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Assessing risk management interventions from the perspective of intergenerational justice: preserving options and avoiding irreversible planetary loss

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ABSTRACT

Many of today's societal challenges involve temporal risk-risk tradeoffs. Given the bias toward short-term safety, these temporal risk-risk tradeoffs pose intergenerational justice concerns. There are currently no risk management frameworks that adequately include these concerns. This paper aims to fill this gap by exploring what intergenerational justice entails in the context of large-scale physical risk management interventions and to see to what extent intergenerational justice can be included in two existing frameworks: the Planetary Boundaries framework and the Dynamic Adaptive Policy Pathways approach. By examining common currencies from intragenerational justice, the paper argues that intergenerational justice requires preserving resources that maintain choice and option space. Applying these frameworks to the Northern European Enclosure Dam case suggests that the two frameworks together provide a comprehensive assessment of large-scale risk management interventions, balancing capability and resource-based justice while safeguarding adaptive capacity and ecological integrity. The paper also discusses the limits to the right to safety. Two fundamental open questions that require further research are the scope of intergenerational justice (or: how far in the future does intergenerational justice extend?) and how to deal with tradeoffs between different planetary boundaries.

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1. Introduction

Many of today's societal challenges require technological interventions with potentially significant future impacts (Aven 2020). Examples include geoengineering to address climate change (Sovacool, Baum, and Low 2023); CRISPR gene editing to create bioengineered organisms for environmental cleanup (bioremediation), which may also disrupt existing ecosystems (Qattan 2025); and increased pharmaceutical use due to aging populations, leading to the risk of drug residues in water systems and the rise of antibiotic resistance (Ben et al. 2019). The precise nature of these interventions and their outcomes are frequently unknown in advance due to the uncertainty surrounding the new technology and the lack of related historical data (Jansen and Herber 2024). Moreover, the costs and benefits of these interventions are often unevenly

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distributed, and interventions can reduce one risk while inadvertently introducing new ones. These so-called risk-risk tradeoffs, whether intentional or unintentional, are frequently the result of incomplete or rushed decision-making, as well as bounded specialization of risk managers (Löfstedt and Schlag 2017). Globalization further amplifies the likelihood of undesirable risk-risk tradeoffs.

One specific form of these tradeoffs involves intertemporal risk transfers. Efforts to prioritize traditional safety often conflict with sustainability goals by increasing energy consumption and resource use (Kishimoto 2013). For example, a heavier car is generally safer for the driver but consumes more fuel. Because sustainability concerns often relate to future generations, choosing a heavier (and safer) car can increase environmental risks for them. Scientific evidence for long-term risks is often weaker than for immediate risks, leading to a bias among both the public and policymakers in favor of short-term safety (Sahlin and Rundlöf 2017).

A growing body of scholarship emphasizes the need to address ethical and justice concerns in intertemporal risk-risk tradeoffs (e.g. Burger 2024; Rickard, Deline, and Smith 2024). Yet, ethical and justice frameworks are often developed in isolation from risk management tools, limiting their incorporation into decision-making processes (Siders 2022), especially for future and emerging risks characterized by high uncertainty. This gap is particularly concerning because intertemporal risk-risk tradeoffs can disproportionately shift risk burdens onto future generations. While intertemporal risk-risk tradeoffs in general carry the danger of postponing problems into the future, *intergenerational* risk-risk tradeoffs are particularly problematic, as they shift the risks to other risk audiences and thereby raise questions of justice. This paper addresses the research question: What should be considered when discussing distributive justice for future generations? Specifically, it examines what intergenerational distributive justice entails in the context of large-scale physical risk management interventions and explores how it can be more effectively embedded within existing risk management frameworks.

The paper uses the Northern European Enclosure Dam (NEED) as an illustrative case. This ambitious climate adaptation strategy proposes constructing two massive dams to transform the North Sea into a freshwater lake and to protect a large part of northern Europa against the risk of sea-level rise (Groeskamp and Kjellsson 2020). While the plan may be technically and economically sound, its ethical implications - particularly the risks it presents to future generations - require careful evaluation.

After a discussion of risk-risk tradeoffs in the context future risks and how this has so far been discussed in relevant literature (Section 2), this paper presents the example of the NEED (Section 3). After that, the paper elaborates on the concept of justice and maps the three most common currencies of justice discussed in the philosophical justice literature (Section 4). Section 5 introduces two existing frameworks that have been developed to guide environmental and climate-related decision-making. The section discusses to what extent these frameworks are compatible with the currencies discussed in Section 4. One of the lessons from this section is that there are limits to safety, which is discussed in relation to the right to climate adaptation in Section 6, where the paper elaborates a two-tier approach for intergenerational risk-risk tradeoffs. Just as certain risk interventions are required to ensure 'minimum safety levels' (or maximum allowable risks) for current generations, certain risk interventions may also require the establishment of a maximum threshold if they pose excessive risks to future generations. The concluding Section 7 summarizes the findings and presents some open questions that require further research.

2. Risk-risk tradeoffs and future risks

Before examining intertemporal risk-risk tradeoffs in greater detail, this section first defines the key terms. In this paper, risk is defined as 'the chance of an adverse outcome to human health, the quality of life, or the quality of the environment' (Graham and Wiener 1995, 12). This

Table 1. A typology of risk-risk tradeoffs. Source: Sovacool (2025); adapted from Graham and Wiener (1995) and Rascoff and Revesz (2002).

	Same type of risk	Different type of risk
Same population	*Risk Offset*: When the same target risk or adverse outcome is created in the target population	*Risk Substitution*: When one type of adverse outcome or target risk is replaced by another adverse outcome in the same target population
Different population	*Risk Transfer*: When the same target risk is shifted from one group to the other	*Risk Transformation*:When the countervailing risk is different in both outcome and affected group

definition is therefore broader than the narrow technical understanding of risk as the product of probability and consequence, as it also encompasses what is commonly referred to as Knightian uncertainty; that is, adverse events whose probabilities are not known (Knight 1935).

To further demarcate the type of risk-risk tradeoffs examined in this paper, the typology developed by Sovacool is instructive. Sovacool (2025) distinguishes four types of risk-risk tradeoffs, categorized along two dimensions: the populations at risk and the types of risk (Table 1). The intertemporal risk-risk tradeoffs that this paper focuses on fall into the bottom row of the typology; they involve tradeoffs where the countervailing risk is shifted to a different population, namely populations that are not yet alive (risk transfer and risk transformation). While intertemporal risk-risk tradeoffs could, in principle, involve the same type of risk (risk transfer), it is more likely that future populations will be exposed to different types of risk. For the purpose of this paper, future risks are therefore defined as countervailing risks in which the individuals potentially harmed by a present action are not yet alive at the time the risk is introduced. Climate policy, in particular, can inadvertently trade one type of risk for another, future risk, often affecting different groups in unequal ways (Sovacool, Baum, and Low 2023).

Although there is growing consensus that risk transformations require attention to distributive aspects, there are few concrete tools for determining what exactly is being distributed and what constitutes a fair distribution. Discussions often remain at the level of acknowledging that equity considerations are important (e.g. Burger 2024; Rickard, Deline, and Smith 2024). Similar calls for attention to equity considerations can be found outside the risk management literature (e.g. Pamplany, Gordijn, and Brereton 2020; Scholz and Schuppert 2025), yet these too generally fail to specify how such considerations should be integrated into decision-making.

One of the challenges with risk transformations is that the resulting risks are of a different nature, making it unclear, even if the issue is framed as a matter of distribution, what exactly is being distributed. This is particularly the case when the nature of future risks is itself uncertain, as it is far from straightforward to determine what is to be allocated. To date, the risk literature has paid little attention to the question of what, precisely, constitutes the distributive issue in such cases. Given the nature of the topic, this question has received more attention in the philosophical literature, where it is discussed under the headings of the 'metric' or 'currency' of justice, but this debate has primarily focused on justice among people living today ('intragenerational justice'). Justice towards future generations ('intergenerational justice') more generally has been widely discussed, originally primarily in the context of resource depletion and pollution, but in the last decades mostly in the context of climate risks, focusing on distributing the burdens of mitigation and adaptation actions among present and future generations. However, much of this literature emphasizes general obligations toward future generations without providing practical guidance for specific interventions. While climate change has undoubtedly spurred extensive philosophical discussions on intergenerational justice, most of these debates center on the extent of our mitigation duties to future generations. They often overlook the question of the appropriate metric of justice and offer little practical guidance for evaluating risk transformations, such as specific climate mitigation or adaptation interventions, or comparable issues like nitrogen use in agriculture (Battye, Aneja, and Schlesinger 2017). Moreover, philosophical discussions are often so abstract that they fail to provide actionable guidance for decision-making (Siders 2022).

A preliminary starting point for addressing the question of the metric of justice in risk transformations involving future risks can be found in the empirically oriented maladaptation literature. This literature originates in the observation that many adaptation actions unintentionally worsen climate change impacts or produce outcomes worse than the problem they were intended to address (Magnan et al. 2016; Schipper 2020). Hence, this body of literature takes risk-risk tradeoffs as its starting point and looks at which tradeoffs to avoid. Barnett and O'Neill (2010) identify five types of maladaptation: (1) increasing greenhouse gas emissions, (2) disproportionately burdening vulnerable populations, (3) incurring high opportunity costs, (4) reducing incentives to adapt, and (5) creating path dependencies. While some of these are specific to the climate context (types (1) and (4)), the second, third, and fifth are relevant for risk-risk tradeoffs more generally. Avoiding risk-risk tradeoffs that disproportionately burden vulnerable populations (2) aligns with the earlier discussion in the risk literature, which emphasizes that equity considerations should be addressed, and thus offers little that is substantively new. When Barnett and O'Neill (2010) refer to risk-risk tradeoffs that incur high opportunity costs (3), they mean that risk interventions should not consume resources that could have been invested in more effective or sustainable solutions, such as time, money, labor, or political capital. These interventions might seem beneficial in the short term, but they divert resources from better options, ultimately undermining long-term resilience or adaptive capacity. This type of maladaptation locks communities into suboptimal paths and limits future choices. Similarly, risk-risk tradeoffs that create path dependencies (5) are also undesirable.

Hence, both the philosophical literature and the maladaptation literature may provide useful insights to the risk literature on risk-risk tradeoffs involving future risks. The philosophical literature emphasizes the importance of identifying the appropriate metric of justice to advance the debate on how equity considerations should be incorporated into risk-risk tradeoffs with future risks. The maladaptation literature offers some initial clues about where to look for such a metric: avoiding lock-ins and path dependencies. However, Sovacool (2025) also warns against inaction solely because some actions may involve risk transformation. Not all future risks can be avoided, and not all path dependencies are equally problematic (Doorn 2018). Sovacool (2025) therefore argues for more refined risk assessment, in which the type and timing of risk impacts are duly considered in practical tools and decision-support systems to help policymakers systematically evaluate and resolve these tradeoffs.

This article explores how philosophical insights on justice, combined with maladaptation concepts, can inform risk management for intergenerational risk-risk tradeoffs. The Northern European Enclosure Dam (NEED) serves as a case to illustrate these discussions.

3. The Northern European Enclosure Dam

This section presents the Northern European Enclosure Dam (NEED) in more detail. The NEED was chosen as an illustrative case because it is an enormous project with implications that extend far beyond current generations and are of a different nature than the original risk it aims to prevent, namely, the risk of flooding due to sea level rise. In that sense, it constitutes a paradigmatic case of intergenerational risk transformation. Moreover, it is also a climate adaptation intervention, allowing for the incorporation of insights from the maladaptation literature. Lastly, the type and sheer scale of the intervention are such that it has irreversible impacts on the environment, making it a compelling case for exploring lock-ins and path dependencies.

As mentioned in the introduction, the NEED involves constructing two extensive dams - one extending between France and the southwestern tip of England, and another between the northeastern part of Scotland and Norway - which together would transform the North Sea into a lake. The NEED would protect over 25 million people, as well as key economic regions in northern Europe, from rising sea levels (Groeskamp and Kjellsson 2020). Over time, the lake

would become a freshwater lake. Groeskamp and Kjellsson (2020) compared the construction of the NEED with three other options: (1) doing nothing, (2) protection on a country-by-country basis, and (3) managed retreat. They conducted a preliminary quantification and assessment of the financial feasibility and technological challenges of the NEED, relative to the other options. Their calculations indicate that, in terms of monetary value alone, the cost of doing nothing would be 5 to 10 times higher than that of protection or managed retreat. This estimate does not account for the additional non-monetary losses and the potential social and political instability that could arise from inaction.

While Groeskamp and Kjellsson (2020) acknowledge that managed retreat could theoretically be a viable option if implemented well in advance of a potential disaster, they argue that for the North Sea, it is already too late. The result would likely be significant intangible costs, including social and psychological difficulties from displacing people from their homes, as well as the loss of cultural heritage (Nicholls and Klein 2005). Consequently, they view a project as extensive as the NEED or continuing with current country-by-country protection measures as the only realistic and effective solutions. Comparing these two options on economic and technical grounds, Groeskamp and Kjellsson (2020) suggest that, over the next 100 to 200 years, the NEED could prove to be both technically and economically superior to scaling up existing protection strategies (Figure 1).[1]

Groeskamp's and Kjellsson's assessment focuses on economic aspects. While they acknowledge the significant impacts the NEED would have on regional and global marine life, the livelihoods of local residents, and potentially on atmospheric circulation and rainfall patterns, these factors are not included in their assessment.

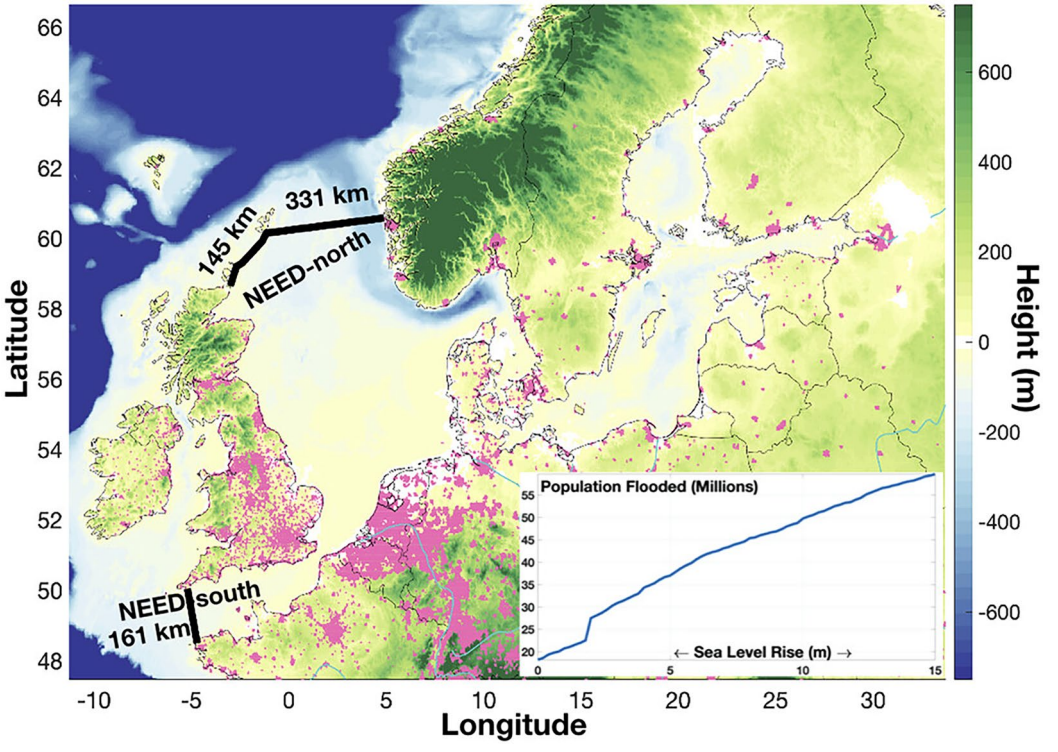

Figure 1. The proposed location of the Northern european enclosure Dam (NEED; thick black lines), with pink dots indicating flood-prone areas where population density exceeds 200 persons per square kilometer in 2020 (source: Groeskamp and Kjellsson (2020) under license CC by 4.0).

Although the NEED might offer future generations protection against sea level rise, it is questionable whether this is the only risk that should be included in the analysis. If we decide to construct such a dam today, we will significantly alter the future state of the earth. From a distributive justice perspective, this is far from a marginal side effect and it must therefore be included in the project's ethical evaluation. This raises the question: What exactly should we consider when discussing distributive justice for future generations in such evaluations? In the next section, we will explore the concept of distributive justice within the context of future generations.

4. Defining distributive justice

This paper examines what intergenerational distributive justice entails in the context of large-scale physical risk management interventions. As outlined in Section 2, this includes identifying the appropriate metric for expressing distributive justice. The focus is thus on one specific tenet of justice: distributive justice.

Before addressing this core question, it is helpful to briefly introduce the broader justice framework discussed in the justice literature and explain why other tenets are insufficient for adequately addressing intergenerational risk transfers. In the justice literature, justice is commonly conceptualized through two or three main dimensions: distributive justice, procedural justice, and, increasingly, justice as recognition. Procedural justice refers to the perceived fairness, transparency, and inclusiveness of decision-making processes (Schlosberg 2007). In the context of environmental and risk governance, it highlights the importance of meaningful participation, access to information, and the ability of all stakeholders, particularly those affected by decisions, to influence outcomes (Aven and Renn 2010; Klinke and Renn 2002).

Recognition, within risk governance and environmental justice, pertains to the acknowledgment and respect of diverse identities, values, experiences, and knowledge systems, especially those of marginalized or historically disadvantaged groups. Unlike procedural justice, which focuses on participation, recognition addresses whether individuals are regarded and treated as legitimate contributors to decision-making (Schlosberg 2007).

Especially in situations that concern people's local environment, procedural justice and justice as recognition are considered important to guarantee a careful process when decisions are made about this environment and to avoid decisions being made without giving directly affected people a voice (Juhola et al. 2022). The problem with intergenerational justice, however, is that future people are not yet alive. In that sense, procedural approaches – broadly conceived, that is, including justice as recognition – cannot straightforwardly be applied to address issues of intergenerational justice. We cannot directly listen to future people's voices. Contemporary procedural justice is often also thought to conflict with future distributive concerns (Goodin 1992; Wallack 2006), so to adequately deal with the concerns of future generations, approaches have been proposed to represent future generations in policy-making today (e.g. by reserving parliamentary seats for specialized representatives of future generations (Ekeli 2005), or *via* the establishment of independent Offices for Future Generations (OFGs) that provide oversight of parliament and/or executive bodies (Boston 2017)). However, these approaches still take our contemporary values as a starting point and there is increasing recognition that certain values may change over time (Van de Poel 2022; Van der Weij et al. 2023). Procedural approaches alone thereby provide insufficient guidance on what to safeguard for future generations.

I will therefore focus on distributive justice as the substantive side of justice. In the risk literature, distributive justice is commonly defined as the fair allocation of risks and benefits (or burdens and protections) among individuals, communities, or social groups (e.g. Adger et al. 2006; Renn and Klinke 2015). There is broad consensus that distributive justice requires that risks should not fall disproportionately on already disadvantaged or marginalized populations (e.g. Bullard 2018; Renn 2017), and that those who benefit from risk-generating activities (such

as industry or consumers) ought to bear a fair share of the associated risks (e.g. Hermans, Fox, and van Asselt 2012; Renn 2017).

However, despite this general agreement, the literature provides relatively little discussion of the underlying nature of this distribution problem, particularly regarding what constitutes a 'fair' or 'proportional' distribution of risks and benefits. Moreover, it is not trivial to determine what exactly ought to be distributed (Doorn 2015). The literature variously refers to, amongst others, resources (Méndez-Barrientos et al. 2024), risk exposure (Mohai, Pellow, and Roberts 2009), risk reduction (Ciullo et al. 2020), preventive measures (Thaler and Hartmann 2016), or a combination of these (De Goër de Herve, Schinko, and Handmer 2023), each of which implies a distinct perspective on the distributional problem.

Here, the philosophical literature on justice complements the risk literature. Broadly sharing the definition of distributive justice as found in the risk literature, the philosophical literature elaborates distributive justice around three issues: the scope, the metric, and the pattern or shape, sometimes also described as the 'who' (scope), the 'what' (metric), and the 'how' (pattern) of justice (Robeyns 2017). The scope of justice concerns the group of people among whom justice applies. This paper starts from the assumption that intergenerational justice matters, so in that sense, the scope is partly 'a given'. However, even if we agree that intergenerational justice matters, it still an open question how far into the future justice applies, as we will see in Section 5.

Compared to discussions about scope and metric, discussions on the allocation pattern are probably the most widely known beyond the philosophy literature. It is now common practice to distinguish between, at least, utilitarian allocation principles and egalitarian allocation principles, which aim to maximize the aggregated sum of costs and benefits and aim to reduce inequalities respectively. However, also sufficientarian principles (aimed at bringing people above some threshold level; e.g. Crisp 2003; Dorsey 2008) and prioritarian principles (giving priority to the people worst-off; e.g. Parfit 1997) are increasingly used in the more applied multidisciplinary literature (e.g. Adler et al. 2017; Ciullo et al. 2020; Gourevitch et al. 2020).

The metric of justice is about the currency in which to express justice. If we say that something should be distributed according to a utilitarian, egalitarian, sufficientarian, or prioritarian principle, what unit is it that we apply the principle to? Three central approaches are usually distinguished: welfarist approaches, resource-based approaches, and the capability approach, where capabilities refer to individuals' genuine opportunities to do and to become things of value. This approach was initially developed by Amartya Sen (2009, 1980) and further developed in partial collaboration with Martha Nussbaum (2000, 2011).

While the scope, metric, and pattern cannot be treated in isolation from each other - certain combinations of especially pattern and metric are difficult to defend - distinguishing between these aspects of justice helps to think in a more nuanced way about justice. To that end, let us look in more detail at the characteristics of the different metrics of justice to see what they have to say about intergenerational justice. The aim of this exploration is not to identify one single best metric but rather to explore which aspects require attention when thinking about intergenerational justice.

4.1. Welfarist approaches to justice

Welfarist approaches assert that overall welfare, or essential well-being (Dworkin 1981), is the only intrinsic value, and any allocation should reflect how welfare is distributed among people. Utilitarianism, which seeks to maximize well-being ('the greatest happiness for the greatest number'), is a prime example. Welfarist theories face a key issue: they struggle with the implications of expensive and cheap tastes respectively. If a person develops costly tastes, welfarism may require providing extra resources to ensure their pleasure aligns with distribution patterns. Conversely, it may neglect the needs of those who, having adapted to deprivation, do not express preferences for what they lack, such as a green city park for someone unaccustomed

to urban greenery (Doorn 2019). Most people would agree it is unjust to deny such individuals resources or opportunities based on their adapted preferences. Adapted preferences pose a particular challenge in risk management, because they can mask actual vulnerabilities and reduce motivation to pursue alternative strategies. When people adjust their expectations to limited protection or ongoing exposure, it may appear that current arrangements are sufficient. This can weaken the case for change, reinforcing institutional lock-ins and path dependencies (Sovacool, Baum, and Low 2023). Over time, these dynamics not only limit the flexibility to respond to emerging risks but also reduce the capacity to anticipate and prepare for future threats, leaving systems increasingly brittle in the face of uncertainty.

The root of these problems lies in using welfare, initially a measure of individual quality of life, as a basis for distributive justice. This issue becomes particularly significant in the context of future risks, where present actions shape not only future people's resource access but also their preferences. Future generations might adapt to degraded environments by not desiring cleaner conditions or better climates. For instance, if the presence of the NEED were to cause the disappearance of the main migratory bird routes over northwestern Europe, people might not realize the joy that the presence of birds can bring. However, this does not imply that the disappearance of these bird routes is acceptable or desirable. Subjective welfare theories thus fail to provide a robust metric for distributive justice.[2]

4.2. Resource-based approaches to justice

Resource-based approaches to distributive justice focus on the means available to individuals, aiming to allocate these according to some to-be-specified pattern. The political philosopher John Rawls' is one of the earliest philosophers who developed resource-based account of distributive justice, advocating for an equal distribution of goods universally valued, such as basic rights, liberties, income, and wealth (Rawls 1999[1971]). The list of potential risk-related metrics for distribution presented at the start of this section (resources, risk exposure, preventive measures) indicates that many proposals for distributive justice in the risk literature rely predominantly on resource-based approaches. However, a key criticism of these approaches is their failure to account for individual differences; the utility derived from resources varies significantly depending on personal characteristics. Indeed, numerous research shows how different populations respond differently to the same exposure (e.g. Modaresi Rad et al. 2023; Schwartz, Bellinger, and Glass 2011; Varshavsky et al. 2023).

Despite this limitation, resource-based approaches offer valuable insights when applied to intergenerational justice. Brian Barry provides a notable account, arguing that the depletion of non-renewable resources should be compensated so that future generations are not left worse off in terms of productive capacity (Barry 1989). Writing before climate change became a central concern, Barry focused on environmental issues such as pollution and resource depletion. He rejected the extreme view that justice requires leaving future generations an untouched stock of resources, which would prohibit any use of non-renewables. Instead, he argued for compensating future generations by leveraging improved technology and increased capital investment to create new productive opportunities that offset the loss of easily accessible natural resources.

Barry's approach emphasizes that resource depletion is unjust when it reduces the productive potential available to future generations. Compensation, in his view, ensures fairness by maintaining equivalent opportunities for production and well-being over time. While this framework provides a practical starting point, it focuses narrowly on economic opportunities. It overlooks other significant risks, such as the loss of homes and ecosystems due to pollution or climate change, which go beyond economic valuation. An assessment of the NEED, or similar intervention, is more than an assessment of the economic opportunities the interventions offers. Nonetheless, Barry's shift from resources to opportunities is an important conceptual insight, not only highlighting why intergenerational justice matters, but also helping to distinguish

between desirable and undesirable irreversible consequences: those that can be compensated or generate new opportunities are less concerning than those that cannot be reversed and diminish future possibilities. By broadening the scope of considerations beyond strictly economic ones, a more comprehensive approach to intergenerational justice can be developed.

4.3. Capability approach to justice

The capability approach critiques resource-based models for overlooking human diversity, emphasizing that equal resources do not guarantee equal achievements. Instead, it focuses on individuals' opportunities to pursue what they value, considering personal characteristics (e.g. talents, skills), social environment (e.g. legal rules, social norms), and material environment (e.g. physical infrastructure) (Sen 1980). For instance, communal sanitary services in unsafe areas may be inaccessible to women and children due to safety concerns, highlighting the importance of real opportunities over mere resource availability (Doorn 2019). How individuals differ in their ability to use various resources to achieve well-being is referred to as the individual conversion factor (Sen 1999[1985]).

In the context of intergenerational justice, some scholars argue that future generations' advanced technologies and adaptive capacities will enable them to manage or resolve the environmental and social risks we leave behind (Silver 1999). However, this assumption risks unjustly shifting the burden of current challenges onto those future populations. Given the uncertainties about future generations' actual capacities and the nature of future risks, relying on their presumed adaptability to justify passing on present vulnerabilities is ethically problematic. It does not mean that our obligations to future generations could not change, depending on how they fare under new conditions, but a detailed exploration of how to assess this change is beyond the scope of this paper.

Setting aside the 'conversion factor', resource-based approaches and capability approaches converge in the context of intergenerational justice in risk distributions in that they both emphasize that future generations should have enough opportunities or options to choose from. However, the capability approach also highlights the importance that people should be free to make their own choices (i.e. that they should have agency), which is particularly relevant in the context of intergenerational risks. The capability approach draws attention to the diversity of potential future lives and values, emphasizing the importance of preserving a broad range of adaptive options and respecting possible differences in aspirations and priorities (Byskov 2024). The pluralism found in the capability approach reflects the inherent pluralism in risk governance, with the existence of multiple, often incommensurable values and vulnerabilities that must be balanced (Klinke and Renn, 2002). The capability approach offers a valuable framework by emphasizing the preservation of diverse freedoms and adaptive capacities rather than simply distributing resources or minimizing single risk metrics (Robeyns 2006). The freshwater lake created by the NEED may deprive some people of their livelihoods, while offering others opportunities for a new means of living, and both perspectives are equally valid. As such, the capability approach's emphasis on preserving options aligns with a resilience-approach to risks, promoting flexibility and agency to navigate uncertain risks (cf. O'Brien 2012, Doorn 2017).

In the next sections, we will see how these insights can be translated into the context of intergenerational risk-risk tradeoffs.

5. Including intergenerational justice in risk management tools

So far, we discussed three approaches that are primarily developed for the context of intragenerational justice. Only Barry's resource-based account of justice explicitly dealt with intergenerational justice. Looking at welfare-based approaches, the current literature on intragenerational

justice provides convincing arguments as to why individual welfare is not a suitable metric for justice (see Page (2006) for an overview of this critique).

The discussion of resource-based approaches and the capability approach suggests convergence on the idea that we need to preserve those things that provide people with a choice or option space. However, the operationalization of this option space and the underlying justifications differ. For Barry, the primary concern is ensuring that the opportunities that people would otherwise have are not taken away, with these opportunities being defined rather narrowly and aimed at a specific goal (in Barry's example, the goal was productive potential). In contrast, for Sen, the intrinsic value of having agency is equally important in justifying the preservation of this option space. Intergenerational justice should not focus solely on goals set by current generations, but rather on ensuring that future generations have the freedom to adapt in ways that are meaningful to them (Byskov 2024).

Focusing on this option space, any framework for assessing the intergenerational aspects of interventions involving intertemporal risk-risk tradeoffs must, at a minimum, be capable of evaluating the options or choices available to future generations. How can these considerations of intergenerational justice be incorporated into decision-making frameworks? To this end, I examine two existing frameworks that have been developed to guide environmental and climate-related decision-making and future actions and apply them to the Northern European Enclosure Dam (NEED). These two frameworks are selected because they both incorporate intertemporal elements and have attracted attention in policy circles. In other words, they are more than merely theoretical constructs. However, they differ in how they incorporate the intertemporal dimension. The Dynamic Adaptive Policy Pathways framework does so explicitly, whereas the inclusion of intertemporal aspects in the Planetary Boundaries framework is more implicit. Additionally, while both emphasize the importance of keeping options open, they do so in different ways, reflecting similarities with resource-based approaches and the capability approach to justice, respectively. In this sense, these two frameworks offer promising avenues for exploring how intergenerational justice can be integrated into decision-making processes.

5.1. Planetary Boundaries framework

The Planetary Boundaries framework is a concept introduced by scientists in 2009 to demarcate a safe operating space for human activities (Rockström et al. 2009). It defines the safe limits within which human activities should operate to ensure the stability and resilience of critical Earth system processes. The Planetary Boundaries framework currently consists of nine boundaries.[3] Transgressing these boundaries could lead to abrupt or irreversible changes to the Earth's biosphere and its ability to sustain human life. As such, the Planetary Boundaries framework involves a radical shift in focus, away from people and their needs and towards Earth itself (Rockström et al. 2009).

The Planetary Boundaries framework has not been developed with the explicit aim to account for justice, neither intragenerational nor intergenerational. In fact, it is sometimes even criticized for not adequately including intragenerational justice issues (cf. Steffen and Stafford Smith 2013). Also the link with intergenerational justice is not made explicit. However, the idea of thinking in terms of 'planetary guardrails' provides a helpful metaphor: if intergenerational justice requires not taking away opportunities that cannot be compensated, as both a resource-based approach to justice and a capability approach to justice indicate, we should take environmental limits much more seriously as the cornerstone of intergenerational justice. This would not require us to make assumptions about what people will value many years from now. The advantage of basing intergenerational justice on the Planetary Boundaries framework is that it does not come with a commitment to either a resource-based approach or the capability approach; both approaches are consistent with the framework.

However, we are currently already far beyond some of the nine planetary boundaries. It, therefore, requires further elaboration on what to do with boundaries that have been transgressed already and how to make inter-boundary tradeoffs (Doorn, 2026). In that sense, an account of intergenerational justice based on the Planetary Boundaries framework comes with a commitment to value pluralism (Chang 2015); that is, the recognition that there are many different values in the world, and that these values are not always commensurable and that there is no single scale on which all values can be measured or ranked. This leads to genuine conflicts between values that cannot be resolved through straightforward calculative tradeoffs or simple rankings (Chang 2014). Indeed, the nine boundaries cannot be reduced to one overarching boundary or scale; as such, they are incommensurable. In this sense, using the Planetary Boundaries framework to address intergenerational justice appears to be more about explicating the risk-risk tradeoffs than resolving them. Nevertheless, it does provide the constraints within which these tradeoffs must be made. Any attempt at making such tradeoffs should begin with the recognition of the incommensurability of these boundaries and it may thus set 'upper limits' to the safety of certain risk interventions if they lead to a transgression of some boundaries. Yet even if we treat the planetary boundaries themselves as non-negotiable, determining the corresponding allocation pattern remains a non-trivial task. For example, can current generations use all the 'planetary space' on the boundaries that have not been transgressed yet, or should this be distributed between current and future generations (and if so, how)?

When applied to the NEED, rather than assessing it primarily in terms of economic costs, it is essential to consider how it performs across the various planetary boundaries. Although a full ecological assessment lies beyond the scope of this paper, it is reasonable to assume that transforming the North Sea into a freshwater lake would significantly alter local ecosystems, potentially placing pressure on the biosphere integrity boundary or disrupting global biogeochemical flows, depending on the extent of ecological change induced by the dam. Such ecological implications are a crucial part of the broader set of tradeoffs that must be evaluated.

In the context of risk-risk tradeoffs, potential benefits often receive far less attention than the associated risks (Löfstedt and Schlag, 2017). The Planetary Boundaries framework offers a means to address this imbalance by specifying not only risks but also potential long-term benefits, particularly those related to maintaining or restoring a safe operating space for humanity. Assessing how the NEED affects each of the boundaries, both in terms of possible transgressions and in terms of alleviating pressures or enhancing resilience, enables a more balanced and future-oriented analysis.

For example, the creation of a large freshwater body could improve conditions for certain endangered freshwater species. If these species are native and non-invasive, their proliferation could contribute positively to the biosphere integrity boundary, potentially offsetting some ecological risks. Such developments might strengthen biodiversity and ecological resilience over the long term, factors that matter greatly for future generations. By making explicit how interventions interact with multiple planetary boundaries over time, the framework clarifies whether an action supports long-term Earth system stability. In doing so, it supports a more forward-looking, and also more just, distribution of both risks and benefits across generations.

5.2. Dynamic adaptive policy pathways

The Dynamic Adaptive Policy Pathways (DAPP) approach concerns a planning paradigm for decision-making under conditions of deep uncertainty (Haasnoot et al. 2013). The idea behind the DAPP approach is that planning requires a combination of commitment to short-term actions and a vision of the adequacy of these actions in the longer future. It combines adaptive policy-making, a theoretical approach describing a planning process with different types of actions and signposts to monitor to see if adaptation is needed, with adaptation pathways, which provide an analytical approach for exploring and sequencing a set of possible actions

based on alternative external developments over time. The normative idea underlying adaptive planning is that policies should be treated as experiments, with the aim of promoting continual learning and the possibility to adapt to new information, emerging risks and opportunities as they arise, and in response to experience over time (Dewey 1927). Exactly because many aspects are uncertain or completely unknown, we should be flexible in our strategies and strive to maintain the option to correct our decisions and extensively monitor possible side effects (Collingridge 1980). In the field of decision theory, Rosenhead, Elton, and Gupta (1972) and Rosenhead (1990) formalized flexibility, in terms of keeping options open, as an indicator to evaluate the robustness of strategies under uncertainty.

DAPP builds directly on these insights by explicitly addressing both uncertainty and path dependency. It acknowledges that the future cannot be predicted with certainty and instead focuses on designing strategies that are robust across a range of plausible futures. At the same time, it recognizes that early decisions can constrain or enable future choices, and therefore encourages the careful sequencing of actions to avoid lock-ins and preserve flexibility.

The DAPP approach has been applied to sea level rise and the evaluation of different flood risk strategies (Haasnoot et al. 2019). Teodoro et al. (2023) link the DAPP approach to the concept of intergenerational justice. Using the decision tree of the Dutch delta's DAPP as an illustration, they explore how flexibility can be operationalized within a framework for intergenerational justice (see Figure 2). Each pathway in the DAPP represents a sequence of choices, with the x-axis capturing a dynamic phenomenon (here: sea level rise). By mapping out multiple pathways and identifying adaptation tipping points, the DAPP provides a structured way to navigate uncertainty regarding the exact amount and timing of sea level rise. Placing sea level rise on the x-axis, rather than time, allows the DAPP to avoid presupposing a specific rate or amount of rise by a certain date.[4] Instead, it illustrates the adequacy of different flood risk strategies in relation to varying levels of sea level rise. In this way, precise projections are not required; the approach explicitly acknowledges uncertainty as a starting point.

As sea levels rise, some strategies may become inadequate, requiring reassessment and possibly new interventions. A given choice along the pathway may foreclose future options, or conversely, open up new ones. Hence, the DAPP makes visible how certain decisions create

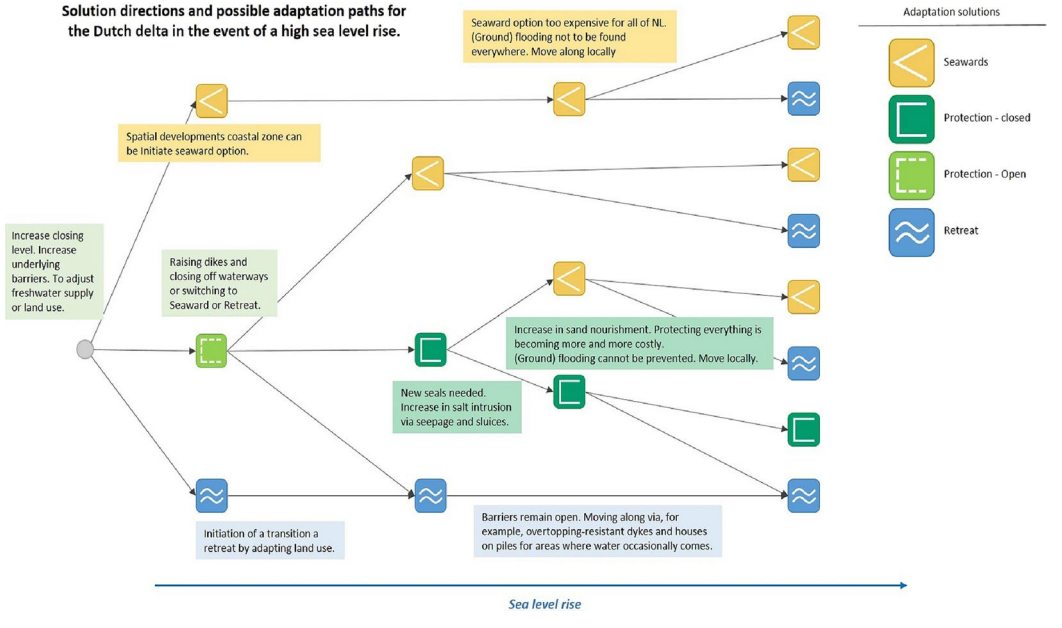

Figure 2. *Dynamic adaptive policy pathways (source:* Teodoro et al. (2023); adapted from Haasnoot et al. (2019*).*

lock-ins, while others maintain flexibility to shift between pathways and adapt to changing conditions. Some choices, therefore, offer more flexibility than others. Teodoro et al. suggest that the number of options available within a choice pathway could serve as the 'currency' to optimize, which helps preserve opportunities for future generations to shape their living environment according to their needs and values.

A strength of the DAPP approach is that it explicitly pays attention to the temporal aspects of some phenomenon (here: climate adaptation), not only some abstract future point in time but also the intermediate moments in time. In the operationalization, some further choices need to be made as to the exact scope (e.g. to what future moment in time should the pathways extend?) and allocation pattern (e.g. should there be a minimum number of options to choose from at all times?), but also regarding the value of different options (e.g. are all options equally desirable?).

The implicit theoretical commitment of this approach is that the availability of choices is inherently valuable. Its focus on a singular purpose makes it more consistent with a resource-based approach rather than the capability approach as the application to the NEED illustrates. Applied to the NEED, the DAPP approach may probably identify the NEED as currently presented as the less preferable option compared to other strategies as the construction of the dam forecloses most other options. At the same time, if the freshwater lake formed by NEED also creates new options, the assessment may be more positive. However, these benefits are not included in the DAPP. This immediately shows an important drawback of an evaluation based on the DAPP. The pathways are derived for a specific purpose, in this case protection against sea level rise. Spill-overs to other objectives (be it recreation or eco-system conservation) are not part of the assessment through the DAPP, but they may affect the desirability of a protection strategy. As such, it is less consistent with the pluralism of the capability approach.

6. Intergenerational risk-risk tradeoffs and limits to safety

This paper started with the observation that many of today's societal challenges require technological interventions with potentially significant future impacts and that existing ethical and justice frameworks are often developed separately from risk management tools, limiting their integration into decision-making processes. The discussion of the NEED reveals that interventions implemented by current generations may sometimes affect the broader interests of future generations, even when such interventions provide a safer living environment for those future generations. Climate adaptation is a useful policy objective to illustrate that there are also limits to the right to safety and this paper used a concrete climate adaptation intervention to do so. While climate adaptation is a central pillar of climate policy under the Paris Agreement, both the Planetary Boundaries framework and the dynamic adaptive policy pathways (DAPP) suggest that there are limits to the scale and type of climate adaptation interventions that can be pursued. In that sense, including intergenerational justice concerns in intertemporal risk-risk tradeoffs does not mean that future protection should always prevail.

In a recent paper, Morten Fibieger Byskov explores whether there is a right to climate adaptation, and if so, what that right entails (Byskov 2024). He argues that such a right exists but applies only to 'individuals and communities who are or will be negatively affected by climate change through no fault of their own' (477). While the exact delineation of who holds this right is beyond the scope of his paper, Byskov's analysis of *how much* adaptation people are entitled to is relevant for our discussion. In his discussion of the right to climate adaptation, Byskov explicitly addresses the limits of this right. First, for those who possess this right - a right that, *in his view*, does not apply universally - the adaptive capacity provided should be sufficient to ensure that individuals and communities can effectively adapt. Second, this right is constrained by ecological limits; any individual or short-term excess in ecological consumption must be

offset by a corresponding reduction in someone else's ecological consumption (493) (for a similar argument, see Holland 2008 and Green 2021).

The Planetary Boundaries framework appears to offer a plausible approach for assessing the upper limits of the right to climate adaptation, particularly concerning what to protect for future generations. But what about the lower limits? Here we see that justice requires that there is sufficient adaptive capacity throughout time. Inaction today may lead to less adaptive capacity in the future. Safeguarding sufficient adaptive capacity now and in the future requires a continuous assessment, and here the DAPP, with its explicit inclusion of a time-dimension, may prove useful. While it is true that the DAPP alone may be narrowly focused on one single objective, it does seem quite helpful for assessing whether this single objective is met throughout time and to a sufficient extent. As such, the DAPP is a helpful framework for assessing whether some intervention meets the lower limit of people's right to climate adaptation.

Although discussed in the context of climate adaptation, this two-tier approach could serve as a valuable lens for examining intergenerational risk-risk tradeoffs more broadly. The upper tier aims to prevent the introduction or aggravation of future risks that exceed a critical boundary. This boundary may represent a tipping point beyond which the resulting damage becomes irreversible or irreparable.

7. Concluding remarks

This paper examines potential currencies for intergenerational justice in the context of risk management and explores how these fit within two existing frameworks developed to guide environmental and climate-related decision-making and future actions. Applying these frameworks to the NEED suggests that, together, they offer a comprehensive assessment of large-scale physical risk management interventions, incorporating elements of both the capability approach to justice and a resource-based approach. Some questions are still open.

First, the paper tentatively applied two existing frameworks that have not explicitly been developed for intergenerational justice and discussed which role they could play in assessing large-scale interventions. The paper did not discuss how effective these frameworks are in a real-world policy context. In the literature, different criteria for effective frameworks have been developed, dependent on the intended purpose of the framework. In the context of natural hazards, for example, Murphy and Gardoni (2007) derived a list of five criteria that a framework should fulfill to be effective for decision-making. The list comprises three internal criteria (soundness and consistency, completeness, and accuracy) to ensure the quality of an analysis provided by the framework and two external criteria (practicality and acceptability) to capture the characteristics of the decision-making and policy environment within which the framework is used. More recently, Biermann and Kalfagianni (2020) listed four requirements for any conceptual framework on planetary justice that could serve empirical purposes rather than normative ones. Biermann and Kalfagianni mention research activities, such as integrated assessments and foresight analyses, but also the systematic analysis of political processes, institutions, and policy documents, and even reflection on the normative foundations of major research networks working on transformations of the earth system. A next step is to see how the insights from the current paper and the two frameworks fit the criteria proposed by Murphy and Gardoni, and by Biermann and Kalfagianni respectively.

Second, linking the two frameworks to discussions on the right to adaptation suggests that assessing large-scale risk management interventions may require two distinct evaluations: a lower limit and an upper limit. The lower limit deals with a specific risk and it determines whether this risk is adequately managed. The upper limit deals with tradeoffs between this concrete risk and other risks, and as such, it is intended to identify undesirable risk-risk tradeoffs. Since these thresholds are of a different nature, they may necessitate the use of different types of assessment frameworks.

For large-scale physical interventions, the Planetary Boundaries framework may be appropriate for assessing upper limits. However, when addressing non-physical future risks, other frameworks might be more suitable. From the perspective of intergenerational justice, it is crucial that these frameworks can evaluate boundaries beyond which risks result in irreversible damage or damage that cannot be compensated otherwise, such as to preserve choice for future generations.

Notes

1. It should be noted that the authors explicitly mention that they see their plan as an argument for mitigation. If such a radical solution against extreme sea level rise comes out as the most favorable one, then we must above all ensure that we will not be confronted with such an extreme sea level rise, the authors argue.
2. While some attempt to address this through objective theories of welfare - defining well-being in terms of objective or mind-independent factors as constituents of well-being - these basically boil down to resource-based justice theories (Dworkin 1981). Therefore, objective list theories are not discussed further here.
3. The nine planetary boundaries are: climate change, novel entities, stratospheric ozone depletion, atmospheric aerosol loading, ocean acidification, modification of biogeochemical flows, freshwater change, land system change, and biosphere integrity.
4. Building on the concept of different timescales introduced by Zaheer, Albert, and Zaheer (1999), the DAPP approach typically visualizes a validity interval (that is, the timescale over which a given theory or strategy is expected to hold) rather than the existence interval, which represents the duration required for a specific process, pattern, phenomenon, or event to occur or unfold. In the context of sea level rise, the existence interval would generally correspond to the projected trajectory of sea level rise over time.

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