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AN ACTION THEORY OF ADAPTATION TO CLIMATE CHANGE

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ABSTRACT

Many observers currently agree that substantial barriers inhibit measures to cope with the impacts of climate change. However, the incoherent use of terms like planned adaptation or adaptive capacity seems to be of little help in analyzing the nature of these barriers or suggesting ways to overcome them. The paper thus presents a novel theory to analyze adaptation to climate change in a systematic way. It rigorously clarifies the notion of adaptation in specific research contexts. The theory's potential is demonstrated by a systematic deduction of crucial barriers to adaptation and by the elucidation of some prominent concepts in adaptation research. It combines established analyses of (social) action with terminology from the Intergovernmental Panel on Climate Change (IPCC) in an innovative way that is open to perspectives from different scientific disciplines. The theory puts emphasis on the purpose of adaptations, and on the implications of the fact that exposure units, operators and receptors of adaptation are frequently not identical: adaptations tend to connect up in means-end chains. We argue that it is crucial to focus on these issues for a better understanding of the governance of adaptation.

KEY WORDS

Stimulus, exposure unit, operator, barriers to adaptation, adaptive capacity

SERIES FOREWORD

This working paper was written as part of the Earth System Governance Project, a ten-year research initiative launched in October 2008 by the International Human Dimensions Programme on Global Environmental Change under the overall auspices of the Earth System Science Partnership.

Earth system governance is defined in this Project as the system of formal and informal rules, rule-making systems and actor-networks at all levels of human society (from local to global) that are set up to prevent, mitigate and adapt to environmental change and earth system transformation. The science plan of the Project focusses on five analytical problems: the problems of the overall *architecture* of earth system governance, of *agency* of and beyond the state, of the *adaptiveness* of governance mechanisms and processes, of their *accountability* and legitimacy, and of modes of *allocation and access* in earth system governance. In addition, the Project emphasizes four crosscutting research themes that are crucial for the study of each analytical problem: the role of power, of knowledge, of norms, and of scale. Finally, the Earth System Governance Project advances the integrated analysis of case study domains in which researchers combine analysis of the analytical problems and crosscutting themes. The main case study domains are the global water system, global food systems, the global climate system, and the global economic system.

The Earth System Governance Project is designed as the nodal point within the global change research programmes to guide, organize and evaluate research on these questions. The Project is implemented through a Global Alliance of Earth System Governance Research Centres, a network of associate faculty members and research fellows, a global conference series, and various research projects undertaken at multiple levels (see www.earthsystemgovernance.org).

Earth System Governance Working Papers are peer-reviewed online publications that broadly address questions raised by the Project's Science and Implementation Plan. The series is open to all colleagues who seek to contribute to this research agenda, and submissions are welcome at any time at workingpapers@earthsystemgovernance.org. While most members of our network publish their research in the English language, we accept also submissions in other major languages. The Earth System Governance Project does not assume the copyright for working papers, and we expect that most working papers will eventually find their way into scientific journals or become chapters in edited volumes compiled by the Project and its members.

Comments on this working paper, as well as on the other activities of the Earth System Governance Project, are highly welcome. We believe that understanding earth system governance is only feasible through joint effort of colleagues from various backgrounds and from all regions of the world. We look forward to your response.

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1. INTRODUCTION

As the prospects for an effective global environmental agreement on climate change are currently not the best, at least in the short-term, more emphasis is currently being placed on the need for adaptation to the inevitable consequences of global warming. Although adaptation research is assuming greater prominence on the scientific agenda, this interdisciplinary field is still characterized by an evolving epistemological base. It is widely recognized that there are crucial barriers to adaptation (E.G. ADGER ET AL., 2009), but a comprehensive set of theories to explain these is still not in sight. General difficulties in operationalizing theories for concrete research design might be one explanation for the current limits of generalized explanations of barriers.

To address these challenges, we introduce a novel action theory of adaptation in this paper. The purpose of the argument is twofold. The first aim is to contribute to the clarification of the concept of adaptation in a way that enables it to be applied in the design of adaptation assessments. This opens a new view on adaptation that also sheds light on other concepts often used in adaptation research. This, secondly, provides a frame to analyze re-appearing decision and governance structures for adaptations, and allows for the systematic deduction of meaningful hypotheses about barriers to adaptation.

There is a broad body of theoretical literature that conceptualizes adaptation to climate change and reflects on the relation to vulnerability and resilience. Here we can only mention some examples. Kelly and Adger (2000, drawing on Blaikie 1994) differentiate between biophysical and social conceptions of vulnerability. This also holds for Brooks (2003) who is careful to distinguish between (actual) adaptation and adaptive capacity (potential adaptation that is not necessarily actual). This distinction underlies much of the literature on vulnerability, although it is not always clearly stated. He further differentiates between social and biophysical vulnerability. The latter refers to the likely consequences of exposure to a hazard, while the former is a property of the exposed system that is independent from the occurrence of a specific hazard event. In this framework, biophysical vulnerability is a function of hazard and social vulnerability. In a similar vein, O'Brien et al. (2007) distinguish outcome vulnerability from contextual vulnerability. The former refers to the likely residual effect of climate change on an exposure unit after adaptive measures have been taken. Contextual vulnerability focuses on the characteristics of the exposure unit itself. Adaptation to climate change can be aimed at changing contextual conditions or at reducing damage. Similar distinctions are widely discussed in the literature. The resulting diversity of vulnerability definitions has motivated a systematization undertaken by Füssel (2007B). He argues that the distinction between potential adaptation (adaptive capacity) and actual adaptation is also needed to reflect the temporal dimension of climate change. Turner et al. (2003) try to integrate social and biophysical vulnerability by adopting the perspective of coupled social-ecological systems (SES). This brings the concept of resilience into play: Symmetric to the IPCC (2001) they define vulnerability as a function of sensitivity, exposure and *resilience*. The latter is partially determined by adaptation and is seen as related to the concept of

adaptive capacity. In a similar vein, Gallopín (2006) thoroughly analyzes the relations between vulnerability, resilience and adaptive capacity from the SES perspective.

Nelson et al. (2007) also link adaptation to the resilience discourse. They define adaptation as decision-making processes and actions that enhance adaptive capacity. Conversely, they also claim that adaptive capacity encompasses the enabling conditions for adaptation, and is one component of resilience. Last but not least, Ionescu et al. (2008) expend some effort in order to obtain a very precise definition of vulnerability. This approach specifies adaptation as the values of control variables that prevent a system from becoming vulnerable. Adaptive capacity is then the set of possible values that can be selected as adaptations.

The literature that tries to disentangle these different interpretations of vulnerability is quite complex, and some of the above authors critically reflect on whether this effort is indeed productive. The conceptual complexity, in our opinion, arises from the difficulties involved in maintaining the distinction between potential and actual action and, sometimes, from a lack of clarity about whether the primary motivation for the research is prescriptive or analytical. We argue that it would be helpful to concentrate on the basic ingredient of this discourse: adaptations as singular actions that are taken by actors.

While most of the approaches outlined above take a system-oriented view, one can also take an action-oriented perspective. While the former investigates *system properties* that might enable action, the latter focuses on the *purposeful activities* ("adaptations") that moderate harm from climate change. Here, "adaptation is concerned with actors, actions and agency" (NELSON ET AL., 2007, P. 398). In their seminal paper, Smithers and Smit (1997) analyze crucial components of (single) adaptations to climate change. Both the characteristics of climate disturbance and of the affected system are relevant for adaptation. Adaptation is a response to climate change in the form of environmental change or human action. The latter can *inter alia* be distinguished by the intentions of the action (e.g. whether it purposefully or only incidentally addresses climate change) and by actor type (e.g. public or private). A similar analysis is provided by Smit et al. (2000). They pose four core questions. "Adaptation to what?" refers to climate-related stimuli that affect a "sensitive system" or "exposure unit". The exposure unit and its characteristics are specified by answering "who or what adapts?" An exposure unit can both be a biophysical or social entity. It is acknowledged in a short note "… that 'who' and 'what' are not necessarily synonymous. For example, actions by forest managers (who) may result in bio-physical adaptations in a forest (what)" (p. 236), but that relation is not further investigated. The third question is "how does adaptation occur?" and refers to aspects such as the intent, timing, localization and type of measures that are taken. The evaluation of these measures provides the answer to the final question: "how good is the adaptation?" These contributions provide a sound basis for understanding adaptation and propose some crucial variables for adaptation theory. These authors are, however, less comprehensive in drawing conclusions about barriers to adaptation. This requires consideration of the actors and decisions involved in adaptation.

There are some approaches that are more decision-oriented, called adaptation assessments by some authors. Burton et al. (2002) and Lim & Spanger-Siegfried (2004) consider the design of adaptation assessments, where the vulnerability concept is seen as instrumental or "subordinate". Instead, adaptation moves more to the center because there have always been adaptations to climatic *conditions* that offer a starting point for identifying specific adaptations to deal with climate *change*. This could be further refined by being more specific about the systems or actors that adapt, and by refining the conceptualization of the *process* of adaptation. Although several papers informally characterize adaptations as "actions", there is little work that explicitly exploits this framing (but see Bohle (2001) with a reference to Giddens' relationship between structure and agency, and Jetzkowitz (2007), for the norms and conditions that shape adaptive action in a particular application to tourism).

Our paper takes up this thread by introducing an action theory of adaptation. We will refrain from using the difficult terms "vulnerability" and "adaptive capacity". By referring to established theories of action we want to clarify the meaning of adaptation in an applicable way and to derive potential barriers to adaptation. We thus restrict ourselves to adaptations that are made by human actors, in contrast to, e.g., adaptations by eco-systems.

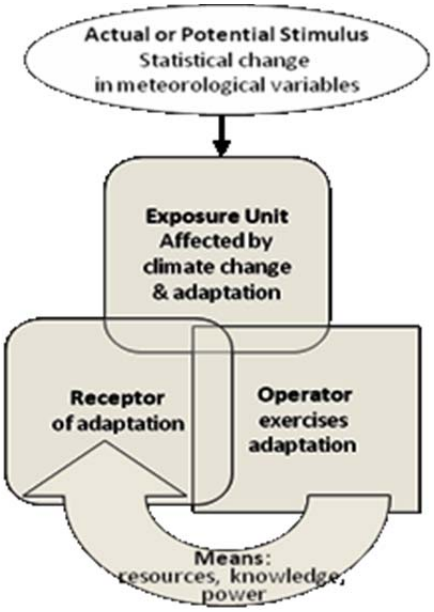
The next section introduces the basic ingredients of the action theory of adaptation and then relates them to other theories. Examples to illustrate concepts are taken from Eisenack et al. (2011). The third section utilizes the theory to derive some generic types of barriers to adaptation, and to analyze some established concepts in adaptation research. We conclude with a critical reflection on the theory, potential extensions and further applications.

2. AN ACTION THEORY OF ADAPTATION

2.1 CORE CONCEPTS

In the IPCC definitions and the analysis of Smit et al. (2000), adaptation is a response to (potential) environmental stimuli that affect given entities, subjects or systems. Adaptations are processes within entities and systems, or adjustments made by human systems. In our approach, we specifically refer only to human individuals and collective actors. This leads to the following outline of the action theory that can partially be built around established concepts (see Fig. 1). Action requires actors and an intention. The intention is directed towards an impact of climate change. Furthermore, adaptations require the use of resources as means to achieve the intended ends. This outline will be detailed and qualified in the following discussion. It is crucial to note here that the theory presented in this section serves as a basic unit of analysis. It describes a core configuration that is meant to be as simple as possible. When complex real-world adaptations are to be analyzed with the theory, the following concepts need to be recombined in different ways to consider multiple interrelated actors.

Fig. 1: Schematic representation of some core concepts of the action theory of adaptation. Boxes with rounded corners can be either actors or biophysical units, while operators are always actors. Operator, receptor and exposure unit are not necessarily identical (indicated by overlapping boxes).



In the theory, a **stimulus** is defined as a change in biophysical (in particular meteorological) variables associated with climate change. In a very precise meaning, this has to be distinguished from weather events. Stimuli can refer to changed values of statistical parameters such as average intensity, frequency, or higher statistical momenta (e.g. variance). Actions must be `actual´ but stimuli may be potential or actual. They can also refer to abrupt large-scale events in the earth system. In many practical cases it is not relevant to insist on this distinction. There is also a difference between strictly meteorological effects, such as temperature and precipitation patterns on the one hand, and more or less indirect effects such as rising sea level or greater frequency of river floods (we further discuss this issue below).

A stimulus is only relevant for adaptation when it influences an **exposure unit**. The latter term broadly refers to all those actors, social, technical or non-human systems that depend on climatic conditions, and are therefore exposed to stimuli (cf. IPCC, 2001). The abstract term is necessary to encompass the broad diversity of affected entities or systems that may be considered in an adaptation assessment. Although we are concerned with an action theory here, we explicitly do not restrict exposure units to human systems.

By an ***impact*** of climate change we understand a combination of a stimulus and an exposure unit. More broadly, it can be a set of stimuli with an associated set of exposure units. For example, reduced energy production of a thermal power plant (exposure unit) due to more frequent scarcity of cooling water (stimulus) is an impact. This is not a quantitative definition, e.g. in terms of a damage measure. Such a measure is not needed in the following, but might be a relevant extension of the concept.

The following example of an adaptation illustrates the different concepts introduced so far. It is likely that a changing climate results, inter alia, in heavier or more frequent

precipitation extremes (the stimulus). Consider as one possible adaptation to this trend a public early warning system that informs about upcoming extreme weather conditions (say, heavy rain) that causes safety problems for specific modes of transport (e.g. travelling by car, bicycle or by foot). The exposure units are users of the above-mentioned modes of transportation.

In our theory, the individual or collective actor that exercises the response is called the **operator**. We need this distinct term, since actors will also play other roles in this theory (see below). An operator can be, for example, a private household, a firm or a government. But in all cases it is a social entity, so that machines, artifacts and natural systems are ruled out as operators.

Not all activities of an operator are actions. Only those activities with a **purpose** qualify for this term. The operator tries to achieve intended ends that are associated with (other) actors, social or non-human systems. The question if the ends need to be ultimately targeted at an exposure unit will be extensively discussed in the next section.

The actor or system that is the target of an adaptation (the purpose) is called the **receptor**. Receptors can be both biophysical entities (e.g. the crops of a famer) and social systems (e.g. the farmer household), depending on the objective of analysis. It is further not required that the receptor of an adaptation is an exposure unit at the same time. This is a crucial point that will become clear in what follows.

We illustrate this with the early warning system example introduced above. The operator is a public body that runs the system. It receives weather forecasts and transmits them to the public in an accessible way. The purpose of that adaptation is to reduce harm to individual transport users (that can decide to use other modes of transportation or avoid travelling in the case of a warning). The intention is to change behaviour of transport users, making them the receptors. The public body is not the exposure unit (it is not affected by heavy rain); the receptors of the early warning system are the exposure units.

The emphasis on the purpose of an action requires further comment. There are, of course, many social phenomena that are not purposeful. In this case, we do not call them actions, but mere processes. Processes are sequences of events in time that may occur in a biophysical, technical or social entity or system. They can be framed as being linked through causality, that is, in a mechanistic way. Actions are a special class of social processes that additionally have a teleological component (cf. WEBER, 1922, and the discussion in the next section).

To implement the adaptation, the operator needs resources, here called **means.** These could be access to financial or other material resources, legal power, social networks, knowledge, or availability of information. Action is further shaped by constraints and resources that cannot be controlled by the operator. These are called the **conditions** (cf. PARSONS, 1937, see next section).

In the example, the primary means employed by the operator of the early warning system is the information that is provided to the receptors. Further means involved are the public funding and the education of the people running the system, but these are not channeled directly to the transport users. As an example of a condition, we can cite the attitudes of the receptors toward the early warning system: Do they actually listen to the forecasts? Do they trust the forecasts? Does the information they are given lead to behavioral change? Another is the institutional and legal context: Is there stable funding for the early warning system? Are operators liable if forecasts are incorrect?

It is helpful to further differentiate three notions of means: ***available means***, ***employed means*** and **necessary *means***. *Available means are those that are disposable by the operator, while the employed means is that part that is actually used for a specific adaptation. That does not imply that the adaptation is effective, since success requires the use of the necessary means – which might be available or not. It is important to note that these three types of means are not necessarily identical.*

In the early warning system, there is probably (unused) capacity to provide more detailed information (available means are greater than employed means). However, the conditions, for example reluctance by the transport users to take heed of the warnings, may additionally require the temporary closure of certain roads to achieve the desired effect – other means than just information are necessary.

2.2 TYPES OF ADAPTATION

Based on the above concepts, further key characterizations can be made. The most straightforward adaptations are those where the receptor is also an exposure unit. The purpose of the action is then to improve the situation of a system that is affected by a climate stimulus. We may call this **direct** adaptation. In contrast, in the case of actions where receptor and exposure unit are not identical, adaptations can be described as **indirect**, in the sense that the action is intended to enable the receptor to take certain measures, and only these are finally targeted at an exposure unit. For example, it might be necessary to provide an actor with resources such that she has sufficient available means. The early warning system is a direct adaptation, since the receptors of the information are the transport users that are exposed to the weather. An indirect adaptation would be, for example, an internal reform of the system to improve its quality. This action is only indirectly targeted at the exposure units. The distinction between direct and indirect adaptation has some similarity to the difference between material and institutional intervention as described by Pelling and High (2005).

Similarly, operators and receptors may or may not be identical. When operators act with the purpose to change something for other actors or biophysical systems, this is called a **facilitating** adaptation (cf. HINKEL, 2007). If the operator's purpose is to change something for herself, we can call this a **reflexive** adaptation. For an adaptation that is both direct and reflexive, the operator, receptor and exposure unit would all be identical. The early warning system is a facilitating adaptation, since it is distinct from the transport users (the receptors of the adaptation).

Investigating the case of the early warning system more closely shows that the public body for information provision was set up by a political administration. This is a further adaptation that can be distinguished from the early warning system itself. The operator is now the political administration, employing legal means and financial resources to set up the public body that now has the role of a receptor. The stimulus and the exposure units that motivate the adaptation are the same as before, but now distinct from both operator and receptor. The action of the political administration is thus an indirect and facilitating adaptation. One can intuitively see that the roles of operators, receptors and exposure units may be combined in various different ways. Actors that appear as operators in one respect may be receptors in another. There can also be multiple operators that act on the same receptor.

One might object that by admitting indirect and facilitating adaptations nearly every action can be classified as an adaptation, since it is not required that adaptations directly improve the situation of an exposure unit towards a stimulus from climate change. Depending on the objective of research we might narrowly consider only direct adaptations, since only those will actually affect exposure units. However, the relevance of indirect and of facilitating adaptations is that they illustrate a basic property of social actions: means and ends tend to come in chains where the effect of one action is the precondition for another one. It might thus be practicable to consider (again depending on the research objective) only those adaptations where at least one means-end chain ends up in an exposure unit. This is, by the way, structurally similar to cause-effect chains that link direct and indirect impacts. It will also depend on the boundaries of analysis whether only first and second order stimuli are considered (e.g. increased precipitation and rising sea level), or also higher order stimuli (e.g. coastal flooding, closed harbor due to flooding, economic losses due to close harbors etc.).

A further distinction relates to the purpose of adaptation and the case where the ultimate exposure unit is not an explicit target of the action. Smithers and Smit (1997) already consider purposeful and incidental adaptations. There are many actions that are not explicitly taken with adaptation in mind, but nevertheless have strong (harmful or beneficial) side effects with respect to consequences of climate change. The purpose of such actions is not linked to any exposure units, neither directly nor indirectly. We propose to call direct adaptations with a purpose targeted at an impact of climate change *explicit* adaptations. An indirect adaptation is also called **explicit**, if the ultimate purpose refers to an impact of climate change. Otherwise, the action is labeled as an **implicit** adaptation. Thus, adaptations where means-end chains do not end up in an exposure unit, but have an unintended co-benefit, can be considered in the analysis as well. Should actions that are only implicitly linked to exposure units be regarded as adaptations at all? The decision again will depend on the research objectives.

2.3 THEORETICAL BACKGROUND

Since the action theory of adaptation was not developed in a vacuum, we shortly want to illuminate its intellectual roots in this section. First, a theory of adaptation requires considering more than social processes alone, as might be appropriate for a purely

socio-economic issue. As the focus is on climate change, we need to widen the scope of our inquiry beyond social processes and actions, since interlinkages to the natural environment are crucial. We have to deal with an interdisciplinary problem of interlinked biophysical and socioeconomic systems. One of the most straightforward options for doing so is to employ the IPCC terminology, where the exposure unit is defined as "an activity, group, region, or resource that is subjected to climatic stimuli" (IPCC, 2001, P. 987), and adaptation is an adjustment of "natural or human systems in response to actual or expected climatic stimuli or their effects". These definitions remain compatible with conceptions of contextual vulnerability used by O'Brien et al. (2007, see introduction), since it is possible to focus on the means and conditions for operators independently from the actual occurrence of a stimulus.

The definition of action as being the subset of social processes ('acts') that are associated with intention is established in analytical philosophy (e.g. WILSON, 2008). The other terminology we employ is rooted in the "action frame of reference" from Parsons (1937), that analyses actions in terms of the actor, the ends, the situation, and the mode of relationship between these elements. The situation is decomposed into the conditions, referring to those elements the actor cannot control, and the means, which can be controlled. Action is further shaped by norms and values. The ends of actions can be made more specific for our purpose, since they are directly or indirectly targeted at actors or systems that are influenced by changing climatic conditions (exposure units). Parsons is criticized for not explaining if and how norms and values are different from each other or not considering how they might change. This critique is valid but not so relevant for our purposes. We recognize that norms and values strongly influence the behaviour of an actor. However, the aim here is not to explain how norms and values evolve, but to compare the outcomes of different actions. Moreover, the action frame of reference is an established starting point for discussing alternative action theories.

Many terms of the action theory of adaptation outlined here can be mapped to the clarifying questions of Smit et al. (2000). "Adaptation to what?" inquires about the purpose of an adaptation in terms of an impact, i.e. a stimulus that affects a considered exposure unit. "Who or what adapts?" asks for the operator, receptor, and their relation to the exposure unit. Finally, "how does adaptation occur?" is answered by providing description of how means and purpose are interlinked, and whether just processes, or even actions are considered.

3. ANALYZING IPCC CONCEPTS

In this section we want to demonstrate how the action theory of adaptation links to some other established concepts of adaptation and vulnerability research. The authors of the IPCC (e.g. 2007) distinguish between autonomous and planned adaptation. The precise meaning is not as clear as it first seems. Füssel (2007A) claims that planned adaptation makes use of information about expected future conditions, while autonomous adaptation does not. For example, ecological changes in natural systems are typically considered as autonomous, while government programs are planned.

However, at least two further interpretations are possible. The difference could be interpreted as being between adaptations as actions (as discussed in this paper) and mere processes that lead to improvements. Alternatively, the term "planned adaptation" could refer to the type of operator, i.e. to the actor category involved. However this seems problematical, since there is a broad spectrum of relevant entities to consider between biophysical entities and governments, e.g. technical infrastructure, companies, markets, local authorities, educational institutions or NGOs. Where is the appropriate place to draw the line between actors that adapt in a "planned" and "autonomous" way? This would need to be defined with reference to the specific research context.

A similar distinction can be made between anticipatory and reactive adaptation (e.g. IPCC, 2007), which is often defined in terms of the temporal dimensions of adaptations (e.g. SMIT ET AL., 2000; FÜSSEL, 2007B). The core of the distinction appears to be the question of whether or not action is taken in advance. How can this be rooted in the action theory? One interpretation relates to the purpose of the action (cf. FÜSSEL, 2007A). For some adaptations there is a substantial time lag between employing the means for the adaptation and its effect. Thus, an adaptation is reactive when it is intended to have effects in the present, and is anticipatory when it is planned to come into effect only in the future (anticipatory adaptation in the "purpose sense"). Alternatively, a distinction can be made between the means available to the operator, in particular knowledge. A reactive adaptation is based on knowledge about the present and the past while an anticipatory one also responds to assumptions about the future, e.g. to climate change projections or scenarios (anticipatory adaptation in the "available means sense"). Finally, adaptation can also be anticipatory in the sense of expectations about means that will become available in the future (anticipatory adaptation in the "conditions sense"). These interpretations are not equivalent. Adaptations that are reactive in the available means sense are likely also to be reactive in the purpose sense as well, since in most cases actions that are planned to take effect in the future will take assumptions about the future into account. In contrast, it is not unlikely that actions that are reactive in the purpose sense are based on anticipatory assumptions about the future. Of course, adaptations can also be anticipatory in both senses. This discussion supports the claim that the distinction often made between anticipatory and reactive adaptation is anything but clear.

A classic IPCC typology of adaptations is provided by Carter et al. (1994). They differentiate infrastructural, legal and legislative, institutional, administrative, organizational, regulatory, financial, research and development, market mechanism and technological adaptations. This are basically means categories that may also be associated with typical operator types.

We finally want to try our best to shed light on the difficulties involved in defining vulnerability and adaptive capacity as set out in the introduction. When adaptive capacity refers to potential adaptation, it might be, in the simplest case, a measure of the available means. However, since we have seen that the available means are unlikely to completely explain the implementation of adaptations, adaptive capacity refers to conditions as well. This aspect was also discussed by Gallopín (2006). In any case we are able to avoid confusion between the statement that adaptive capacity enables

adaptation on the one hand, and the statement that adaptations are reducing vulnerability on the other hand. In the first statement, adaptive capacity considers the means and conditions for action. The second one talks about more complex means-end chains, where an action has the purpose to change the means and conditions for another action.

4. BARRIERS TO ADAPTATION

By applying the concepts introduced in the previous sections we can identify sets of conditions that might limit the implementation of adaptations. That is, we can identify barriers to adaptation. This is closely related to analyzing the governance of adaptation. Mapping adaptation situations by means of the action theory helps to identify those barriers and their underlying reasons that might be addressed by successful rules and institutions. The barriers to adaptation, shown below, outline possible examples for such an analysis. The extent to which they apply in a specific case, is, of course, an empirical matter. We can, nevertheless, expect from the action theory of adaptation that they will be encountered quite often. They may be compared to generic barriers to adaptation proposed by Füssel (2007a), and by the economic analysis of Lecocq and Shalizi (2007):

- *The necessary means are not available although there is an operator*. Although the problem is perceived as urgent (e.g. by exposure units themselves), institutional capacity or budget constraints hinder appropriate adaptation. This is crucial, in particular, for many developing countries that are disproportionally exposed to climate change and already have limited capacities to cope with other severe stresses. In the worst case, failure to adapt due to unavailable means might result in poverty traps. Another variant of this situation is when the legislative framework limits adaptation; that is, when motivated operators do not have the legal power to act.
- *Means are not sufficiently employed although there is an operator to whom the necessary means are available*. When an adaptation has positive externalities for other actors, the operator may choose to under-adapt if she considers that other exposure units that benefit from the adaptation are not contributing their share to the means. Conversely, it might happen that an operator over-adapts when the action has negative external effects on other exposure units. There are also moral hazard situations where perverse incentives encourage actions that increase the impacts of climate change. For example, settlements may be (re)built in areas where there is a high risk of flooding by investors (exposure units) who expect to receive compensation from a public agency (as operator) in the case of a disaster. The roots of this type of barrier lie in misaligned economic incentives.
- *There is no operator due to ignorance of impacts*. Although there might may be a vague awareness of that a problem exists, adaptation is hindered by missing means in terms of individual or collective knowledge about impacts, or due to conditions (such as incomplete or faulty information, or rigid social

habits and normative standards) that prohibit understanding of the underlying stimulus. This hinders adaptation, even though action is not constrained by limited available means.

- *The network of exposure units, operators and receptors is too complex to come to decisions*. Since climate change has very diverse effects that are relevant for many exposure units in different ways, it is likely that there are many decisional conflicts to be. These might be amplified by institutional arrangements that are not tailored to respond to the new challenges posed by climate change. Reckien et al. (2008) show how different types of actor can become entangled in conflicts around adaptations in the transport sector. Moreover, when new problems arise, it is not always *ex ante* clear who the relevant actors are. Economically speaking, all these problems raise the transaction costs of information collection, monitoring and enforcement. This increases the necessary means, and can result in a shortfall of available means.

These proposed barriers also give a flavor of how the action theory can be used to be very precise about further barriers to adaptation, e.g. resulting from different interests of operators and receptors, or specific combinations of indirect and facilitating adaptations.

5. CONCLUSIONS

This paper presents a new way to analyze adaptation to climate change from an action-oriented perspective. Our action theory proposes a way to think about adaptation that emphasizes the interconnectedness of complex activities that address societal consequences of climate change along means-end chains, and considers multiple actors in different roles. It is crucial for analysis to spell out the purpose of adaptations, and to consider that operators and receptors of adaptation may be different from the exposure units. The rigorous definitions provided in our contribution help elucidating prominent types of adaptation in a crisp way. By combining the core concepts proposed by the theory in different ways, and by employing it as a basic unit of analysis to map actor constellations, crucial barriers to adaptation can be deduced and precisely formulated. Identifying the roots of those barriers in terms of the means-end chains between operators and receptors of adaptation, the networks of actors that take different roles, further but unintended receptors, and the resources that are available to them, gives indications about the governance mechanisms that may help to overcome such barriers.

Based on the theory one could define adaptations as individual or collective actions that are explicitly or implicitly intended to affect exposure units of climate change, or that indirectly achieve this end. However, this is still just one possible definition using the terms introduced by the action theory of adaptation. The theory leaves partially open what is to be considered as an adaptation. Depending on the research design or on practical considerations, it may be useful to consider only, e.g., direct or reflexive adaptations. We argue, however, that the theory is in particular fruitful to make precise statements about what adaptations are considered in a concrete context. This

is not only crucial for terminological reasons, but also to operationalize adaptation assessments: The theory makes explicit statements about key variables for understanding the governance of adaptation.

One difficulty is that the approach taken by the action theory of adaptation is very analytic in the following sense. Already Parson's action frame of reference (1937) is intended to analyze a *unit act*. This incorporates the notion of an "atomistic" action unit into which all more complex actions can be decomposed. "Simple" adaptations may be part of more "comprehensive" adaptations. Indeed, a careful investigation of *prima facie* single adaptations from this perspective is likely to reveal a broad bundle of "atomistic" adaptations that are linked together in a kind of "molecule". Similar problems are known from the literature on policy classification (cf. STEINBERGER, 1980): policies are difficult to demarcate (when does a policy begin and end in time?, where does it enter the domain of another policy?, etc.), and classification schemes are known to depend on the frame of reference.

On the other hand, there are further interesting applications of the action theory. As indicated above, the terminology of the operator, receptor and exposure unit can be applied to map complex actor networks. This could provide the basis for understanding adaptation conflicts between different actors, or used to measure transaction costs associated with the coordination of multiple actors in developing and implementing adaptation policies. The theory can also be used to classify and systematize groupings of adaptations (as is done, e.g., in EISENACK ET AL., 2011). There is also room for promising extensions. Parson's action theory gives a prominent role to the norms and values that shape social action. This is currently not discussed by the action theory of adaptation, but could – together with investigation of available means and conditions – improve the analysis of the institutional dimensions of adaptation. Finally, the important role of uncertainty and time in adaptation suggest promising lines of research that give more explicit consideration to how stimuli and means unfold in time, along with the perceptions and beliefs of actors. These remarks illustrate the interdisciplinary potential of the theory, and are a major motivation for its design. Although it is termed an "action theory", the components referring to climate change and to the causal effects of stimuli and actions provide a link between the natural and the social sciences.

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