Title: Institutional analysis in climate change adaptation research: A systematic literature review

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Abstract
Appropriate institutions are essential for climate change adaptation. Yet diverse approaches to institutional analysis are available, encompassing different ontological and epistemological assumptions, and thus yielding insights on very different aspects of institutions in adaptation. Therefore, efforts to expand knowledge in this domain can be usefully informed by an assessment of approaches to institutional analysis in the adaptation literature, which is to date lacking. We address this gap by conducting a systematic review of the adaptation literature addressing institutions. Our review characterises approaches to institutional analysis by identifying methodological choices and the philosophy of science underpinning them. We then analyse the distribution of approaches to institutional analysis across different adaptation situations, contextualizing our results within methodological debates in adaptation research regarding the appropriateness of positivist, interpretative, or post-normal approaches. We find that institutional analysis of adaptation is now engaging with 'how' and 'why' questions, beyond descriptive questions that characterise the adaptation 'barriers' literature, that diverse philosophies of science drive methodological choice, and that post-normal approaches, e.g. co-design approaches, hardly address institutions. We conclude that support for interpretative approaches, and for institutional analysis in post-normal approaches is needed. The latter is important for adaptation planning processes in developing countries under the UNFCCC.

Keywords: adaptation; institutions; governance; philosophy of science; post-normal science

1 Introduction

As climate change adaptation has moved onto policy agendas around the world, implementation has been impeded by various institutional barriers (Biesbroek et al. 2010). Appropriate institutions are thus increasingly seen as essential to advancing adaptation (Eisenack et al. 2014; Moser and Ekstrom 2010), particularly with respect to integrating societal and ecological dimensions (Paavola and Adger 2005). In order to design and shape appropriate institutions, more research to improve understanding of institutions in adaptation is needed (Adger et al. 2009). The recent IPCC AR5 (2014) emphasizes that not only are institutional dimensions of adaptation generally under-researched, but theoretically-grounded empirical research in this area is particularly limited (Wong et al. 2014).

Yet a wide diversity of approaches and theories are available for institutional analysis in adaptation. The social science literature makes clear that these various approaches encompass different ontological and epistemological assumptions, leading to methodological choices that influence the research questions addressed, the types of knowledge produced and explanations invoked regarding a given phenomenon (Grix 2002; Little 1991). For adaptation, such different approaches to institutional analysis can yield complementary insights on very different aspects of institutions. For instance, rational choice scholars may focus on incentives for adaptation created by resource characteristics, e.g. a depleting water aquifer, generating insights regarding the design of institutions for monitoring and evaluating water appropriation (Varela-Ortega et al. 2016). In contrast, anthropologists studying the same situation may focus on the meaning given to a shared water resource in a specific cultural context generating insights regarding power relations in rural communities (Mosse 2006). The particular approach to institutional analysis taken thus influences the development of knowledge on institutions in adaptation. Moreover, as several decades of debate in climate adaptation research, and particularly vulnerability assessment, has shown different approaches and methods can influence policy prescriptions resulting from a study or assessment (O'Brien et al. 2007).

Given this influence, efforts to expand knowledge on institutions in adaptation can be usefully informed by an assessment of approaches to institutional analysis applied in the adaptation literature (Roggero et al. 2017). Indeed, given the diversity of approaches available, important questions are which approaches to institutional analysis have been applied to empirically analyze institutions in the adaptation literature? Which approaches dominate and what are the consequences of such dominance, for example, in terms of giving rise to patterns in methodological choices and limiting particular types of research questions or data collection methods? Further, given that adaptation is heterogeneous involving different configurations of actors at different levels of political and social organization, which approaches to institutional analysis are appropriate for tackling these heterogeneous situations?

To date, an assessment addressing such questions is lacking. Studies of methodological choices in adaptation have addressed the wider transdisciplinary domain, e.g., including climate impact modelling or decision-analysis (Hinkel and Bisaro 2015; Hofmann et al. 2011), without a specific focus on institutional analysis. Some studies have addressed institutions in particular, analysing their role in planning or implementing adaptation, but not addressing methodological issues (Berrang-Ford et al. 2011; Biesbroek et al. 2010). Others have focused on only a limited part of the adaptation literature addressing institutions, i.e. the barriers literature (Biesbroek et al. 2013).

This article addresses this gap, and tackles the above questions by conducting a systematic review of the climate adaptation literature addressing institutions. Our systematic review characterises approaches to institutional analysis, by identifying sets of methodological choices within the literature and the philosophy of science underpinning them. We then quantify the distribution of approaches in the literature, and identify gaps in methodological choices observed. Further, starting from the assumption that different problems may require different approaches and methods (O'Brien et al. 2007, Hinkel and Bisaro 2016) we distinguish between different adaptation situations and analyse the distribution of approaches to institutional analysis across these different adaptation situations.

We are thus able, first, to identify dominant and under-represented approaches to institutional analysis of adaptation. Second, by differentiating our analysis by adaptation situation, we are able to situate our results within broader methodological debates on the appropriateness of positivist, interpretative and post-normal approaches in the adaptation domain (Dessai et al. 2009; O'Brien et al. 2007). Such debates are rooted in long-standing debates in climate vulnerability assessment, e.g. on top-down versus bottom-up approaches (Dessai et al. 2009; Wolff et al. 2013), and appropriate approaches in developing countries contexts for national adaptation planning (Huq et al. 2004) and associated adaptation finance decisions (Persson and Remling 2014). Our assessment thus allows us to draw insights useful to informing future research directions for institutional analysis in adaptation that may be relevant to, e.g., current debates on national adaptation planning in developing countries.

The paper is organized as follows. In the next section, we introduce key concepts, discussing different philosophies of social science underpinning approaches to institutional analysis and their influence on methodological choices. We also introduce the concept of an adaptation situation, and discuss the appropriateness of institutional analysis approaches to different adaptation situations. In Section 3, we describe our methodology. Section 4 presents our results, identifying dominant approaches to institutional analysis, and differentiates these by adaptation situation. Section 5 discusses these results in the context of current debates on the influence of "barriers" thinking on institutional research in adaptation, and on appropriate approaches to supporting adaptation planning in developing countries. Section 6 concludes.

2 Concepts and theory

2.1 Institutions

A key criterion for inclusion of a study in our systematic review is naturally that it analyses institutions (see Section 3). Following Roggero et al. (2017), we understand institutions as shared practices through which individuals address their mutual interdependencies (Paavola 2007), attaching meaning and normativity to particular situations (Vatn 2005). Institutions are thus never "only" a written rule, but also include a "practical" referent, i.e. the practices entailed or influenced by such written rules. Laws, regulations, professional codes, protocols, agreements, standard practices as well as habits, customs, conventions, and traditions, all represent institutions to the extent that they shape individual behavior in a social setting, regardless whether they are formal or informal. In our systematic review, organizations only count as institutions when analysis focuses on their internal rules and practices, as opposed to treating them as single actors (North 1994).

2.2 Philosophy of science and methodological considerations

Different theoretical approaches provide alternative analytical lenses through which the same study object, i.e. institutions, can be explored. An approach to institutional analysis relies on various ontological and epistemological, i.e. meta-theoretical, assumptions, which embody the philosophy of science underlying it (Little 1991). The particular philosophy of science underlying an approach to institutional analysis determines how ontological and epistemological issues are resolved, thus influencing methodological choices, e.g. regarding research questions and data collection methods, in a specific analysis (Rodela et al. 2012). To avoid confusion, it is worth briefly noting here that the term "philosophy of science" can be used in two senses. First, in the general sense, philosophy of science denotes the activity of analysing the conditions required, and assumptions made, in the production of knowledge. Second, in the particular sense, philosophy of science denotes a particular set of meta-theoretical assumptions made by a researcher working within a given approach or discipline. In the remainder of this article, we use the term in the second (particular) sense.

Three principle philosophies of science are salient to social and institutional aspects of climate adaptation: positivist, interpretative and post-normal (McLaughlin and Dietz 2008). To these, we add a fourth category, "descriptive", which is generally prevalent in emerging domains of research (Poteete and Ostrom 2008), including the adaptation literature (Biesbroek et al. 2013; Moser and Ekstrom 2010). Descriptive scholarship can be seen as agnostic regarding core ontological and epistemological issues, as describing adaptation without aiming to provide explanations or evaluations of outcomes obviates the need to take a position on epistemological issues, such as, criteria for establishing causal mechanisms.

We wish to emphasize that these 4 categories – positivist, interpretative, post-normal and descriptive – are not meant to be exhaustive. Further differentiations within and across these categories are possible. For instance, radical constructivism, critical realism, etc. are also taken up in the literature. We would nonetheless argue that these 4 categories generally represent the main contrasting positions with respect to methodological choice in adaptation research and related domains, e.g. vulnerability research (McLaughlin and Dietz 2008).

A further remark is due regarding critical realism in particular because this approach is gaining in importance in environmental science more generally. Critical realism makes the meta-theoretical assumption that the social world consists in open systems, i.e. systems that generally in exchange with their environment (Bhaskar 1978). This implies that the observation of correlations cannot be used to ascertain causal relationships. From a methodological perspective, this implies the need for multiple methods applied to questions of understanding or explaining institutions. In this sense, critical realism is compatible with methodological choices of both positivist and interpretative approaches. Thus, for the research questions addressed here, we do not include it as a distinct category.

Finally, for reasons of space, our discussion of the different categories is necessarily brief and must leave aside nuances and ongoing debates within the philosophy of social science. Rather than aiming to be comprehensive, our aim is to describe key influences on methodological choice from a philosophy of science perspective in order to develop an operational framework for empirically reviewing the adaptation literature involving institutions. The framework developed here is operationalized in our coding described in Section 3.3.

Below we describe each of these four categories of philosophy of science, and discuss their influence on methodological choices. These four categories of philosophy of science are prominent in the adaptation domain (e.g. McLaughlin and Dietz 2008, Biesbroeck et al. 2013, and Moser and Ekstrom 2010). We focus our discussion on methodological choices that have been previously highlighted as varying across different studies in the adaptation domain. These are the choice of: i) research questions addressed (Hinkel and Bisaro 2015); ii) data collection methods; and iii) the role of researcher (Rodela et al. 2012). We do note however that the four categories are not mutually exclusive in terms of the methodological choices they imply; different approaches may in some cases employ similar methods. We elaborate this issue in detail in Section 3.3.

As noted, the philosophy of science underpinning a research approach comprises several meta-theoretical assumptions made by a researcher. One meta-theoretical assumption covers ontology, which describes "the nature of social reality, claims about what exists, what units make it up and how these units interact" (Blaikie 1994). We can generally distinguish between realist and constructivist ontological positions. Realism takes the world to exist external to the human observer, to be observer-independent and accessible via the senses, while constructivism considers the world to consist of observer-dependent phenomena (Hodgson 2006). A second meta-theoretical assumption concerns epistemology, which describes the nature of knowledge about the world. Epistemological assumptions regarding what is possible to know influence the ultimate goals of a particular approach, for example, attaining either universal or contextual knowledge (Bhaskar 1975). Ontology and epistemology are closely related because a researcher's view on knowledge production is naturally influenced by what she assumes to exist. Thus, a realist ontology is associated to *positivist* philosophy of science, whereby the scientific endeavor aims at uncovering empirical regularities in the observer independent world (Popper 1963). Positivism holds that the ultimate goal of science is to produce objective, observer-independent knowledge, often in the form of universal general laws (Little 1991). Positivist approaches to institutional analysis are thus concerned with research questions aimed at explaining or evaluating the performance of institutions. Study designs cover multiple different contexts, and generally do not include single case studies, while data collection is conducted through text analysis, questionnaires, and semi-structured interviews, but generally not through participant observation. The role of the researcher is that of a neutral or learning observer.

Beyond positivism, the logical complement to constructivist ontology is an interpretative epistemology, which aims at understanding actors' interpretation of the world. *Interpretative* social science is concerned with understanding the meaning of social actions or practices to the actors involved. The focus of analysis is on interpretation of the meaning social action acquires through the beliefs, motivations and goals of actors. Interpretation uncovers "a semiotic state of affairs (the way things stand in terms of meaning in a culture or individual)" (Little 1991). Interpretative approaches are concerned with research questions addressing the explanation of institutions and governance processes. Data collection methods involve case study designs in combination with a range of data collection methods, or various study designs using semi-structured interviews or direct observations, e.g. field visits. The role of interpretative social scientists is self-conceived as that of a participant with a constitutive role in knowledge production, i.e. the double hermeneutic (Giddens 1984).

More recent authors have identified the emergence of *post-normal* science (Funtowicz and Ravetz 1993). Post-normal science is characterized by an environment of high uncertainty and addresses questions of high societal relevance in which the stakes of decision are also high. Post-normal

science is thus strongly issue focused, and aims to solve societal problems by providing policy relevant information to decision-makers (Cash et al. 2003). Because of the high societal stakes, post-normal science is subjected to extended quality control that has a strong transdisciplinary character in which stakeholders are directly involved in the research and generating feedback regarding results. It thus favors an action research methodology in which the research questions, or objectives, are concerned not only with producing knowledge, but also with mobilizing knowledge (Lewin 1956). Data collection methods thus are participatory workshops, in addition to semi-structured interviews and other forms of stakeholder elicitation that allows societal actors to shape research questions from an early stage (Rodela et al. 2012). The role of the research is that of an active participant.

Finally, the descriptive approach to institutional analysis is orthogonal to the approaches described above in that it does not propose explanations, e.g., of why barriers emerge in practice (Hinkel and Bisaro 2015). Examples of such descriptive scholarship are found in the literature addressing adaptation barriers. The dominant framing in the barriers literature is that of identifying the "right" or "most important" barrier to design better strategies to overcome these barriers (Biesbroek et al. 2013). This literature tends to address descriptive questions (i.e. "which" barrier), and not questions of explanation (i.e. "why" or "how" institutional barriers emerge) (Eisenack et al. 2014). Evaluation questions are addressed for single cases, e.g. describing a setting in which adaptation did not occur. For data collection, research design tends to be small-n studies, and the role of the researcher is that of an observer.

The key terms introduced in this section are summarized in Table 1.

Term	**Definition**
Institutional analysis	Institutional analysis explicitly analyses institutions, i.e. laws, schemes, conventions, shared practices, habits or traditions, as independent variables, dependent variables, intervening variables or several of these.
Philosophy of science	1. denoting the activity of analysing the conditions required, and assumptions made, in the production of knowledge. 2. denoting a particular set of meta-theoretical assumptions made by a researcher working within a given approach or discipline.
Ontology	Ontology comprises the nature of social reality, claims about what exists, what units make it up and how these units interact (Blaikie 1994).
Epistemology	Epistemology describes the nature of knowledge about the world.
Positivism	Positivism is an approach that aims to produce objective, observer-independent knowledge, often in the form of universal general laws (Popper 1963).
Interpretative	Interpretative approaches aim at understanding the meaning of social actions or practices to the actors involved. The focus of analysis is on interpretation of the meaning social action acquires through the beliefs, motivations and goals of actors.
Post-normal	Post-normal approaches aim to solve societal problems by providing policy relevant information to decision-makers and is subjected to extended quality control that has a strong transdisciplinary character in which stakeholders are directly involved.

Table 1. Definitions of key terms.

2.3 Heterogeneity of adaptation situations

Adaptation is heterogeneous, involving a range of different hazards, sectors, and configurations of public and private actors. Such different configurations of actors imply various roles for institutions in regulating these interdependencies, and thus different approaches may be appropriate for analyzing institutions (Schmid 2004). To structure this heterogeneity, we introduce the concept of an *adaptation situation*, which is closely related to Ostrom's (2005) action situation. An adaptation situation involves one or more actors interacting within a common biophysical and institutional environment in which outcomes are altered through climate change (Bisaro and Hinkel 2016).

Different types of adaptation situation may be distinguished. First, adaptation situations may involve individual or collection adaptation measures. Individual measures involve only one adapting actor, for example, a home-owner flood-proofing her home. In contrast, collective measures involve several adapting actors, for example, users of a shared water resource reducing appropriation when faced with climate change induced water scarcity (Eisenack 2016). Second, adaptation situations may be distinguished based on whether they involve operational, collective choice or constitutional levels (Ostrom 2005).

Operational situations are those in which involved actors directly affect resource or risk levels through their actions, e.g. farmers appropriating groundwater. Collective choice situations are those in which outcomes are institutions (formal or informal) affecting operational situations. For example, collective choice situation may involve members of a water association committee deciding on rules regarding who is allowed to appropriate water and in what amount. Constitutional situations are those in which outcomes are institutions (formal or informal) affecting collective choice situations. To extend the water association committee example, a constitutional situation would involve decisions regarding, for instance, the criteria for membership in the water association committee.

We describe in Section 3 how we attributed the action situation address in each article reviewed.

2.4 Expected approaches to institutional analysis per adaptation situation

Different approaches may be appropriate to different adaptation situations (Schmid 2004), and thus we expect a diversity of institutional analysis approaches to adaptation. Further, we offer a couple of hypotheses, or analytical reasons, regarding the appropriateness of different approaches to types of adaptation situation. We emphasize that these hypotheses are not intended to be prescriptive regarding the appropriateness of a given approach for a particular adaptation situation. Rather, they are meant as heuristics against which to reflect upon tendencies observed in the literature.

A first hypothesis is that, as climate change operates through material, e.g. biophysical, variables, one can expect institutional analyses of adaptation to explicitly account for material variables, e.g. by including such variables in its analytical framework. The operation of climate change through biophysical variables thus provide reason to favor materialist-realist explanation and positivist approaches well-suited to develop such explanations (Bisaro and Hinkel 2016). For instance, positivist-underpinned new institutional economics (NIE) approaches explicitly emphasize material variables, analyzing interdependencies between actors that arise from physical characteristics of a resource, e.g., rivalry in consumption (Ostrom 2005) or jointness in production (Hagedorn 2008, Roggero 2015).

A second and complementary hypothesis is that the need to account for material variables is

mediated by certain characteristics of adaptation situations, which affect the *feedback from the physical system to the involved actors*. Characteristics such as, high uncertainty, long time-lags between actions and outcomes (Schlüter 2007), or low dependency of actors on the resource in question (Schlager et al. 1994) decrease the salience of material variables in explaining outcomes because they weaken feedbacks to actors involved in the adaptation situation (Schlüter 2007). In such adaptation situations, approaches that emphasize ideational variables, e.g. mental models, discourses, power and cultural values can be expected. Analyzing ideational variables is a strength of interpretative approaches.

Taking these two hypotheses together, we expect positivist approaches to be most prominent in operational level adaptation situations involving individual adaptation measures. At the operational level, feedbacks to actors are generally strong, as time-lags between actions and outcomes are short, e.g. in natural resource use, such as agriculture or fisheries. Further, the resource dependence of actors in operational level situations is generally higher than for those in collective choice situations (Agrawal and Perrin 2009). Situations involving individual adaptation measures involve stronger feedbacks because of fewer involved actors, thus reducing complexity in action-outcome linkages for individual actors (Ostrom 2005).

In contrast, collective choice and constitutional situations tend to offer weaker feedbacks, due to longer time-lags between actions and outcomes, e.g., policy cycles last 3-10 years. Situations involving collective adaptation measures also involve weaker feedbacks due to more involved actors and thus greater complexity in action-outcome linkages. For instance, emerging research on the robustness of the Great Barrier Reef governance regime, shows the importance of ideational variables in explaining regime development and change (Morrison 2017). Thus, we expect ideational variables and interpretative approaches to be more prominent in collective choice and constitutional level situations involving collective adaptation measures. These hypotheses are summarized in Table 2.

	Individual adaptation measure	**Collective adaptation measure**
Constitutional / Collective choice	FIA: ++ FPS: Mixed	FIA: + FPS: Interpretative
Operational	FIA: +++ FPS: Positivist	FIA: ++ FPS: Mixed

Table 2. Types of adaptation situation and favoured type of explanation. FIA: Feedback to involved actors; FPS: Favoured philosophy of science.

3 Materials and methods

3.1 Systematic reviews

Systematic reviews, having emerged first in health studies, are increasingly being used in climate change adaptation (Berrang-Ford et al. 2015). Systematic review is generally more formal than other review methods, requiring explicit inclusion and exclusion criteria for materials reviewed, and thus provides additional transparency and reproducibility (Ford et al. 2011). Identifying and

selecting articles for systematic reviews is generally carried out via a combination of automated database queries and manual filtering (Berrang-Ford et al. 2011; Ford et al. 2011; Porter et al. 2014). To reduce the number of articles to a manageable amount, articles are usually filtered using automation on based on titles, keywords, and abstracts. Subsequently, manual filtering is carried out based on full texts of the relevant articles.

Manual filtering removes false positives. Yet when automated filtering precedes manual filtering, however, analyses are prone to false negatives, i.e. excluding articles that should have been included on the basis of their contents, but were not formulated in such a way to be identified via titles, keywords and abstracts. This problem is particularly acute here, since "adaptation" can be expressed in various ways or be implicit to the analysis. For instance, in the disaster risk reduction community the label "mitigation" is used to denote activity that reduces climate risks, which in the climate community has a very different meaning, namely, that of reducing greenhouse gas emissions. Furthermore, how agricultural practices adjust to climate variability is a staple of agricultural economics, but may not be termed adaptation, though highly relevant to the present analysis.

Addressing the issue of false negatives ideally requires eliminating the automated filtering. However, manual filtering thousands of articles obviously runs into hard resource constraints. We thus propose to work around the problem and focus on the adaptation articles referenced in the most recent IPCC Fifth Assessment Report (AR5) currently available. Specifically, we focus on peer-reviewed scientific journal articles referenced in the adaptation chapters (Chapters 14-17) of the Working Group II contribution. Articles included in AR5 Working Group II had to be accepted for publication by August 31, 2013. The role of the IPCC is "to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation" (IPCC 2013a). Key criteria IPCC chapter authors are expected to observe in synthesizing the literature include relevance and quality (IPCC 2013b). Articles referenced in the IPCC reports can thus be safely considered a representative subset of the current adaptation literature.

There are naturally limitations with this approach that should be noted. First, representativeness of the IPCC sample is limited for several reasons, including geographical distribution of authors (Corbera et al. 2016), or disciplines (Carey et al. 2014). Further, using AR5 to identify articles results in a time-lag between the cut-off for published articles and the present analysis. Thus, the present analysis provides a picture of methodological choice for institutional analysis of adaptation with some delay. However, such limitations are difficult to avoid given the resource intensive nature of systematic reviews. The results here thus should be treated with caution regarding their representativeness. The analysis does however provide a relevant benchmark of the field prior to AR5.

3.2 Data collection and selection

The IPCC AR5 chapters on adaptation reference 1124 journal articles, which is still beyond the available resources to manually filter. We therefore further restricted our sample to articles between 2010 and 2014, in-line with other systematic review procedures to ensure feasibility (Berrang-Ford et al. 2015), giving us 533 articles. We sought full copies of these 533 articles, either through open-

access means, university subscription services or contacting authors directly, obtaining all but 15 full articles.

We then filtered articles based on the full texts. We excluded articles that did not conduct empirical analyses. By empirical analysis, we mean analysis of indirect or direct observation or experience of adaptation in a real-world setting. Thus, theoretical or conceptual articles were excluded, as were letters, editorials, opinions, book reviews and commentaries. Meta-analyses, reviews and summaries were also excluded, as they encompass analyses of analyses, and therefore cannot be tied to a particular underlying philosophy of science, nor to a particular empirical adaptation situation. As a general rule, articles that provided less than one page of empirical materials were excluded. This filtering procedure led to a set of 336 articles.

From this set, we then identified articles addressing institutions based on Hinkel and Bisaro (2015), who classify approaches to adaptation based on the class of variable addressed. They distinguish between impact analysis, behavioral analysis, institutional analysis and decision analysis. Impact analysis, for instance, assesses the effects of climate variables on socio-economic and biophysical variables, e.g, crop productivity or water availability. In contrast, behavioral analysis explains human behavior through the cognitive variables, e.g., perceived or experienced climate change.

Institutional analysis explicitly addresses institutions (Hinkel and Bisaro 2015). Two aspects are important here. First, a study counts as an institutional analysis when institutions are explicitly articulated variables. In an institutional analysis, institutions may be independent variables, dependent variables, intervening variables or several of these. For instance, institutional analyses may explain particular institutions as an outcome of climate impacts. Alternatively, institutional analyses may explain adaptation outcomes as influenced by institutions in a particular setting. Second, based on our definition of institutions, articles were considered "institutional analyses" if they address laws, schemes, conventions, shared practices, habits or traditions. Articles that linked behavior directly to biophysical phenomena without reference to institutional variables were excluded, e.g. farming choices to changes in precipitation patterns (Zhang et al. 2013). Although institutions are certainly present in the situations analyzed by such studies, they were not explicitly analyzed and therefore we did not consider such articles institutional analyses.

The selection process led to a set of 128 papers for in-depth analysis (see Supplementary Materials).

3.3 Coding

Each paper was coded in terms of methodological dimensions and adaptation situations, based of literature reviewed in Sections 2.2 and 2.3. The codebook contained 7 methodological dimensions and 2 dimensions for adaptation situation (see Supplementary materials). The key methodological dimensions are: i) type of research questions addressed; ii) data collection methods; and iii) the role of researcher. Data collection was further differentiated in 5 key dimensions of methodological choice: study design; sample selection; data collection methods; stakeholder role in problem definition; stakeholder role in data collection (Rodela et al. 2012).

The adaptation situation addressed in a given paper was coded by the level of analysis it addressed, i.e. operational, collective or constitutional choice levels. For instance, a paper that analyses national adaptation strategy development (e.g. Biesbroek et al. 2010) is coded as a collective choice

situation, as the strategies, which themselves collections of rules, and thus institutions, are outcomes of a collective choice adaptation situation in which multiple actors interact to produce a set of rules governing operational adaptation situations, e.g. regarding resource use in different sectors. In contrast, a community using natural resources based on its communal practices (Adhikar and Taylor 2012), where community rules and norms (i.e. the institutions) influence resource use, is coded as an operational adaptation situation, because actors interact to make resource use decisions while being influenced by existing institutions.

The coding proceeded iteratively between June 2015 and July 2016, with around 40% of the papers (53 of 128) assigned to two authors of the present article so as to ensure reliability. The iterative coding allowed authors to discuss conflicting entries, revisit their own coding, and develop a shared understanding in order to reliably code the remaining papers individually. The remaining 75 papers were thus coded by one of the three authors of this article. In a final step, remaining conflicting coding was resolved through randomization. Randomization was applied when the instances of conflicting codes were low enough for the randomization method not to significantly affect the results (Lombard et al. 2002) (see Supplementary materials).

3.4 Data analysis

The coded papers produced a first set of results, i.e. the distribution of methodological choices in the coded literature, including across different adaptation situations (see Supplementary Materials). We then conducted further analysis to identify the philosophy of science underpinnings of methodological choices observed.

Identification of the philosophy of science underpinnings was conducted in two steps. The first step consisted in an inductive analysis. We tallied the number of instances for all combinations of the 7 methodological variables producing a list of all occurring combinations from the most to least frequent. In a second step, we then grouped the most frequently occurring combinations according to the philosophy of science underpinning they were consistent with, in line with Rodela et al. (2012). This second step was no longer a purely inductive step, as it was informed by the conceptual discussion of philosophy of science approaches in Section 2.2, whereby we attributed to particular category of philosophy of science a set of methodological choices consistent with it.

Let us note two limitations of our methodology. First, the philosophy of science categories described above were not operationalized in a mutually exclusive way. That is, several combinations of these dimensions are consistent with more than one philosophy of science identified. The analysis may thus have an ambiguity problem, where particular articles fall into multiple philosophies of science. Yet, “ambiguous” articles amount to only 5% of the overall set of articles for in-depth review (see Figure 1). This means that the way the four philosophies of science were operationalized capture rather sharply the methodological differences between the articles at stake.

Second, the four philosophies of science where operationalized in rather narrow terms. A loose, broad operationalization would create false positives: articles that do not belong to a particular group but happen to fit into the corresponding operationalization. Conversely, a narrow operationalization generates false negatives – articles that belong to a particular group but do not fully fit into the corresponding operationalization. Further, we did not include further philosophy of science categories, e.g. critical, radical constructivist, because we found those included are most

salient for current methodological debates in adaptation, e.g. regarding inclusion of social science knowledge (O'Brien et al. 2007; Dessai et al. 2009) or explanatory approaches (Biesbroek et al. 2013). One would thus expect a low coverage of the articles considered.

Surprisingly, coverage is reasonably high: only 17 articles out of 128 articles (13%) did not fit any of the four categories. This is, at first, a very good sign for the validity of the analysis. Moreover, we find it unlikely that the philosophies of science not considered here, such as critical realism and radical constructivism, would account for these uncategorized articles. This is because such philosophies of science advocate multiple methods. As such, in the specific set-up of the present analysis, they are more likely to represent what we defined above as "ambiguous" articles, rather than articles with completely different methodological attributes. These are indeed observed, and prove to be marginal. In these respects, the 17 "outliers" we observe here are more likely to represent the unavoidable false negatives caused by the narrow definition of the categories at stake.

The sets of combinations of methodological choice that could be associated to a philosophy of science are expressed using Boolean logic in Table 3. Thus, each row of Table 3 presents a combination of methodological choices associated to the philosophy of science approach in that row. Taking the first row as an illustrative example, we apply the positivist label to any article that takes as a 'research question type' 'governance explanation' or 'governance evaluation'; any 'study design' other than 'single case'; any 'data collection' method other than 'direct observation' or 'unobtrusive observation'; and any 'researcher role' other than 'activist'.

[TABLE 3]

4 Results

4.1 Distribution of approaches to institutional analysis

The results regarding methodological choices in all papers are presented in the Supplementary Materials. One result of note is some diversity in study design, as single case studies (44%) do not strictly dominate and multiple case-studies are in fact more prevalent (51%).

Figure 1 (left panel) shows the distribution of approaches to institutional analysis in the reviewed sample. The results have been obtained by applying inductive and deductive reasoning procedure described above (see Table 3) to sets of methodological choices in the reviewed papers. As noted, the classifications in Table 3 are not mutually exclusive, nor comprehensive. We therefore added the categories "Ambiguous" and "None" respectively.

[FIGURE 1]

Overall the descriptive approach is the most prominent with 37% of studies, as a lower bound, taking this approach. This is not a surprising result and is consistent with the general observations in the literature regarding the prominence of the adaptation barriers approach (Moser et al., 2010, Biesbroek et al. 2010). Moreover, of the papers taking this approach, the most common combination was that of governance description based on text or document analysis, also consistent with other authors (Biesbroek et al. 2013).

Positivist approaches are the next most prevalent category. They make up 32% of the sample and 51% of non-descriptive approaches. This is in-line with our hypothesis that materialist approaches are appropriate for institutional analysis of adaptation. Beyond such analytical reasons, the prevalence of positivist approaches may also reflect the pull of modeling approaches, such as, e.g, integrated assessment modeling (Rotmans and Dowlatabadi 1998), which are widely used in adaptation research and demand quantitative inputs (Bisaro et al. 2016).

Interpretative approaches make up 12% of the sample and 19% of non-descriptive approaches. This relatively lower prominence may be explained by the same reasons given for the prevalence of positivist approaches, namely, that material considerations are less directly accounted for within interpretative approaches, and that such approaches are less easily reconciled with climate impact modeling.

Surprisingly, post-normal approaches are hardly represented. This is particularly unexpected because of the well-established scholarship on community-based adaptation (Reid et al. 2009), which takes up methods such as participatory rural appraisal and rapid vulnerability assessment (Chambers 1994), is grounded in a post-normal philosophy of science (Whyte 1991). Our findings show that post-normal approaches generally tend leave institutions out of the explicit analysis. We discuss the implications these findings in Section 5.

4.2 Approaches to institutional analysis per adaptation situation

We now assess the distribution of approaches to institutional analysis across adaptation situations, and compare these to our baseline distribution in the entire sample (shown in Section 4.2). We focus

on three types of adaptation situation (defined in Section 2.3) in which the vast majority (n=118) of institutional analyses were situated: collective measure*collective choice, collective measure*operational choice, and individual measure*operational choice. Other types of adaptation situation were hardly addressed. Notably, hardly any approaches addressed constitutional level situations (n=5).

Based on the hypotheses introduced in Section 2.4, we expect positivist approaches to be particularly prominent at the operational level. At the collective choice and constitutional levels, we expect ideational explanation to be more important and therefore expect interpretative approaches to be relatively more prevalent.

A note of caution is however in order regarding assessing approaches for a given adaptation situation compared to the entire sample: far more studies analyzed the collective measure*collective choice level (n=82), compared with the operational choice level (n=36). Thus, the overall distribution in the literature is significantly influenced by the collective choice situation. By the same token, due to the relatively small sample size for the operational level, observations of over or under-representation of approaches at this level must also be treated with caution.

Figure 1 also shows the distribution of approaches for the collective measure*collective choice adaptation situation (centre panel) and for the operational choice level (right panel). For the collective measure*collective choice situation, we see little difference from the entire sample distribution, which, as noted, is not a surprise. The main difference from the entire sample is that the descriptive approach is represented in the slightly greater proportion, and interpretative approaches are slightly under-represented. Positivist approaches are the same compared to the baseline. These are surprising results because our hypothesis is that the longer time-lags, and lower direct resource dependence present in collective choice situations favor interpretative approaches.

Regarding the operational level, we see wider variation from the entire sample distribution. In particular, a surprising result here is the over-representation of interpretative approaches (17%). Descriptive approaches are also slightly over-represented with 39% compared to baseline (37%), and positive approaches (36%) are over-represented relative to baseline (32%). However, this must be qualified by the observation that the descriptive approaches are somewhat dominant at this level of analysis. Excluding the descriptive approaches, we can see that both interpretative (27%) and positivist approaches (59%) are over-represented as a share of the non-barrier approaches relative to baseline (interpretative 19% and positivist 51%). This is due to the fact that post-normal approaches are not present at all. Thus, we find that positivist approaches are more prevalent at the operational level, amongst non-descriptive approaches, which is consistent with our hypothesis regarding operational level adaptation situations. Regarding interpretative approaches, their prevalence at the operational level shows that the mechanism leading to under-representation of interpretative approaches is more influential in collective choice situations. We discuss explanations for these observations below (Section 5.2).

For post-normal approaches, we would expect these to be more prevalent at the local level, where the community-based adaptation perspective has advocated such approaches. Instead, we find the opposite offering support for the notion that these approaches generally do not explicitly consider institutions at all.

5 Discussion

5.1 Insights regarding current methodological debates on institutional analysis of adaptation

One general insight emerging from our results relates to the stage of development of the institutional analysis of adaptation as a research domain. A long-running debate exists regarding whether adaptation constitutes a distinct domain (Patt 2013) and to what extent terminology and research objectives are commonly shared by the broader research community (Smit et al. 1999; Patt et al. 2005; O'Brien et al. 2007). However, the specific focus on institutions within the adaptation domain is more recent (Wong et al. 2014), thus an open and pertinent question is whether the study of institutions in adaptation is perceived by active scholars to be a well-defined area. In this regard, the diversity of study design methods we observed – that is, beyond single case studies – is instructive. The prevalence of single study designs generally occurs, when a research domain is not yet well-defined. Researchers encounter difficulties in developing shared terminology and common research objectives (Janssen and Ostrom 2006). Under such conditions, co-operative research undertakings are difficult, and single case studies often represent the limit of what individual researchers can undertake (Poteete and Ostrom 2008). The variety of research designs in our results supports the view that a well-defined adaptation research domain on institutions is taking shape. We note however that these findings are tentative. Follow-up to explore reasons for the observed methodological choices, e.g. through interviews among scholars, is desirable.

Our results also have implications for improving understanding of the role of institutions in adaptation. Here, one prominent current debate concerns the appropriateness of barriers thinking as a way forward in adaptation research. On one hand, some scholars have advocated expanding and deepening the focus on barriers, further exploring the interaction of different barriers and explanations for their emergence based on e.g., agency or interdependence (Eisenack et al. 2014). On the other hand, Biesbroek et al. (2015) have criticized barriers thinking as overly-reductionist and thus limiting understanding of governance and institutional processes that are crucial for success in implementing adaptation. These critics argue that dominance of barriers thinking in institutional analysis of adaptation limits its relevance for informing adaptation policy and practitioners; the barriers approach being limited in addressing 'how' and 'why' questions essential for informing policy.

Our results shed some light on the salience of this debate and on the impact of barriers thinking on institutional analysis of adaptation in general. We found that the "mainstream" research design identified in our results was not based on single case studies, which is generally the predominant study design in the barriers literature. (Biesbroek et al. 2013). Many approaches are being carried out that do not appear to be influenced by barriers thinking. Therefore, the concern that the dominance of 'barriers thinking' currently limits the relevance of institutional analysis of adaptation appears to be overstated.

Other drivers of methodological choices in institutional analysis of adaptation may be more influential than barriers thinking. Indeed, our results provide some quantitative data showing that ideational approaches with a greater emphasis on explaining and understanding dynamics of governance and institutions (Cashmore and Wejs 2014) and policy and decision-making processes (Dowd et al. 2014) are being taken up in institutional research on adaptation. This implies that "barriers to adaptation" frameworks (e.g. Moser and Ekstrom 2010, Eisenack et al. 2014) may be appropriate for integrating across different case studies because it does appear to limit the application of ideational or other approaches to understand institutions, as argued by Biesbroek et

al. (2015). These results of course must be treated with caution, due to the reasons discussed above, including relatively small sample size.

We do however note that while our results show a diversity of approaches generally, we also found that ideational and interpretative approaches were somewhat under-represented particularly at the collective choice levels. Looking forward, this observation gives some cause for concern both due to the arguments of Biesbroek et al. (2015), and the tendency of modeling approaches to privilege positivist approaches. Therefore, research policy should aim to support ideational approaches, e.g., through research funding and other incentives.

5.2 Implications for future research on institutions in adaptation

Section 4.3 on the distribution of approaches across adaptation situations illustrated tendencies in the literature. Here, in light of our hypotheses in Table 2, we propose tentative explanations for these tendencies, and draw implications for future research. Of particular interest are: i) the observed over-representation of the positivist approaches at collective choice level; and ii) a near absence of post-normal approaches at both levels, and complete absence at the operational level.

Regarding i), one potential explanation of the over-representation of positivist approaches at the collective choice level is the push in interdisciplinary adaptation research to produce research results that can be used in conjunction with climate impact models. Climate impact models favor quantitative inputs and integration with such models favors positivist social science approaches, e.g. indicator-based approaches (Hinkel 2011). Importantly, this push generally only applies to collective choice, i.e. policy, levels because the operational level tends to involve geographical scales that are too fine-grained to be meaningfully addressed by current climate impact modeling (Dessai et al. 2009).

The implication for future research is that, in light of under-representation of interpretative approaches at the collective choice level, there is a need to promote research focusing on ideational explanations and interpretative approaches. Such ideational approaches are available, for example, in the institutional economics approaches that analyze environmental problems through the lens of complex socio-ecological systems (Marshall 2013) and thus incorporate institutional path dependencies that arise in complex adaptive systems (North 1994). These have yet to be extensively applied to adaptation.

Regarding ii), these results imply that post-normal approaches tend not to address institutions when applied to adaptation. This was a surprising result at the operational level because institutions have consistently been found to be important in operational adaptation outcomes, e.g. shaping livelihood strategies of vulnerable households (Argawal and Perrin 2008), influencing flood risk reduction decisions (Grothmann and Patt 2005) or shaping co-ordination between actors (Roggero 2015).

At the operational level, post-normal approaches to adaptation encompass action research approaches, such as, participatory rural appraisal and rapid vulnerability assessment. One potential explanation for why these approaches tend to ignore institutions in adaptation is that institutions are particularly difficult to discuss in the group settings used by such methods. Discussion of informal institutions in particular, e.g. culture or informal networks, may be inherently difficult due to power dynamics and other social factors in group settings (Stringer et al. 2009).

At the collective choice level, post-normal approaches encompass participatory decision methods, such as, multi-criteria analysis. Such methods are more data and resource intensive than those applied at the operational level, often incorporating scientific results, e.g. from climate impact or integrated assessment models (Bisaro et al. 2016). A potential explanation for why such approaches tend not to include institutions is similar to push for integration with climate impact modeling mentioned above: such methods downplay the role of institutions because of the push for quantitative data needed for integration with climate impact modeling (O'Brien et al. 2007; Dessai et al. 2009) and for the same reason, they tend to limit the set of measures considered to technical measures amenable to economic cost-benefit analysis, as opposed to 'soft' institutional measures (Bisaro 2015).

This is an interesting result in the context of current discussion on adaptation finance for developing countries. Critics of the United Nations Framework Convention on Climate Change (UNFCCC) processes of support to developing countries have argued that the inclusion of such participatory methods in conjunction with climate impact models in, for example, National Adaptation Plans Technical Guidelines (LEG 2012), favor funding of technical or infrastructural measures and downplays measures with a strong institutional dimension, e.g. 'soft' capacity building measures (Persson and Remling 2014). Critics argue this is a missed opportunity because soft institutional and capacity measures can help solve collective action problems around shared resources, such as, water aquifers or coastal protection infrastructure, that often characterize adaptation (Bisaro and Hinkel 2016). While to be treated with caution, our systematic review lends supports to these critics, whose analysis is largely based on a small number of cases, and thus provides robustness to this criticism of participatory decision-making methods in adaptation.

The implication for adaptation research policy is that greater support should be provided for analyzing institutions in such post-normal participatory approaches at operational and collective choice levels. This support includes providing tools and techniques, as well as incentives to individuals and within the design of research funding programs.

6 Conclusion

This article has carried out a systematic review of the adaptation literature focusing on institutions. Our review is motivated by, on one hand, the increasing recognition of the key role of institutions in climate change adaptation, and on the other hand, the current lack of assessments of approaches and methodological choices for institutional analysis of adaptation beyond the barriers literature. Our review identified 7 dimensions of methodological choice, and linked combinations of these choices to the philosophy of science underpinning an approach to institutional analysis. By doing so, we identified dominant and under-represented approaches to institutional analysis in the adaptation literature. We further analyzed the distribution of approaches to institutional analysis across the different adaptation situations, finding an under-representation of ideational explanations and interpretative approaches at the adaptation policy level (i.e. collective choice or constitutional level), and an under-representation of post-normal approaches across all adaptation situations.

Our results have implications for current methodological debates on appropriate approaches to institutional analysis in adaptation research. First, our results shed light on current debates regarding whether "barriers" thinking represents an approach that should be expanded and deepened, focusing further on explaining the emergence of barriers and how to overcome them, or whether the "barriers" approach should be discarded altogether because it is overly restrictive for understanding institutional processes. We found that concerns regarding the dominance of "barriers" thinking are as yet overemphasized and a diversity of philosophy of science underpinnings, beyond barriers thinking, are present in the literature.

Second, our results shed light on current discussions regarding participatory methods in adaptation assessments carried out by developing countries in the frame of the UNFCCC. We found that such participatory approaches hardly address institutions, and more generally that ideational and interpretative approaches are under-represented at the policy level (i.e. collective choice or constitutional level). The implication is that, given the recognized key role of institutions in adaptation, more support should be given for analyzing institutions in such adaptation assessments. While we discussed several explanations for this observed relative lack of ideational approaches, further research is needed to better understand drivers of methodological choice, and to design appropriate adaptation research programs and incentives to address trends observed here.

Finally, most generally, we find that analytical reasons are not the only driver of methodological choices. Therefore, adaptation research policy can, through well-designed research programs and incentives, support progress towards developing more theoretically-grounded social science approaches to the role of institutions in climate change adaptation.

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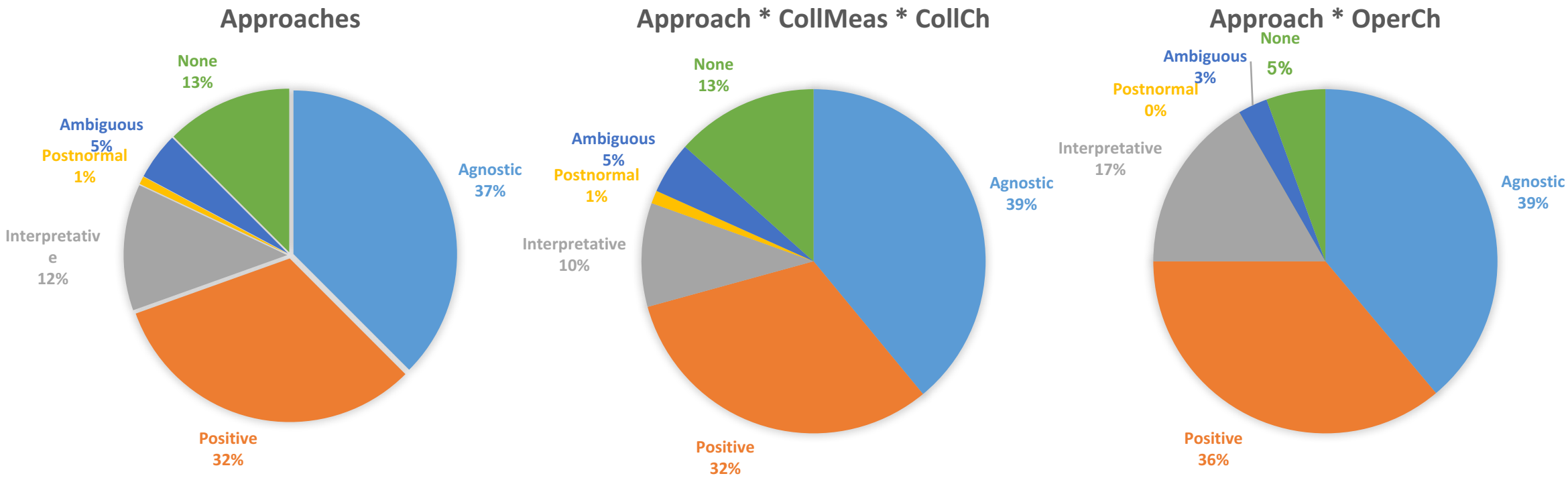

*Figure 2. Distribution of approaches to institutional analysis for the entire sample (left panel), for collective choice*collective measure adaptation situations (centre panel), and for operational adaptation situations (right panel).*

		Methodological dimension					
		Research question	**Study design**	**Data collection**	**Stakeholder role in data collection**	**Stakeholder role in problem definition**	**Researcher's role**
Philosophy of science	**Positivist**	Gov. Explanation *OR* Gov. Evaluation	*NOT* Case Study	*NOT* (Direct Observation *OR* Unobtrusive Observation)			*NOT* Activist
	Interpret-ative	Gov. Explanation		Semi-structured Interviews *OR* Direct Observation		Researcher+Community *OR* Researcher+ Community+Policymakers	*NOT* Activist
		Gov. Explanation		Semi-structured Interviews *OR* Direct Observation	Community *OR* Researcher+ Community		*NOT* Activist
		Gov. Explanation	Case Study				*NOT* Activist
	Post-normal	Gov. Evaluation *OR* Not Applicable	Case Study			Researcher+Community *OR* Researcher+ Community+Policymakers	
							Activist
	Agnostic	Gov. Description					
		Gov. Evaluation	Case Study	Text Selection			

Table 3. Possible combinations of methodological dimensions per philosophy of science underlying approach to institutional analysis. Italics indicate a Boolean operation (e.g. OR, NOT).

Supplementary materials

Article Title: Institutional analysis in climate change adaptation research: A systematic literature review

Journal: Ecological Economics

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1 Article selection

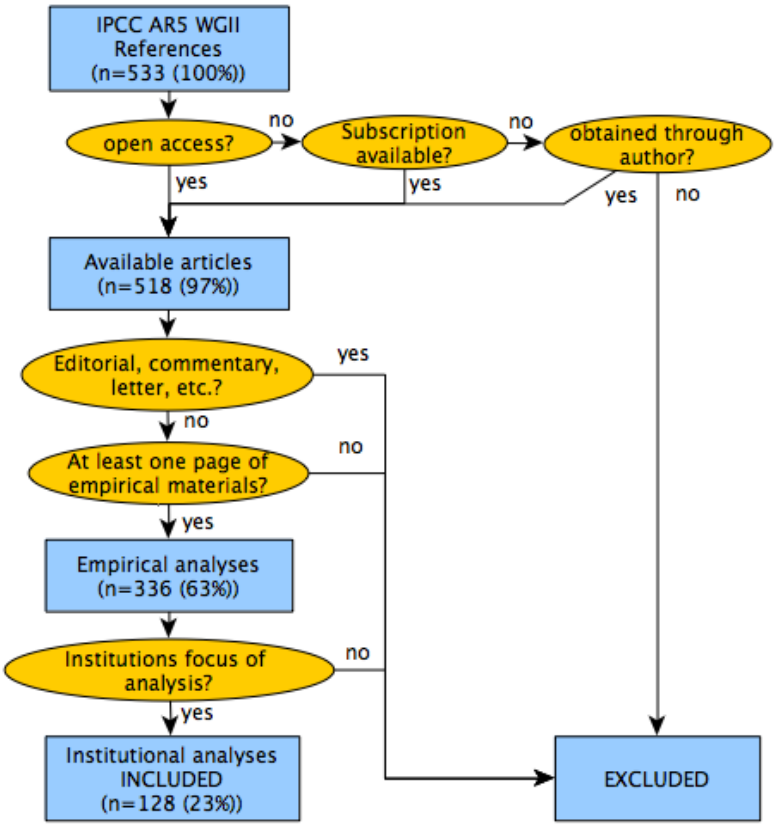

Figure 1: Article selection steps.

2 Codebook

Table SM.1 presents the codebook developed on the basis of literature reviewed (Rodela et al. 2012; Hinkel and Bisaro 2015).

Variable name	Value	Value label
Research question type	0	Not applicable
	1	Governance description only
	2	Governance explanation
	3	Governance evaluation
Study design	0	Not applicable
	1	Case study
	2	Multiple-case study
	3	Experiment
	4	Longitunidal
	5	Report/analysis of completed research
Data collection method	0	Not applicable
	1	Interviews unstructured
	2	Interviews semi-structured
	3	Observation direct
	4	Observation unobtrusive
	5	Text selection
	6	Questionnaire
	7	Not revealed
Sample selection	0	Not applicable
	1	Not revealed
	2	Random sampling
	3	Non-random sampling
Subjects involved in research problem definition	0	Not applicable
	1	Researcher alone
	2	Researcher + community
	3	Researcher + policy-makers
	4	Researcher + community + policy-makers
Subjects involvement in data collection	0	Not applicable
	1	Researcher alone
	2	Community
	3	Researcher with community
Researcher's role	0	Not revealed
	1	Neutral outsider
	2	Participant
	3	Learning agent
	4	Activist
Level of analysis	0	Operational choice
	1	Collective choice
	2	Constitutional choice
Individual/collective	0	Individual adaptation
	1	Collective adaptation

Table SM.1. Codebook.

3 Coding process

Table SM.2 shows the number of conflicts between coders that arose for a particular methodological dimension, and the method from resolving these conflicts. Random assignment was used for dimensions where the number of conflicts was low (Lombard et al. 2002).

Dimension	**Number of conflicts (%) (n=128)**	**Method for resolving coding conflict**
Research question (M2)	26 (20.3%)	Discussion
Study design	9 (7.0%)	Random assignment
Data collection	10 (7.8%)	Random assignment
Sample selection	6 (4.6%)	Random assignment
Stakeholder role in problem definition	13 (10.2%)	Random assignment
Stakeholder role in data collection	16 (12.5%)	Random assignment
Researcher's role	29 (22.7%)	Discussion

Table SM.2: Dimension, number of conflicts and method for resolving code.

4 Descriptive statistics of methodological choices

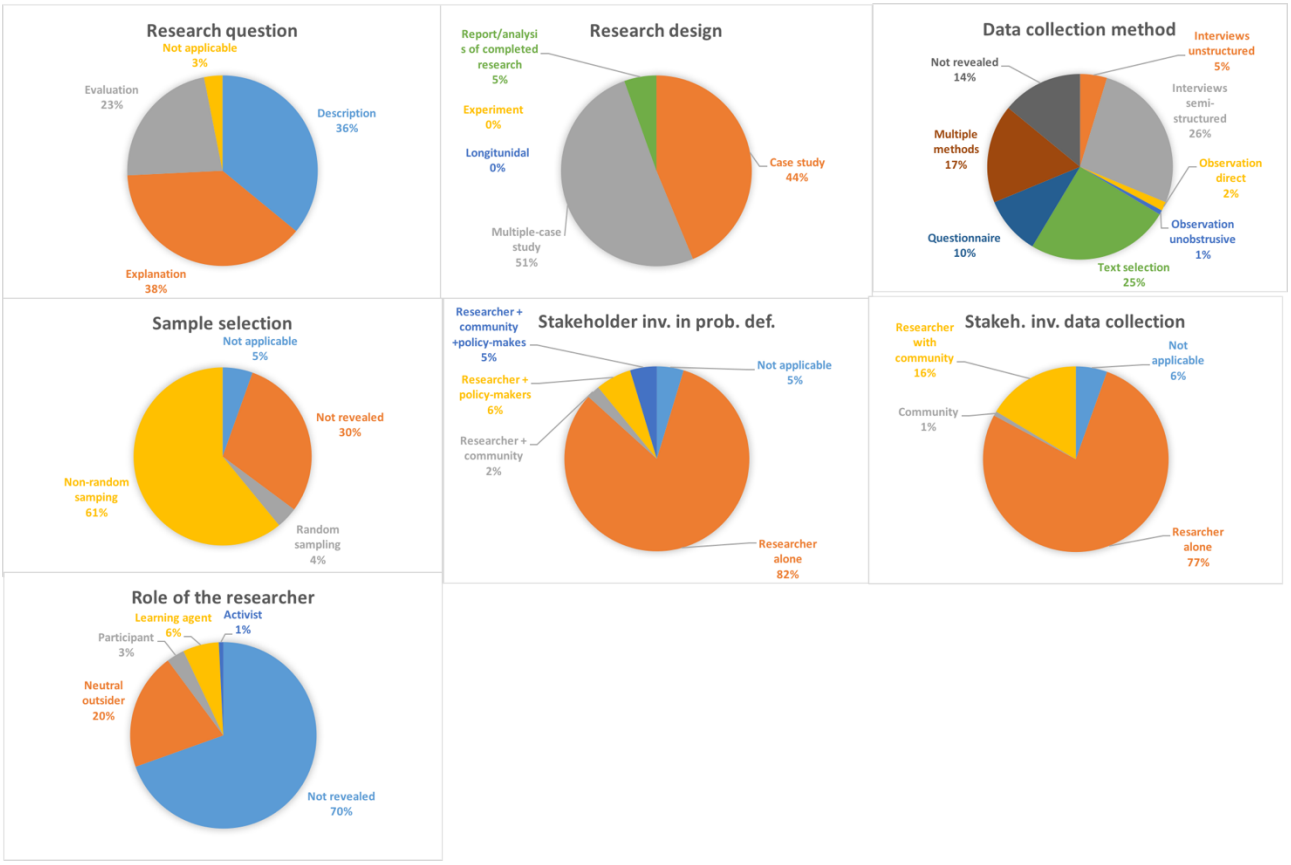

Figure SM.1: Distribution of methodological choices for entire sample.

Figure SM.1 shows how the 128 papers score in terms of the 7 methodological choice dimensions. Based on these results, a picture of the methodological choices articles tend to make *in average* emerges. The results suggest a "mainstream" approach to methodological choices, characterized by multiple case-studies, chosen in purposeful ways (non-random sampling) explored from the point of view of the researcher (problem definition and data collection by the researcher alone), usually without self-reflection (role of the researcher not revealed). Indeed, almost half of the reviewed articles feature at least four of these five characteristics (43%).

Two further results to highlight relate to study design choices. First, Figure 2 shows that, while important, study design is not strictly dominated by single case studies (44%), and multiple case-studies are in fact more prevalent (51%). Second, Figure 2 also reveals gaps, as longitudinal studies and experimental designs are completely absent in the sampled literature.

5 List of articles carrying out institutional analysis

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