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OPINION

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Governing climate risks in the face of normative uncertainties

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Abstract

Governing risks is not only a technical matter, but also a matter of ethical and societal considerations. In this article, we argue that in addition to scientific and technical uncertainties, we need to also address normative uncertainties of risk decisions. We define normative uncertainties as situations where there are different partially morally defensible -- but incompatible -- options or courses of action, or ones in which there is no fully morally defensible option. We conceptualize normative uncertainties, distinguishing between the four categories of evolutionary, theoretical, conceptual, and epistemic normative uncertainties. We will show different instances of normative uncertainties in climate adaptation strategies. We finally present two methods for identifying and dealing with normative uncertainties, namely, the Wide Reflective Equilibrium and adaptive planning. Situations of normative uncertainties have always been and will continue to be present in risk decisions and they have often been dealt with in an implicit manner. In this article, we make them explicit, which could lead to better morally informed and justified decisions about climate risks.

This article is categorized under:
Climate, Nature, and Ethics > Ethics and Climate Change.

KEYWORDS

adaptive governance, epistemic uncertainty, normative uncertainty, risk governance, wide reflective equilibrium

1 | INTRODUCTION

Dealing with risks has too often been considered to be purely a technical matter, based on classic definitions of risk in terms of numerical probability distributions. The literature on risk governance has emerged as a response to this. Many risks such as climate risks cannot be simply calculated as a function of probability and effect, because they are essentially "systemic risks". That is, they are complex risks that involve uncertainty and ambiguity (Klinke & Renn, 2002; Lempert, 2002; Lempert, Nakicenovic, Sarewitz, & Chlesinger, 2004; Renn, 2008; Dessai, Hulme, Lempert, & Pielke, 2009; van Asselt & Renn, 2011).

Whereas risk governance has both a descriptive and a normative purpose, the literature on risk governance has predominantly focused on the descriptive challenges (e.g., van Asselt, 2005; Keohane & Nye, 2000; van Asselt & Vos, 2006, 2008). While some literature has focused on acknowledging and dealing with the normative issues of risk governance, some key normative questions remain unanswered. An important exception is the work of van Asselt and Renn (2011) who have put forward a set of principles, including the communication, the integration, and the inclusion principles. Indeed, as these authors stress, these principles have clear normative dimensions; for example, the integration principle emphasizes that not only probabilities and effects but also "values and [other morally relevant] issues such as reversibility, persistence, ubiquity, tolerability, equity, catastrophic potential, controllability, and voluntariness should be integrated in risk assessment and evaluation" (van Asselt & Renn, 2011, p. 442). However, how to deal with complex moral issues that could emerge from applying such principles—for instance, what to do when complying with one of these principles would stop us from complying with another one—remains unclear and unanswered.

In this opinion article, we argue that when governing risk, we need to acknowledge and address *normative uncertainties*—that is, when there is not one unequivocal right or wrong answer to an ethical question regarding risk—along with scientific and technical uncertainties. This is particularly relevant for climate risks because we often have to deal with international, and intergenerational risks, which will give rise to intricate instances of normative uncertainties. We will use climate adaptation as an example to illustrate this.

This article is organized as follows. Section 2 expands on the notion of normative uncertainties in risk, while Section 3 discusses why it is a relevant notion for climate risk, using examples of climate adaptation. Section 4 presents the conclusions, showing different ways forward for addressing and including normative uncertainties in climate risk decisions.

2 | WHAT ARE NORMATIVE UNCERTAINTIES?

Before introducing our notion of normative uncertainty, let us first briefly discuss the common definitions of uncertainty, as used in the model-based decision-making literature and of moral uncertainty as discussed in the philosophy literature, to show how both definitions could be complementary. Uncertainty in model-based decision-making often relates to the state (and availability or lack of) knowledge and information. It is described by Funtowicz and Ravetz (1990) as situations of inadequate information and it consists of inexact and unreliable information but also situations of plain ignorance. Walker et al. (2003) further refine this definition by distinguishing three dimensions of uncertainty: nature, location, and level. The nature of the uncertainty is whether uncertainty is due to intrinsic variability in the phenomenon of interest, or due to either a lack of knowledge or ambiguity (Dewulf, Craps, Bouwen, Taillieu, & Pahl-Wostl, 2005; J. H. Kwakkel, Walker, & Marchau, 2010). The location of uncertainty is often mentioned to specify what is uncertain. The level of uncertainty specifies the severity of the uncertainty, ranging from well-characterized uncertainty to recognized ignorance.

Moral uncertainties have been defined by Lockhart (2000) as situations in which it is uncertain how one ought to act, for example, because different moral theories would recommend different courses of action.[1] The literature in ethics and philosophy on the subject mostly deals with the question of what an individual agent should do in case of competing moral theories (Sepielli, 2008). The notion of ethical uncertainties has also been mentioned in the literature to emphasize the intricacies of dealing with choices that are morally laden. For instance in bioethics where ethical uncertainties "cannot be eliminated by resolving (even imagining that we could) the factual dimension of uncertainty" (Cribb, 2020). Another example is in ethics of technology and in dealing with ethically laden uncertainties in the governance of geoengineering technologies such as Solar Radiation Management (Roeser, Taebi, & Doorn, 2019), for instance in establishing which ethical principle should be applied for compensation scheme for geoengineering technologies (Svoboda & Irvine, 2014).

Our notion of normative uncertainty integrates the model-based decision-making notion of uncertainty and the notion of ethical uncertainty in the philosophy literature. It builds on the basic rationale presented by Funtowicz and Ravetz (1990) in that it is referring to situations of inexactness, unreliability, and ignorance, but not only with respect to the state of knowledge, but also with respect to the normative dimensions of such situations. It further broadens the definition of Lockhart (2000) by including several other situations of moral or normative uncertainties.

We speak of normative uncertainty as a situation, in which there are different partially morally defensible but incompatible options or courses of action, or in which there is no fully morally defensible option. Choosing between different (partially) morally acceptable options resembles the distinction that Ross makes between "prima facie duties"—

as duties that one has moral reason to follow as long as they are not overridden by morally more compelling duties—and the "actual duty" as an all things considered duty in which moral conflicts have been properly addressed (Ross, 1930, pp. 19–21).[2]

We will distinguish between four categories of normative uncertainties, namely evolutionary, theoretical, conceptual, and epistemic normative uncertainties. Let us first introduce all four, while briefly discussing examples in conjunction with each category. Extensive example will be deferred to the next section, in which we show how normative uncertainties feature in climate adaptation policies.

Evolutionary normative uncertainties relate to situations in which it is unclear which moral norm will apply in the future to a certain situation creating risk. That is because both the technology and moral views could *evolve* in the future. That is, the development and implementation of a specific technology (e.g., climate adaptation technologies) could give rise to unanticipated consequences, which could render an earlier identified norm irrelevant, or it could add a new (not yet known) norm to the discussion. Furthermore, societies will evolve and so too could the meaning of what is considered "good" or desirable. A clear example of this is offered by the Dutch flood risk management practices. In response to the floods of 1916 and 1953, the Dutch built massive levee systems to regulate water levels and to block off dangerous invasions of water. However, in the late 1960 and early 1970, environmental concerns became more prominent and simply blocking off water was deemed no longer adequate due to the ecological consequences it could cause. This was reflected in a change in the design of flood defense systems, first with a moveable barrier in the Easter Scheldt Estuary, and nowadays with building with nature concepts such as room for the River and the Sand Engine. We will discuss this example more elaborately, while briefly reviewing almost a century of Dutch flood risk management in the next section.

Similar changes could take place when we have to deal with policy-making regarding technologies that require long-term planning such as nuclear waste disposal. When choosing a certain strategy for nuclear waste management, we have to find a balance between the interests of current and future generations, but also among future generations—namely, between near and distant future generations (Kermisch, 2016; Kermisch & Taebi, 2017). When we keep certain options open to near-future generations (e.g., retrievable nuclear waste disposal), it could in the future pose new normative challenges as a result of new available technology (e.g., to retrieve and further deactivate that waste; Taebi, 2012).

The second category is theoretical normative uncertainty, that is, when different ethical theories offer different answers to an ethical question in risk governance. The best example is the stark contrast between aggregate consequentialist theories that aim to maximize the greatest good for the largest number of people and deontological often more individualistic approaches to what is deemed as acceptable risk (Hansson, 2013, Chapter 2).

Conceptual normative uncertainties are the third category. They refer to the situation where different ethically relevant concepts (e.g., values) could be *prioritized* or *interpreted* differently. These differences could be revealed at both the conceptual and the empirical level, showing—for instance—that different prima facie ethically relevant concepts cannot be realized simultaneously and a trade-off is inevitable. Concerning prioritization differences, in choosing environmentally significant behavior, stakeholders could, for instance, prioritize values differently in terms of their moral relevance (de Groot & Steg, 2008). Concerning interpretation differences, there could be different legitimate interpretations of the same concepts[3]; for example, different stakeholders could interpret the value of sustainability in energy transitions differently; this is also referred to as normative diversity (Cuppen et al., 2019; Gaus, 2016).

The fourth category is epistemic normative uncertainty, that is, a situation in which there is incomplete knowledge about fundamental phenomena, or different interpretations are possible about the same body of knowledge (Paté-Cornell, 1996). This is where the model-based decision-making definitions of uncertainty, such as those offered by Funtowicz and Ravetz (1990) or Walker et al. (2003), and normative uncertainties to a great extent converge. One might argue that epistemic normative uncertainties are a specific type of epistemic uncertainties, because not all epistemic uncertainties carry normative weight, but in many instances, epistemic uncertainties have a normative dimension.

For instance in the formulation of climate change scenarios based on the interpretations of computer simulations anticipating future climate, many instances of epistemic uncertainties will raise (Petersen, 2000, 2012). The extent and severity of potential climate risks, along with the question to whom those risks would accrue would then comprise normative questions that would make many (bit not all) uncertainties in these future scenarios epistemic *normative* uncertainties. Two important questions with regard to this category are, can we reduce (or maybe even remove) epistemic uncertainties by acquiring more knowledge and information and, assuming that we can, should we reduce these uncertainties?

Let us start with the first question. Sometimes acquiring more information can simply reduce epistemic uncertainty, but as correctly argued by Walker et al. (2003, p. 8), "[n]ew knowledge on complex processes may reveal the presence of uncertainties that were previously unknown or were understated." As regards epistemic normative uncertainties, it is also safe to assume that more knowledge is unlikely to reduce them. For example, when an identical assessment result could lead to different interpretations (with different normative implications), or when there is contention about what is considered acceptable risk, acquiring more information neither removes nor reduces epistemic normative uncertainties.[4] As a matter of fact, normative uncertainties (for instance in which value should prevail) can be a major factor in why more research can even exacerbate controversies (Sarewitz, 2004).

As regards the second question, it should be noted that uncertainty in decision-making is not necessarily an undesired state of affairs that we should get rid of. As correctly argued by Stirling (2010), sometimes uncertainties could better help decision-makers appreciate the complexity of certain decisions (whose complexity cannot be simply reduced with more scientific knowledge), including its normative dimensions. If we try to reduce such uncertainties, we will be throwing the baby out with the bathwater.

Before moving on to the next section, four remarks seem to be in order. First, our categorization of normative uncertainties is merely a pragmatic heuristic following instances of normative uncertainties as we have come across in our investigation of the subject and in exploring this notion. In so doing, we are indeed building on the literature in ethics and decision theory but also in environmental governance (e.g., Stirling, 2003, 2010). In the latter field, for instance, discussions on the Precautionary Principle are rather prominent. The Precautionary Principle (PP) is, however, a strategy to shift the burden of proof to the developer, when dealing with epistemic uncertainties. As such, it is a normative response to epistemic normative uncertainties, as we have introduced in this paper. For instance, when there are concerns about long-term health impact of a certain substance, the PP could recommend refraining from further application of that substance for normative reasons—that is, concerns for the health of future people—even if there is no scientific evidence showing those long-term negative consequences (Hansson, 2018).

Second, some uncertainties described above could also be interpreted as instances of ambiguity. When, for instance, in a decision two incompatible values are at stake, one could argue that there is an ambiguity regarding which value is relevant. For instance in discussions on synthetic biology, the value of wellbeing (i.e., agricultural and medical benefits) could potentially conflict with the value of security (i.e., the potentially of manufacturing very harmful warfare); there could then be an ambiguity regarding about the relevance of each value (van de Poel & Robaey, 2017). Alternatively, one could argue that it is (normatively) uncertain whether well-being or security should prevail. Without getting too much involved in the semantic differences between the two notions, for the purpose of this article, we will retain our focus on normative uncertainties.[5]

Third, we have distinguished different but not necessarily crisply distinct categories of normative uncertainties; overlaps between the categories are very much possible. For instance, a conceptual normative uncertainty on what justice to future generations entails could at the same time give rise to a theoretical uncertainty in how justice in different normative theories has been perceived.

Fourth, it is one thing to acknowledge the normative dimension of risk decisions, but it is a whole different matter of how to address such issues in decision-making. While the latter is not the main focus of this piece, in the concluding section we will allude to some ways for including such normative uncertainties in the decision-making on risk.

3 | WHY NORMATIVE UNCERTAINTIES MATTER FOR GOVERNING CLIMATE ADAPTATION

In this section, we will illustrate how normative uncertainties feature in climate policies, focusing on climate adaptation policies. For each type of normative uncertainty, we will present an example, delving into what that uncertainty exactly entails.

Evolutionary normative uncertainties relate to situations in which it is unclear which moral norm would apply to a certain situation of climate risks. The history of Dutch Water Management over the last century is a case in point. In response to the 1916 flood, the Dutch build the closure dam. This dam closed off the Zuiderzee and turned it into a massive freshwater lake. The dominant concern was back then flood safety, and this was to be achieved through massive coastline shortening. In doing so, a very large estuary of high ecological value was destroyed. Moreover, many villages on the coast of the Zuiderzee depended on fishing as a major source of income. By closing of the estuary, they also lost their direct access to sea.

Later on, in response to the 1953 flood, the Dutch responded initially in the same way. Coastline shortening as design principle resulting in the closing of various bays and estuaries. However, there was a growing discontent with this strategy, resulting in a policy deadlock regarding the closing of the Eastern Scheldt. The trade-off between safety on the one hand, and environmental impacts and the loss of livelihoods was decided prominently in favor of safety; this proved to be unacceptable in the discussions following 1953 floods. After extended technical analysis and negotiations, a solution was found in the form of movable barriers, such that they could shut down and accommodate safety whenever needed, and remain open at all other time, ensuring ecological values. This solution was much more expensive, but was deemed to better balance the other impacts (Correljé & Broekhans, 2015).

In response to the near floods in 1993 and 1995, environmental concerns became even more prominent. Rather than using massive strengthening of embankments, room for the river and building with nature were the preferred strategy for reducing flood risk. Moreover, in the mid-2000, climate change worries triggered a debate on moving from reactive to pro-active flood risk management, with a strong emphasis on nature-based solutions in lieu of more traditional embankments and hydraulic structures. In short, a century ago the overriding concern was affordable flood safety. Nowadays, ecological concerns are at least as important as flood safety, potentially resulting in more costly solutions. We call these instances of evolutionary normative uncertainties.

The second category is theoretical normative uncertainty, that is, when different ethical theories offer different answers to an ethical question. Climate change adaptation is rife with such examples. An illuminating case is the adaptation of rice farmers in the Vietnamese Mekong Delta. In the past, the national government has been stimulating triple rice cropping (Käkönen, 2008; Tran, van Halsema, Hellegers, Ludwig, & Wyatt, 2018). Three crops possibilities is, however, only possible to farmers behind high dikes while farmers behind the so-called August dikes can only grow two crops of rice. August dikes means that the protected areas are flooded once the rain season starts in late august. Under normal circumstances, this means that you can only have two cropping seasons per year. However, the floods starting in late August provide new nutrients and remove diseases from the fields. High dikes enable three cropping seasons, without the natural renewal of nutrients and removal of disease. Hence, you need to invest more in fertilizer and pesticides. This increases year after year. However, given climate change, as well as upstream hydropower developments, the runoff of the Mekong is changing (Dang, Cochrane, Arias, & Tri, 2018); there are now increasingly years with a runoff in the flood season which stays below the august dikes. Increasingly, people with field protected by august dikes are gambling by planting a third crop and hoping that the floods are not substantial. Farmers behind high dikes can thus grow three crops of rice per year, while farmers behind August dikes can only grow two crops of rice. In the third growing season, they have to find alternative employment for income as their paddy fields are inundated for weeks.

How should farmers adapt to this change? Farmers that currently are doing triple rice farming generally have a higher income (Chapman & Darby, 2016). They thus have more options to autonomously adapt by, for instance, changing to other crops like fruits. The double rice farmers have less options at their disposal. If this problem is approached from an aggregate point of view, for example by maximizing agricultural production, quite different policy options are preferred, than when this problem is viewed from the Rawlsian point of view of favoring the least (or less) well off (Rawls, 1971). Maximizing agricultural production would entail stimulating triple rice cropping, mechanization, and a move to higher valued crops. Richer farmers are in a better position to benefit from this than poorer farmers, thus reinforcing existing inequality, and giving rise to inequity. From the perspective of pro-poor development, instead, the focus would be on the double rice farmers and how to supplement their income when their fields are flooded. The theoretical normative uncertainty here leads to substantially different adaptation options. This highlights an instance of normative theoretical uncertainties. That is, ethical approaches favoring the maximization rationale of utilitarianism would then put the richer farmers in a better position (thus exacerbating inequalities), while Rawlsian approaches that emphasize taking into account people's starting position would help a completely different group of (poorer) farmers. Similarly, Ciullo, De Bruijn, Kwakkel, and Klijn (2019) demonstrate that utilitarian approaches to flood risk management are intrinsically risk averse and might disproportionately favor downstream regions, while Rawlsian approaches, although technically more complex to apply because of the need to account for hydrologic interactions, can help in balancing the distribution of flood risk along with a river system.

Conceptual normative uncertainties are the third category: that is, when different ethically relevant concepts (e.g., values) could be *prioritized* or *interpreted* differently. The history of Dutch Flood Risk management, introduced to illustrate evolutionary normative uncertainty, is in part also characterized by this category. At present, there is still an ongoing debate between mostly civil engineers on the one hand and ecologists on the other hand. Both agree that costs, safety, and the environment are ethically relevant. However, there is a profound disagreement on how to balance these values. On the one hand, there exist ample examples of research where, drawing on cost–benefit arguments, it is argued that traditional flood measures such as embankments are much more cost efficient than nature-based solutions. The issue here is that the ecological values created by nature-based solutions, as well as the optionality created for future adaptation are hard to include in this cost–benefit analysis. On the other hand, there are those who argue that there should be a cost assigned to the lock-in that is being created by embankments (Haasnoot et al., 2019). Lock-inn is then treated as a negative externality; a transfer cost could help internalize the externality. Although the debate is often shaped in economic terms, its root cause, we content, is a fundamentally different interpretation of flood safety, costs, and environmental values.

The fourth category is epistemic normative uncertainty, that is, a situation in which there is incomplete knowledge about fundamental phenomena, or different interpretations are possible about the same body of knowledge. The very choice of mitigation versus adaptation is one that gives rise to a host of epistemic normative uncertainties. The ongoing debates on intergenerational justice in climate change and the question as to how to consider the interests of different people in the future when deciding on (the extent of) mitigation versus adaptation is a manifestation of epistemic normative uncertainties. That is, how we value future interest determines the choice for mitigation versus adaptation. While sizable resources need to be spent in the near future to keep the stable climate, as the argument goes, the benefits will be enjoyed in the next hundreds of years as reduced harmful impacts of climate change; different people will then pay the costs and receive the benefits (Posner & Weisbach, 2010, p. 146). Future value will then be discounted, at a rate called the discount rate. What this annual rate will be determined then, how we assess current and future impacts, all of which have tremendous normative consequences. The contention is between the positivists who often assign the actual market rate of return, as opposed to the ethicists who add qualitative (ethics) arguments when assessing future costs and benefits. In the climate policy debate, the positivists are best represented by Nordhaus who assigns 5.5% and argues that adaptation in the future is the most sensible option and the ethicists best represented by Stern, who uses 1.4% and argues for large-scale mitigation efforts (Posner & Weisbach, 2010, p. 150).

4 | CONCLUSIONS: HOW TO IDENTIFY AND DEAL WITH NORMATIVE UNCERTAINTIES

In the proceeding sections, we have argued that normative uncertainties need to be acknowledged and included in policy decisions regarding climate risk. We have further presented four categories of normative uncertainties and shown why acknowledging normative uncertainties is highly relevant in climate policy. In this concluding section, we will present two methods that could be helpful in identifying and dealing with such normative uncertainties. First, we will discuss the Wide Reflective Equilibrium (WRE), as a common approach in moral philosophy and practical ethics for dealing for ethically intricate matters. We argue here that WRE could help us to identify instances of normative uncertainties and to address some of these instances. Second, adaptive governance will be discussed, which is—due to its longitudinal approach—perfectly suitable to deal with the temporal aspects of normative uncertainties. Let us explain these two approaches in more details.

When dealing with normative uncertainties, the decision-maker needs to be able to assess, to the extent possible, the moral justification of a decision. In applied ethics, this justification could be provided by following either a top-down approach, in which moral theories are central and should guide us in addressing specific morally relevant questions, or a bottom-up approach, in which justification is sought in existing social agreements and practices, from which we make moral decisions (Beauchamp, 2003, pp. 7–9). However, neither of these methods alone is capable of providing moral justification for a complex and morally intricate risk decision in the face of normative uncertainties. What could help is a combination of both methods in a coherent theory.

Building on the Wide Reflective Equilibrium, as introduced by Rawls (1971, 2001) and developed by Daniels (1979, 1996, 2011), a method could be developed to identify and to the extent possible deal with normative uncertainties. This iterative method will alternate between analyzing the lower level of *considered judgments* of individual stakeholders about specific risk decisions, and analyzing the top level of theoretical moral considerations; between these two levels of judgment and theory, there is a mid-level of *principles* or *rules* that we believe govern our intuition. Normative uncertainties can be found at all three levels.

The WRE will require both top-down and bottom-up investigations, and different normative uncertainties will be identified for each type of investigation. As for the top-down philosophical investigations, a first challenge will be to operationalize the ethical theory (or the top level) for the specific choice (i.e., a specific technology or decision) at hand. The top-down investigations will mostly reveal theoretical and conceptual uncertainties. The bottom-up investigations will focus on how different stakeholders in different stages of risk governance arrive at decisions with respect to normative uncertainties, concerning specific choices made. It will require an analysis of the debate concerning a proposed choice as well as the information provided by the policy-making and NGOs as well as interviews with key stakeholders. The bottom-up investigations will mostly reveal epistemic and conceptual uncertainties.

WRE has been applied mostly for dealing with practical moral problems in biomedical ethics (Beauchamp & Childress, 2009). In the context of technological development, WRE has been used to account for the moral judgments of the actors involved in R&D networks (van de Poel & Zwart, 2010) and to organize moral deliberation on the topic of responsibility distribution in the research setting (Doorn, 2012). It has further been proposed to be used in the context of technological risks, while acknowledging its methodological and practical difficulties for application (Doorn & Taebi, 2018); WRE is “certainly no panacea for resolving moral conflicts” (Taebi, 2017, p. 1823). Yet, as correctly argued by van de Poel (2016, p. 191), WRE could be considered a “source of debate, argumentation and reflection” in risk decisions. More importantly, WRE could help us identify and sometimes respond to situations of normative uncertainties.

Let us finally review a more hands-on approach in policy-making—that is, adaptive planning—when dealing with deep uncertainties,[6] that is a situation in which multiple possible future could be enumerated, but without a likelihood (J. H. Kwakkel et al., 2010). The idea of adaptive planning entails that policy-making needs to be dynamic with built-in flexibility (Albrechts, 2004; Eriksson & Weber, 2008; Lempert, Popper, & Bankes, 2003; Neufville & Odoni, 2003; Schwartz & Trigeorgis, 2004; Swanson et al., 2010; Walker, Rahman, & Cave, 2001). Adaptive planning means that plans are designed from the outset to be adapted over time in response to how the future may actually unfold or to account for changing understandings of what society values. The way a plan is designed to be adapted in the face of potential changes in conditions is announced simultaneously with the plan itself rather than taking place in an ad hoc manner *post facto*. The flexibility of adaptive plans is a key means of achieving decision robustness. While the future is unfolding, many deep uncertainties are being resolved. Having an adaptive plan allows decision makers to adapt the implementation of the plan in response to this. This means that a wide variety of futures have to be explored during plan design. Insight is needed into which actions are best suited to which futures, as well as what signals from the unfolding future should be monitored to ensure the timely implementation of the appropriate actions. The timing of plan adaptation is not known a priori; it depends on how the future unfolds. In this sense, adaptive planning differs from periodic planned adaptation (Petersen & Bloemen, 2015; Sowel, 2019), where changes can occur at predetermined moments (e.g., every 5 years,) and which entails a periodic review of conditions which might result in an adaptation to the original plan. Adaptive planning involves a paradigm shift from planning in time to planning conditional on observed developments (J. Kwakkel & Haasnoot, 2019).

The initial ideas for adaptive planning were developed almost a century ago. Dewey (1927) put forth an argument that policies be treated as experiments, with the aim of promoting continual learning and adaptation in response to experience over time (Busenberg, 2001).[7] Early applications of adaptive policies can be found in the field of environmental management (Holling, 1978; McLain & Lee, 1996), where policies are designed from the outset to test clearly formulated hypotheses about the behavior of an ecosystem being changed by human use (Lee, 1993). A similar attitude is also advocated by Collingridge (1980) with respect to the development of new technologies. Given ignorance about the possible side effects of technologies under development, he argues that one should strive for correctability of decisions, extensive monitoring of effects, and flexibility. Policy learning is

BOX 1 We distinguish between four categories of normative uncertainties

1. Evolutionary normative uncertainty related to situations in which it is unclear which moral norm would apply in the future to a certain situation creating technological risk. That is because both the technology and moral views could *evolve* in the future.

2. Theoretical normative uncertainty related to when different ethical theories offer different answers to an ethical question in risk governance.

3. Conceptual normative uncertainty occurs when different ethically relevant concepts (e.g., values) could be *prioritized* or *interpreted* differently.

4. Epistemic normative uncertainty is a situation in which there is incomplete knowledge about fundamental phenomena, or different interpretations are possible about the same body of knowledge.

also a major issue in evolutionary economics of innovation (de la Mothe, 2006; Faber & Frenken, 2009; Mytelka & Smith, 2002). Rosenhead, Elton, and Gupta (1972) drew attention to the importance of flexibility in the field of operations research, in contrast to the more typical focus on optimality. They argued that for many real-world decision problems, optimality is not the true focus of the decision maker. More recently, Brans, Macharis, Kunsch, Chevalier, and Schwaninger (1998) and Walker et al. (2001) developed structured, stepwise approaches for developing flexible plans. Walker et al. (2001) advocate that policies should be adaptive: one should take only those actions that are non-regret and time-urgent and postpone other actions to a later stage. To realize this, it is suggested that a monitoring system and a pre-specification of responses when specific trigger values are reached should complement a basic policy. Adaptive planning could help decision-makers be prepared for and—to the extent possible—respond to evolutionary normative uncertainties, both as a result of evolving knowledge and the state of technology as well as evolving moralities in the society.

In conclusion, normative uncertainties are present in different stages of decision-making about risk. This is very much the case for climate risks with transnational and intergenerational risks. Situations of moral uncertainties have always been and will always be present in risk decisions and they have often been dealt with in an implicit manner. In this article, we have tried to make them explicit, which could hopefully lead to better morally informed and justified risk decisions. Therefore, we have conceptualized them and presented methods for identifying and responding to them (Box 1).

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

AUTHOR CONTRIBUTIONS

Behnam Taebi: Conceptualization; resources. **Jan Kwakkel:** Conceptualization; resources. **Céline Kermisch:** Conceptualization; resources.

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ENDNOTES

[1]Lockhart uses the term "moral uncertainty"; in this article, we will use normative uncertainties to denote a broader meaning of uncertainties with a normative dimensions than the definition presented by Lockhart.

[2]See also how Beauchamp and Childress (2009) have used this notion in biomedical ethics.

[3]Rawls (1971) refers to this with the distinction between a concept and a conception; see also (Hart, 1961). In defending his theory of justice, Rawls argues that there could be a consensus about the *concept* of justice, whereas different *conceptions* of this concept could be different. Assuming that this distinction extends to other morally relevant concepts, the existence of different conceptions indicates normative uncertainties.

[4]Renn (2008, p. 77) calls these interpretative and normative ambiguity, respectively (see also Stirling, 2003). It should be noted that also interpretative ambiguity has normative implications in risk governance, for instance, to whom would a certain risk accrue.

[5]We acknowledge that some authors choose to distinguish between uncertainties and ambiguities (e.g., Renn, 2008; Walker et al., 2003).

[6]A note on "deep uncertainties" is in order, because at least on the surface of it, it looks like our notion of normative uncertainties. In Lempert's conception, deep uncertainty merely means that different actors have different weights on criteria, in a Multi-Criteria Decision-Analysis (MCDA) or a different utility function. Our notion of normative

uncertainty is broader than that and includes many other instances. For example, with many long-term issues, we do not really know what our future values might be. It is well established that revealed preferences and expressed preferences can be quite different even for the same individual facing the same choice.

[7]The idea of considering technology development as a social experimentation stems from the same thinking; see for instance (Taebi, Roeser, & van de Poel, 2012; van de Poel, 2009).

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