability in the context of climate change and Climate Engineering. At the core of this restricted validity I find the particular form of uncertainty we are confronted with in the intricate climate system, further underpinned by the ongoing debate within the insurance sector regarding the feasibility of insuring against climate change.

Secondly, the often-mentioned *Precautionary Principle* has been formalized by economists in order to substantiate it. This article covers a particularly promising approach which normatively addresses the dissatisfying situation when decisions need to be made, but science disagrees on relevant key parameters. Finally, this article touches briefly on a topic which will be covered in much more depth in subsequent contributions (*Amelung*; *Wiertz*). Risk is not restricted to scientific variables and concepts, but extends into the social realm, constituting a *social uncertainty*. A striking example of this in the context of Climate Engineering is the concern, often referred to as *moral hazard,* that the availability of such an option could undermine efforts to reduce greenhouse gas emissions.

Cost-Benefit Analysis and how we can – sometimes – eliminate risk

In the debate about climate change and Climate Engineering the term *risk* is omnipresent. But what is risk, and how is it usually dealt with? Risk arises when *uncertainty* and *valuation* come together. Uncertainty, the first ingredient, is present when there are several possible outcomes, while it is unknown which of them will occur in the future. This is the case, for instance, with a coin toss. However, for this situation to become a *risky* one, yet another dimension is important; the possible outcomes have to differ with regard to how much *value* is assigned to them. Continuing with the coin toss example, we could think of a bet defining the payoffs for

each outcome.[1] Focusing on our topic, climate change and the potential use of Climate Engineering clearly create risk. Food production and land safe for human habitation and health (to name just a few) are at stake; to what extent they are threatened, both by climate change and the side effects of Climate Engineering deployment, is highly uncertain.

A tool widely used to combine the purely scientific variables of greenhouse gas concentration and temperature with the resulting economic damages is *DICE* – a model thus covering the *risks* of climate change.[2] It has become a standard measure used to evaluate different policies to combat climate change, so it is by no means surprising that it has been used to evaluate different CE measures as well.[3] A deeper look inside the 'machine room' of DICE provides an interesting insight into the prevailing attitude towards risk. Instead of representing uncertainties by means of *random variables,* merely their *expected value* is used in the defining equations. To give an example, the (highly discussed, see below) *climate sensitivity* variable is ascribed a value of 3.0[4] instead of taking into account the whole probability distribution. The latter would assign the likelihood of occurrence to each possible outcome. Using the approach actually taken, DICE becomes risk-free, deterministic.

To replace a random variable with its expected value is tempting as it significantly simplifies the mathematical analysis. This is not bad per se. Take, for instance, car insurance policies. Car accidents clearly belong to the realm of risk as if they occur, substantial value is destroyed. Unfortunately, and this constitutes uncertainty, a car owner does not know whether such an accident is going to happen to him. Fortunately, an insurance company can take on the risk for the car owner. The latter pays a certain premium which leaves him *independent* of whether the car accident happens or not. Thus, the risk disappears. But where does the risk disappear to? Why is the insurer willing to take over the risk? Two facts put her in this position: Firstly, huge amounts of car accident data exist from which the insurer can determine the correct likelihood of a car accident. No insurer would insure without a clear idea regarding these probabilities. Secondly, the insurance company insures thousands of drivers, each of whom can be seen as being independent from the others with regard to the probability of having an accident. Thus, by the *Law of*

[1] Clearly, these payoffs need not necessarily be monetary ones but can also be derived from elaborate *utility functions*, thus generalizing Cost-Benefit Analysis to *Expected Utility Theory.* Yet, as will become clear in the following, this distinction neither generates nor resolves the difficulties that I want to shed light on. For the sake of simplicity I will exclusively use the term Cost-Benefit Analysis.

[2] William D. Nordhaus: *A Question of Balance – Weighing The Options on Global Warming Policies*, New Haven, CT: Yale University Press 2008.

[3] Eric J. Bickel, and Lee Lane: *An Analysis of Climate Engineering as a Response to Climate Change – Copenhagen Consensus on Climate*, Copenhagen Consensus Center 2009; Marlos Goes, Nancy Tuana, and Klaus Keller: *The economics (or lack thereof) of aerosol geoengineering*, in: *Climate Change* (2011), pp. 1-26.

[4] This means that a doubling of CO2-concentration in the atmosphere would lead to a temperature rise of 3°C.

Large Numbers, the number of car accidents will converge to the expected value that can be calculated in advance. By mathematics and iteration, the insurer gets rid of the risk as well.

Implosion of cost-benefit analysis – the case of climate change and Climate Engineering

Is this approach also valid when dealing with climate change? No, unfortunately it is not. Besides the obvious problem that we do not have anywhere near enough data on climate change to assess likelihoods, even the assumptions under which risk vanishes *in the long run* seem to be incorrect. Uncertainties are much wilder than we usually assume. The standard distribution we typically use – mostly due to its mathematical simplicity and tractability – is the *normal distribution*. This can be regarded as a refined form of neglecting risk: One of the normal distribution's defining properties is that the probability of large deviations of the expected value is so exceedingly small that these large deviations – catastrophic events in respect to the climate system – can be neglected. But the facts seem to contradict this notion. There is strong evidence for the assumption[5] that extreme climate events occur much more often than can be explained by a normal distribution. As a consequence, we experience *no* convergence of damages to the expected value but rather a wild oscillation. This has led to an intense discussion within the insurance sector as to whether it is actually possible to insure against climate change.[6] The insurer would take on a risk she cannot manage as catastrophes could hit her unpredictably.

With respect to Climate Engineering, what are the implications of these exceptional probability distributions, which are called *fat-tailed* or *heavy-tailed* distributions? The answer is: so far, we do not know. On the one hand, if the correct distribution of climate sensitivity was a fat-tailed one, using Climate Engineering would prove to be a more beneficial situation than the one derived from a *normal* analysis. This is because by using SRM, "a significant increase in expected welfare might be obtained if the upper extremes of the fat tail could be truncated before reaching catastrophic temperatures"[7]. On the other hand, the deployment of CE actually adds another uncertainty component to an already uncertain system, which could lead to a further fattening of the probability distributions of damages.

[5] Carolyn Kousky, and Roger M. Cooke: *The Unholy Trinity – Fat Tails, Tail Dependence, and Micro-Correlations*, in: *Resources for the Future Discussion Paper* 09-36-REV (2009).

[6] Howard C Kunreuther, and Erwann O. Michel-Kerjan: *Climate Change, Insurability of Large-scale Disasters and the Emerging Liability Challenge*, NBER Working Paper Series No. 12821 (2007).

[7] Martin L. Weitzman: *Some Basic Economics of Extreme Climate Change*, Harvard University Mimeo 2009.

Thus, this article does not want to make the case for or against CE but, more fundamentally, suggests a different way of conceptually dealing with risk. It is inappropriate to use methods that ignore risk and only deal with expected values, but even economic modeling by means of normal distributions is not valid when the observed data show a clear deviation from such benign behavior. Climate Engineering might serve as an insurance policy against severe climate change, but, with regard to the comments above, clearly not in the naive sense we are used to. Risk will not disappear.

Ambiguity and a new formulation of the Precautionary Principle

So far arguments have been presented from within the expected utility framework, where it was taken as given that, in principal, the setting is suitable, although it has suffered from an implosion of one of its defining primitives, the probability distribution. But there is even more to it. A look at Figure 1[8] makes it clear that the probability aspect of the risk evaluation is even more complicated. It shows different estimations of the probability distribution of the key variable *climate sensitivity*, which determines how great the rise in temperatures will be. Considering the fact that all of them are scientifically established results, it is surprising how strongly the curves differ from each other. This problem goes beyond Cost-Benefit Analysis, as the latter relies on a *distinct* probability distribution for the calculation of expected values. In order to calculate the expected damages caused by climate change, we need the probability of occurrence *for every single value* which climate sensitivity might take on. Unfortunately, however, scientists disagree dramatically on these probabilities. For example, the range for the climate sensitivity being equal to 3 is the huge interval from approx. 0.15 to approx. 0.65.[9] How can this situation be dealt with? An obvious answer would be to identify *the correct* result by eliminating all the inferior ones. This, one could argue, must be feasible since there can be only one correct answer. However, this proves to be an illusion. From the current level of our scientific knowledge, we *are not able to* discriminate between the good and bad results. Scientists have struggled to single out the correct value but thus far have failed to agree, underpinning the notion that we are confronted with epistemological uncertainty due to the complexity of the climate system (*Fernow*). Another idea to overcome this dissatisfying situation might be the following: If we cannot choose among all the probability distributions, why should we not simply calculate the av-

[8] Antony Millner, Simon Dietz, and Geoffrey Heal: *Ambiguity and Climate Policy*, NBER Working Paper Series No. 16050 (2010), Figure 1.

[9] This lack of a certain probability distribution is called “Knightian uncertainty”, named after Frank Knight, who laid the foundation for the important distinction of uncertainty, where the lack of knowing the right probability distribution inhibits calculability, and risk, where the confidence in a single distribution (encompassing calculability) is either based on fact or induced by the subject itself (“subjective expected utility”).

erage over all of them? This would yield the necessary input for a Cost-Benefit Analysis, a distinct distribution.[10] Still, such an approach remains unsatisfactory because we are not sure whether any two models are *equally* likely! Rather, the state of knowledge we have is much more confusing: For a given model, we veer between either considering it wrong or considering it to be the only correct one.[11] This ambiguity is not resolvable.

In order to overcome the constraints outlined above, an interesting suggestion has been made by Claude Henry and Marc Henry[12]. They developed a new decision theoretic framework that includes ambiguity by differentiating between *scientifically ambiguous acts* and *scientifically unambiguous acts*. While the latter merely comprises acts that rely on knowledge science *fully agrees* on, the former also embraces acts which draw upon ambiguous knowledge. By doing so, they are able to provide a precise formulation of the frequently-discussed *Precautionary Principle*: According to their position, precautionary behavior calls for *not* restricting oneself to make the choice among those acts which are scientifically fully assured, but enlarging the choice set by including the scientifically ambiguous acts. This formulation thus tackles one of the major problems inherent to complex systems, namely that the uncertainty with respect to the true probability distribution should not impede us from taking important measures against impending danger. In other words: Using a decision rule that refrains from including ambiguous data about, for example, precipitation pattern shift due to SRM would be *equivalent* to the use of a model in which there is *no* precipitation pattern shift at all. But this would imply a severe loss of information. This determines the value of the approach by Henry and Henry[13]: It offers a clear methodology to incorporate the information provided by ambiguous results in a rigorous manner.

With respect to applicability, it is clearly crucial to define criteria that determine which models we should neglect and which, on the contrary, belong to the set of results we consider to be non-resolvable ambiguous. This cleanup is important since the wider the set, the blurrier our results become. This difficult choice opens up the field for other disciplines. The question as to which criteria we want to base our decision on clearly cannot be answered solely from within the field of economics.

[10] As proposed by Millner et al.: *Ambiguity and Climate Policy*, fn. 8.

[11] This is in line with David W. Keith (*When is it Appropriate to combine expert judgements?*, in: *Climatic Change* 33(2) (1996)), who finds that “it is rarely appropriate to combine divergent expert judgments”.

[12] Claude Henry, and Marc Henry: *Formalization and application of the precautionary principle*, Department of Economics Discussion Paper No. 0102-22, Discussion Papers Series, Columbia University 2002.

[13] Ibid.

Climate Engineering – new concepts of dealing with uncertainty and the emergence of social risk

From a risk perspective it is undoubtedly much too early to commit oneself to the decision to rule out the option of Climate Engineering technologies entirely. Nor would it be prudent to set one's focus on one particular technology. Rather, it seems desirable to learn as much as possible about both the climate system and the effects (and side effects) of the various technological measures. Uncertainties, and thus also the risk, should be reduced whenever possible.

Even so, it is neither probable that we will succeed in completely resolving the ambiguity issue, nor is it likely that a benign form of uncertainty will prevail in the context of climate change and Climate Engineering, no matter how much experimentation and learning takes place. This strongly calls for exerted effort to be put into overcoming the limitations we are currently facing in economic methodology. The issues of ambiguity and fat-tail distributions outlined above both advise us that a lack of alternative munition must not be the reason for relying on inapt simplifications. This would pay off twice, as issues like the financial crisis also share the discrepancy of real world behavior and theoretical modeling that is so obvious in relation to the climate change issue. Thus the suggested approach could prove to be useful in other contexts as well. How to deal with deep uncertainties has to be made an acknowledged major criterion and thus be released from its subordinate position relative to the expected value.

Having said so much about the *probability* aspect, and thus focusing on the technical and scientific aspects, I want to close this contribution by providing an outlook on the fact that the societal processes are prone to uncertainty as well. An issue often raised in the Climate Engineering debate is that of a so called *moral hazard*[14], a term designed to reflect the concern that the technological option to cool down the planet might lead to reduced efforts to mitigate CO2 emissions. This evidently raises a completely new issue which goes beyond risk due to *scientific uncertainty*. We could refer to this kind of phenomenon as *social uncertainty*. But under what circumstances does this kind of technology, which by itself simply enlarges the scope of action, lead to a suboptimal reduction in mitigation? As shown by Goeschl et al.[15], this kind of deviation from an optimal abatement policy could result from an asymmetry in the assessment of side-effect damages of Solar Radiation Management techniques between the current and a future generation. Uncertainty with respect to the notion a coming generation might have could make a de-

[14] Note that from an economic perspective this term is not precise.

[15] Timo Goeschl, Daniel Heyen, and Juan B. Moreno-Cruz: *Long-term environmental problems and strategic intergenerational transfers*, Working paper (2010).

cision as complicated as one being made under scientific uncertainty. Whether social uncertainty is in principle the same as its scientific counterpart (and whether the economic approach is sensible here, cf. *Wiertz*) is an interesting topic for further examination.

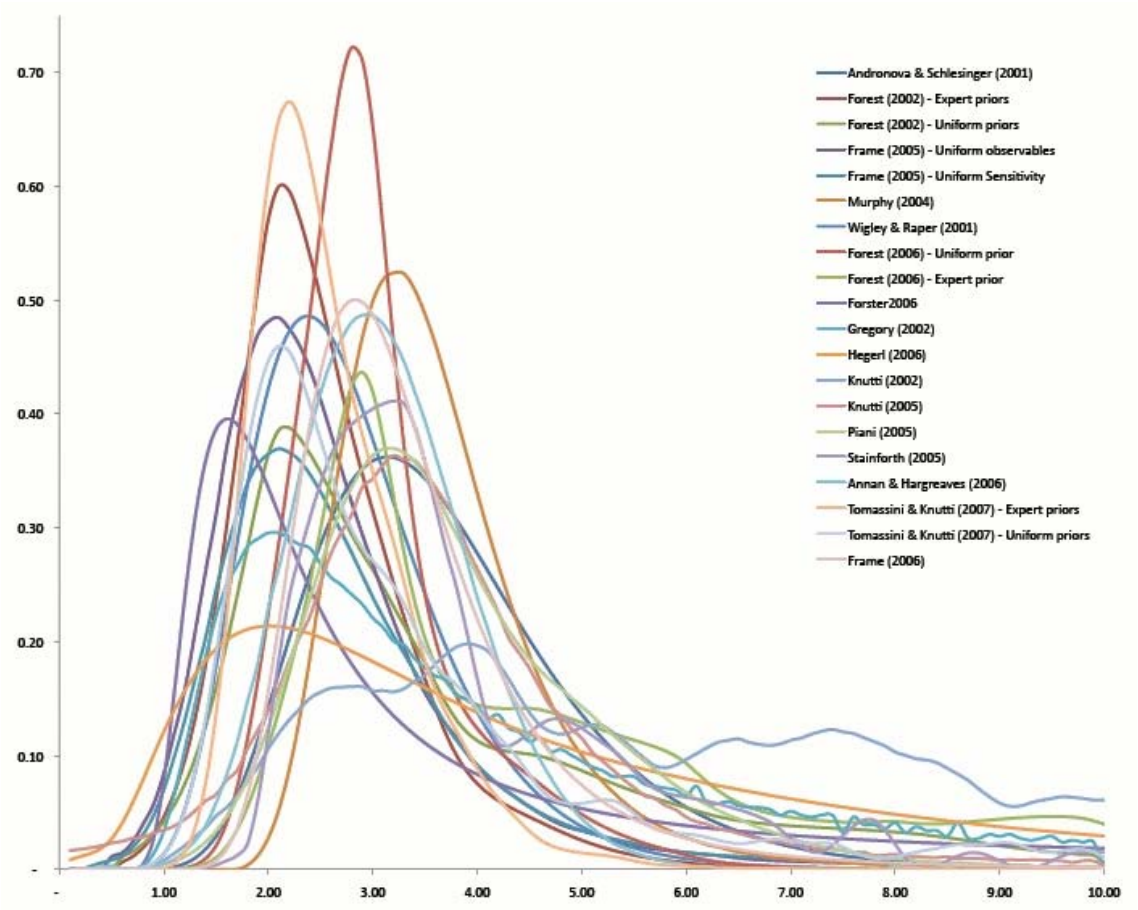

Figure 1 - Estimated probability density functions for the climate sensitivity from a variety of published studies, Antony Millner, Simon Dietz, and Geoffrey Heal: *Ambiguity and Climate Policy*, NBER Working Paper Series No. 16050 (2010).

Psychological and Social Risk Evaluation Criteria

Dorothee Amelung

Introduction

The moral hazard argument as it was mentioned by *Daniel Heyen* in the preceding section can be seen as one exemplary factor contributing to the human or societal dimension of uncertainties associated with SRM. However, in contrast to the economic understanding of the term 'moral hazard' (*Heyen*), in the field of psychology, the focus would rather be set on an individual level; from such an individual perspective, the term refers to a decrease in the motivation to change one's behavior and become energy and climate friendly in a manner that would help reduce carbon emissions. This lack of motivation is said to be due to the future prospect of having an alternative option to combat climate change. Changing one's behavior in a pro-environmental manner is often perceived to be costly as, for example, it implies breaking old habits, which is why this option is not the most popular one in the first place. Thus, the emergence of a second, much 'easier' option would free people of their feeling of obligation to actively contribute to emission reduction targets. This notion has given rise to some concern among experts, as reducing emissions is still believed to be the safest option and thus should not be abandoned for the sake of any type of geoengineering technology.

However, assuming that geoengineering is something society would not want to accept – if the idea of such a technology rather elicits strong feelings of opposition, even fear – in this case, it is hardly imaginable that geoengineering could free anyone of a feeling of obligation. On the contrary, it might even strengthen people's motivation to help reduce carbon emissions in order to prevent the implementation of such a technology. Public reactions to first experimental attempts at fertilizing the ocean, e.g. during the LOHAFEX expedition in 2009, a German-Indian collaboration coordinated by the Alfred-Wegener Institute in Bremerhaven, confirm the assumption stated in the Royal Society Report that "*the public is likely to be concerned about the unintended impacts of deliberate large-scale release of sulphates into the atmosphere or nutrients into the oceans*"[1]. In accordance with this prediction, the negative reactions led to a significant delay in the undertaking due to a detailed examination of the question as to whether it should be permitted. Similar experiences have been made with the SPICE field experiment in the UK, designed to test the technical feasibility of a device to inject sulfur into the stratosphere. Tak-

[1] The Royal Society: *Geoengineering the climate – Science, governance and uncertainty*, London: The Royal Society 2009, p. 42.

ing these considerations into account, it appears to me that there is not much support for a phenomenon like 'moral hazard', at least with regard to the lay public and on an individual level, although this assumption is certainly in need of empirical validation. That being the case, the moral hazard is only one example for a psychological factor that contributes to the uncertainties associated with geoengineering and as such demands attention. This is because a 'psychological moral hazard' in the sense described above – as an individual motivational and maybe even behavioral change – must be regarded as only one possible and rather moderate public reaction to signs of political actors adopting a policy strategy involving geoengineering. Therefore, this contribution shall elaborate on these psychological factors in general, and outline their social implications on a group level.

At this point it is important to note that, although group behavior is not simply the sum of its members' behavior, every single member contributes to the group process all the same. Thus, psychological phenomena on an individual level form the basis of group processes and should therefore be considered when trying to explain phenomena at the group level. This becomes especially clear when taking a look at some of the central ideas in the field of social psychology, for example, the concept of 'social cognition' that helps us understand how information is processed in social situations.[2] Accordingly, the feelings and perceptions of every single individual regarding this technology might very well combine with certain group processes into a phenomenon called 'social mobilization'. A mobilized public would enhance the pressure on political decision-makers. This is a term I will come back to later in this section.

With that said, the following sections aim to demonstrate the importance of incorporating psychological and social aspects into a risk[3] assessment of geoengineering. This could be achieved by extending the range of risk evaluation criteria. As a first step towards this aim, the specific characteristics of geoengineering are described from the viewpoint of psychological risk perception research as well as from a more sociological viewpoint by conceptualizing it as a systemic risk. The implications will be shown. As a second step, this contribution assesses the social and psychological risk evaluation criteria developed by the German government as a means to improve general guidelines for an effective risk management approach. These criteria are then briefly discussed with regard to their relevancy for the geoengineering debate.

[2] Miles Hewstone, and Wolfgang Stroebe (eds.): *Introduction to Social Psychology – A European Perspective*, Malden, MA: Blackwell Publishing 2001.

[3] Within this section, the term "risk" is understood in a way that can best be described by the use of a definition suggested by Terje Aven and Ortwin Renn(*On risk defined as an event where the outcome is uncertain*, in: *Journal of Risk Research* 12 (2009), p. 6): "Risk refers to uncertainty about and severity of the events and consequences (or outcomes) of an activity with respect to something that humans value".

Psychological perspective: Why public concerns with geoengineering technologies?

Why is it that geoengineering is able to provoke sometimes very strong reactions and that, at the very least, the public is believed to hold and express concerns regarding these technologies? The authors of the Royal Society Report on geoengineering have already mentioned some criteria they believe to be critical: a low degree of encapsulation, a high degree of interference with biological systems, activities that are widely dispersed rather than localized, effects of global proportions as well as unfamiliar and novel processes.[4] Psychological research on risk perception further supports these notions. Results from this field indicate that people tend to perceive hazards to be less acceptable if they are unknown, catastrophic, uncontrollable, involuntary, inequitable and likely to affect future generations.[5] Most of these attributes can certainly be applied to the risks frequently associated with geoengineering technologies given the global scale, the long-term time scales as well as the regional variability of their potential impacts, not to mention the large insecurities and unknowns involved. Thus, geoengineering is unique in that it concurrently comprises several of the qualitative risk attributes that are well-known in psychological research for their potential to raise opposition among the public.

Sociological viewpoint: Geoengineering as Systemic Risk and the Social Amplification of Risk Framework

The risks associated with geoengineering can be regarded as so-called systemic risks (cf. *Fernow*). Systemic risks can be characterized by a transgression of time boundaries as well as regional boundaries and a high degree of complexity, insecurity and ambiguity.[6] This kind of risk is especially prone to the emergence of secondary effects (or spill-over effects) which are due to a phenomenon called the Social Amplification of risk. This phenomenon has been introduced together with the integrative Social Amplification of Risk Framework.[7] It refers to "*… the phenomenon by which information processes, institutional structures, social-group behavior, and individual responses shape the social experience of risk, thereby contributing to risk consequences*"[8]. Thus, in the context of geoengineering, secondary effects can be seen as the effects of public responses to this technology on society and/or

[4] The Royal Society: *Geoengineering the climate*, fn. 1.

[5] Paul Slovic: *Perception of Risk*, in: *Science* 236(4799) (1987).

[6] Ortwin Renn et al.: *Risiko – Über den gesellschaftlichen Umgang mit Unsicherheit*, München: oekom Verlag 2007.

[7] Nick Pidgeon, Roger E. Kasperson, and Paul Slovic (eds.): *The Social Amplification of Risk*, Cambridge: Cambridge University Press 2003.

[8] Roger E. Kasperson et al.: *The Social Amplification of Risk – A Conceptual Framework*, in: *Risk Analysis* 8(2) (1988), p. 181.

economy that occur in addition to primary physical effects with the potential to amplify them. According to the authors of the framework, examples for secondary effects could be: a loss of credibility and trust in public institutions, political and social pressure, social disorder (e.g., protesting, rioting or sabotage) or impacts on local business sales or economic activity, to mention only few. These secondary effects can even give rise to higher-order effects as they themselves are perceived and processed and thus amplified by social groups and might well be spread in space (to distant locations) and time (to future generations).

Taking the characteristics of systemic risks mentioned above into consideration, it becomes clear that new practices to manage these risks must be developed (cf. *Fernow*). These new risk management practices must be able to deal with higher-order effects in addition to the primary effects and their interactions. The identification and incorporation of relevant social and psychological risk criteria in the risk assessment process can be seen as a first step towards achieving this aim. This approach has already been adopted by the German and UK governments, for example. In the following section the criteria proposed by the German government will be introduced and briefly discussed with regard to their relevancy for the geoengineering debate.

How to deal with systemic risk: Social and psychological risk evaluation criteria

The debate about risks associated with geoengineering has largely been dominated to date by a technical perspective focusing on risk evaluation criteria such as the possible extent of damage, probability of occurrence (e.g. of that damage) or questions of reversibility and timeliness.[9] Risk evaluation criteria that go beyond the technical scope by including social and psychological aspects are marginally mentioned at best. Still, a technical risk analysis on its own, although a necessary starting point, cannot provide us with an answer to the question as to whether certain risks are socially accepted, especially those involving complexity and ambiguity as well as uncertainty, as it is the case with geoengineering.[10] There is growing consensus on the two assumptions that:

[9] The Royal Society: *Geoengineering the climate*, fn. 1.

[10] Renn et al.: *Risiko*, fn. 6.

"1. It is possible and necessary to distinguish physical [11] *from social and psychological attributes of risk.*
2. Both sets of criteria are important for evaluating and managing risks".[12]

This is reflected in attempts to establish guidelines for effective risk management by governmental agencies or advisory boards in Germany[13] or the UK[14] that incorporate social and psychological criteria. The criteria defined by the German proposal under the superordinate concept of "mobilization" are systematically divided into the four elements *inequity and injustice*, *psychological stress and discomfort*, *potential for social conflict and mobilization* and *spill-over effects*.[15] These elements clarify the way in which the term 'mobilization' must be understood: as a description of public response to either the risk itself or the way public agencies deal with it, respectively. In the following, the criteria will be discussed with regard to their relevancy for the geoengineering discussion. However, a comprehensive evaluation of the various geoengineering options using these criteria is clearly beyond the scope of this chapter and will therefore not be aspired to.

A general assessment of the criteria at hand makes it clear why they can be subsumed under the joint concept of *mobilization*. *Perceived inequities* as well as feelings of *psychological stress and discomfort* can be combined in their ability to contribute to the emergence of secondary or *spill-over effects.* These in turn are able to enhance the *potential for social conflict and mobilization*. One can even assume feedback processes such as a rising degree of public pressure on risk regulatory agencies (as the *potential for social conflict* criterion is defined) could also raise public awareness of the issue and therewith lead to an intensification of experienced psychological stress. It is important to take into account the coherencies as well as the interactions between the four criteria, although in the following they will be discussed one after another in order to facilitate a more structured discussion of the issue.

Inequity and injustice. This criterion is defined as: perceived inequities in the distribution of risks and benefits over time, space and social status. It certainly plays a role when taking into account the inequities that already exist in the distribution of

[11] Within this context, "physical" attributes of risk refer to "physically measurable outcomes" as opposed to a socially constructed, rather subjective dimension of risk.

[12] Andreas Klinke, and Ortwin Renn: *A New Approach to Risk Evaluation and Management: Risk-Based, Precaution-Based, and Discourse-Based Strategies*, in*: Risk Analysis* 22(6) (2002), p. 1076.

[13] German Advisory Council on Global Change (WBGU): *World in Transition – Strategies for Managing Global Environmental Risks*, Annual Report 1998, Berlin: Springer 2000.

[14] Environment Agency: *Strategic Risk Assessment – Further Developments and Trials*, London: Environment Agency 1998.

[15] Klinke, and Renn: *A New Approach to Risk Evaluation and Management*, fn. 12.

present as well as future effects of climate change with regard to space.[16] This problem is probably not able to be solved by means of a possible implementation of geoengineering technologies, as it is not unlikely that their effects will even aggravate existing inequalities.[17]

Regarding the distribution of risks and benefits over time, the potential for inequity is certainly there; with climate change we face an intergenerational problem in that what we decide now will affect future generations. For example, when considering SRM techniques that do not alter the CO_2 concentration within the atmosphere, but only combat its 'symptoms', unforeseeable adverse side effects might not manifest themselves until some decades later. This would lead to a shifting of the 'problem', i.e. some of the risks, to some future generation. Thus, the possibility of 'unknown unknowns' makes it very likely that we may be confronted with an unequal distribution of risks and benefits over time.

The inequity issue over social status can be assumed on a state level, a fact which is made clear in the Royal Society Report in the following statements: "*the actual benefits and drawbacks of doing this* [injecting sulphate aerosols into the upper atmosphere; author's note] *are unlikely to be evenly distributed across regions*" and "*may exacerbate existing economic disparities between wealthy and less developed nations*."[18]

Beyond that, there are even more issues of equity, again on a state level. The following section, again from the Royal Society Report, makes clear that "*even for a 'perfect' geoengineering method that returned climate to some prior state, those who had already adapted to climate change may be disadvantaged. Other issues will include the equitable participation in the use and deployment of new technologies, amelioration of transboundary effects, and potential liability and compensation regimes to address, if and when the technology is 'shut off.'*"[19] These are questions that should mainly be addressed by experts in the field of international law and international relations. Nonetheless, they are also relevant for this contribution because feelings of inequity and injustice on a state level have the potential to affect the general public and lead to social mobilization.

[16] Intergovernmental Panel on Climate Change (IPCC): *Summary for Policymakers*, in: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. by Susan Solomon et al., Cambridge, New York, NY: Cambridge University Press 2007.

[17] The Royal Society: *Geoengineering the climate*, fn. 1.

[18] Ibid., p. 40.

[19] Ibid., p. 51.

Psychological stress and discomfort. Risks associated with technologies can be seen as potential stress factors.[20] The widely accepted stress theory from Lazarus argues that the degree to which a situation is perceived as threatening and thereupon experienced as stressful does not necessarily depend on the objective attributes of the situation, but rather on its (cognitive) appraisal.[21] There is growing consent in the field of psychology that the cognitive evaluation of a (risky) situation cannot be separated from its emotional aspect.[22] Having said this, it is hardly surprising that emotional reactions are being increasingly acknowledged as an important factor contributing to the way people perceive and evaluate risks.[23] The influence of people's emotional handling of geoengineering inherent in public perceptions of this technology remains to be investigated more closely. Still, we can readily conclude that the criterion *psychological stress and discomfort* is of great importance as it refers to emotional aspects of public reactions, especially considering the specific characteristics of geoengineering from the viewpoint of psychological risk perception research outlined earlier.

Potential for social conflict and mobilization. This criterion is defined as the degree of political or public pressure on risk regulatory agencies. As mentioned above, it can hardly be separated from the other three criteria because the potential for social conflict and mobilization might result from public perceptions of inequity and injustice as well as from the experience of psychological stress and discomfort. As these two criteria play a role for the geoengineering discussion, one can readily assume an existing potential for social conflict and mobilization with the emergence of these technologies. Moreover, the degree of political or public pressure on risk regulatory agencies would also increase and therefore be of importance regarding the emergence of spill-over effects, as explained below.

Spill-over effects. A useful model to explain the emergence of spill-over effects (or secondary effects) has already been introduced above: the integrative Social Amplification of Risk Framework.[24] It provides a useful conceptualization of the processes underlying a social amplification of risk which ultimately lead to the emergence of secondary impacts. This is especially helpful for understanding complex

[20] Barbara Hinding: *Muster der psychischen Verarbeitung des globalen Klimawandels und Energiesparen*, in: *Umweltpsychologie* 6(2) (2002).

[21] Richard S. Lazarus: *Stress and emotion – A new synthesis*, in: *The Praeger handbook on stress and coping*, Vol. 1, ed. by Alan Monat, Richard S. Lazarus, and Gretchen M. Reevy, Westport, CT: Praeger Publishers/Greenwood Publishing Group 2007.

[22] Jochen Musch, and Karl Christoph Klauer (eds.): *The Psychology of Evaluation – Affective Processes in Cognition and Emotion*, Mahwah, NJ: Lawrence Erlbaum Associates 2003; Josef Nerb, and Hans Spada: *Evaluation of environmental problems – A coherence model of cognition and emotion*, in: *Cognition and Emotion* 15(4) (2001).

[23] Carmen Keller, Michael Siegrist, Heinz Gutscher: *The Role of the Affect and Availability Heuristics in Risk Communication*, in: *Risk Analysis* 26(3) (2006); Paul Slovic, and Ellen Peters: *Risk Perception and Affect*, in: *Current Directions in Psychological Science* 15(6) (2006).

[24] Pidgeon, Kasperson, and Slovic: *The Amplification of Risk*, fn. 7.

systemic risks like geoengineering. Of course, the same mechanisms which explain a social amplification of risk could lead to social attenuation as well, i.e. the opposite effect. Therefore, in order to predict either amplification or attenuation regarding geoengineering technologies, it is crucial to take a closer look at the following two stages of the communication process at which amplification is likely to occur: The first one concerns the mechanisms through which the public will be informed, i.e. mass media or public agencies. The second stage is related to the response mechanisms. They include, for example, *values* of individuals or groups that determine the importance ascribed to a certain risk.[25] With regard to geoengineering, an evaluation of the possible amplification stages, e.g. the relevant context factors that are suggested within the framework, could prove to be insightful for a risk assessment of this technology. One important starting point would be an experimental evaluation of the effects different kinds of media coverage could exert on the individual. As personal experience with the effects of climate change is lacking for most people in western countries and personal experience with geoengineering technologies is lacking for most people on this planet, they would have to rely on information they get from the media.[26] This is why the media can be seen as one of the most important possible amplifying agents in the context of geoengineering.

Conclusion

The sections above make it clear that the criteria defined by the German government are relevant for a risk assessment of geoengineering. Furthermore, the Social Amplification of Risk Framework could prove to be useful to embed these criteria into a broader framework that could help understand social and psychological mechanisms underlying the handling of systemic risks. These social and psychological mechanisms must be understood as factors contributing to the technical insecurities and risks already involved in a complex set of technologies like geoengineering, a notion that is clearly put forth by the Social Amplification of Risk Framework. Nevertheless, much research remains to be done with regard to these social and psychological mechanisms and the way they interact. The moral hazard argument mentioned in the introduction is one example for a social/psychological factor contributing to the inherent uncertainties, but certainly not the only one. Despite the fact that it is unclear if we will ever be able to significantly reduce these uncertainties by conducting research, (which certainly also holds true for the technical risk evaluation) this should not be used as an excuse for neglecting the social and psychological aspects altogether during the risk assessment process.

[25] Kasperson et al.: The Social Amplification of Risk, fn. 8.
[26] Ibid.

From Prediction to Critique: The Moral Hazard Debate

Thilo Wiertz

Moral hazard as a risk

The topic of the preceding essays has been the perception, evaluation and regulation of the technological risks related to Climate Engineering. However, as *Daniel Heyen* and *Dorothee Amelung* have indicated, there is another 'risk' associated with the development of the technologies, namely that society will not act responsibly if equipped with a seemingly cheap and quick insurance against the consequences of anthropogenic global warming. Within the debate on Climate Engineering this is usually referred to as a 'moral hazard', but its characterization in the debate indeed closely resembles that of a risk: a function of an uncertainty about social reactions to the technologies and a (moral) value at stake. Several overview publications on Climate Engineering have thus called for verification of the claim by means of empirical studies. While such studies may contribute significantly to our understanding of risk evaluation processes, the expectation that social science can predict reactions to Climate Engineering prematurely limits the scope of the moral hazard argument. In this essay, I reflect on the limitations and political implications of a purely empiricist perspective on a moral hazard linked to Climate Engineering and suggest an approach more sensitive to the political dimension of the argument. I sketch out a possible extension of the topic that focuses on power relations in contemporary environmental discourses and that relocates the moral hazard argument within the context of the climate change debate.

The empiricist approach to 'moral hazard'

Uncertainty about social processes features prominently in debates about a 'moral hazard' linked to Climate Engineering. The term has been used in different ways, all of which share the notion that the prospect of the technologies "may weaken conventional mitigation efforts"[1]. The Royal Society report concludes that social science research needs to clarify "the existence or extent of any moral hazard associated with climate engineering"[2] and indeed, the perception that the 'moral hazard' argument is an empirical problem to be addressed by social science research is widespread. A report commissioned by the German Federal Ministry of

[1] The Royal Society: *Geoengineering the climate – Science, governance and uncertainty*, London: The Royal Society 2009, p. 37.

[2] Ibid., p. 39.

Education and Research concludes that, although the moral hazard phenomenon has been proven statistically for other technologies, "there is no empirical material within the climate engineering context to support the moral hazard thesis"[3]. An early article on the ethics of Climate Engineering states that "whether climate engineering will suppress individual and group incentives for action (or alternatively galvanize some sections of society) is an empirical issue, pointing to the need for quite subtle social research on climate engineering's impact on attitudes to climate change, as well as behavioural intentions and responses"[4]. And a study on risk perceptions carried out by the Natural Environment Research Council in Great Britain tentatively interprets its results as being "contrary to the 'moral hazard' argument that climate engineering would undermine popular support for mitigation or adaptation"[5].

These perspectives render the moral hazard argument subject to research and prediction. Whether the argument is of relevance is expected to be clarified by social scientists, an expectation that assigns the social sciences a role analogous to that of the natural sciences: It implies a need to study the universal principles and causal mechanisms of individual and social risk evaluations of Climate Engineering and to predict whether reduced mitigation efforts are to be expected to coincide with research and development of the technologies.[6] In this view, the moral hazard phenomenon is the determined – and determinable – result of the interaction between technological properties, expert communication and individual risk perception, and the argument is assigned the status of a hypothesis to be tested. The positivist ontological position that appears in this approach to the moral hazard argument has several implications. Firstly, the ambition to generalize results and provide predictions (as guidance to debates on governance) leads to a latent technological determinism. This also has a political implication: independent variables and assumptions of social science theories demarcate a field inaccessible to political debate, since they are assumed to reflect the *natural* behavior of, for example, states, markets or individuals. Related to that, secondly, is the assumption that a phenomenon is amenable and *insensitive* to scientific methods: "the process of becoming a producer of knowledge […] involves setting oneself apart from the

[3] Wilfried Rickels, Gernot Klepper, Jonas Dovern (eds.) et al.: *Gezielte Eingriffe in das Klima? Eine Bestandsaufnahme der Debatte zu Climate Engineering*, Sonderstudie für das Bundesministerium für Bildung und Forschung 111, Kiel Earth Institute 2011, p. 86, my translation.

[4] Adam Corner, and Nick Pidgeon: *Geoengineering the Climate: The Social and Ethical Implications*, in: *Environment* 52, 1 (2010), p. 31.

[5] Natural Environment Research Council (NERC): *Experiment Earth?* Report on a Public Dialogue on Geoengineering, 2010.

[6] The critique of a positivist social science I follow in this essay and arguments for an alternative approach are particularly inspired by Jason Glynos and David Howarth (*Logics of Critical Explanation in Social and Political Theory*, Abingdon, New York, NY: Routledge 2007), Doreen Massey (*For Space*, London: Sage 2005) and Bruno Latour (*We have never been modern*, New York, NY: Harvester Wheatsheaf 1993).

things one is studying"[7]. Both these assumptions are problematic considering the role science is currently playing as the main driver of the Climate Engineering debate and it also has implications for the way we think about political regulation of the technologies.

The political role of social science

Within the field of Climate Engineering, there is no clear boundary between the political and the scientific debate. On the contrary, science has become the most active contributor to the debate on technologies *and* their political regulation. The report to the German Ministry of Education and Research is structured around a catalogue of different arguments articulated *pro/contra* Climate Engineering, from which it deduces empirical questions to be tested, and the Royal Society positions the discussion of a moral hazard in its report's section on governance. This fuzzy boundary between the academic and the political debate puts critics of Climate Engineering in a defensive position in two ways. Firstly, confronted by a fleet of scholars, the only possible way of sustaining the moral hazard argument is through methods of empirical research. Secondly, if the argument cannot be supported by such studies, it will lose its political momentum. As the Royal Society report states, "if it could be shown empirically that the moral hazard issue was not serious, one of the main ethical objections to climate engineering would be removed"[8]. Thus, if an empirical study could indeed 'prove' that the moral hazard argument was not serious it would considerably affect the structure of the debate. Scientific proof of a moral hazard becomes a precondition for upholding the argument in the political debate.

Attributing science with objective access to society also has implications for the way we think of governance. The presumption that social reactions to Climate Engineering are predictable, on the one hand, and that there is a potential for political regulation on the other creates tension. This tension is resolved through a notion of governance as an *external intervention* into social processes, as an instrument to achieve specific goals. Social scientists and politics become the equivalent of physicists and engineering. This perspective, implicitly or explicitly, reduces the realm of debate and participation to defining what (measurable) outcome is desirable. If 'we' only knew what world 'we' would like, scientists and politicians might furnish 'us' with the required instruments to achieve that goal. 'Politics' in this understanding, however, is limited to technical management.

[7] Massey: *For Space*, fn. 6, p. 74.

[8] The Royal Society: *Geoengineering the climate*, fn. 1, p. 39.

Critiques of positivist ontology for social sciences have emphasized that neither technology development nor governance are simply means to achieve predefined ends, but are interrelated and contingent processes.[9] Studies within science and technology studies, political science and geography have stressed the contingency of socio-political developments around environmental and technological change.[10] Shifts in discourses on, for example, large dam projects or nuclear power – labeling them either as hubristic and hazardous attempts to control 'nature' or as climate protection measures – point to the discursive dimension in the political regulation of technologies and the impossibility of predicting such shifts.

Discursive dimensions of the moral hazard

This is not to say that there is no individual dimension to the moral hazard debate that can be studied through experimental studies and surveys. On the contrary, such studies do give intriguing insights into public understandings of Climate Engineering. However, the currently predominant framing of the moral hazard within the debate as an *exclusively* empirical problem remains oblivious to the discursive and political questions the argument raises. In their submission to the Royal Society, Douglas Par and David Santillo[11] write on behalf of Greenpeace that "Geoengineering enters a highly politically charged context where action on reducing greenhouse gas emissions is being opposed and watered down". They take this as the starting point to argue that "the concept creates a 'moral hazard' that we will not take the safest and most sustainable options available for countering climate change […]". In this brief take on a moral hazard, reframed by the Royal Society as a problem of individual risk evaluation and scientific inquiry, *the context of contemporary climate politics* is rendered problematic. That a 'moral hazard' arises not from the technologies and their interaction with individuals, but from the power relations and regulatory logics characteristic to the international climate regime, is a concern that has remained absent from serious social scientific consideration so far. The political critique expressed in the argument, furthermore, may not be curbed as easily by empirical research.

What could an alternative consideration of the moral hazard argument look like – one that does not foreclose a political debate and that remains sensitive to the contextuality of social science? One approach that may contribute to understanding the

[9] Cf. Massey: *For Space*, fn. 6; Glynos, and Howarth: *Logics of Critical Explanation*, fn. 6.

[10] Sheila Jasanoff (ed.): States *of Knowledge – The Co-Production of Science and Social Order*, London: Routledge 2004; Edward J. Hackett et al.: *The Handbook of Science and Technology Studies*, Cambridge, MA: The MIT Press 2007.

[11] Doug Parr, and David Santillo: *Greenpeace evidence to Royal Society on Geo-engineering,* URL: http://royalsociety.org/WorkArea/DownloadAsset.aspx?id=4294969100 (9.08.2010), 2008, pp. 11-13.

problem in its wider political context comes from post-structuralist work on governance or governmentality. Studies influenced by this strand of discourse theory sketch out the *logics* or *rationalities* of social practices as stable but historically explicable and thus contingent expressions of discourses. Hence, while not dismissive of a physical world, they focus on how social and material changes are rendered meaningful in particular ways. In that sense, the risks of Climate Engineering and a potential trade-off between technology development and mitigation efforts are beyond the scope of social scientific prediction, because their relevance to political processes depends on the particular historico-political contexts in which problems are articulated and solutions negotiated. Rejecting a positivist ontology, not the predictive capacity of research marks social scientific success, but the plausibility of explanations given for an observed phenomenon. Furthermore, since the goal is to *critically explain* political changes and the underlying power relations which lead to regimes of social practices, social science itself is considered part of the discourse it studies.[12]

In this light, Climate Engineering governance presents itself as an arena of conflicting voices, characterized by different logics competing over the meaning of the technologies. Whether Climate Engineering is framed as, for example, a challenge to national security, global equity, or as a scientific risk management strategy renders very different values as being worthy of protection and calls for very different logics of political regulation. Since Climate Engineering is likely to become a question of international environmental politics and the climate regime, it seems worthwhile to consider the topic within these wider discursive contexts.

Technology and development within the climate regime

One possible way to explain how and why Climate Engineering may be rendered as an alternative to mitigation measures focuses on the strong link between technology and economic development within the current climate regime. Since Paul Crutzen sparked the debate in 2006,[13] justification for research on Climate Engineering has frequently been given in reference to the failure of past and contemporary policies to reduce emissions. However, there has been little reflection on *why* the international regime has failed – and what this might mean for new technologies. One possible reading is that climate politics has just been lacking the right (political or technological) instrument. However, as a justification for Climate Engineering this would make the assurance that the technologies may not and must not

[12] Glynos, and Howarth: *Logics of Critical Explanation*, fn. 6.

[13] Paul J. Crutzen: *Albedo enhancement by stratospheric sulfur injections – A contribution to resolve a policy dilemma?,* in: *Climatic Change* 77(3-4) (2006).

become an alternative to abatement look bleak. If a second explanation is that the logics constitutive for contemporary climate politics have inhibited achieving sustainable and equitable results, the question is what characterizes these logics and what changes are required to prevent Climate Engineering from becoming another 'failure'.

Economic development forms a key element of the climate regime and is closely linked to technology development and transfer. One reason for this is the attested right of 'the global south' to development, but at least as important is the primacy of economic growth in 'developed nations', a fact which becomes obvious in the frequent debates carried out on the bearable or unbearable burdens put on national economies by environmental policies. The paradox that, while economic development remains linked to an increased consumption of fossil fuels, emissions urgently need to decline, but sustained growth is non-negotiable, is resolved foremost through the promise of technology development and transfer. A background paper by the UNFCCC on "Realizing the full potential of technology" notes that "[t]he deployment, diffusion and transfer of existing climate-friendly technologies and the future development of new and more efficient technologies could contribute to the evolution of less carbon intensive economies without compromising economic growth"[14]. Consequently, most international climate agreements, including the more recent Bali Road Map, the Copenhagen Accord and the Cancun Accord on Long-term Cooperative Action, are packed with references to technical innovation and technology transfer.

Hence, one piece of the puzzle explaining the failure of climate politics is indeed the lack of a technology allowing for uninhibited economic development and climate protection at the same time – since the need for the former remains incontestable. Scientists have put strong emphasis on the point that Solar Radiation Management is not an alternative to determined emission reductions. I fully endorse the argument, but my concern is that, without challenging the principles inscribed in contemporary environmental policies, it may not be heard. More efficient coal- and gas-fired power plants, carbon capture and storage[15], or nuclear power are only a few examples of technologies that do not address the 'root cause' of climate change – contemporary structures of production and consumption – but function as 'bridging

[14] United Nations Framework Convention on Climate Change (UNFCCC): *Realizing the full potential of technology. Background,* paper by the secretariat, in: *Dialogue working paper* 3, Bonn 2007.

[15] Surprisingly, the unresolved question of permanent storage – arguably the one that has prevented Carbon Capture and Storage so far from becoming a method under the flexible mechanisms of the Kyoto Protocol – is almost completely absent from debates about carbon air capture; see for example Rie Watanabe, Renate Duckat, and Wolfgang Sterk: *Carbon Capture and Storage under the Clean Development Mechanism – Impact on the Long-term Climate Goal, Energy Supply Planning, and Development Paths*, in: *JIKO Policy Paper* 4 (2007).

technologies', leaving the solution to future generations while producing new risks in the present.

It is beyond the scope of this short essay to delve into the shifting discourses and far more complex power relations that have shaped these debates. Still, I would argue that 'technology' has become a powerful logic by means of which environmental protection and development are, at least provisionally, reconciled. The disquieting feeling that many have about Climate Engineering, and to my mind the more important dimension of the moral hazard argument, is that SRM fits perfectly within this logic. From this arises a need to outline more thoroughly and *challenge* the dominating principles guiding international politics – the commitment to economic development being but one example – rather than taking them as empirical givens and 'injecting' the technology into the current regime on a scientific prescription – even if the package insert warns of the risks and side effects.

Conclusions

The aim of this essay has not been to dismiss the merit of empirical studies of a moral hazard *per se*. As I have noted, such studies are an important contribution to the debate and help to show which different logics of evaluating Climate Engineering are currently influencing public perceptions. Rather, the problematic issue I have pointed to is a potential misconception, namely that scientific evidence can resolve the question of a moral hazard and thereby disempower an important argument within debates on the political regulation of Climate Engineering. Furthermore, the role of (social) science in producing the contemporary Climate Engineering discourse, thereby shaping attitudes and political positions, calls for thorough consideration. As Doreen Massey writes, 'research' needs to be reconsidered as "an activity, a practice, an embedded engagement *in* the world of which it is part"[16], as opposed to a detached observation process. Reflexive social science, critical about its assumptions and aware of the contextuality of the knowledge it produces, can enrich the debate particularly through the multiplicity of perspectives it has to offer.

If there is no location 'outside' of the discourses in which governance principles are shaped, there is a strong need to be sensitive to and critical about the logics employed to justify specific modes of regulation. Governance, rather than a set of static rules or thresholds, must then be more adequately understood as an open and on-going process. The challenge for current debates, in this light, lies on the

[16] Massey: *For Space*, fn. 6, p. 28.

creation of *fora* that facilitate debate and the possibility of political intervention alongside Climate Engineering research. This suggestion resonates well with the demands and attempts to involve a variety of stakeholders and interest groups in Climate Engineering debates, in particular people from ‘developing nations’. However, engaging people in the debate is not enough if such engagement is based upon the same power relations and exclusions of contemporary global politics. The crucial question, also for social science, is how to challenge those modes of policy making that have led us to a point where more and more people consider Climate Engineering to be an alternative to climate politics.

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