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ARTICLE

# Positive Externalities in the Polycrisis: Effectively Addressing Disaster and Climate Risks for Generating Multiple Resilience Dividends

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## Abstract

With multiple risks interacting and shocks proliferating across geographies and sectors, the concept of polycrisis has come to the fore. Polycrisis describes interwoven and overlapping crises that cannot be understood or resolved in isolation. Analysts have suggested that many of the Polycrisis symptoms have been at least partially triggered by negative externalities, that is, costs arising from economic activity that are not covered by market prices and thus not internalized in national and international decision making, leading to suboptimal decisions on climate action, energy and food security, global financial stability, among others. Externalities have generally been framed as negative. Positive externalities, that is, societal benefits that indirectly arise from activities and transactions have less often been considered. International policy debate on disaster risk reduction (DRR) and climate change adaptation (CCA) over the last years, as stipulated by international compacts in 2015 (the Sendai Framework, the SDGs, and the Paris Agreement), has built on positive externality discussion, albeit not explicitly so. Disaster risk reduction and CCA analysts have emphasized the need for orienting risk management investments towards interventions that generate so-called multiple or triple resilience dividends. This means extending the focus in decision making from avoiding and reducing impacts and risks to also considering development (co-)benefits arising irrespective of disaster event occurrence. In this context, the "Triple Dividend of Resilience" (TDR) concept and framework has suggested that in addition to risk reduction benefits (dividend 1), dividends would also arise from benefits associated with unlocked development (dividend 2) as well as from co-benefits (dividend 3), for example, from investments into disaster-safe and energy efficient housing. Yet, despite the increasing burdens imposed by systemic disaster and climate risks and wide-spread recognition of this concept over a decade as well as solid evidence regarding the benefits of reducing risk, it has remained difficult to motivate sustained investment across scales into disaster and climate risk reduction. We argue that this systemic underinvestment is, at least partially, due to a lack of conceptual clarity of the TDR with regard to the framing around the dividend 2, a lack of awareness and solid evidence on the positive externalities, as well as interrelationships between resilience dividends in space and time. Based on a snowballing review of the limited literature on the TDR as well as an examination of empirical and model-based evidence, we present the state of the art on the TDR framework. We examine the various dividends in terms of epistemological and methodological contributions building on empirical and modeling methods for supporting decision making as well as evidence for decision making across scales from local to global. Overall, we suggest that there indeed can be positive externalities and solid co-benefits from disaster and climate risk reduction. Systemic risk research and practice coupled with resilience dividend reasoning may thus help to better identify those dividends for improved decision making on disaster and climate risk (reduction). We further show how analysts and decision makers may better consider those various resilience dividends beyond the reduction of losses as well as assess dependencies in risk and benefits' creation across micro and macro scales. As we suggest, enhanced methods and better awareness for potential externalities may enable more comprehensive consideration of DRR and CCA interventions with benefits arising at various scales. This may eventually also lead to enhanced disaster risk and climate risk governance, which is key for tackling relevant risk challenges in a polycrisis context.

**Keywords** Decision making · Polycrisis · Positive externalities · Systemic risk management · Triple Dividend of Resilience

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## 1 Addressing Multiple Risks in the Context of the Polycrisis

With increasing attention to various individual and collective risks interacting and shocks cascading across regions and sectors, the concept of "Polycrisis" has emerged. Polycrisis refers to a series of interconnected, overlapping, and mutually reinforcing crises that cannot be fully understood or resolved in isolation (Lawrence et al. 2024; Liu and Renn 2025). Some scholars have proposed that aspects of the Polycrisis have at least partially been precipitated by negative externalities—costs associated with economic activities that are not reflected in market prices and other transactions (Rose 2025), thus contributing to partial or complete failure in resolving complex social-ecological issues including climate change, energy provision, food security, and global financial stability. While externalities have typically been characterized as negative (Pigou 1920; Baumol 1972; Stiglitz 1989), positive externalities have also been discussed, such as for sectors and issues like education (Moretti 2004), technological change (Romer 1990), health (Grossman 1972), and economic development (Lucas 1988), in terms of the materialization as unintended societal benefits from decisions targeting other objectives, such as human health benefits from climate mitigation when air pollution is reduced. While externality reasoning has its origins in neoclassic economic thinking premised on market optimality or failure, it has conceptually evolved and entered heterodox economics to inform better (rather than optimal) decision making also involving a case for public sector governance (Frischmann and Ramello 2022).

As we argue, the potential for positive externalities has often been overlooked, both prospectively and retrospectively, particularly in decision making on disaster risk reduction (DRR) and climate change adaptation (CCA). We argue that in the context of systemic risk and the Polycrisis, characterized by the interaction of multiple risks and shocks proliferating across sectors and geographies, these positive externalities ought to see further attention as to their potential to lead to sustained, positive, and potentially transformational risk management outcomes. We discuss and motivate this for decision making on DRR and CCA[1] building on the concept and framework of "Triple Dividend of Resilience decision making," which has been proposed to extend the standard decision-making focus on avoided and reduced disaster impacts only.

International disaster, climate, and development policy over the last years has emphasized the need for orienting investments toward interventions that generate broader resilience and development impact. This shift in perspective occurred most prominently a decade back, through agreements on the seminal international compacts of 2015 on DRR (Sendai Framework), climate (Paris Agreement), and development (the SDGs). In terms of guidance for decision making, one analytical line has operationalized relevant framing through the TDR framework (Tanner et al. 2015), which proposes that DRR (and CCA) policy and implementation should focus on achieving three dividends: (1) preventing and reducing direct and indirect disaster risks, damages, and losses; (2) reducing underlying risks to unlock development potential; and (3) generating co-benefits that are independent of disaster occurrence (Surminski and Tanner 2016; Rözer et al. 2023).

According to this concept, in addition to risk reduction benefits from project investment (dividend 1) as well as co-benefits (dividend 3), dividends would arise from positive externalities as unlocked development potential (dividend 2). Yet, as highlighted by Mechler and Hochrainer-Stigler (2019) and Heubaum et al. (2022), while triple (and multi) resilience dividend decision making has received substantial attention in policy and practice strategizing and rhetoric over the last decade, actual implementation and thus evidence has remained scarce, particularly what concerns the dividend 2 (the positive externalities) as well as the interrelationship between externalities and benefit and co-benefits, that is, links from dividends 1 and 3 to dividend 2.

Despite widespread recognition of the burdens imposed by climate and disaster risks as well as solid evidence regarding the benefits of reducing risk, the Intergovernmental Panel on Climate Change (IPCC) noted in 2022 that climate risk management has remained "largely fragmented, incremental, reactive and near-term-focussed" rather than supporting deeper systemic change as increasingly required to contain rising risks (IPCC 2022). Not only is disaster and climate risk becoming increasingly systemic, but it is also becoming increasingly intertwined with risks from other sectors and policy domains, such those related to finance, health, social cohesion, political instability, and artificial intelligence (Lawrence et al. 2024). Such multiple, often potentially existential, risks are emerging and there is evidence on global and local physical tipping points and adaptation limits. In this context, many argue that to maximize the benefits of managing disaster and climate extremes, it is essential to further position resilience within the context of polycrisis with a view towards the disaster-climate-development nexus. Such positioning may help to better manage interconnected systemic and global catastrophic risks

[1] As the special report of the Intergovernmental Panel on Climate Change on "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" (IPCC 2012) shows there are many and close overlaps between managing disaster risk in a changing climate and climate change adaptation. One difference is that climate adaptation also deals with slow-onset processes, such as sea level rise (see Birkmann and Mechler 2015).

for informing efforts towards transformational resilience across systems.

In our discussion, we suggest that systems-oriented risk research with its focus on interdependent systems analysis coupled with resilience dividend decision making reasoning may point a way forward for improved decision making for managing disaster and climate risks. This goes beyond enhanced policy integration and coherence (as suggested by Peters et al. (2016)), towards better understanding causal and dynamic relationships between dividend 1 and dividend 3 on the one hand and the development dividend 2 in terms of potentially creating positive externalities.

Based on a snowballing review of the still limited literature on the TDR, we examine, discuss, and reorganize the empirical and model-based evidence. We particularly build on Mechler and Hochrainer-Stigler (2019) and Heubaum et al. (2022) as well as a recent comprehensive review by the World Resources Institute (WRI 2025). In our review, we examine the state of art on the TDR narrative and examine dividends in terms of epistemological and methodological contributions from empirical and modeling methods for supporting decision making as well as evidence across scales from local to global. The discussion aims to inform the crafting and implementation of solutions towards (systemic) resilience by addressing the need for such synergistic development-centered investments, which may help communities and societies to build forward to enhanced development stages and higher resilience levels rather than just bounce back to prior vulnerabilities.

The article is further organized as follows. Section 2.1 discusses what resilience analysis may lead to in the context of managing disaster and climate risks. Section 2.2 expands on the added saliency in the wake of the Polycrisis, and Sect. 2.3 presents the TDR approach as a framework for supporting decision making. Section 3 identifies methods and models for assessing the three dividends and provides further specific insight into assessment methods and evidence generated for the three types of dividends. Section 4 revisits our hypothesis and provides further insights into the role of the TDR in the Polycrisis.

## 2 Resilience in the Polycrisis

Resilience concepts and methods have been undergoing change in order to provide needs-driven support for addressing salient challenges in social-ecological systems.

### 2.1 Evolution of Resilience Conceptualization: From Building Back to Bouncing Forward

The concept of resilience has strongly evolved over time. Originally rooted in ecological resilience theory developed in the 1970s (Holling 1973), concepts have over the last few years gained renewed attention, partly in response to the financial crisis, COVID-19, and a growing need for innovative approaches to tackling disaster and climate challenges integrated with attention to development concerns (Rockström et al. 2023).

Recent discussions have focused on finding synergies between resilience, development, systemic risks, and actionable solutions. In the DRR context, where disasters are increasingly recognized to threaten lives and livelihoods, resilience offers a way to reduce future risks by balancing risk management with opportunities for sustainable development. In this regard, Keating et al. (2017) provided a forward-looking definition of resilience, emphasizing that systems, communities, or societies may pursue social, ecological, and economic goals while managing disaster risks in a way that strengthens them over time. This dynamic perspective, which can be referred to as "bouncing forward" to a modified (improved) system state, contrasts with earlier views of resilience as merely returning to a stable state ("bouncing back") (Holling 1973). In line with this general definition of resilience by Keating et al. (2017), resilience in the context of disaster risk and climate change can thus be seen as the ability of societies to absorb, cope with, and reorganize after adverse climate impacts by continuing to develop their economies, which, in turn, reinforces their capability to address challenges of climate change.

Yet, as climate change amplifies risks of disasters and endangers ecosystem services on which well-being of human population relies (IPCC 2022), there is considerable uncertainty in spatial and temporal distribution (occurrence probability) of climate-induced risks, which makes it difficult to sway funders to provide sufficient investments into individual projects managing climate risks at a local level, as direct benefits of such projects are realized only when climate-induced risks materialize (Kunreuther and Heal 2003). As climate change is global and systemic problem, policies addressing it need to be conceived also at regional and/or global scales, as portfolios of (spatially distributed) projects (Hochrainer-Stigler et al. 2025). At an aggregate regional (or global) level, adverse impacts of climate change are much more likely to materialize, making it easier to appreciate benefits of investing in an entire suite of resilience-oriented projects across different locations. Nonetheless, small scale adaptation projects (< USD 10 million) constitute the bulk of adaptation investments, which, in total remain substantially beyond below actual needs identified at about USD 360 billion per year (UNEP 2024). Overall, while some suggest that resilience may be the "new sustainability" (Sample 2017; Scordato and Gulbrandsen 2024), it remains to be seen how broad resilience framing can truly spur necessary transformational action on climate change and disaster risks, and how it can integrate social, ecological, and economic dimensions into addressing sustainability challenges.

### 2.2 Increasing Saliency: The Emergence of the Polycrisis

Disaster risk reduction and CCA decision making have long been considered to manage single hazard risks. Yet, as there has been increasing awareness that multiple risks increasingly interact and shocks proliferate, multi-hazard risk assessments are seeing strong attention (Sakic Trogrlic et al. 2024). In this context, the notion of polycrisis has also come to the fore. The term "polycrisis" is attributed to the philosopher and sociologist Edgar Morin who used it (in his 1999 book, *Homeland Earth: A manifesto for the New Millenium*) to describe "interwoven and overlapping" crises that cannot be understood or resolved in isolation and result in "the general crisis of the planet" (Morin 1999). This concept has gained further traction since the World Economic Forum gathering in 2023, as it was used to describe multiple shocks of COVID-19 pandemic, inflation, food insecurity, rise of polarization, military coups, violent conflicts, financial instability, and so on against the backdrop of worsening inequality and a warming planet (Henig and Knight 2023). For the first time since measurements started, the Human Development Index registered a global decline for two successive years in 2021 and 2022 (UNDP 2022). World Economic Forum's Global Risks Perception Survey (WEF 2024) results underscore a predominantly pessimistic global outlook for the next two years, becoming more negative over a 10-year time horizon with almost two-thirds of respondents foreseeing a stormy or turbulent future.

As a result, the Polycrisis phenomenon has started receiving more rigorous academic and scholarly attention (for example, Homer-Dixon et al. 2021; Lawrence et al. 2024) also with regard to resilience (Zebrowski 2013). Lawrence et al. (2024) defined a "global Polycrisis" as the causal entanglement of crises in various global systems that lead to degrading humanity's prospects. The combined harm of multiple crises is considered to exceed the impact of each crisis in isolation. Polycrisis is characterized by multiple causes, nonlinear dynamics, hysteresis (irreversible phase shifts in the system state), permeability (not confined to rigid scales for example transnational contagion), and non-negligible risks of extreme "black swan" outcomes (Kwamie et al. 2024; Lawrence et al. 2024). Near-simultaneous appearance of these crises is not a coincidence and compels research approaches that focus on cross-systems causal relations. For example, it has been argued that policies designed to contain climate change must consider longer-term cross-systemic effects to avoid unintended effects on other nested systems, that could ultimately and inadvertently make the climate problem worse, not better. Polycrisis is thus best seen as a complex predicament to be navigated rather than a complicated problem with fixed set of solutions. Polycrisis analysis is an emergent field that requires methodologies that can deepen explanatory power; use global, multi-dimensional, and longitudinal datasets that contain indicators (Kwamie et al. 2024); and develop more standardized research practices. Overall, research on the Polycrisis phenomenon has been largely diagnostic. Less is known about the solutions space, where an enhanced development-centric resilience framing may be instrumental.

### 2.3 The Triple Dividend of Resilience Decision-Support Framework

Disaster risk reduction and CCA interventions are crucial for adapting to risks arising from increasing frequency and intensity of climate hazards intersecting with exposure and vulnerability of people and assets. Despite widespread recognition and rhetoric regarding the burdens imposed by simple and systemic risks as well as solid evidence regarding the benefits of reducing disaster and climate risks, it has remained difficult to motivate sustained investment into DRR and CCA at project level as well as at aggregate scales (Mechler and Hochrainer-Stigler 2019; IPCC 2022). Implementation is often hindered by the perception that risk management only yields benefits in the event of a disaster happening (Wachinger et al. 2010). To this effect, international policy debate over the last years in the wake of the international compacts of 2015 has emphasized the need for focusing DRR (and CCA) investment towards interventions that generate multiple resilience dividends, including reducing loss of lives and livelihoods, unlocking development, and creating development co-benefits. Yet, those potential benefits, while being discussed generally are generally not well captured in decision making, which has given rise to the development of the concept of triple dividend decision making (Surminski and Tanner 2016).

The triple dividend concept suggests that in addition to risk reduction benefits from intervention investment (dividend 1), dividends would also arise from benefits associated with unlocked development (dividend 2) and co-benefits (dividend 3), for example, from disaster-safe and energy efficient housing or investment into health systems with returns from treating disaster-affected patients and those affected by idiosyncratic events, such as from disease or accidents (Fig. 1).

While similar issues have been discussed over decades in the literature on multicriteria decision making (Scrieciu et al. 2014), the TDR decision-support framework suggests to capture resilience benefits comprehensively by gauging the three dividends integrated into an enhanced cost-benefit analysis rationale, where monetized benefits ought to surpass monetized costs to motivate investment into interventions

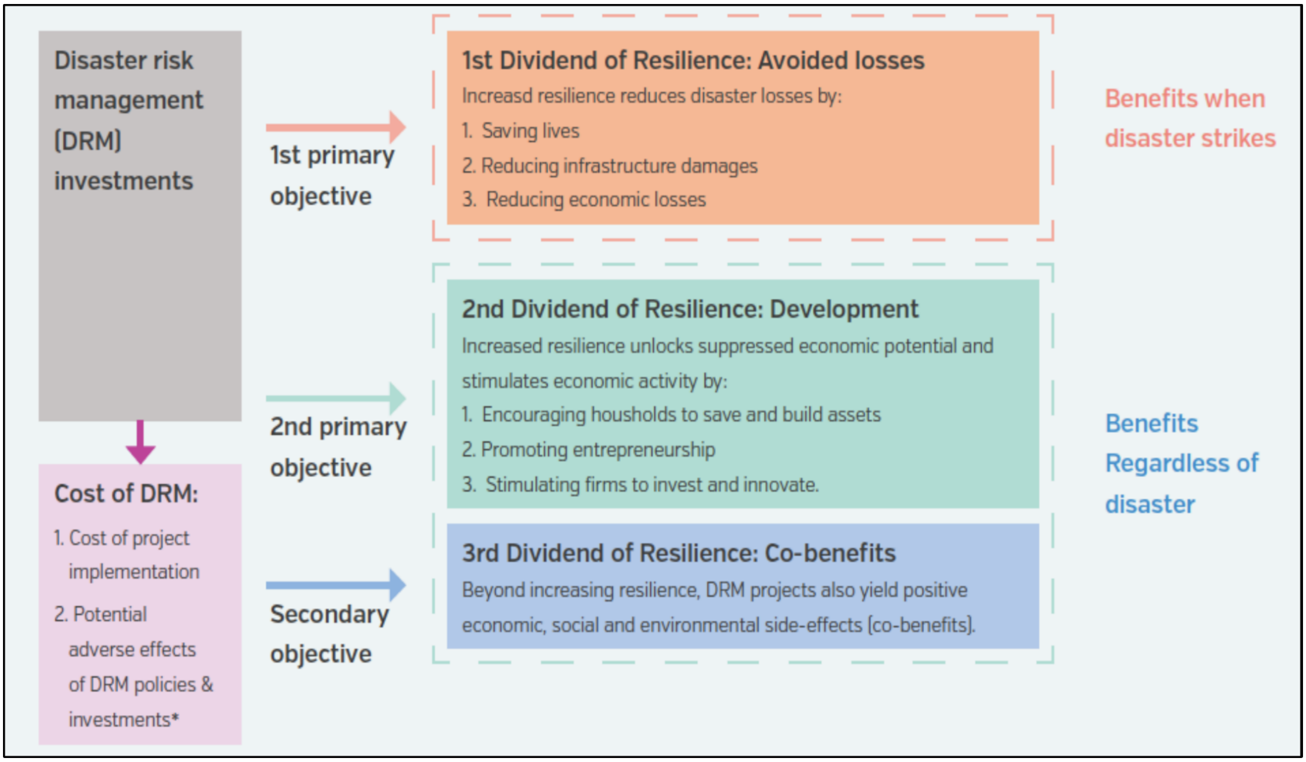


**Fig. 1** The Triple Dividend of Resilience framework as presented by Surminski and Tanner (2016)

(Mechler and Hochrainer-Stigler 2019). There are other similar frameworks in climate change-related decision making. For example, Risk-Opportunity Analysis as presented by Sharpe et al. (2021) for climate mitigation builds on cost-benefit analysis (CBA) as a semi-quantitative method for considering (uncertain) benefits from risk reduction as well as opportunities arising from large transformative policies, such as heavy subsidies for electric vehicles.

Overall, the case for the TDR appears powerful. It has been understood that dividends 2 and 3 may create substantial additional value to the benefits from avoiding losses (dividend 1) (Heubaum et al. 2022). For example, Mechler and Hochrainer-Stigler (2019) examined 65 cost-benefit studies of DRR across the world as to whether they considered dividends 2 and 3. The majority of studies done are pre-event appraisals (compared to post-event evaluations) and only 15 assessments can be said to have covered dividends beyond the first. Yet, for this non-representative sample, the research found an average benefit-cost ratio of 6.7 compared to the average cost-benefit of around 5.1 for standard dividend 1 studies. The World Resources Institute (WRI 2025) assessed the full value of 320 climate adaptation projects across agriculture, health, water, and infrastructure sectors from 2014 to 2024 in 12 lower and middle-income countries. While not framing the TDR as externality-based, the analysis revealed substantial and wide-ranging benefits, showing that every USD 1 invested in adaptation can generate more than USD 10.5 in returns over a 10-year observation period, with estimated average annual financial returns estimated at ranging from 20% to 27%, while not all benefits have been monetized. As the authors suggest, these findings provide compelling evidence to expand adaptation financing, enhance data and evaluation approaches, and better integrate climate adaptation with mitigation efforts to maximize overall impact. The authors find the second and third dividends to often outnumber the first, and the second and third dividends combined to amount to double the value of the first.

Yet, uptake and comprehensiveness of the TDR in decision making has been somewhat limited. For example, in 2019 the Global Commission on Adaptation (2019) proposed to use the TDR approach for global adaptation advocacy and suggested that investing USD 1.8 trillion in early warning systems, resilient infrastructure, water resources, dryland agriculture, and mangrove protection could yield USD 8.9 trillion in benefits, with a benefit-cost ratio (BCR) of 4.8 and a net present value (NPV) of USD 7.1 trillion. Yet, the assessment only well accounted for dividend 1, partially for dividend 2, and in a very limited way for dividend 3, where flood protection from mangroves had only been considered.

## 3 Reviewing the Potential for Methodological and Empirical Innovation for the Resilience Dividend Discourse

We suggest that for the TDR to become more relevant, further attention is needed to epistemology, methodology, and evidence, whereby more awareness for externalities forming part of the framework is needed. We proceed to exploring this proposition by exploring the current state of play for the TDR and, in particular, reviewing the implementation of positive dynamic feedbacks between social and environmental co-benefits and economic externalities (that is, between dividends 3 and 2 in our broader framing). We do so by reviewing insights pertaining to the three types of dividends in terms of epistemology, methodology, and evidence across scales from local to global as summarized in Table 1.

### 3.1 The Triple Dividend of Resilience Business Case: Epistemological Insight

Externalities have long been considered in neoclassically-driven sustainability decision making for public sector investment decisions for many issues, such as greenhouse gas emission and air pollution mitigation (Rose 2025). Analysts have widely suggested that negative externalities should be considered in decision making for public sector investment decisions and costs ought to be internalized through regulation based on command-and-control or market-based initiatives; while researchers, such as those with Ecological Economics background, have suggested that internalizing externalities may be a necessary, but not sufficient condition for sustainability (van den Bergh 2010; Bithas 2011). Positive externalities have been overlooked somewhat, although the insurance proposition has been exactly about the creation of such benefits due to systemic risk reduction (see Bernstein 1998). While triple and multi resilience dividend decision making has received some attention in policy and practice, comprehensive understanding of the narrative, solid evidence, and sustained uptake has remained limited. This is, as we suggest, owing to conceptual and methodological challenges pertaining to dividend 2 and 3 assessment.

We suggest that, in order to work towards progress, it is essential to revisit how the dividends link to externalities debate, how dividends are interlinked, and how these finally can be more effectively communicated. Reviewing the TDR concept and the logic, it appears useful to better distinguish between deliberate (targeted) (1st order) benefits from risk management as well as co-benefits from synergistic investment and induced 2nd order benefits from indirectly induced benefits in terms of unlocked development that arise as a consequence of targeted actions. This may relate to the logic of rendering systems/sectors risk-free, thus allowing risk-taking investors to invest into upside risk efforts. It may also relate to co-benefits creating higher socioeconomic potential that can be unleashed (see Fig. 2).

We thus seek to examine where and how social and environmental effects of interventions do not only create co-benefits but may act as enablers of further benefits. These co-benefits (in a broader sense) are of increased importance as they may be critical factors for resilience. For example, lower economic inequalities and improved social cohesion reduce risks of political turmoil. Urban greening and agroforestry reduce acute health risks during heatwaves but can also reduce chronic respiratory diseases by reducing air pollution. Additional benefits from second and third dividends are especially important as they largely are non-stochastic and materialize even in the absence of events. Following our logic laid out in Fig. 1, after discussing dividend 1, we will turn to discussing insights regarding dividend 3, then turn to dividend 2.

### 3.2 Dividend 1: Benefits from Reducing Risk

Dividend 1, arising from benefits generated through avoiding and reducing losses, has been well understood in line with strong progress in the application of project-based cost-benefit analysis and other tools for the economic evaluation of interventions (Mechler 2016; Heubaum et al. 2022) as well as economic risk (damages and losses) modeling (Botzen et al. 2019). Still less is known about the valuation of “softer,” systemic interventions including the management of often largely non-economic (intangible) impacts—although valuation methods have been developed over decades, they are not used at project scale (WRI 2025). Also, with changing risk drivers, including changes in climate hazards, the effectiveness of interventions may reduce strongly, and there has been interest in understanding adaptation limits (Juhola et al. 2024). Avoided and reduced losses in TDR-based studies have been mostly gauged for extreme events risk, such as fires, storms, floods, or droughts, which are characterized as low probability and high consequence episodic events, while slow-onset processes, such as rising sea levels and changing temperature, have received less attention (Heubaum et al. 2022).

#### 3.2.1 Evidence for Decision Making

Mechler (2016) conducted a global review of CBA studies including appraisals of planned DRR projects as well as evaluations of completed efforts. He identified overall

**Table 1** Coverage of three dividends in socioeconomic disaster and climate risk assessment (epistemological and methodological opportunities in green)

| Epistemology | Methodology | | | Evidence in decision-making applications |
|---|---|---|---|---|
| | Type | Key methods | Metrics | |
| Dividend 1: avoided losses<br>Clarification of role in generating Dividend 2 | Empirical analysis | Project appraisals and evaluations for investment into risk management benefits from risk management<br>Multi (instead of multiple single) hazard and cascading risk to be considered, consider soft adaptation options | Probabilistic reduction of direct risk (potential losses and damages) as well as indirect, economic risk | Cost-benefit analysis (CBA) assessments have solidly assessed the benefits of risk reduction and management, with a focus on ex ante appraisals, less ex post evaluations. The first dividend may amount to half of dividends 2 and 3 combined.<br>Further evidence for slow-onset processes and polycrisis contexts |
| | Country-level modeling | Economic modeling including input-output models, general equilibrium models, as well as agent-based modeling approaches for considering risk reduction interventions | Annual average losses and damages<br>Stochastic representation of disaster shocks in economic modeling | Economic modeling employs input-output models, general equilibrium modeling, as well as agent-based modeling approaches.<br>Consider polycrisis context |
| | Global modeling | Integrated assessment modeling (IAM)-based benefit-cost analysis at aggregate level using damage function approach (regional or global)<br>Enhanced explicit representation of adaptation options in models | Reduced climate impacts due to adaptation (measured as gains in discounted total welfare)<br>Enhanced explicit representation of risks in stochastic terms | A few IAMs feature explicit climate damage reduction from adaptation. |

**Table 1** (continued)

| Epistemology | Methodology | | | Evidence in decision-making applications |
|---|---|---|---|---|
| | Type | Key methods | Metrics | |
| Dividend 2: unlocking development potential<br>Understanding of externalities and links between Dividends 1 and 2 vs 3 | Empirical analysis | Analysis of indirect benefits, hedonic pricing<br>Understanding of behavioral change and role of fairness | Changes in output of local economy after resilience-enhancing measures<br>Identify concrete metrics for positive externality | Solid evidence that there are high dividend 2 returns in sustainable agriculture and forestry subsectors through poverty reduction<br>For health strong links between third and second dividends have been observed (albeit not framed as part of a TDR logic), as improvements also have indirect economic benefits, such as through reduced healthcare costs and productivity gains from a healthier workforce.<br>Fairness/inequality rarely considered although techniques exist<br>Expand evidence base, consider fairness |
| | Country-level modeling | Some analysis for country-level modeling, fiscal risk and insurance assessment<br>Consider agent-based insight and assessment of spillovers | Changed risk profile and risk preference, change in elasticity parameter<br>Improve understanding of role of externalities | CGE and other models show enhanced performance of local economy subject to external shocks (for example, changes in population, changes in external demand) in cases with and without resilience-improving investments.<br>Further applications beyond insurance and fiscal risk |
| | Global modeling | Analysis of ripple-effects of disasters along value chains as a baseline for assessment of indirect benefits of resilienceUnderstanding mechanism triggered in private sector, and link to Dividend 3<br>Slack in potential that is unleashed? | Additional reduction in consumption losses due to extreme weather events<br>Further understanding of role of fairness for externality | Tentative model-based evidence of increased output for fairness-adjusted objective function specification<br>Expand evidence base |

**Table 1** (continued)

| Epistemology | Methodology | | | Evidence in decision-making applications |
|---|---|---|---|---|
| | Type | Key methods | Metrics | |
| Dividend 3: co-benefits<br>Clarification of role in generating Dividend 2 | Empirical analysis | Health impact assessments (HIAs)<br>Insufficient data linking climate change adaptation measures and health outcomes | Health outcomes such as all-cause mortality, disability-adjusted life year (DALY), and disease-specific indicators<br>Consider metrics for productivity gains, and indirect benefits<br>Simple fairness principles to include | Factoring in health co-benefits has been found to increase the value of interventions beyond values from conventional economic analyses. Large returns from climate mitigation co-benefits<br>Empirical valuation should also account for reduced healthcare costs, productivity gains, and indirect benefits like improved social health cost-benefits |
| | Country-level modeling | National computable general equilibrium (CGE) models incorporate health-related variables, such as air quality improvements and reduced mortality. | Simple fairness principles to include | Co-benefits are considered for climate mitigation, less for adaptation and risk reduction.<br>More research is needed to describe total value of different co-benefits and to develop guidelines for policy making |
| | Global modeling | Global IAMs can incorporate health-related variables, such as air quality improvements and reduced mortality.<br>Design of climate policies that also reduce social inequalities<br>Improved representation of intra- and inter-generational fairness and health outcomes in IAMs and CGEs | Inequality indicators, distribution-sensitive social welfare functions<br>Simpler and empirically determined fairness metrics | Globally cost-efficient climate action that fairly redistributes burdens of climate action and adequately compensates climate-induced losses more ambitiously, creates enhanced resilience to political challenge, and results in lower economic inequalities (improving social cohesion)<br>Better leverage existing evidence base |

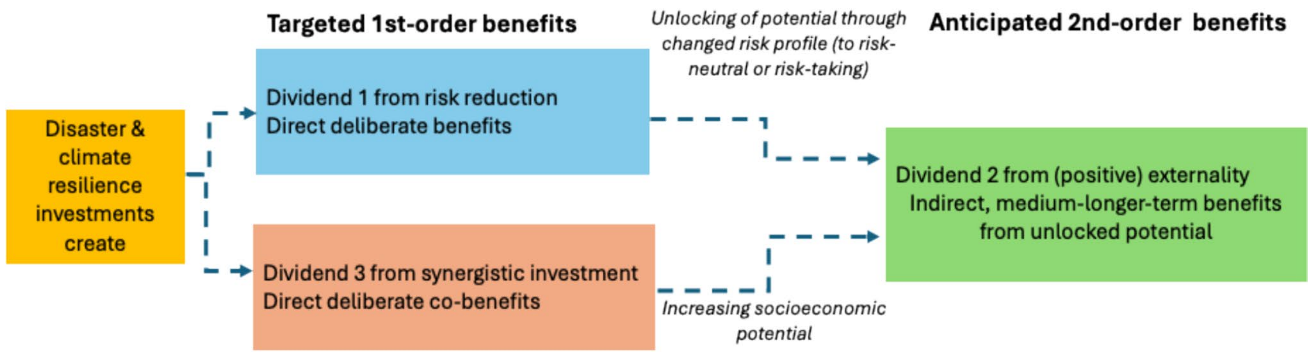


**Fig. 2** Reconceptualizing the resilience dividend framework in the context of externalities and systemic risk. *Source* Adapted from Surminski and Tanner (2016).

solid returns as summarized in CBA studies as well as best-practice issues to take analytical techniques forward, such as properly accounting for the probabilistic nature of disaster risk. The study saw CBA as a useful decision tool for deciding on "hard-resilience-type" of interventions (such as building dams). Yet, given a rising demand for "softer" and systemic (DRR) investment projects and programs, there is need, as the author suggested, to have appraisals more intensively also consider non-economic risks, impacts, and benefits, and thus more effectively employ broader decision-support tools such as multicriteria assessment. The recent World Resources Institute (WRI 2025) study, which analyzed appraisals of 320 climate adaptation projects across agriculture, health, water, and infrastructure sectors from 2014 to 2024 in 12 lower and middle-income countries, found combined dividends 2 and 3 to outnumber first risk reduction dividends, which occur only in case of shocks, thus supporting the case for development returns from adaptation and risk management. It reported solid evidence that there are high dividend 2 returns through poverty reduction in sustainable agriculture and forestry sectors. As well, the assessment showed large returns from climate mitigation co-benefits. Broader well-being and inequality dividends were not monetized or respectively considered at all in the project appraisals.

Reviews by the Multihazard Mitigation Council (MMC 2005) and Shreve and Kelman (2014) had similar results and insights. At country level, economic modeling for decision support has used input-output models, general equilibrium models, as well as agent-based modeling approaches for considering risk reduction interventions. Regional and global integrated assessment modeling (IAM)-based benefit-cost analysis has been using the damage function approach (Botzen et al. 2019).

#### 3.2.2 Advancing Methodological Insight

Dependencies between risk can induce polycrisis events and processes and there is the question of how to address such risks in terms of methodology modeling and empirically. In the disaster risk community, a paradigm shift from single hazard risk to a systemic risk perspective has been observed over the last decade, leading to the appreciation of dependencies across and between systems, sectors, and stakeholders. Recent multi-hazard and multi-risk frameworks in the disaster domain are trying to explicitly embed dependencies in their assessment (De Angeli 2023; Hochrainer-Stigler et al. 2023). Several statistical assessment efforts are proceeding to including statistical approaches such as copula models and triggering models (Claassen et al. 2024). Risk measures for such assessments are focussing on tangible to intangible effects for single hazard events (so called storyline approaches) as well as fully probabilistic ones (such as in catastrophe modeling approaches) using classic measures such as mean changes as well as tail measures. Systemic risk research further contributes in that regard as it focuses on the contribution of individual elements to systemic risk realization (Hochrainer-Stigler et al. 2023). Integrated assessment odeling-based benefit-cost analysis at aggregate level has been using damage functions (countries, regions, or global perspectives), yet stochastic risk has not been introduced to models and adaptation/risk management has often not been made explicit.

### 3.3 Dividend 3: Assessing Co-benefits

Co-benefits have long been considered in climate mitigation assessments and other sustainability policy domains, but less so in DRR and CCA decision making. This is surprising, as decision-making literature and economics have long developed procedures for considering tangible and valuing intangible co-benefits in health, ecosystem management, infrastructure, biodiversity, among others (Venkatachalam 2004). In TDR work, the limited evidence available has considered co-benefits from risk management to include reduced air pollution, health impacts from contaminated drinking water, environmental damage, and inequitable social costs from precarious working conditions, such as in seaport employment (Heubaum et al. 2022). While documented here and there, the link from co-benefits generated to development potential enhanced has not been comprehensively achieved.

While many types of co-benefits can arise from DRR and CCA investments (including those linked to biodiversity, employment, and infrastructure), we focus primarily on health and inequality. We do so for three reasons. First, both are foundational determinants of societal resilience and are tightly linked to both disaster vulnerability and adaptive capacity. Second, they are among the most empirically supported and methodologically mature domains for assessing co-benefits, with well-established tools and data availability. Third, health and equity outcomes are cross-cutting, having the potential to enable or reinforce other resilience dividends, including development gains (dividend 2), climate change mitigation, and biodiversity conservation, thus offering particularly strong potential for synergies. While not exhaustive, this focus reflects domains where evidence is strongest and policy relevance is highest, particularly in the context of polycrisis governance.

### 3.3.1 Health Systems Co-benefits

Considering health co-benefits in decision making and implementation of CCA and DRR measures is crucial but has often been overlooked, particularly in terms of its potential for socioeconomic unlocking potential (World Bank 2020).

**3.3.1.1 Evidence for Decision Making** Well-designed CCA and DRR measures can provide significant health benefits, including preventing chronic diseases, enhancing mental well-being, and improving food security (see Box 1). Benefits can be substantial; for instance, air quality co-benefits of climate policy are often of the same order of magnitude as mitigation costs, and in some instances even larger (Karlsson et al. 2020).

While integrated valuations remain rare, the limited evidence demonstrates that including health co-benefits and indirect economic benefits significantly increase the value proposition of CCA and DRR measures. Cost-benefit analyses that included health benefits and were conducted in China and Australia for wetland restoration, and in the United States for urban heat mitigation, found benefit-cost ratios as high as 49.6; their benefits thus far outweighing the costs (Heubaum et al. 2022). In some cases, social and environmental benefits have been assessed to be greater than the direct avoided losses (Heubaum et al. 2022).

Despite their recognized importance, health and indirect economic benefits of climate change adaptation measures, such as lower healthcare costs and increased labor productivity, are often not fully considered by decision makers (Hutton 2011; Karlsson et al. 2020) and are often excluded from cost-benefit analyses (CBAs) in the DRR space (Mechler 2016), while better, but not comprehensively, accounted for in CCA assessments (Hess et al. 2014). A review of 74 World Bank DRR projects found that only three projects explicitly considered health co-benefits, highlighting a significant gap in quantifying these outcomes (World Bank 2020). This omission limits financing opportunities and underestimates the full value of such measures (Doeffinger and Rubinyi 2023). Box 1 provides an overview of multiple health co-benefits of CCA and DRR measures. More research is needed to describe the total value of different co-benefits and to develop guidelines for integrating these into policy making.

**3.3.1.2 Advancing Methodological Insight** Health interventions can enhance health outcomes by addressing immediate risks (for example, injuries from extreme weather events) and longer-term negative outcomes (for example, chronic diseases linked to environmental degradation) both individually as well as at health systems level. Factoring in health co-benefits has been found to increase the value of interventions beyond values from conventional economic analyses, which typically focus on infrastructure damage or economic disruptions (World Bank 2020; Bikomeye et al. 2021). Box 1 lays out intervention types with likely multiple health co-benefits from DRR and CCA interventions.

Rigorous methodologies have quantified health co-benefits, such as through health impact assessments (HIAs), which provide evidence of the health outcomes of DRR measures, such as reductions in mortality and morbidity. These assessments often rely on epidemiological studies to measure changes in health outcomes. To assess health co-benefits effectively, relevant indicators can be identified. These include reductions in all-cause mortality (for example, from improved air quality from urban greening), disability-adjusted life year (DALY), and disease-specific metrics hypothesized to co-benefit from specific measures, such as decreased prevalence of cardiovascular and respiratory diseases or reductions in malnutrition rates.

Box 1: Intervention Types with Likely Multiple Health Co-Benefits from Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA)

**Nature-based Solutions (NbS)** are effective CCA and DRR measures with considerable potential for health co-benefits. For example, urban greening mitigates the urban heat island effect, reducing heat-related deaths and illnesses. Green spaces also promote physical and mental health through recreational spaces and contact with nature (Aram et al. 2019; Coventry et al. 2021; Jimenez et al. 2021). Additionally, they can reduce air pollution, contributing to preventing the current 320,000 annual deaths in the European Union (European Health Agency 2023). These benefits lower healthcare costs and protect productivity. Nevertheless, the development and implementation of urban greening and other NbS should explicitly consider distributional aspects and redress existing inequalities. For example, research shows that historically marginalized groups tend to have lower access to and utilization of green spaces, requiring participatory approaches (Finney 2014; Roberts 2022). In the following examples (such as agroforestry for heat protection of farm workers, or community-based disaster preparedness) the intention is precisely to underscore cases where benefits can accrue to those most at risk.

**Heat Risk Reduction for Outdoor Workers:** Agroforestry, which provides shade and evapotranspiration cooling, protects outdoor workers, such as agricultural workers, from extreme heat, preventing heat-related illnesses (Neither et al. 2020).

**Flood Risk Reduction:** Restoring floodplains reduces flood risks while improving air and water quality and providing recreational spaces. These interventions offer indirect health benefits similar to urban greening (Nagelkerken et al. 2008; Blankespoor et al. 2017).

**Coral Reef and Mangrove Protection:** Coral reefs and mangroves are coastal ecosystems acting as natural barriers against storm surges and coastal erosion, protecting communities from flooding and associated health risks (Blankespoor et al. 2017). They also support biodiversity, fisheries, and tourism, contributing to livelihoods and economic well-being (Nagelkerken et al. 2008). These biodiverse environments also provide important co-benefits in the form of potential new drug discovery (Sandilyan and Kathiresan 2012).

**Climate-Smart Agriculture:** Practices like agroforestry increase agricultural resilience to climate risks and protect food security, preventing malnutrition and associated health risks. They can also enhance the nutritional quality of food, improving public health outcomes (Jansen et al. 2021; Tscharntke et al. 2021).

**Pandemic Prevention:** Ecosystem protection can reduce the risk of zoonotic disease spillovers, potentially preventing pandemics such as COVID-19. Pandemic-related medical and economic costs can be vast, with COVID-19 estimated to have caused losses equating to 10% of global GDP (Faramarzi et al. 2024).

**Community-Based Measures:** Early warning systems and community empowerment initiatives can reduce disaster-related stress, promote mental health, and foster social cohesion, which can lead to reduced crime and enhanced community resilience (Holt-Lunstad et al. 2010; UNDRR 2021).

Aggregate economic models can integrate health co-benefits into broader analyses. For example, global integrated assessment models (IAMs) and national computable general equilibrium (CGE) models incorporate health-related variables, such as air quality improvements and reduced mortality, to evaluate the economic implications of climate interventions (Mayeres and Regemorter 2008; Weber et al. 2023). Assessing health co-benefits of CCA and DRR measures still faces significant challenges. It has been suggested that empirical valuation should also account for reduced healthcare costs, productivity gains, and indirect benefits like improved social health, which has not been done generally. The reinvestment of economic gains into health-focused CCA and DRR measures can amplify these benefits, highlighting their substantial and often underappreciated value (Heubaum et al. 2022; Becvarik et al. 2024).

There are insufficient data linking CCA measures and health outcomes, making evaluation challenging. Coupling environmental and health datasets and improving data collection will be essential to address this gap. Quantifying economic benefits of mental well-being or social cohesion is challenging but necessary for a comprehensive analysis of co-benefits. Additionally, models also often lack sufficient detail to capture these aspects, leading to an undervaluation of health benefits. Incorporating health co-benefits into economic assessments could motivate additional financing for CCA and DRR projects. By demonstrating a broader range of returns on investment, these projects can attract greater support. Moreover, including health outcomes in CBA ensures more holistic policies, prioritizing both environmental sustainability and human health. This can also lead to more resilient communities, better prepared for future pandemics and disasters.

### 3.3.2 Co-Benefits from Reducing Inequality

Implementation of resilience-improving measures requires collective action at multiple levels, for which the burdens and benefits are unevenly distributed across regions and within populations. To foster successful collective action, aspects of fairness ought to be considered, especially in creating transformative resilience for climate change action (Zimm et al., 2024) and to navigate the Polycrisis (ASRA 2024). Such calls are formally reflected in the framework of the Paris Agreement, where nationally determined contributions (NDCs) constitute fair and equitable contributions to collective efforts of the international community. While currently the combined effect of implementing unconditional NDCs is expected to result in larger than 3 °C global warming (UNEP 2023), it is believed that fairness is key to ratchet-up the willingness of countries towards more substantial contributions to climate action (Anderson et al. 2017; Klinsky et al. 2017; ASRA 2024). On the other hand, insufficient attention to a fair distribution of burdens of climate action or resilience-improving measures may lead to backlash and social unrest (Blavier 2021; Driscoll 2021), or take less overt forms, for example, non-compliance and foot-dragging (Vargas Falla et al. 2024), ultimately leading to failure of such policies. Thus, the fair distribution of burdens of collective climate mitigation and adaptation action is critical for successful resilience-building, including through climate finance and Loss and Damage policies.

**3.3.2.1 Evidence for Decision Making** Fairness and distributional concerns have long been proposed in guidance on cost-benefit assessments (Adler 2011). Yet, in practice generally and for disaster risk reduction specifically, these aspects have been rarely considered. While techniques for evaluating the distribution of costs and benefits exist, they are relatively complicated (Little and Mirlees 1990) and, consequently, they have not found wide usage (see Mechler 2016).

Vargas Falla et al. (2024) reported cases of adaptation measures, which failed due to public perceptions that those would be unfair, exclusionary, or having adverse economic effects (for example, loss of livelihoods or additional financial or labor burdens) that were not anticipated or ignored by decision makers. Policies that are purposefully designed as fair and inclusive are thus more likely to garner wide popular support, improve social cohesion and reduce economic inequalities.

**3.3.2.2 Advancing Methodological Insight** In addition to empirical analysis, integrated assessment models provide important lines of evidence for the effectives of fairness-oriented policies and synergistic effects between resilience dividends 1, 2, and 3. We illustrate such synergy assessment with the help of the "Nested Inequalities Climate-Economy" (NICE) model, a multi-regional medium-complexity benefit-cost optimizing integrated model (Dennig et al. 2015; Budolfson et al. 2021).

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Box 2: Understanding Macro-Economic Benefits of Decreased Inequality for Climate Action

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The NICE model (and other IAMs) allows for measuring resilience dividend 2 of climate action in terms of economic output increases relative to baseline. The increased economic output supports the build-up of capital that improves resilience of regions and households to climate damages. We compare results for the optimal policy under discounted prioritarian policy (DP), which acts to maximize both dividends 1 and 3 of climate action, and the optimal discounted utilitarian (DU) policy, which focuses solely on dividend 1. This comparison reveals that the inclusion of fairness co-benefits (dividend 3) as one of the policy objectives also enables a higher dividend 2 of resilience globally and regionally (Fig. 3).

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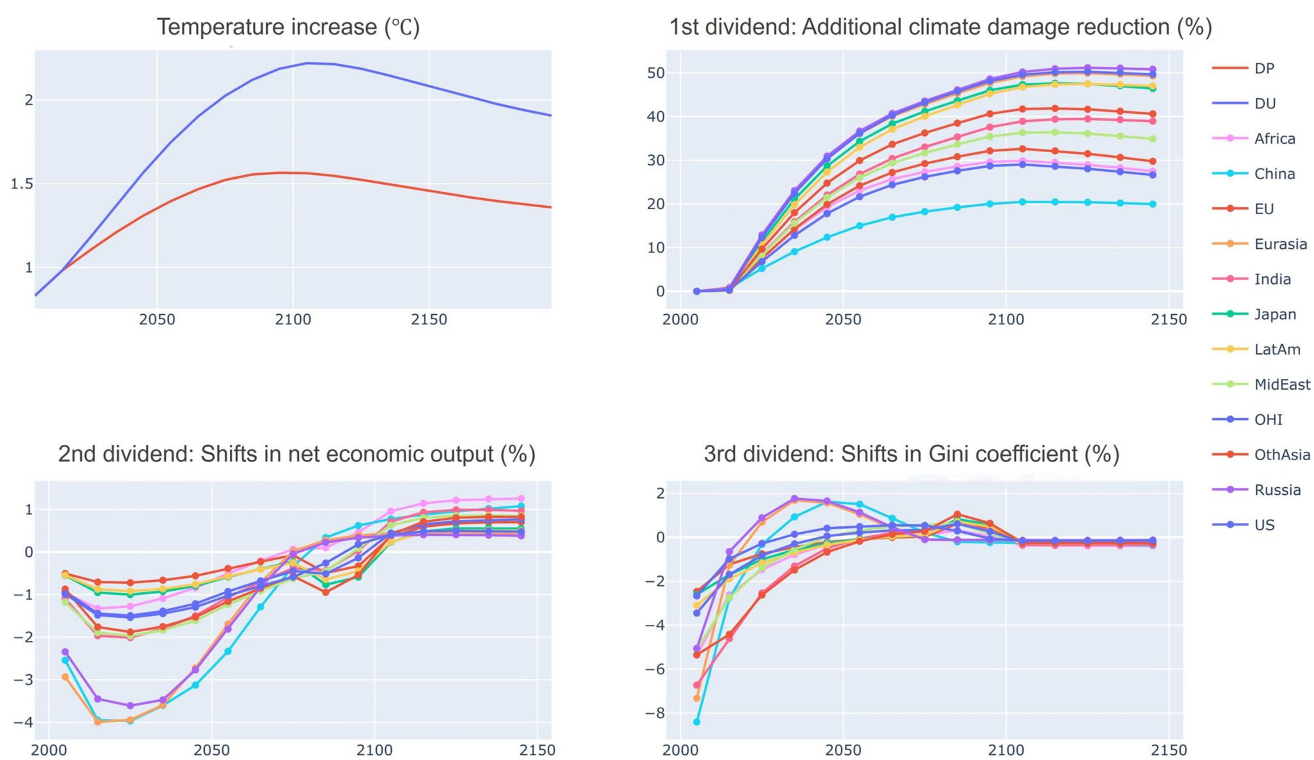


**Fig. 3** Dividend 1, 2, and 3 gains for optimal discounted prioritarian (DP) policy vs the standard discounted utilitarian (DU) approach (left upper panel shows absolute warming for DP and DU policies)

Box 2: Understanding Macro-Economic Benefits of Decreased Inequality for Climate Action

The optimal DP policy recommends more ambitious climate action compared to DU, limiting the global temperature increase to 1.6 °C in case of DP, compared to 2.2 °C for DU (see top left panel for absolute global warming for DU and DP policies). Lower global peak temperature leads to strongly reduced climate damages, which affect the poor disproportionally hard. The DP results in 20–50% lower damages in 2100 compared to DU, and thus in dividend 1 gains. The DP policy delivers also a higher dividend 3, that is, reduction of economic inequalities, measured by the changes in Gini coefficients. Initial high reductions in inequality within regions (up to 8%) are due to redistribution of carbon tax revenues. These initial improvements are slightly reversed around 2050 as the revenue of carbon tax decreases, but towards 2100 inequalities again (slightly) decrease due to avoided climate damages. More ambitious climate action under DP comes at a price of initial slowdown in economic output compared to DU, but output (and utility) steadily improves, unlocking additional growth potential beyond 2050. Thus, fairness-sensitive DP policy that promotes both dividend 1 and 3 gains in the long run also realizes returns to dividend 2.

In its standard set-up, NICE optimizes investments in climate risk reduction (avoided economic losses represented by damage functions)—and thus maximizes dividend 1, that is, the direct benefits from climate mitigation in terms of total utility derived from consumption and avoided adverse climate effects. This approach, equated with maximization of economic efficiency, can be dubbed a discounted utilitarian, DU, approach (Adler et al. 2017) and is insensitive to how welfare is distributed across regions; it thus may result in policies that exacerbate economic inequalities and can be perceived as unfair. To model redistributive co-benefits of a fairness-oriented climate action, that is, as a dividend 3, a representation of within-region inequality is required, which is achieved by disaggregating regional populations into income quintiles. Moreover, NICE introduces dependencies between income and risk of climate damages to represent differences in adaptive capacity between poor and rich. To model a fairness-oriented climate policy, in place of total welfare, we optimize an appropriate fairness-sensitive objective (Żebrowski et al. 2022). Specifically, in the example presented in Box 2 (see supplementary materials[2] for details) we maximize the objective representing the so-called discounted prioritarianism, DP, that is, a principle that prioritizes welfare improvements of disadvantaged groups over comparable welfare improvements for better-off social strata across regions.

[2] https://pure.iiasa.ac.at/20802.

### 3.4 Understanding Dividend 2: Induced Benefits from Positive Externalities

Dividend 2 benefits can accrue from dividend 1 gains through risk reduction leading to changes in risk preference as well as through dividend 3 incurring increased socioeconomic potential.

#### 3.4.1 Evidence for Decision Making

At project level, a review of DRR investment in the United States showed how analyst considered second dividends (in addition to reduced losses from storm and flood damage), in terms of lower-cost and more extensive insurance coverage, deepened investment where risks had been reduced with reputational gains for business (WEF 2015). There is some limited evidence for greater entrepreneurial activity, such as developed through the Multihazard Mitigation Council (MMC 2019), finding that resilience investments in the United States—for example, as enhancement of new building codes or retrofits—not only avoided risk, but also induced greater entrepreneurial activity in the construction materials industry. However, with limited evidence on such resilience dividends, more work will be needed, also as a study estimated that a 1% increase in disaster event frequency may lead to a 4–5% decrease in start-up activity (Boudreaux 2020).

There has been some discussion for aggregate, often country-level modeling and empirical literature focussed on disaster insurance, risk management, and fiscal repercussions. Only a few analyses studied how financial instruments may help governments mitigate fiscal shocks induced by climate disasters. Mechler (2004) used stochastic macroeconomic modeling in World Bank country planning models to show that sovereign disaster insurance for vulnerable countries helped to stabilize and improve socioeconomic growth outcomes, albeit effects identified were small. Melecky and Raddatz (2015) found that countries with high insurance penetration rates did not increase their deficit but also did not experience a decline in growth compared to countries with low insurance penetration. Hsiang (2010), Ouattara and Strobl (2013), and Strobl (2012) found that hurricanes lead to a short-term increase in government spending of countries in Caribbean countries, in turn leading to a lower budget balance. Hadzi-Vaskov and Ricci (2019) suggested that an expanding economy with manageable debt levels, financial protection, and steady growth expectations generally enjoyed improved credit ratings and greater access to global capital markets, yet these authors did not produce substantive evidence.

### 3.4.2 Methodological Insight

At micro/project-level for health interventions, strong links between the third and second dividends have been observed (albeit not framed as part of a TDR logic), as improvements also have indirect economic benefits, such as through reduced healthcare costs and productivity gains from a healthier workforce, contributing to unlocking economic development (Sharifi et al. 2021; Orlov et al. 2024). Studies have shown that positive gains may help to strengthen health systems overall, creating a multiplier effect by further reducing the health burden, thus improving productivity and reducing healthcare costs, freeing resources to reinvest in CCA and DRR measures. Climate change adaptation and DRR measures can also provide broader well-being benefits, such as higher social cohesion, lower crimes, and increased tourism and employment opportunities (see Box 1; Heubaum et al. 2022). Co-benefits of reduced economic inequalities are also enabling factors for dividend 2 to occur, as they are known to have detrimental effects on economic performance (Stiglitz 2013; Piketty, 2014) and may lead to political strife and social unrest, which rarely are conducive to sustained development progress.

Results obtained with the NICE model (see Box 2) indicate evidence of a measurable second resilience dividend of fair and equitable climate action (DP policy) as compared to the baseline focused only on cost reduction (DU policy). The costs of the DP policy are somewhat higher compared to DU, as DP is more stringent, but benefits of DP are more evenly distributed, with the current poor being compensated for costs of climate action and incurred damages while the future poor can avoid some of the worst damages. This results in higher and more evenly distributed capital formation (net economic output), enhancing the resilience of regions and households against climate-related damages.

## 4 Discussion

We began our discussion by suggesting that, in the context of the Polycrisis, further investment is needed to address the underlying drivers of crises and associated risks, in our case largely disaster and climate risks. We argued that systemic underinvestment into actions that address global and local sustainability challenges as evidenced in the era of the Polycrisis is at least partially due to limited understanding of a compelling "public sector business case" for investment. We suggested for disaster risk reduction (DRR) and climate change adaptation (CCA) the triple resilience dividend (TDR) could be at the heart of such a more compelling narrative to motivate bigger and sustained funding into disaster and climate risk reduction.

The Triple Dividend of Resilience (TDR) framework advocates for decision makers in policy and practice to better consider three key benefits arising from risk management: (1) preventing and minimizing both direct and indirect disaster risks, damages, and losses; (2) reducing underlying risks to unlock development opportunities; and (3) generating co-benefits that are not dependent on disaster events (Tanner et al. 2015). While the TDR framework, which emerged in the decisive global policy year of 2015, has shown promise, in order for it to become even more relevant we found that it requires a clearer articulation, stronger evidence, and more comprehensive consideration of how benefits are generated and interrelated. We proposed that further attention is needed towards epistemology, methodology, and evidence challenges, whereby more awareness for the concept of externalities is needed.

In particular, as we identified, more emphasis is needed on understanding the second dividend, which involves further focus on positive externalities and the complex interactions between resilience dividends over space and time.

Based on insights and examples from decision-making analysis as well as systemic risk research we show how analysts and decision makers may better consider the various resilience dividends, that is, positive externalities and co-benefits of disaster risk reduction measures beyond the reduction of losses and assess dependencies in risk and benefit creation across micro and macro scales. As we suggested, this may enable more comprehensive evaluation of interventions with benefits arising at various scales and irrespective of disaster occurrence (WRI 2025); thus in many cases, where there are strong dependencies across systems, such benefits may result in reduced cost (trade-offs) and increased benefits (or synergies) for risk reduction and resilience. We found tentative evidence, that these additional co-benefits and developmental benefits are not marginal and thus may indeed sway decision making towards more sustained investment. This may relate to the case of larger projects, where co-benefits and unlocked development may play more of a role of enablers for transformational change; yet, as also shown in Mechler et al. (2025) transformation may as well proceed through small, incremental change where there is leverage for impact.

The TDR approach thus encourages policymakers accustomed to making decisions guided by cost-benefit analysis to take a broader and more systemic perspective on how benefits and costs accrue within the economy. Our analysis indicates that the question of how these costs and benefits are distributed across different stakeholder groups, space, and time should also be considered in TDR decision-making process. The fair distribution of benefits and inequalities reduction (third dividend) is an important enabler for the second dividend to occur. Moreover, the second dividend may accrue unevenly, benefitting specific sectors and groups in the society and thus may not be clearly visible in more aggregated accounts. A more fine-grained perspective may thus provide more evidence for currently often elusive second dividends of resilience.

## 5 Conclusion: Implications for Assessment and Decision Making—Governance in the Polycrisis

In the context of the Polycrisis, we suggest that policymakers need greater focus on addressing underlying stresses that set a system up for collapse. Analysts have suggested that policymakers ought to overcome "trigger fixation," that is, a tendency to focus on most immediate shock trigger events alone (Lawrence et al. 2024). Trigger fixation has been described as the "normalcy bias" in disaster risk reduction work (Mileti 1999), where it has remained difficult to motivate sustained pre-disaster investment into resilience-generating DRR and CCA policies at project level as well as aggregate scale, while post-disaster major, yet insufficient spending for rehabilitation and recovery is being done.

What seems necessary is thus to focus on shock (risk) driver interactions, not just examine isolated crises and shocks. Early action to reduce risk and potential impacts becomes even more important due to possibilities adaptation limits and negative social tipping points (Juhola et al. 2022). As some suggest, decision making is charged to address system architecture and high-leverage intervention points with an integrated assessment of the interlinked crises to ensure addressing one crisis will not exacerbate others. Resilience thus becomes an equally important consideration alongside efficiency in policy evaluation and decision making (Wernli et al. 2023; Lawrence et al. 2024).

Addressing risk in the context of the global Polycrisis, characterized by more enduring and human-induced changes in the environment than those of the past, thus requires governance approaches that embrace innovative analytical methods and involve a diverse set of stakeholders to be brought together by interdisciplinary and transdisciplinary approaches. Overall, the governance and management of systemic risk in a polycrisis context may present a departure from traditional risk governance, which typically focus on specific sectors and responses (Florin and Nursimulu 2018; Renn et al. 2020; Sillmann et al. 2022) to discern interventions, reforms, or behavioral changes holding the greatest potential for reducing vulnerability while creating multiple resilience dividends with positive and potentially transformational socioeconomic development outcomes.

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