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Nine lives of uncertainty in decision-making: strategies for dealing with uncertainty in environmental governance

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ABSTRACT

Governing complex environmental issues involves intensive interaction between public and private actors. These governance processes are fraught with uncertainties about, for example, the current state of environmental affairs, the relevant set of decision alternatives, the reactions of other actors to proposed solutions or the future developments likely to affect an issue. Uncertainty comes in different shapes and sizes and different strands in the literature, which has placed emphasis either on the substance of the issue (e.g. in environmental sciences) or on the decision-making process (e.g. policy sciences). In this paper, we bring together these different strands of literature on uncertainty to present a novel analytical framework. We build on the argument that the nature of uncertainty consists of three types: epistemic uncertainty (involving the lack of knowledge about a particular system), ontological uncertainty (irreducible unpredictability due to inherently complex system behavior) and ambiguity (conflicts between fundamentally different frames about the issue at hand). Scholars have also argued the importance of differentiating between three different objects of uncertainty: substantive uncertainty (uncertainty about the content of decisions or policy issues), strategic uncertainty (uncertainty about the actions of other actors in the strategic game of decision-making) and institutional uncertainty (uncertainty about the rules of the game in decision-making). The framework is useful for analyzing and addressing the nine lives of uncertainty in decision-making. Better understanding of the range of uncertainties is crucial to design more robust policies and governance arrangements and to deal with wicked environmental problems.

KEYWORDS

Uncertainty; ambiguity; wicked problems; decision-making; environmental governance

Introduction

Governing environmental issues is increasingly characterized by social–ecological complexity and uncertainties (Torfing, Peters, Pierre, & Sorensen, 2012). Environmental issues, including climate change, food insecurity, freshwater availability, nature conservation and natural resource depletion, require the active involvement of public and private actors from a range of different backgrounds and with (vested) interests in decision-making. Decisions need to be made about, for example, which goals to pursue, which policies to develop, how to implement them, how to mobilize resources and how
to evaluate the results (Peters & Pierre, 2016). Making such decisions is not only challenging because of the technical complexities of environmental impacts and ecosystems but also because of the social complexity of the network of other actors who have a stake in these decisions, and because of the complexity of the institutional settings in which these decisions are made (Klijn & Koppenjan, 2016). Furthermore, many of such issues can be characterized as *wicked*, meaning different actors are framing the issue differently, in which the stopping rule is not clear and, in many cases, the solution does not exist.

Decision-making in this kind of complex environmental governance contexts is fraught with uncertainties, for example about the current state of affairs, the relevant set of decision alternatives, the reactions of other governance actors or the future developments likely to affect the issue under consideration. Some environmental issues like climate change are prime examples of long-term policy problems with uncertainties due to time lags between policies and their effects, often spanning over one or more generations, and due to the interconnectedness of environmental issues with other policy issues (Nair & Howlett, 2017; Underdal, 2010). Environmental impacts on, for example, water systems originate from such a diverse set of human activities that tracing the exact sources of the impacts becomes exceedingly difficult and that predicting the responses of the multitude of actors to new policy measures is close to impossible. Not surprisingly, uncertainties have attracted considerable scholarly attention in the environmental science and environmental governance fields, in relation to, for example, climate change (Asseng, 2013; Buurman & Babovic, 2016; Buytaert et al., 2010; Mitchell, 2015), forestry (De Koning et al., 2014; Petr, Boerboom, Ray, & van der Veen, 2015) and water resources (Jensen & Wu, 2016; Sigel, Klauer, & Pahl-Wostl, 2010; Thissen et al., 2015; van den Hoek, Brugnach, Mulder, & Hoekstra, 2014). Subsequently, several studies have called for alternatives to design more robust policies that are better equipped to manage the intractable uncertainties of wicked problems (Capano & Woo, 2017; Nair & Howlett, 2017).

The literature is rather divergent and in several cases biased in how uncertainty is understood and conceptualized. A recent review of the research on policy-making regarding uncertainty in the water sector has identified several such systematic biases (Jensen & Wu, 2016). First, there is bias toward physical and natural sources of uncertainty at the expense of human and behavioral uncertainty, particularly in relation to flood risk. Second, different sources of uncertainty are mostly treated as independent, while these different sources of uncertainty may be part of an interlinked system. Third, the focus is generally on tools to reduce or contain uncertainty, rather than on approaches such as learning to accommodate the design of robust policies.

This paper aims to contribute to the emergent literature on policy robustness and uncertainty by developing a comprehensive framework to conceptualize uncertainties in environmental governance. We first discuss the main classifications of uncertainty on which our framework rests (section 2), followed by a discussion of the *natures of uncertainty* (epistemic, ontological and ambiguity) in section 3, and the *objects of uncertainty* (substantive, strategic and institutional) in section 4. In section 5, we present the resulting three by three matrix of the nine lives of uncertainty in decision-making and the associated go-alone and collective strategies actors can use to manage the uncertainty. The paper ends with a reflection on the value of a more
comprehensive understanding of uncertainty for the design of robust policies to manage wicked environmental problems.

Classifications of uncertainty

Many different types of classifications to catalog uncertainty exist. As early as 1990, Funtowicz and Ravetz (1990, p. 22) identified the ‘increasingly popular activity of classifying uncertainties’. The Numeral, Unit, Spread, Assessment and Pedigree (NUSAP) system they proposed is focused on the uncertainty of scientific measurements, values and numbers and concerned about their quality as policy inputs (Funtowicz & Ravetz, 1990; van der Sluijs et al., 2005). It outlines a notation system for expressing uncertainty in terms of the relevant unit of measurement, the spread or inexactness of the number, an assessment of the unreliability and the pedigree – a qualitative indication of the strength of the evidence and of the process through which the number was produced.

Other frameworks include the uncertainty matrix proposed by Walker et al. (2003) which aims to provide a conceptual basis for uncertainty management in model-based decision support, relying on a definition of uncertainty as ‘any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system’ (p. 5). The uncertainty matrix distinguishes the location of uncertainty in the model, the level of uncertainty between deterministic knowledge and total ignorance and the nature of uncertainty. The latter dimension introduced the distinction between epistemic uncertainty and variability uncertainty into the classification of uncertainties. Epistemic uncertainty refers to the imperfection of our knowledge that may be reduced by more research. Variability uncertainty, also termed indeterminancy (Brown, Heuvelink, & Refsgaard, 2005; Dewulf, Craps, Bouwen, Taillieu, & Pahl-Wostl, 2005; Refsgaard et al., 2005) or ontological uncertainty (Kwakkel, Walker, & Marchau, 2010; Walker et al., 2003), is due to inherent variability in human and natural systems. Hence, doing more research may not attain reducing these uncertainties.

While ambiguities in the interpretation of numbers (Funtowicz & Ravetz, 1990) or ambiguity in the definition of the boundaries of the system (Walker et al., 2003) had been mentioned in preceding uncertainty classifications (Janssen, Petersen, van der Sluijs, Risbey, & Ravetz, 2005), ambiguity was not considered to be a different type of uncertainty (Dewulf et al., 2005; Koppenjan & Klijn, 2004). Emphasizing uncertainties as a challenge for decision-making, uncertainty has been conceptualized as a knowledge relationship between a decision maker and the socio-techno-environmental system at hand (Brugnach, Dewulf, Pahl-Wostl, & Taillieu, 2008). In the resulting uncertainty framework, three types of uncertain knowledge relationships are proposed: unpredictability (ontological uncertainty), incomplete knowledge (epistemic uncertainty) and multiple knowledge frames (ambiguity). The latter was defined as the situation in which there are ‘different, and sometimes conflicting, views about how to understand the system to be managed’ (Brugnach et al., 2008). A broader definition of uncertainty, encompassing the three different types, was proposed as well: ‘the situation in which there is not a unique and complete understanding of the system to be managed’ (Brugnach et al., 2008). The distinction of ambiguity as a separate type of uncertainty was picked up in a revision of the uncertainty matrix (Kwakkel et al., 2010), now
including ambiguity, epistemology and ontology as three different natures of uncertainty.

In parallel, policy scholars recognized the increasingly complex networks of public and private actors that have an influence in the decision-making process. The increased wickedness of problems meant that understanding the uncertainties in decision-making is of paramount importance for making decisions (Roberts, 2000; Van Bueren, Klijn, & Koppenjan, 2003). One of the explicit frameworks referencing uncertainty in governance processes is the work by Koppenjan and Klijn (2004) who distinguish between three types of uncertainty. The first is uncertainty regarding the content of decisions or policy issues, which can either because of due to either the lack of information or because of diverging frames about the information. In the second, they point to the importance of strategic uncertainty, which refers to the uncertainty about the actions of other actors in the strategic game of decision-making. With the third, they argue that decision-making is influenced by institutional uncertainty, which refers to uncertainty about the rules of the game in decision-making (Koppenjan & Klijn, 2004). In the second edition of the book (Klijn & Koppenjan, 2016), the authors move away from explicitly conceptualizing uncertainty and reformulated their key concepts into substantive, strategic and institutional complexity. Distinctions between the types of substantive uncertainty that have been developed elaborately in the uncertainty literature are thereby largely disregarded.

Building a more comprehensive framework for understanding and addressing uncertainties in decision-making can benefit from (a) covering the broad range of social and behavioral uncertainties by including substantive, strategic and institutional uncertainties; (b) distinguishing between ambiguity, ontological and epistemic uncertainty as fundamentally different natures of uncertainty; and (c) combining these categories into a three by three matrix yielding nine different types of uncertainties.

**Nature of uncertainty: epistemic, ontological or ambiguity**

Building on earlier research and classifications discussed in the previous section (Brugnach, Dewulf, Henriksen, & Van der Keur, 2011; Dewulf et al., 2005; Koppenjan & Klijn, 2004; Kwakkel et al., 2010), we distinguish the nature of uncertainty into three types. The main reasons for distinguishing between ontological uncertainty, epistemic uncertainty and ambiguity are that they (a) pertain to different phenomena, (b) imply a different scale for assessing their degree and (c) require different types of strategies.

**Epistemic uncertainty** refers to uncertainty due to our lack of knowledge about a phenomenon and is therefore a characteristic of the human state of mind. The relevant range for assessing the degree of epistemic uncertainty varies between perfect knowledge and total ignorance. Epistemic uncertainty can in principle be reduced by increasing our knowledge about the phenomenon of interest, gathering more information, doing more research or building better models.

**Ontological uncertainty** refers to uncertainty due to inherent variability in the phenomenon of interest such that its chaotic behavior precludes full predictability. Ontological uncertainty is therefore a characteristic of the ‘state of the world’ (the phenomenon of interest itself), rather than a ‘state of mind’ (our knowledge about the phenomenon). The relevant range for assessing the degree of ontological uncertainty
varies between completely deterministic behavior and completely chaotic behavior by the phenomenon of interest. By definition, ontological uncertainty cannot be reduced by doing more research or building better models about the phenomenon of interest.

Ambiguity refers to uncertainty due to the simultaneous presence of multiple frames of reference about the phenomenon of interest. Because multiple frames of reference are linked to multiple sensemakers, ambiguity is a characteristic of a ‘state of society’. The relevant range for assessing the degree of ambiguity varies between unanimous clarity and total confusion. Ambiguity is not likely to be reduced by more information or research but rather by methods that aim at aligning frames and supporting joint sensemaking.

Object of uncertainty: substance, strategies or institutions

Clearly, the substance, content or knowledge of environmental issues is a relevant object of uncertainty, but not the only one. Of critical importance are the decisions other actors are going to take in relation to their own decisions, and those are often hard to predict (Edelenbos & van Meerkerk, 2015; Klijn & Koppenjan, 2016; Torfing et al., 2012). In complex policy problems, actors are often highly interdependent in their decision-making, for example, for majority voting, access to resources or coalition building. Moreover, these decision-making processes take place in different – often loosely coupled – policy arenas in which decisions of one arena can influence the outcome of other arenas. The institutional context in which these decision-making processes take place is also not self-evidently clear. It may not be clear which formal and informal rules apply, how decision authority is distributed or who decides, which creates significant institutional uncertainty. Therefore, we adopt the distinction between substantive, strategic and institutional uncertainty by the object to which it refers, or what it is that we are uncertain about (Klijn & Koppenjan, 2016; Koppenjan & Klijn, 2004).

Substantive uncertainty refers to uncertainty about the nature of the problems that are addressed in an environmental governance process and about their causes or solutions. For example, whilst it is clear that there is large natural variability in the global climate, increase of greenhouse gas emissions as result of human influence (i.e. industrialization) has substantially amplified natural variability of the climate causing significant climate risks. Yet uncertainties remain as to how much can be attributed to human activities, which impacts are expected and what their magnitude will be or how climate change will develop in the (near) future. In other words, the complex interplay of a large number of variables may defy our predictive abilities, relevant information may be lacking or conflicting, our scientific understanding of the problems might be incomplete or different actors may work from very different understandings of what the problem is really about.

Strategic uncertainty refers to uncertainty about the strategic choices made by actors involved in the governance process. Particularly in highly complex problems, actors are interdependent when it comes to making decisions about complex issues but generally have very different ideas and interests with respect to the outcome of the decision-making process. Consequently, their interaction becomes a strategic policy game (Scharpf, 1997) in which actors can choose, for example, to compete or collaborate,
to build coalitions or rather to go alone in trying to achieve their goals. For example, in the transboundary water governance case of the Nile basin, riparian countries are uncertain about the other’s future intentions and political actions regarding major new infrastructure projects in the Eastern Nile Basin, introducing a form of strategic uncertainty (Wu, Jeuland, & Whittington, 2016). Actors also make decisions in various arenas, some of which are inaccessible to other actors yet having consequences for these others. Consider, for example, how new EU emission policy influenced by strategic NGO lobbying can affect domestic agricultural policies and practices. The complex interplay of anticipating and reacting to strategic moves by other actors introduces considerable uncertainty into the process.

Institutional uncertainty refers to uncertainty about the formal and informal rules of the game that apply in an environmental governance context (Ostrom, 2005). Institutions can be understood as ‘systems of rules that structure the course of actions that a set of actors may choose’ (Scharpf, 1997, p. 40). Formal rules are those that are described and made explicit and in principle often open to anyone, for example, written in legal documents, guidelines or explicitly discussed during meetings. However, there are many informal rules that are not made explicit and are more difficult to understand, such as logics of what is appropriate, certain ways of working and cultures within organizations (March & Olsen, 1989). These are often the result of slowly growing and solidified practices of actors that are difficult to pin down and hardly ever written down. The many actors involved in environmental governance do not only have different ideas about the substance of the issues and different strategic interests but they also work from different institutional backgrounds. This can result in high uncertainty about which institutional frameworks will guide the governance process. As has been shown in the case of the fisheries sector (Young, 1998), vagueness in rules arising from the pressures of negotiation processes, gaps between the rules on paper and the rules in practice, conflicts between local and international rules or uncertainty about the future development of rules are exemplary for institutional uncertainties.

**Nine lives of uncertainty: types and strategies**

Combining the three natures of uncertainty and the three objects of uncertainty creates a three by three matrix, which we refer to as nine different types of uncertainty (see Table 1).

Each of these captures a different type of uncertainty that is relevant to complex decision-making. Each of the nine uncertainties also requires a different approach for addressing it. Building on different strands of the environment and policy literature, we discuss relevant strategies for dealing with each of them. An important choice for selecting a strategy is whether uncertainties are dealt with through go-alone or concerted strategies (Klijn & Koppenjan, 2016). Go-alone strategies are unilateral actions that aim to maximize one’s own benefits, while concerted strategies seek to address the uncertainties through coordination with other actors. We will discuss relevant strategies for dealing with each of the nine types of uncertainty, each time distinguishing between go-alone and concerted strategies.

Instead of claiming that these are the best or most optimal strategies, we rather point out the relevant repertoires of strategies from which governance actors can choose when engaging in complex decision-making processes. Which strategy to pursue is
ultimately a choice to be made by governance actors, depending on their means, goals and position with the network, as well as experience with previous strategies about other issues in other arenas (learned experience), the outcomes of previous rounds of decision-making (accumulation of strategies) and success/failure of previous strategies attempted.

**Substantive epistemic uncertainty**

Lack of knowledge about the substance of an environmental governance issue can be addressed by strategies that increase knowledge and information about the topic. This may involve gathering information about well-understood environmental parameters, such as water pollution indicators. In other cases, a better understanding of the system is needed, requiring more research or modeling efforts (Brugnach et al., 2008). In an environmental governance context, however, knowledge and information is usually not available to all actors but fragmented across the network of actors.

Go-alone strategies include all forms of information gathering and knowledge acquisition about the environmental issue at hand, whether self-generated or obtained from others, when this information and knowledge are not shared with other actors and used for one’s own purposes. When particular knowledge or information brings a competitive advantage to actors, a go-alone strategy may involve keeping it hidden or inaccessible for others.

Concerted strategies for dealing with substantive epistemic uncertainty include not only information and knowledge sharing activities between different actors but also more coordinated activities like joint fact finding (Matsuura & Schenk, 2016), knowledge co-creation (Mauser et al., 2013) or participatory model development (Brugnach, Tagg, Keil, & Lange, 2006).
Substantive ontological uncertainty

The inherent unpredictability of complex environmental processes challenges actors to make choices, even when they cannot know how exactly the system will develop or what exactly the consequences of their choices will be. Assuming there are no viable options to bring the unpredictable environmental processes under human control (e.g. damming a river to bring unpredictable river discharge under human control), the relevant strategies to deal with substantive ontological uncertainty involve adapting decisions to unpredictable future changes (Brugnach et al., 2008). Anticipating a broad range of possible future scenarios and evaluating decision options against those scenarios are central to approaches like robust decision-making (Lempert, Groves, Popper, & Bankes, 2006). Including flexibility to change course when circumstances change is central to approaches like adaptive management (Allen & Garmestani, 2015; Pahl-Wostl, Sendzimir et al., 2007) or dynamic adaptive policy pathways (Haasnoot, Kwakkel, Walker, & Ter Maat, 2013) that have been designed to deal with substantive ontological uncertainty.

Go-alone strategies for dealing with substantive ontological uncertainty include efforts by individual actors to make their decisions more robust and/or flexible in the light of unpredictable future changes, while concerted strategies include adaptive governance (Folke, Hahn, Olsson, & Norberg, 2005), in which emphasis is placed on system-level coordination and building collective adaptive capacity through developing and linking nodes of expertise in an actor network that can be mobilized to address unexpected developments.

Substantive ambiguity

The presence of different frames about the substance of the issue poses a particular challenge for environmental governance actors because they cannot assume other actors are on the same page in how they understand the problem. Adding knowledge and information is unlikely to be helpful here and may add to the confusion by increasing substantive ambiguity even further (Dewulf et al., 2005). While some strategies aim to increase substantive ambiguity to stimulate richer debate and the development of more creative solution options, most strategies aim for some kind of frame alignment between actors (Klijn & Koppenjan, 2016). An important difference between relevant strategies to deal with substantive ambiguity is whether they aim to reduce the variety of frames or whether they actively try to work with the variety of frames (Brugnach et al., 2011).

Go-alone strategies that deal with substantive ambiguity revolve around promoting one’s own frame and/or trying to getting rid of others’ frames. Oppositional strategies (Brugnach et al., 2011) assume that one’s own frame can be actively imposed upon others (e.g. because of an actor’s powerful position) or that other frames can be safely ignored (e.g. by preventing access to decision-making). The persuasive communication strategy (Brugnach et al., 2011) assumes that, with the right spin, others can be convinced to voluntarily adopt one’s own frame. From a multiple streams decision-making perspective (Zahariadis, 2003), manipulation strategies have been identified that are used by policy entrepreneurs amidst the ambiguity in policy-making to further their
pet proposals. This may involve strategically framing problems and/or solutions such that they can be coupled more easily, or invoking higher order symbols that elicit similar meanings and emotional responses in large numbers of people (Zahariadis, 2003).

Concerted strategies take the variety of frames as a starting point and aim to account for this variety in the decision-making process. Learning is often an important ingredient in these strategies, as in social learning (Pahl-wostl, Craps et al., 2007; Reed et al., 2010), cross-frame learning (Klijn & Koppenjan, 2016) or dialogical learning (Brugnach et al., 2011; Dewulf, François, Pahl-Wostl, & Taillieu, 2007). Learning to understand others’ frames is the first step to achieving integration or connection (Dewulf, Mancero, Cardenas, & Sucozhanay, 2011; Klijn & Koppenjan, 2016) between the variety of frames. A concerted strategy that recognizes the frame variety but does not address the frames directly is trying to negotiate a socially robust (Nowotny, 2003) or mutually beneficial agreement that is meaningful from within the different frames, although possibly for different reasons (Brugnach et al., 2011; Islam & Susskind, 2013). Often a combination of learning and negotiation strategies is needed for decision-making in environmental governance (Leeuwis, 2000).

**Strategic epistemic uncertainty**

Lack of knowledge about the actions and interactions of other actors is a common challenge in networked environmental governance contexts. From the perspective of an actor, the striving of other actors may not be clear with respect to the governance issues at hand, which actions they have already taken, or who else is part of the relevant network. Strategies may vary from ascertaining information to carrying out a full-fledged network analysis (Klijn & Koppenjan, 2016).

Go-alone strategies involve intelligence-gathering activities about other actors, as in uncovering their actions, with whom they are interacting or options regarding the environmental governance issues at hand. While desk research can prove useful here, existing network links may be more important to obtain inside information.

Concerted strategies for addressing strategic epistemic uncertainty involve the mutual exchange of information between actors about their actions, goals and plans. This may take the form of an in-depth network analysis involving a number of steps, for example identifying relevant actors, reconstructing their perceptions, analyzing their positions and interdependencies, mapping the different decision arenas and rounds and identifying interaction patterns, trust relations and the formal and informal rules of the game (Klijn & Koppenjan, 2016). The willingness of actors to share this kind of information with others will often require that actors see the potential for joint decision-making.

**Strategic ontological uncertainty**

Irreducible unpredictability of the (inter)actions of actors has been a central interest in game theory (Camerer, 2003; Scharpf, 1997). The prisoner’s dilemma is a classic example in which a decision needs to be made in which the outcome depends strongly on a decision that somebody else will take, but without the possibility to predict or
obtain information about that other decision (Axelrod, 1980; Ostrom, 1998). Without full insight into other actors’ goals, means and plans, and even when some of that information is available, strategic decisions of other actors remain to some extent unpredictable. Because more information is by definition not helpful for dealing with ontological uncertainties, addressing strategic ontological uncertainty involves a choice between trying to control others’ decisions and trying to adapt to the unpredictability of the others’ decisions.

When actors strongly depend on the resources of other actors, go-alone strategies that deal with strategic ontological uncertainty can take the form of influencing or controlling the others’ decisions. Powerful actors may be in the position to keep other actors in check, influencing their choices such that they effectively make more predictable decisions. When one’s position in the network of actors does not provide leverage to control others’ decisions, adapting to the strategic ontological uncertainty becomes the relevant strategy. In iterated social dilemma situations in which mutual cooperation is rewarded but unilateral defection as well, a tit-for-tat strategy, that is cooperating as long as the other side does, has been shown to outperform other go-alone strategies (Axelrod, 1980). In real-life environmental governance contexts, strategic interaction takes place in a fragmented and dynamic environment, with actors operating in multiple arenas (Klijn & Koppenjan, 2016). It may be uncertain whether other actors will agree to a plan or pull out, whether they will implement their part of the deal or act as free riders or whether they will enter one coalition over another. To deal with situations in which other actors unexpectedly block your preferred plan A, relevant strategies revolve around keeping other options open through preparing a plan B, organizing the capacity to devise a plan B when necessary, preparing to minimize the damage of a failed plan A or actively pursuing multiple plans at the same time.

Concerted strategies that deal with strategic ontological uncertainty try to achieve some form of collective control or adaptation by coordinating the strategies of different actors (Scharpf, 1994). One of the aims is to counter the negative consequences of uncoordinated individual choices resulting in mutual losses in social dilemma situations, for example the depletion of common pool resources (Ostrom, 1999). Actors who are willing to negotiate are able to agree to the mutual adoption of rules such that collective action becomes possible. This implies a commitment to not engage in opportunistic strategies. Collaboration agreements (Gray & Wood, 1991), covenants (Ostrom & Walker, 1992), contracts (Lyons & Mehta, 1997) and associated sanctions (King & Lenox, 2000) have been studied as alternatives to hierarchically imposed rules. Network governance scholars have argued that actors often face big challenges in negotiating these rules by themselves and have proposed process management strategies as a response (Klijn & Koppenjan, 2016). This requires that actors agree to (temporary) process rules on how to interact without asking substantive commitments at the start. Process management then involves strategies like connecting or disconnecting actors and/or decision-making arenas, designing interaction processes and rules of the game and facilitating interaction between actors (Klijn & Koppenjan, 2016).

**Strategic ambiguity**

Different frames about the (inter)actions of actors are likely to emerge in networked strategic action. This ambiguity does not refer to our inability to predict what others
will do, but to different possible interpretations of what others are actually doing. What one actor may frame as an unavoidable defensive response may be framed as an aggressive provocation by another. What one actor may frame as authentic cooperative behavior may be framed as strategic opportunistic behavior by another. This brings us into the realm of process frames (Dewulf et al., 2009) in which differences in constructing the meaning of interaction processes are a central concern. Process frames are often linked to identity frames (Dewulf et al., 2009), referring to different constructions of the meaning of self, others and relationships, employed in activities like stereotyping, impression management and scapegoating.

Go-alone strategies for dealing with strategic ambiguity involve the manipulation of the ambiguity to one’s own advantage. Such strategies can be observed clearly in political games in which the very same act of a politician (e.g. stopping a subsidy program) may be framed as untrustworthy, firm, cowardly or responsible. In networked strategic action, earning respect, trust or credibility is equally crucial and can be significantly affected by how others frame one’s actions.

Concerted strategies for dealing with strategic ambiguity seek to establish constructive interaction processes between actors, with the aim of aligning interpretations of other actors’ characteristics and what they are doing. Entrenched stereotypes, which may keep actors locked into negative expectations and interpretations of others’ behaviors, can thus be explored and challenged (Gray, 2007).

**Institutional epistemic uncertainty**

Lack of knowledge about the rules of the game that apply in any particular environmental governance arena is an important challenge. Governance actors may lack knowledge about the formal rules that are in place, about which formal rules actually apply to this arena and/or about the informal rules of appropriate behavior in interacting with others (March & Olsen, 1989).

Go-alone strategies for dealing with institutional epistemic uncertainty are aimed at filling the gaps in one’s own knowledge about the formal and/or informal rules that apply. Hiring lawyers to map and assess the formal rules and regulations is one way of doing this, potentially creating a competitive advantage over other actors who do not have that overview. Building knowledge about informal rules is more challenging because these are not codified or easily accessible even for the more experienced participants in the networked decision-making arena (Klijn & Koppenjan, 2016). Engaging in interaction and observing the reactions of others (trial and error) is the prime way in which people are socialized into the informal rules of a particular setting, but reflective practitioners will often be able to provide useful accounts of these informal rules to newcomers or outsiders.

Concerted strategies aim at building collective knowledge about the applicable rules and regulations, a process that could be referred to as joint rule-finding (Luetge & Mulerji, 2016). This might involve sharing of the legal expertise available in the network to build a more complete picture of the formal rules and regulations that apply, or jointly reflecting about the informal rules in use – an exercise requiring considerable openness and reflexivity on the part of the involved actors.
Institutional ontological uncertainty

Irreducible unpredictability of the rules of the game is to be expected in crowded institutional spaces such as environmental governance networks (Klijn & Koppenjan, 2016). It is often unpredictable which formal and informal rules, out of the many that are potentially applicable, are actually going to be applied in which arena. But rules can also change in unpredictable directions, both gradually, as they are applied and (re-) interpreted over time, and abruptly, when new formal rules are put in place or existing ones are abolished, as in the United States withdrawal from the Paris Climate Agreement in 2017.

Go-alone strategies that deal with institutional ontological uncertainty can be roughly divided into control and adaptation strategies. The former include attempts to unilaterally influence or determine which rules are going to be applied or whether and how rules are going to be changed. This may involve lobbying or pressuring other actors to create, change or abolish rules on the part of social movements (Gamson, 1995), interest groups (Cigler & Loomis, 2011) or policy entrepreneurs (Mintrom & Norman, 2009). Adaptation strategies aim to develop robust plans for action that safeguard one’s own interests under various scenarios of changes in the rules of the game (institutionally robust solutions), and/or flexible plans for action that keep options open and allow one to change course in response to changes in the rules of the game (institutionally flexible solutions).

Concerted strategies that deal with institutional ontological uncertainty involve attempts at getting a collective grip on what are going to be the rules of the game through negotiated rule-making (Langbein & Kerwin, 2000) or similar collaborative and network governance strategies (Gray & Wood, 1991; Huxham, 2000; Klijn & Koppenjan, 2016). A particularly challenging but important variety of negotiated rule-making for environmental issues is multi-lateral negotiation at the global level, like in the global climate regime (Bodansky, 2001), but also business–NGO partnerships negotiate rules for certifying commercial products like sustainable palm oil (Schouten & Glasbergen, 2012; Seitanidi & Crane, 2014). At the level of (often informal) interaction rules in the network, jointly setting ground rules for network membership, information exchange and decision-making or conflict management procedures are relevant strategies (Klijn & Koppenjan, 2016).

Institutional ambiguity

Different frames about the rules of the game and/or how they should be applied are a common challenge for decision makers (March & Olsen, 1989) and particularly relevant for networked environmental governance processes. In itself, the generality of rules, allowing them to apply across a range of situations and points in time, is at the same time the source of at least some unavoidable ambiguity in their application to any particular case. Situations first need to be understood as instances of the category of situations for which the rule was made, a process that may also involve substantive ambiguity regarding what the environmental issue really is about. It may also be ambiguous as to how to apply the rules, for example, when important criteria are not well defined and may lead to legal uncertainty in the case of formal rules.
Go-alone strategies for dealing with institutional ambiguity involve exploiting rule ambiguity by invoking those rules that work to one’s advantage or trying to get formal backing for one’s own interpretation of the rules of the game through taking the case to court.

Concerted strategies for dealing with institutional ambiguity are aimed at coordinating and aligning interpretations of rules between actors and through informal interactions, multiparty negotiations or more formal processes of mediation as an alternative to litigation (Carnevale & Pruitt, 1992). Institutional ambiguity can also be the starting point for collective efforts to change the rules such that they become less ambiguous and/or better applicable to the environmental issue at hand, making the concerted strategies for dealing with institutional ontological uncertainty relevant here as well.

Discussion and conclusion

Despite the wealth of available knowledge about environmental issues, uncertainties are omnipresent in environmental governance. Where literature systematically has biases for specific types or objects of uncertainty in decision-making (Jensen & Wu, 2016), our comprehensive framework of nine types of uncertainty allows for a more thorough understanding of uncertainties in decision-making.

The comprehensiveness of our framework becomes visible when comparing it with other classifications. Earlier classifications only cover substantive epistemic and ontological uncertainty but not ambiguity (Walker et al., 2003), or they cover the three natures of substantive uncertainty without considering strategic or institutional uncertainty (Brugnach et al., 2008; Kwakkel et al., 2010). A recent attempt to create a roadmap for embracing uncertainty in participatory climate change risk management (Döll & Romero-Lankao, 2016), for example, splits up epistemic uncertainty according to whether its object is the substance (substantive epistemic uncertainty) or the participatory process (strategic epistemic uncertainty) but does not make this distinction for ontological uncertainty or ambiguity. Yet, these are critical components that need to be considered when designing strategies to manage such uncertainties (van Pelt et al., 2015). We argue that combining the three natures of uncertainty with the three objects of uncertainty capitalizes on extant uncertainty scholarship, while at the same time providing a more structured and comprehensive classification and revealing a number of combinations that can be considered blind spots in the uncertainty literature (e.g. strategic and institutional ambiguity).

Our framework clearly goes beyond physical and natural sources of uncertainty that have dominated decision-making on environmental issues and, in doing so, identifies a much wider range of possible strategies than reducing substantive uncertainties only. These different types of uncertainty are not independent, but rather an integral part of the complexity of decision-making processes and institutional contexts. This also means which strategies to select depends on the attentiveness of the policy practitioner to recognize certain types of uncertainty and to develop appropriate intervention strategies to manage the uncertainty. However, which uncertainty is in place is not always clear cut. Is our limited understanding of oceanic methane emissions and its contribution to global warming (Kort et al., 2012) a lack of understanding that can be remedied by more research (substantive epistemic uncertainty) or will it be impossible to know due
to inherent variability (substantive ontological uncertainty)? Similarly, it is important to
differentiate between people not knowing the rules (institutional epistemic uncertainty)
and different viewpoints on the rules in place (institutional ambiguity). Whilst these
demarcations might seem trivial at first, not paying attention to these distinctions may
result in trying to solve the wrong problem. In the latter example, gaining more
understanding of the rules is not going to help if the actual uncertainty is caused by
the different interpretations of the rules. Valuable time, energy and resources might be
lost by implementing strategies that do not fit with the uncertainty at hand, and, in
some cases, the efforts might actually be counterproductive – for example, generating
more knowledge about the impacts of nano-technology (e.g. substantive epistemic)
might actually prove to be fuel rather than solve debates that are fraught with sub-
stantive ambiguity.

Different uncertainties require different strategies to address them, yet very few
comprehensive insights exist in the strategies actors can use to manage different types
and sources of uncertainty. Borrowing from different strands of literature on environ-
mental modeling, conflict and negotiation research, framing theory and game theory,
amongst others, we compiled relevant examples of both go-alone and concerted stra-
teologies. These two types of strategies are often discussed in isolation or even by different
communities of scholars, while we are convinced that much is to be gained by studying
go-alone and concerted strategies in relation to each other. Further research is needed
to better understand what these strategies are, how effective they can be and under
which conditions they are used to manage uncertainties. Particularly empirical studies
that target the link between go-alone strategies and concerted strategies are needed to
advance our thinking in how to navigate the many uncertainties actors face, and then
one can propose concrete recommendations to overcome some of them.

Our insights are relevant for the policy design literature. Many environmental
issues are still governed with the assumption of a causal link between the scientific
evidence and the policy content being discussed. This assumptions have been
debunked in policy literature (Cairney, 2016), and our framework demonstrates
the strategic and institutional uncertainties that play an important role into under-
standing why ‘good’ science does not automatically translate into ‘good’ policy
decisions. Navigating the different types and sources of uncertainty therefore
means broadening our view of what needs to be robust to govern complex environ-
mental issues. As we have argued, it is critical to consider robust policy not as policy
output (e.g. robust policies are those designed to deal with substantive epistemic or
ontological uncertainty) but rather consider robustness as a broader design principle
that affects how we think of policy arrangements more generally. Different strands
have called for more ‘robust’ design of institutional and policy systems. Some of this
literature already exists. For example, building on Ostrom’s work, Anderies and
Janssen (2013) demonstrate how different institutional design criteria might increase
robustness for socio-ecological systems for local natural resource management. They
clearly identify defined boundaries, proportionality between providers and benefici-
aries and specific rules in place as key design principles of robust governance
arrangements. This means leaving enough room to deal with substantive types of
uncertainty in policies plans and instruments, as propagated in most robust policy
and deep uncertainty literature (Buurman & Babovic, 2016), but also designing
robust governance arrangements that allow for accepting unknowns, create room to experiment and articulate flexible rules and procedures, amongst other things. Our framework offers some contours for designing such robust governance arrangements for managing uncertainties on ‘wicked’ environmental issues.

Disclosure statement

No potential conflict of interest was reported by the authors.

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