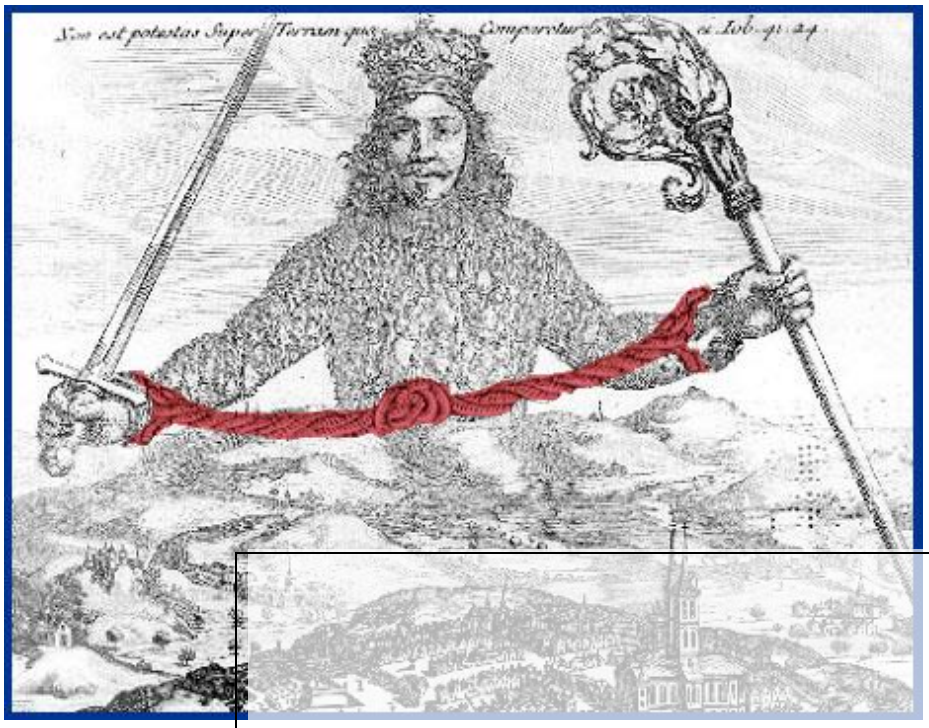

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Institutional Diagnostics of Climate Adaptation

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Abstract

Institutions are one of the decisive factors for climate adaptation. Nevertheless, current understanding of the institutions-adaptation-nexus is fragmented across the scientific community; is often theoretically ad-hoc or eclectic and at times contradictory. Moreover, knowledge claims are typically raised either for specific cases or overly generic, whereas a diagnostic method may be most effective for cross-case learning about institutional deficits and success factors in climate adaptation. This study develops an institutional diagnostics approach to climate adaptation by means of a systematic meta-analysis of 52 studies comprising 120 cases from Europe. The results show that maladaptation, adaptation barriers and limits are rooted in institutional deficits that can be depicted as archetypical patterns of institutional attributes. Moreover, the results reveal success factors that enabled actors to prevent, alleviate or overcome specific institutional deficits in climate adaptation. Based on this, a set of diagnostic questions is provided for future in-depth institutional analyses of adaptation. Enhancing our capacities to diagnose causes of maladaptation, adaptation barriers and limits is crucial so as to device governance arrangements that match the features of specific adaptation problems.

Keywords

Institutional Diagnostics; Climate Adaptation; Archetypes; Europe; Meta-Analysis.

1 Introduction

Vulnerability to climate change would be no problem without adaptation barriers (Moser and Ekstrom 2010), adaptation limits (Dow et al. 2013) and maladaptation (Barnett and O'Neill 2010). Institutions are one of the decisive factors for enabling, constraining and shaping climate adaptation (Adger et al. 2007). Rules, rights and procedures constrain, incentivize and enable actions; link individual actions to social interactions and aggregate outcomes; distribute authority and power and shape dominant beliefs and rationalities (North 1990; Schmid 2004; Vatn 2005; Ostrom 2005; Paavola and Adger 2005; Young et al. 2008). Despite broad agreement among adaptation scholars about these general notions, the specific properties of institutions that delineate successful from unsuccessful climate adaptation remain elusive. This article diagnoses archetypes of institutional deficits and success factors in climate adaptation.

Research on the nexus of institutions and climate adaptation has mostly been conducted by means of case studies and conceptual analyses. Case studies have contributed a sizeable number of empirically rooted, in-depth findings about the institutions-adaptation-nexus in specific contexts. However, cumulative learning across cases has been hampered, *inter alia* due to specialized foci and research questions as well as a lack of research synthesis and integrative concepts that could capture the immense contextual diversity of adaptation factors, interactions and outcomes. On the other hand, conceptual analyses (e.g. Gupta et al. 2010) have provided comprehensive lists of institutional variables with assumed generic relevance for adaptation. However, the empirical validity of such claims and the interactions among the many institutional and non-institutional variables remain unclear. Further, the conceptual frameworks usually answer 'which' institutional dimensions may matter but leave explanations for 'how' and 'why' adaptation processes and outcomes are shaped by specific institutional attributes for future research.

Thus, our current understanding of the institutions-adaptation-nexus is fragmented across the scientific community with regard to specific properties of institutions, particular problems of climate adaptation, and specific locations. It is often theoretically eclectic or ad-hoc, and at times contradictory. Knowledge is typically claimed either for specific single contexts or in an overly generic way, whereas a diagnostic method seems the most appropriate research strategy, if the purpose is to learn most effectively across cases and to match governance arrangements with specific adaptation problems (Young 2002; Ostrom 2007; Moser and Ekstrom 2010). To date, the development of a comprehensive diagnostic method for institutional deficits and success factors for specific problems of climate adaptation is at a very early stage. This limits our ability to diagnose institutional causes for failures of climate adaptation and to identify governance options that enabled participants in comparable situations to prevent, alleviate or overcome adaptation failures.

This paper addresses these gaps explicitly. It conducts a meta-analysis of 51 of 150 cases of climate adaptation in Europe to develop the institutional diagnostics of climate adaptation. It diagnoses archetypes of institutional deficits that impeded climate adaptation and gave rise to maladaptation. It presents related success factors that enabled participants to prevent, alleviate or overcome these institutional deficits. The paper is organized as follows. Section 2 presents the analytical framework. Section 3 describes the methods. Section 4 presents the results and section 5 discusses them. Section 6 concludes.

2 Analytical Framework

2.1 Institutional diagnostics of climate adaptation

The term institutional diagnostics depicts an approach to the study of human-environment-interactions (HEI) and social-ecological systems (SES) that explains the causes of specific governance problems in HEI and SES and reveals governance arrangements that match with specific problems so as to alleviate adverse consequences (Young 2002; 2013; Ostrom 2007; 2009; Cox et al. 2010).

A diagnostic approach to climate adaptation comprises three main elements. First, a parsimonious set of variables is used to map situations of climate adaptation in a common language. This diagnostic framework organizes the relevant dependent and independent variables in a parsimonious conceptual structure. The Institutional Analysis and Development (IAD) (Ostrom 2005; 2010) and Social-Ecological-Systems (SES) frameworks (Ostrom 2009) are major efforts in this direction. This study adopts the IAD and SES framework to as its conceptual and theoretical groundwork to map the many variables relevant in climate adaptation (Oberlack and Neumärker 2013).

The second element of a diagnostic approach is a typology of specific adaptation problems ("archetypes of institutional deficits"). This typology depicts essential features of how combinations of explanatory variables affect incentives, actions, social interaction and outcomes in an adverse way. This is developed for the purpose of diagnosing adaptation failures. Third, institutional success factors capture conditions that enabled participants of adaptation situations to prevent, alleviate or overcome specific adaptation problems.

2.2 Diagnostic framework of climate adaptation

The conceptual basis of this study is Ostrom's Institutional Analysis and Development Framework (Ostrom, 2005) and Social–Ecological Systems framework (Ostrom, 2009). These related frameworks have been adapted to capture particularities of climate adaptation (Oberlack and Neumärker 2013). This framework explains manifestations of climate adaptation processes and interactions (e.g. timing, extent, types of adaptation) and outcomes (e.g. altered exposure, altered sensitivity, altered adaptive capacity) as a result of the interplay of variables that fall into four broad categories (cf. Figure 1): the properties of the climatic and non-climatic stresses, attributes of the governance system, resources, and attributes of the involved actors. These variables determine the actors' action space for adaptation (adaptive capacity). Actors decide about alternatives from this opportunity set given their preferences and values, modes of choosing (e.g. using heuristics) and modes of acquiring and using information (e.g. using mental models) (Ostrom, 2005; Oberlack and Eisenack 2014).

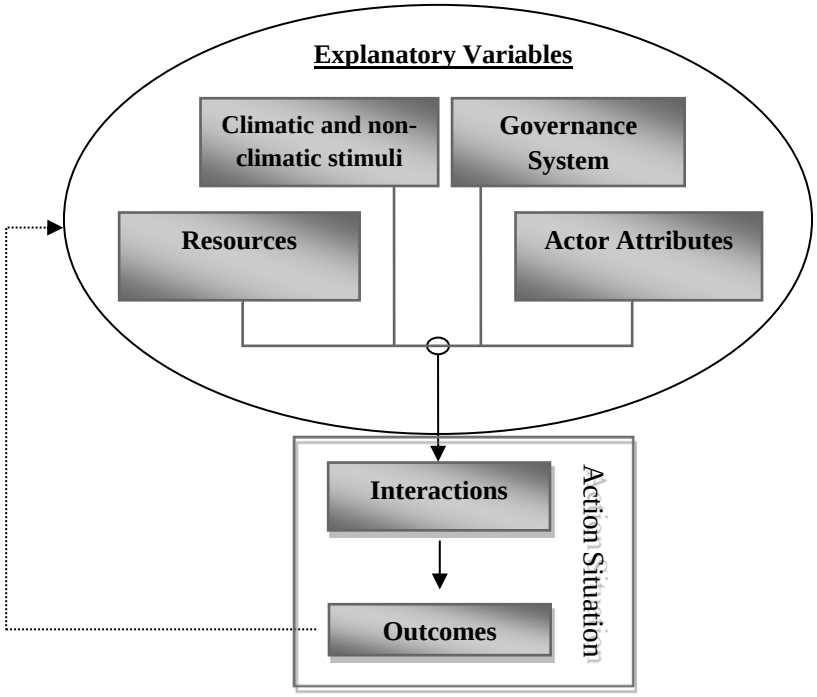

Figure 1: First-tier variables of the diagnostic framework of climate adaptation (adapted from Oberlack and Neumärker 2013, based on Ostrom 2005; 2009).

2.3 The BIO parameters as a response to the dependent-variable problem in climate adaptation

Dupuis and Biesbroek (2013) reveal that comparative research on climate adaptation is plagued by a dependent-variable problem. They show that case studies differ in their adopted notions of climate adaptation. Meta-studies that would not control for this diversity of adaptation concepts would lose their validity as they would compare apples with oranges.

In order to alleviate this problem, this meta-study uses the "BIO parameters" to operationalize the various notions of climate adaptation used in case studies. As shown in table 1 this notion distinguishes behavioral, interaction and outcome parameters of climate adaptation. This typology has been developed in the iterative coding procedures of this meta-analysis to capture the diverse notions of climate adaptation in the case studies. Conceptually, they are rooted in the bounded rationality approach of the IAD framework.

Behavioral parameters	Interaction parameters	Outcome parameters
Mental models	Power	Effectiveness
Awareness	Transaction costs	Efficiency
Values and preferences	Transaction benefits	Equitability
Incentives for adaptation	Type of adaptation activities	Legitimacy, agreement
Incentives for maladaptation	Extent of adaptation	
Opportunity set, means	Innovations	
Trust		

Table 1: The BIO parameters of climate adaptation (BIO: behavioral, interaction, outcome).

3 Method

This study conducted a meta-analysis of case studies to analyze relational patterns between properties of institutions and parameters of climate adaptation. The qualitative research design of most adaptation case studies renders traditional, quantitative meta-analytic techniques inapplicable. Rudel (2008) suggests for this type of primary literature to conduct 'model-centered meta-analyses' rather than 'variable centered' ones in order to synthesize the high-quality information embedded in many case studies. He proposes to extract the 'models' that have been found in primary research rather than the data or effect sizes between variables. A 'model' in this terminology is a statement about the relation between a set of variables that has been found in the primary research.

Retrieval and selection of documents

To identify relevant studies the search strategy comprised the use of literature databases (Web of Science, Academic Search Premier, and EconLit) and snowballing in reference lists of retrieved articles. The following terms were used: "adaptation AND (climat* OR extreme* OR environmental change OR global change OR natural hazard* OR hazard* OR Resil* OR Vulnerab* OR Risk*)", "(adaptive capacity OR adaptability) AND (climat* OR extreme* OR environmental change OR global change OR natural hazard* OR hazard* OR Institution* OR Regime* OR Governance OR Determinant* OR Indicator* OR Assessment* OR Eval* OR Barrier* OR Driver* OR Resil* OR Vulnerab* OR Risk* OR Case study)", "(cope OR coping) AND (climat* OR extreme* OR environmental change OR global change OR natural hazard* OR hazard*)", "(resilienc* OR vulnerab*) AND (climat* OR extreme* OR environmental change OR global change OR natural hazard* OR hazard*)", "disaster risk reduction", and "natural hazard*".

Criteria for inclusion in the meta-analysis were: (i) the article provides empirical evidence on the relation of institutions and public adaptation to climate-related changes and variability in Europe; (ii) the research process has been clearly and coherently documented; (iii) the sources of evidence and theoretical preconceptions are adequate and clearly stated; (iv) the article is written in English; (v) the article is published in a peer-reviewed journal (to ensure scientific and methodological rigor). These criteria imply that conceptual models and reviews are excluded from the meta-analysis if unexposed to systematic observations. Equally, studies that only describe existing governance arrangements without investigating their relation with adaptation are not included. The same applies to articles which assess existing institutions against a pre-defined theoretical framework. As a heuristics, it was required that the revealed 'models' between institutional properties and adaptation parameters must be refutable (or identified differently) by the compiled empirical evidence.

This procedure yielded 52 studies that are included in the meta-analysis. They are based on 120 cases of distinct action situations.

Coding Scheme and Iterative Coding

A detailed coding scheme was developed based on the diagnostic framework of climate adaptation (see figure 1). From each case study this meta-analysis extracted the results that describe relations between institutions and adaptation. The empirical findings were translated into the language of the diagnostic framework as second-, and third-tier variables. Each code comprised (i) governance functions of institutions, (ii) adaptation parameter(s), and (iii) their functional interrelation. Variables for climatic stimuli and stresses, resources and actor attributes were included in the codes if case studies reported them to shape the relation of institutions and adaptation. By stepwise increasing the number of included case studies a typology of governance function, adaptation parameters and

functional relations was developed and continuously refined. If this typology was changed, the previously analyzed studies were re-read and, if necessary, recoded to tailor the concepts such that they fit with all case studies.

This iterative process yielded a typology of governance functions (see section 4.1) and distinct adaptation parameters ("BIO parameters", see section 2.3). With regard to the functional relations it proved useful to distinguish exactly eight basic types of models that describe possible relations between variables: direct effect; relevance; insignificance; differential effect; moderator; conjoint effect; mediator; internal effect. Combinations of these model types are possible so that one coded model could comprise more than three variables as well as multiple interaction effects between the variables. The multi-faceted nature of the coding scheme enabled the analyst to capture the rich and diverse information embedded in the selected case studies. In contrast to other meta-analysis, acknowledging not only the manifestations of institutional and adaptation parameters in cases but also functional relations between them in the coding scheme allowed to go beyond the question of "which" institutional dimensions are relevant and code "how" institutions shape climate adaptation. This was further facilitated by the multi-faceted notion of adaptation parameters.

This code book was used in a final round to code the empirical results of all case studies by means of this standardized flexible coding scheme. An MS-Excel-based data extraction table was developed to systematically compile the meta-dataset.

Analysis of the meta-dataset

The meta-dataset contains coded models that state how institutional attributes shape the BIO parameters, i.e. individual decision-making, social interactions and outcomes in climate adaptation. In order to analyze the meta-dataset the models were compiled separately for each of the institutional attributes. An interpretative analysis was conducted to synthesize the relations between institutional and adaptation parameters and to formulate archetypes of institutional deficits and related success factors for climate adaptation. These results are presented in the following section.

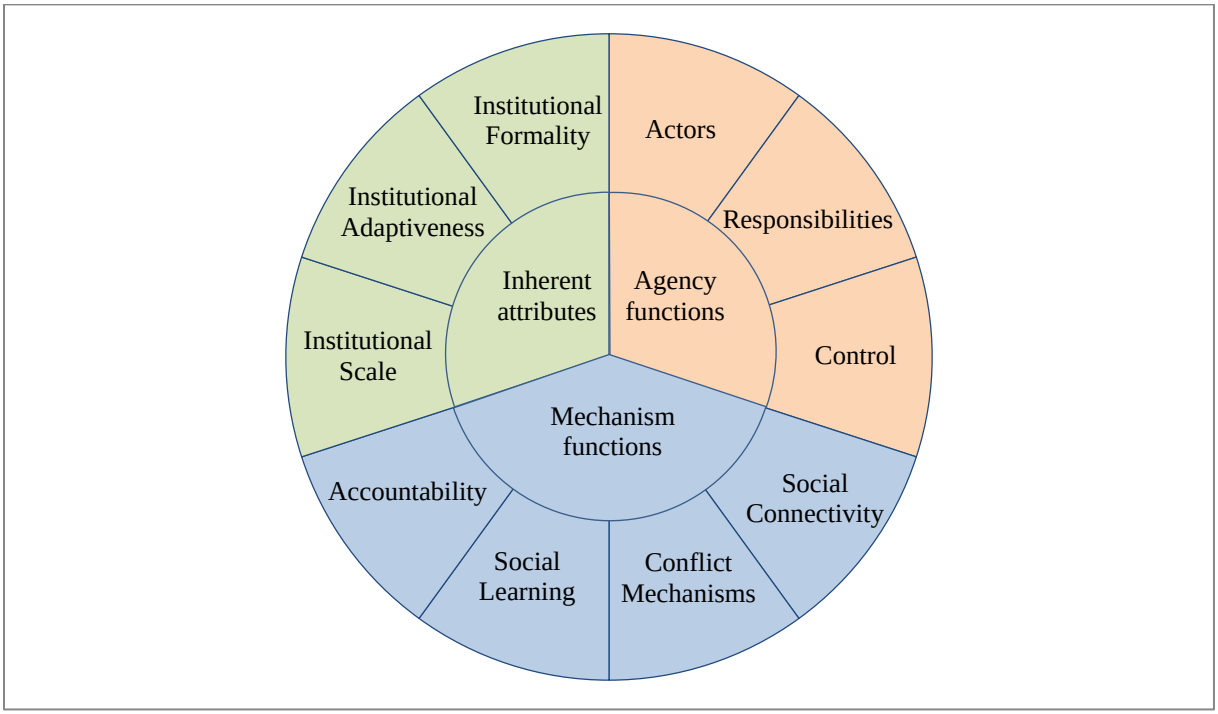

Figure 2: Classification of institutional attributes in climate adaptation.

4 Results

4.1 Relevant attributes of institutions in climate adaptation

A core challenge in developing informative, generalizable institutional diagnostics of climate adaptation is to identify a parsimonious and efficient conceptual structure of the institutional properties that shape interactions and outcomes of climate adaptation across contexts. A parsimonious, efficient conceptual structure tailors concepts in such a way that (i) observations in a case can be interpreted as particular manifestations of them and (ii) the relevant interactions in a case that explain the phenomenon of interest can be translated in this conceptual map.

The result of the iterative coding rounds in this meta-analysis suggests that classifying 10 institutional attributes provides a parsimonious and efficient concept for the institutions-adaptation-nexus. As in the IAD and SES framework (Ostrom 2005; 2009) these categories can be interpreted as holons with sub-classes.

Figure 2 and table 2 present and describe the 10 first-tier institutional attributes that shape climate adaptation. Table S1 in the appendix presents and describes the second-tier attributes that specify sub-categories of the first-tier attributes.

Institutional Attribute	Description
Agency functions	Institutional attributes that affect the actors, their action spaces and influence on outcomes.
A Actors	How institutions specify the set of eligible actors in an action situation.
B Responsibilities	How institutions specify the positions available to participants and the prescribed, prohibited and allowed actions assigned to positions.
C Control	How institutions regulate the control that participants have over outcomes of the action situation.
Mechanism functions	Institutional impact on recurrent processes and interactions through which individual actions are linked and transformed into intermediate and final outcomes
D Social Connectivity	Institutionalized attributes of the network structure that connects actors within and across multiple tiers of social organization and enable actors to build trust about cooperative behavior of others.
E Conflict Mechanisms	Institutional provisions for regulating, preventing or resolving disputes about values, preferences and actions among actors.
F Social Learning	Institutional attributes that shape how information, knowledge claims and values are constructed, communicated, and accepted among participants.
G Accountability Mechanisms	Institutional provisions for monitoring, evaluating, rewarding and enforcing responsibilities.
Inherent attributes	Attributes of the institutional system itself
H Scale of institutions	The spatial boundaries and temporal incentive implications of institutions.
I Adaptiveness of institutions	The extent to which change in the rules-in-use is constrained by transaction costs and by path dependence.
J Formality of institutions	The degree to which the rules-in-use are embedded in written laws, plans, documents.

Table 2: Description of institutional attributes in climate adaptation.

4.2 Archetypes of institutional deficits and success factors in climate adaptation

Archetypes of institutional deficits are reappearing patterns of adverse impacts of the institutional setting on climate adaptation parameters.

The results show that maladaptation, adaptation barriers and limits are rooted in institutional deficits in a variety of ways within the 10 domains shown in figure 1. Institutional quality is not a one-dimensional variable. Instead, a catalogue of 37 archetypical diagnostic patterns helps to diagnose the institutional causes of maladaptation, adaptation barriers and limits in particular cases. This catalogue is provided in Table 3. It describes each diagnostic pattern.

Besides the diagnostic patterns of deficits, the right column of table 3 provides success factors that enabled participants to prevent, alleviate or overcome the related deficient pattern. Two things are important to note.

First, this catalogue traces adverse manifestations of adaptation parameters to institutional attributes based on a synthesis of the findings from 120 cases from Europe. As these diagnostic patterns are archetypes, one case of adaptation failure is usually plagued by a subset of the deficits, but not by all 37 deficits at the same time (Eisenack 2012; Oberlack and Eisenack 2014). Thus, like a doctor, the institutional analyst may use this catalogue to develop hypotheses about the institutional reasons of the observed adaptation failure – keeping in mind that institutions typically affect interactions and outcomes in conjuncture with attributes of their socioeconomic, cultural and biophysical context (Ostrom 2009; Young 2013). As a supporting tool, table S1 in the appendix provides fitted diagnostic questions to identify the relevant institutional attributes in a situation. After diagnosing, the second main step is to analyze which governance mechanisms match a specific problem.

Second, the number of 37 institutional deficits may not seem particularly parsimonious. However, this collection of diagnostic patterns is the result of numerous rounds of iterative coding in pursuit of an efficient conceptual structure that capture all relevant findings from the case studies. The considerable number of 37 can be explained, first, by the considerable number of first- and second-tier attributes through which institutions shape individual decisions, interactions and outcomes in climate adaptation and, second, the detailed notion of the dependent variable in this study, climate adaptation, as embodied by the BIO parameters.

Table 3: Archetypes of institutional deficits in climate adaptation and related success factors.

Agency functions

A. Actors		Rules that regulate the set of eligible actors in an adaptation situation.	
Diagnostic Pattern		**Description of diagnostic pattern**	**Success factors***
A1	Numbers trade-off	▪ Detrimental effect: Increasing numbers of included actors in adaptation governance imply increased transaction costs for communication, coordination, and strategic incentives of opportunistic behavior. This can limit the extent of adaptation. ▪ Fostering effect: Increasing numbers of included actors imply higher likelihood that specific adaptation needs are recognized, dispersed knowledge is brought to adaptation situations and decisions are equitable. This can improve mutual agreement and long-term conflict prevention (reduced transaction costs in the long-term).	▪ Efficient mechanisms for communication and social learning. ▪ Appropriate compensation mechanisms for absolute/relative losers of adaptation decisions. ▪ Necessity to adapt clear to stakeholders (beliefs).
A2	Maladaptive knowledge and value selection	The belief systems, values, and preferences of the set of participating actors strongly shape the types and outcomes of (mal)adaptation by conditioning the relevant framing of adaptation, learning, prioritizing alternatives and opportunity sets in an action situation. For instance, prioritization of technical adaptation to water stress has been attributed to technical belief systems of main decision-makers.	▪ Flexible boundary rules for the set of eligible actors. ▪ Inclusive approach, but cf. diagnosis A1.
A3	Open access trade-off	▪ Detrimental effect: Open access approaches (i.e. no actor-specific restrictions for participation, such as being an elected representative) proved ineffective for adaptation, if actor preferences were too heterogenous, local climate change impacts too uncertain and costs of adaptation too high. They can give rise to inequitable adaptations, if some actors do not participate due to prohibitively high opportunity costs and are not represented otherwise. ▪ Fostering effect: Open access to collective choice arenas is associated with high degrees of innovation and effectiveness in terms of contextually tailor-made plans. However, implementation of developed adaptation plans depends on mobilization of sufficient resources. This can be hampered by lack of leadership and persistent collective action problems.	▪ Open access approaches were effective, if participants gained previous experience with adapting to environmental change, can realize substantial benefits from cooperation and act in social structure of low complexity.
A4	Extrinsically incentivized participation trade-off	▪ Detrimental effect: robustness of adaptation process tends to be weak, if external incentives are no longer provided. ▪ Fostering effect: external resources can incentivize and enable innovations, correct inequities if capacity to participate is inequitably distributed due to skewed resource endowments.	▪ Extrinsically incentivized participants develop own capacities and/or intrinsic interest of continued participation. ▪ Specific type of adaptation can be realized as a project/ does not require long-term, robust process.

Table 3 (cont'd): Archetypes of institutional deficits in climate adaptation and related success factors.

B. Responsibility		Rules that regulate the positions available to participants and the associated set of prescribed, prohibited and allowed actions.	
Diagnostic Pattern		**Description of diagnostic pattern**	**Success factors**
B1	Incentive trap of unclear responsibilities	If responsibilities are unclear and net costs of adaptation positive, actors face limited incentives to act as operators. Thus, the extent of adaptation limited.	▪ Clarification of responsibilities.
B2	Conflict trap of unclear responsibilities	If responsibilities are unclear and net benefits of adaptation positive for multiple actors, unproductive struggles about appropriating these benefits cause high transaction costs and inefficiency.	▪ Clarification of responsibilities. ▪ Cf. conflict mechanisms (E1-4).
B3	Rigidity trap of clear responsibilities	If responsibilities are clear but embedded in a rigid governance system that does not match well the socioeconomic, ecological and behavioral properties of the adaptation problem, coordination needs, conflict risk and potential maladaptation are likely to induce high transaction costs and low efficiency.	▪ Cf. conflict mechanisms (E1-4). ▪ Cf. spatial mismatch (H2). ▪ Cf. institutional rigidity (I2).
B4	Fragmented responsibilities trade-off	▪ Adverse effect: high degrees of fragmented responsibilities among interdependent governance units associated with high transactions costs, e.g. for communication, reaching agreement and enforcing decisions. They arise from the multitude of partly incompatible knowledge and information sources, values and interests in need of accommodation. Limited effectiveness (e.g. pace), efficiency and extent of adaptation. ▪ Fostering effects: high degrees of fragmentation and polycentricity associated with diversity of interventions, decentralized social learning and limited control that single participants hold about aggregate outcomes, thus working against inequalities and misuse of power.	▪ Fragmented, polycentric governance of adaptation, if adaptation problems are multi-scalar. ▪ Quality of horizontal and vertical coordination mechanisms decisive for the extent to which trust emerges, social learning proceeds and transaction costs for coordination, conflict and inconsistency affect institutional effectiveness (cf. D-J).
B5	Overlapping responsibilities trade-off	Fragmented responsibilities can be separated among actors or overlapping. ▪ Adverse effects of overlapping responsibilities: high transaction costs through risks of unproductive conflicts and higher needs to coordinate knowledge, interest and actions. Limited effectiveness, efficiency and extent. ▪ Fostering effects of overlapping responsibilities: organizational redundancy can increase adaptation effectiveness in terms of robustness and flexibility; organizational redundancy can be associated with productive competition among public service providers. Enhanced adaptation innovations, effectiveness, efficiency, extent.	▪ see B4.
B6	Maladaptive responsibility assignment	The assignment of responsibilities to positions and actors implies that participants mobilize particular resources and belief systems for particular preferences. Maladaptive responsibility assignment occurs if this implication yields maladaptive interactions and outcomes, e.g. due to adaptation-inferior preferences, or if responsibilities exceed actors' expertise.	▪ Fit between responsibility assignments, actor resources and human capacities, climatic stimulus, and interaction mechanisms.

Table 3 (cont'd): Archetypes of institutional deficits in climate adaptation and related success factors.

C. Control		Rules that regulate the control that participants have over outcomes of the action situation.	
Diagnostic Pattern		**Description of diagnostic pattern**	**Success factors**
C1	Leadership traps	Adverse effects of institutions that imply a strong role for a small set of actors for guiding direction and outcomes of collective action: ▪ Risk of power misuse: procedural and distributional inequities. ▪ Dependence of collective choice on personal capacities and interests of leaders. ▪ Risk of information filter trap (I3) if new information is filtered by leaders in social learning. ▪ If particular actors dominate the agenda-setting phase of collective action, later adaptations tend to reflect power imbalances, e.g. inequitable outcomes.	▪ Institutional embeddedness of leaders, in particular appropriate responsibility (cf. B) accountability mechanisms (cf. G).
C2	Control asymmetries in participatory approaches	If boundary rules imply broad involvement of actors, but distribution of responsibilities implies inequitable effective control over outcomes among actors, inequitable outcomes patterns, mistrust and disagreement are likely.	▪ Stakeholder participation with rights to construct, discuss and promote adaptation alternatives rather than sole right to comment on pre-determined adaptation alternatives.
C3	Vested interests	Institutionalized protection of special interests, e.g. through participation rules or privileging rights, reinforces social inequities in adaptation.	▪ Legal review options for privileges. ▪ Competition among service providers.

Table 3 (cont'd): Archetypes of institutional deficits in climate adaptation and related success factors.

Mechanism functions

D. Social connectivity		Attributes of the network structure that connects actors within and across multiple tiers of social organization and enable actors to build trust about cooperative behavior of others (Brondizio et al. 2009).	
Diagnostic Pattern		**Description of diagnostic pattern**	**Success factors**
D1	Mistrust trap	Limited trust, i.e. expectation of cooperative behavior by others, and mistrust, i.e. expectation of conflictive behavior by others, increases transaction costs and limits transaction benefits of adaptation cooperation. Aggravated by limited or ineffective communication.	▪ Effective communication ▪ Strong social identity and low fluctuation of participants ▪ Culture of informal consultation
D2	Instable network trade-off	▪ Uncertainty about network persistence can reduce incentives to invest in network and thus limit the opportunity set for coordinating actors. ▪ But loose network structure can incentivize innovations for increased connectivity, e.g. through new boundary organizations.	▪ Shared beliefs of participants about feasible transaction benefits through increased connectivity.
D3	Rigidity trap of strong connectivity	Repeated interactions and strong connectivity are conducive for emergence of strong shared beliefs and norms. Rigidity trap occurs, if this culture implies both maladaptive interactions and low institutional adaptiveness.	▪ cf. institutional adaptiveness [code I1].
D4	Informality trade-off	▪ Informal networks can be associated with low transaction costs for communication, stabilization of trust, learning and innovations (facilitating conditions: see success factors). ▪ But informal networks are vulnerable to social inequities and power misuse, if participation is restrictive and transparency and accountability limited. ▪ Implementation of informally agreed public measures is often dependent on financial, political, legal and procedural support of formal agencies. ▪ Limited stability of informal interactions has been observed.	▪ High trust in communicated information ▪ Shared mental models ▪ Small/medium number of actors ▪ Power balancing mechanisms ▪ Support of formal agencies/arenas ▪ cf. formality of rules [J1].
D5	Inefficient linking of actors across governance levels	▪ Linkage inefficiency type 1: existing linkages of actors (e.g. financial, legal, communicative, political) across organizational boundaries and governance levels yield high transaction costs in cross-level interactions without yielding related transaction benefits. ▪ Linkage inefficiency type 2: maladaptive actions of governance units are rooted in failure to coordinate functionally interdependent actions across levels.	▪ Linking actors across levels according to functional interdependence (influence on aggregated outcomes) of single actions.
D6	Maladaptive public regulation of autonomous actions	▪ Maladaptive interactions and outcomes rooted in public regulation of autonomous actions, e.g. missing monitoring of resource use; arms-length regulation vulnerable to outsourcing of activities; uncertainty about regulatory framework and limited opportunities/power to challenge regulation, if regulators are unconstrained by legal constraints.	▪ Ongoing learning process to evaluate and adapt public regulations. ▪ Legal constraints on legitimate actions of the regulator.
D7	Inefficient policy integration and mainstreaming	The governance system treats climate adaptation as distinct policy issue in a distinct governance unit although outcomes (e.g. vulnerability, resilience) are influenced by activities of multiple governance units (e.g. spatial planning, environmental policy, water management). Organizational separation of functionally interdependent governance units breeds coordination failures of maladaptation and adaptation barriers.	▪ In case of multi-scalar functional interdependence: Climate proofing of the governance system, e.g. based on integrative climate narrative; policy or legal framework at higher governance levels; boundary organization that involves the functionally and politically relevant actors.

Table 3 (cont'd): Archetypes of institutional deficits in climate adaptation and related success factors.

E. Conflict		Institutional provisions for regulating, preventing or resolving conflicting values, preferences and actions among actors.	
Diagnostic Pattern		**Description of diagnostic pattern**	**Success factors**
E1	Conflict trap	Grievances, insecurity and explicit conflict strategies undermine trust among participants; increase transaction costs; limit recognition and increase uncertainty of transaction benefits; limit extent of adaptation.	▪ Transparency mechanisms ▪ Mechanisms for resolution of differing preferences ▪ Conflict prevention mechanisms
E2	Trade-off about competition among public service suppliers	▪ Competition associated with increased efficiency of service provision. ▪ Rationales that underpin the specific meaning of efficiency in an action situation depend on institutional setting, dominant mental models and other factors, e.g. short-term cost efficiency vs. long-term resilience. ▪ Competitors will not prioritize climate adaptation, unless it has a statutory function or is driven through endogenous dynamics (e.g. experienced climate events, leadership and resources). ▪ Competitive setting increases transaction costs of coordination among public service providers for adaptations that cross organizational boundaries.	▪ Adaptation-conducive regulatory framework for competition among public service providers ▪ Coordinating mechanisms for cross-organizational adaptations.
E3	Institutional inconsistency	▪ Several components of the rule-in-use structure activities and interactions in a contradictory way. ▪ If organizational norms, languages and cultures diverge, but climate stimuli crosses organizational boundaries, high transaction costs of inter-organizational coordination and limited effectiveness.	▪ Negotiation of institutional inconsistencies. ▪ Attitudes of individual participants can overcome differences in organizational cultures.
E4	Institutional ambiguity	The rules-in-use are uncertain and subject to competing interpretations among actors. Gives rise to conflict trap, cf. E1.	▪ cf. E1.

F. Social Learning		Institutional attributes that shape how information, knowledge claims and values are constructed, communicated, and accepted among participants.	
Diagnostic Pattern		**Description of diagnostic pattern**	**Success factors**
F1	Absent knowledge coordination mechanisms	Absence of mechanisms to coordinate between holders of tacit operational knowledge, political knowledge, legal knowledge and scientific knowledge constrains adaptation effectiveness in terms of political priorities (e.g. limited priorities on climate risks), knowledge base of political and operational decisions, policy- and operational relevance of research.	▪ Institutionalized arenas for communication, e.g. formal deliberative venues; informal organizational shadow spaces.
F2	Dilemma of science-policy-integration	A weak integration (density of institutionalized interdependence) of science and policy actors can yield low effectiveness of science-policy-interactions or high transaction costs related to grievances and coordination failures due to divergent understanding, language, and mistrust. A strong integration of science and policy actors can yield high transaction costs related to coordination failures due to divergent objectives, needs, scope and organizational logics.	▪ Science-policy boundary organization. ▪ Early interactions in the project cycle and learning about partner's rationalities and conditions; strong face-to-face interactions. ▪ Long-term linkages between universities and research departments in ministries.

F3	Information filter trap	New information is filtered by participants in light of their existing mental models, values and interests. Filtering shapes the dominant notion of climate adaptation used in an action situation, thus is a source of power and pre-determines the types and extent of chosen adaptations. Filtering trap occurs if power asymmetries are reinforced by asymmetric learning.	▪ Mechanisms for inclusive learning. ▪ Diversity of interventions.
F4	Adverse selection of public risk information	Access to publicly produced risk information, e.g. maps for flood risk, limited in high-risk areas, e.g. as public officers expect negative economic consequences from publishing.	▪ Enforced demand for public risk information, e.g. legal requirement.
F5	Accountability trap of uncertain knowledge claims	▪ Provision, access and use of public risk information limited, if accountability for potential damage is unclear should knowledge claims prove inadequate. ▪ Increased transaction costs (e.g. grievances, conflicts) in a blame game and socialization of costs after damage occurred.	▪ Assessment and communication of uncertainties and risk. ▪ Clarification of extent and limits of responsibilities. ▪ Precautionary approach to risk governance. ▪ Ongoing monitoring and evaluation.
F6	Mismatches in social learning	Mismatches reduce effectiveness of social learning about adaptation: ▪ Scale mismatch: Governance scale of knowledge generation (e.g. national/regional vulnerability assessments) does not fit the scale of operational decision-making (e.g. municipal). ▪ Procedural mismatch: Degree of inclusiveness of knowledge generation does not fit the transaction cost and benefit conditions (e.g. number of actors, conflict intensity, functional interdependence of actors). ▪ Substantive mismatch: Content of provided knowledge does not fit knowledge need of decision-makers (e.g. information about hazard vs. impact/vulnerability; varying information needs during the policy cycle)	▪ Rescaling. ▪ Efficient coordination mechanisms; ▪ Institutional innovations, e.g. boundary organizations. ▪ See inclusiveness (codes A1-A4).

G. Accountability		Institutional provisions for monitoring, evaluating, rewarding and enforcing responsibilities.	
Diagnostic Pattern		**Description of diagnostic pattern**	**Success factors**
G1	Absent accountability trap	Absence of accountability mechanisms that monitor, reward and enforce responsibilities for public adaptation is associated with high transaction costs (political conflicts) and limited extent of adaptation.	▪ Innovations were observed in informal arenas despite weak formal accountability mechanisms, if participants have considerable experience with environmental change and live in social structure of low complexity. ▪ Clear rules and capable governance units for monitoring, evaluation, reward and enforcement.
G2	Maladaptive accountability trap	The incentives of (potential) operators of adaptation are heavily shaped by the mechanisms for monitoring, evaluating, rewarding and enforcing. A maladaptive accountability trap occurs, if the standards or actors, that the operators are accountable to, reward and enforce maladaptive activities (including inefficient over-adaptation in the case of an extreme event before elections).	▪ Accountability mechanisms (e.g. procedures, legal standards, policy objectives) expose operators to agreed notions of adaptation success over time.

Table 3 (cont'd): Archetypes of institutional deficits in climate adaptation and related success factors.

Inherent attributes of institutions

H. Temporal and spatial scale of institutions	The spatial boundaries and temporal incentive implications of institutions.	
Diagnostic Pattern	**Description of diagnostic pattern**	**Success factors**
H1 Temporal mismatch	Ineffective adaptation as the temporal incentive implications of institutions and the temporal scope of the climatic stimuli do not coincide: ▪ Type 1: decadal climate change vs. institutionally implied incentives focus on short- or medium-term benefits (e.g. short terms of office) ▪ Type 2: rapid-onset event vs. time-consuming procedures of decision-making, policy evaluation and rule change	▪ Ancillary long-term benefits of present-day adaptations (type 1). ▪ No-regret adaptations to long-term climate change (type 1). ▪ Deliberate institutional reform (type 1+2). ▪ Contingency plans for emergencies (type 2).
H2 Spatial mismatch	Ineffective and inequitable adaptation as the spatial scales of the institution and of the climatic stimuli do not coincide, e.g. lack of coordination of functionally interdependent actions, maladaptation due to functionally caused power asymmetries.	▪ Social connectivity matches the properties of the climate stimuli and the exposed system, e.g. polycentric governance system for multi-scalar climate stimuli; boundary organizations; routine cross-level coordination.

I. Adaptiveness of institutions	The extent to which change in the rules-in-use is constrained by transaction costs and by path dependence.	
Diagnostic Pattern	**Description of diagnostic pattern**	**Success factors**
I1 Institutional instability	<u>Detrimental effect:</u> ▪ Institutional instability can reduce incentives to invest in connectivity that is established through the instable institution. Thus, reduced opportunity sets for adaptations; increased transaction costs. <u>Fostering effects:</u> ▪ Opportunity sets and possible extent of adaptation enhanced, as institutional adjustments are one important subject of climate adaptation. Institutionally established power positions are less likely misused.	▪
I2 Institutional rigidity and path dependence	<u>Detrimental effects:</u> ▪ Reduced opportunity sets for climate adaptation. ▪ Stable informal norms can reinforce power asymmetries. ▪ Continuing disagreement by opposing actors (illegitimacy). <u>Fostering effects on adaptation parameters:</u> ▪ Maladaptive political awareness cycles less likely.	▪

J. Formality of institutions	The degree to which the rules-in-use are embedded in written laws, plans, documents.	
Diagnostic Pattern	**Description of diagnostic pattern**	**Success factors**
J1 Missing or maladaptive formal rules	▪ Formalized rules, such as laws or the statutory duties of a public organization, commit actors to prioritize objectives and alternatives other than climate adaptation. ▪ Lack of legislative edict limits the trust of public implementing entities in political priorities and leaves responsibilities unclear.	▪ Statutory duties of an organization or legislation integrate climate adaptation. ▪ Formalized rules leave sufficient discretionary opportunities in collective or operational decisions, and actors use this action space for adaptation purposes due to non-institutional reasons.

5 Discussion

The specific success factors that relate to particular institutional deficits in climate adaptation are presented in the right column of table 3. This section discusses whether it is possible to formulate aggregated design features of institutions that are useful to explain why some groups or societies adapt successfully while others do not.

The many trade-offs and institutional varieties involved (cf. table 3) challenge the formulation of design principles for successful climate adaptation that hold across all investigated contexts. In fact, a variety of contradicting approaches have worked to deliver adaptation success, e.g. open, informal, participatory approaches vs. elite-driven, technocratic approaches. Vice versa, these approaches delivered adverse effects in other cases.

Rather, successful adaptation seems to be a function of fit between institutions, attributes of actors and the socioeconomic and biophysical context of action situations. More specifically, diverging outcome patterns (i.e. effectiveness, efficiency, equitability and legitimacy of adaptation) can mainly be traced to the individual incentives and opportunity sets for adaptation, transaction costs and benefits, power (a)symmetries and learning.

Thus, this discussion suggests, first, that a particular institutional design feature is never without adverse effects on adaptation across all cases. Second, we may explain diverging adaptation outcomes based on the general heuristics that the specific combination of institutional, actor, socioeconomic and biophysical attributes shape adaptation outcomes through their implications for incentives, opportunity sets, transaction costs and benefits, power, knowledge and values. When confronted with a case of adaptation failure, the analyst's task would be to disentangle this web of relations, e.g. using the detailed institutional diagnostics presented in table 3.

6 Conclusion

This paper analyzes why maladaptation, adaptation barriers and adaptation limits occur. It conducts a model-centered meta-analysis of 52 studies that comprise 120 cases of adaptation situations from Europe. The article distinguishes 10 attributes through which institutions shape adaptation (see fig. 1). Based on this concept, it finds a set of 37 distinct, archetypical diagnostic patterns of institutional deficits in climate adaptation. These institutional diagnostics trace specific adverse manifestations of adaptation parameters to specific institutional attributes. Moreover, the study reveals success factors that enabled participants to prevent, alleviate or even overcome the related diagnostic pattern.

The paper extends previous research on the institutions-adaptation-nexus by adopting a diagnostic approach to the institutional analysis of 120 cases of adaptation situations. It thus avoids blueprint approaches of universal governance principles that mask trade-offs in adaptation parameters. It draws, inter alia, on the Adaptive Capacity Wheel (Gutpa et al. 2010), but alters and extends it in a fourfold manner: the methodical basis of the present study is a meta-analysis of case studies instead of a conceptual rethinking; the conceptual basis is Ostrom's IAD and SES frameworks instead of "ideas in the adaptation literature" (p.461); the explanandum is a detailed account of adaptation parameters here instead of adaptive capacity of society; the functional relations in the AC Wheel are implicitly positive direct effects, while this study extends to eight functional relations that reveal trade-offs and patterns of complex causation.

Future research may use this paper by testing its propositions in a confirmatory study design rather than exploratory study design. Future research may also expand on this by analyzing trajectories and pathways on which participants cycled between the diagnostic patterns of institutional deficits on the one side and the success factors on the other side.

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Appendix:

Table S1 (Draft) Diagnostic questions for the institutional diagnostics of climate adaptation

Institutional Attribute	Diagnostic Question	Subcategories of Institutional Attributes ("second-tier")
Agency functions		
A Actors	i) How many actors are involved?	Number of actors
	ii) Who is eligible to participate?	Boundary rules related to actor attributes, e.g. being an elected member of parliament, registered as NGO, officially recognized as affected
	iii) When, how long, at which stage to participate?	Boundary rules related to a particular time horizon or phase of the adaptation process
	iv) Are resources provided to incentivize or support participation?	Institutionalized incentives and resources for participation
B Responsibilities	i) Is there a clear and mutually understood device that assigns roles and responsibilities to actors?	Clear responsibilities
	ii) Are responsibilities fragmented among actors or centralized?	Fragmented responsibilities
	iii) To what extent do fragmented responsibilities and competences overlap among actors?	Overlapping responsibilities
C Control	i) Are there institutional provisions that define responsibilities of leaders, constrain their opportunity set and hold them accountable?	Leadership
	ii) Which means of participation are available to the various actors and how do their actions map into intermediate and final outcomes?	Distribution of control
	iii) Do boundary, position or choice rules provide privileges to specific actors?	Vested interests
Mechanism functions		
D Social Connectivity	i) Which institutional provisions exist to reinforce trust (e.g. rules and procedures of reciprocity, information rules on transparency)?	Trust
	ii) Do participants expect continued/uncertain/deepened existence of the considered network?	Network stability
	iii) Since when and how often do participants interact? Do they share strong beliefs and norms?	Density of connections
	iv) Are interactions based on formalized procedures and rules?	Informality of network
	v) How do actors assess the linkages to other governance levels?	Cross-level connectivity
	vi) What are the constraints and procedures that public regulation of autonomous activity must follow?	Public regulation of autonomous activity
	vii) Whose activities influence adaptation outcomes? Is climate adaptation an issue on their agenda?	Policy Integration/ Climate Proofing

E Conflict Mechanisms	i) Which institutional provisions exist to prevent, regulate or resolve grievances, conflict risk-based insecurity and open conflicts?	Conflict prevention, regulation and resolution
	ii) What are the properties of the framework that regulates competition between public service providers?	Competition among public service providers
	iii) Do the various institutional devices structure the action situation in a consistent way, and which procedures are used to resolve inconsistencies?	Institutional inconsistency
	iv) Are the rules-in-use subject to competing interpretation, and which procedures are used to resolve institutional ambiguity?	Institutional ambiguity
F Social Learning	i) Which types of knowledge are relevant for interactions and outcomes in the focal action situation and how are the different types of knowledge coordinated?	Knowledge coordination
	ii) According to which rules and procedures do policy actors, practitioners and science actors interact?	Science-policy-interaction
	iii) How is new information generated and integrated into ongoing interactions?	Information filtering
	iv) How do rules commit public officials to generate and disseminate information about hazards, risks and vulnerability in their jurisdiction?	Public risk information
	v) Who is accountable for damages that result from false knowledge claims?	Uncertain knowledge claims
	vi) At which scales, through which procedures and with what expected content is new adaptation-relevant knowledge generated and used?	Learning mismatches
G Accountability Mechanisms	i) How are monitoring, evaluation, reward and enforcement functions organized?	Monitoring, evaluation, reward and enforcement functions
	ii) Do accountability mechanisms explicitly incorporate climate adaptation standards and targets?	Adaptation proofing of accountability mechanisms
Inherent attributes of the institutional system		
H Scale of institutions	i) Which temporal implications do the institutions have on actors' incentives?	Temporal scale
	ii) What are the spatial boundaries of the considered institutions?	Spatial scale
I Adaptiveness of institutions	i) Are legitimate changes in the rules-in-use feasible at low transaction costs?	Transaction costs of institutional change
	ii) To what extent and quality do the current rules pre-determine options for institutional change?	Institutional path dependence
J Formality of institutions	i) To what extent are the rules-in-use embedded in written laws, plans, and documents?	Formality of institutions