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# Intragenerational conflict undermines cooperation with the future

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## Abstract

Future generations have no agency in today's decisions, making their well-being a defining challenge of our time. Climate change, biodiversity loss, and resource depletion all depend on trade-offs between immediate gains and long-term sustainability. These dilemmas are often attributed to shortsightedness. We show instead that the critical obstacle lies within generations themselves: coordination failures among contemporaries can undermine sustainability even when individuals care about the future. Using a lab-in-the-field intergenerational goods game with a threshold-based regeneration rule, we compare settings with a single decision maker per generation to ones with three contemporaries deciding simultaneously without communication. When individuals act alone, resources are almost always preserved; when contemporaries must coordinate, conservation collapses. Our models explain this pattern by combining intergenerational altruism with beliefs about others' restraint: pessimistic expectations erode altruistic motives, driving overextraction. These insights have direct implications for climate governance and natural resource management, where failures in coordination today can be as detrimental as lack of concern for the future.

# 1 Introduction

Ensuring the well-being of future generations presents a profound challenge, particularly when those making decisions today will not be present to witness the consequences of their actions. Climate, social, and economic policies often have long-term consequences. While the costs of preserving natural resources, reducing greenhouse gas emissions, or maintaining sustainable social and healthcare systems are immediate and tangible, a significant part of the benefits typically accrue far into the future, and may never be experienced by the individuals bearing the costs. This tension can be conceptualized as an intergenerational social dilemma, a situation in which the interests of the current generation conflict with the long-term collective interests of society, including those of future generations. As with other social dilemmas, individuals are incentivized to prioritize personal benefits over collective outcomes, leading to suboptimal resource use[1, 2, 3]. However, intergenerational dilemmas differ in one crucial respect: future individuals lack agency. Unlike actors in most standard social dilemmas—where all parties can participate, negotiate, or reciprocate—future generations have no freedom of choice and no voice in the decisions that affect them[4, 5, 6, 7, 8]. They cannot bargain, vote, or punish current decision-makers, such mechanisms usually enhancing cooperation in social dilemmas[9, 10, 11, 12]. Their interests are therefore entirely dependent on the preferences, values, and decisions of the present generation.

While an expanding body of research has explored the intergenerational social dilemma[13, 14, 12, 15, 16, 17, 18, 19, 20], alongside associated social preferences such as intergenerational altruism[21, 22, 23, 24, 25] and behavioral mechanisms[26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 20] that promote future-oriented cooperation, a critical issue remains largely overlooked: the intergenerational dilemma may be driven less by conflict with future individuals than by conflict among present-day individuals whose consequences fall on the future, as in standard social dilemmas. Extensive literature on common pool resource dilemmas has established that conflicts between individual and collective interests often lead to resource overexploitation[1]. Yet, in the context of intergenerational dilemmas, the nature of the conflict is less clear: degradation of shared resources can arise (1) from a clash between the self-interest of current individuals and the collective interest of future generations, or (2) from conflicts among individuals within the current generation that impose negative externalities on those yet to come. Several studies have shown that, in intergenerational common-pool resource dilemmas, cooperation often breaks down, just as in standard intragenerational social dilemmas. On the one hand, weak incentives to cooperate with future generations can be attributed to time discounting[36, 37], the difficulty of extending social preferences toward individuals who do not yet exist, and the impossibility of future people punishing present-day selfish behavior. On the other hand, one could argue that the intragenerational conflict, driven by self-interest and strategic uncertainty among current individuals, is so strong that it crowds out consideration for the welfare of future others. Importantly, existing experimental designs do not isolate the intergenerational dilemma from the intragenerational one, making it difficult to disentangle

these two sources of cooperation failure.

This situation can be studied through an Intergenerational Goods Game (IGG), which combines elements from two established experimental paradigms. The first is the dynamic repeated common-pool resource game [38, 39, 40, 41, 42], which models a dilemma of appropriation of a natural resource subject to overexploitation. The second is the threshold public goods game [43, 44, 45, 46, 47], which incorporates tipping-point dynamics: the current generation can choose to increase their own benefits, but doing so risks degrading the resource below a survival threshold, thereby eliminating the possibility of future use. This structure captures the core tension of intergenerational dilemmas, where present gains come at the potential cost of future viability. The IGG thus serves as a stylized representation of real-world cases such as the extraction of exhaustible natural resources. In this study, we investigate how behavior in IGG dilemmas is shaped by the presence or absence of intragenerational conflict. To do so, we compare two experimental treatments. In the first treatment (*three-players-per-generation* treatment; 3P thereafter), each generation consists of three players, who simultaneously face two distinct social dilemmas: (i) an intragenerational dilemma, involving a conflict between individual self-interest and the collective interest of their current group, and (ii) an intergenerational dilemma, involving a conflict between the interest of their generation and that of future generations. In the second treatment (*one-player-per-generation* treatment; 1P thereafter), each generation has only one player, so the intragenerational conflict disappears and only the intergenerational dilemma remains. In each generation of the IGG, participants make an extraction decision. The initial resource stock is set at 60 units. In the 1P treatment, the participant can extract any amount between 0 and 60 units. In the 3P treatment, each player can extract between 0 and 20 units, preserving the same total group extraction cap. If a generation extracts more than 30 units in total, the resource is considered permanently depleted, and all subsequent generations are unable to extract from it. Conversely, if total extraction is equal to or below the threshold  $T = 30$ , the resource is fully regenerated for the next generation (see Fig.1). This regeneration rule introduces a strong intertemporal dependency between generations, mimicking the sustainability trade-offs observed in environmental and economic systems.

The game spans five generations. Participants make their decisions using a strategy method. Each participant submits three extraction decisions:

- (1) one for the first generation,
- (2) one for the intermediate generations (i.e., generations 2–4), and
- (3) one for the final generation (i.e., generation 5), where the resource has no future value and is expected to be fully depleted.

After participants submit their decisions, a computerized random draw assigns each participant a generation position, along with the positions of the remaining players (four others in the one-player treatment; fourteen in the three-player treatment). Payoffs are then calculated based on the participant’s assigned position, their own extraction choices,



**Figure 1: Experimental structure and treatments.** (a) Intergenerational Goods Game (IGG). Participants make extraction decisions generation by generation. As long as total extraction remains at or below the renewal threshold (red dashed line; 50% of the initial stock), the resource is renewed; exceeding it exhausts the resource for all subsequent generations. (b) Single-Player (1P): one individual determines extraction for the generation. (c) Three-Player (3P): three contemporaries choose simultaneously; regeneration occurs only if the sum of extractions does not exceed the threshold.

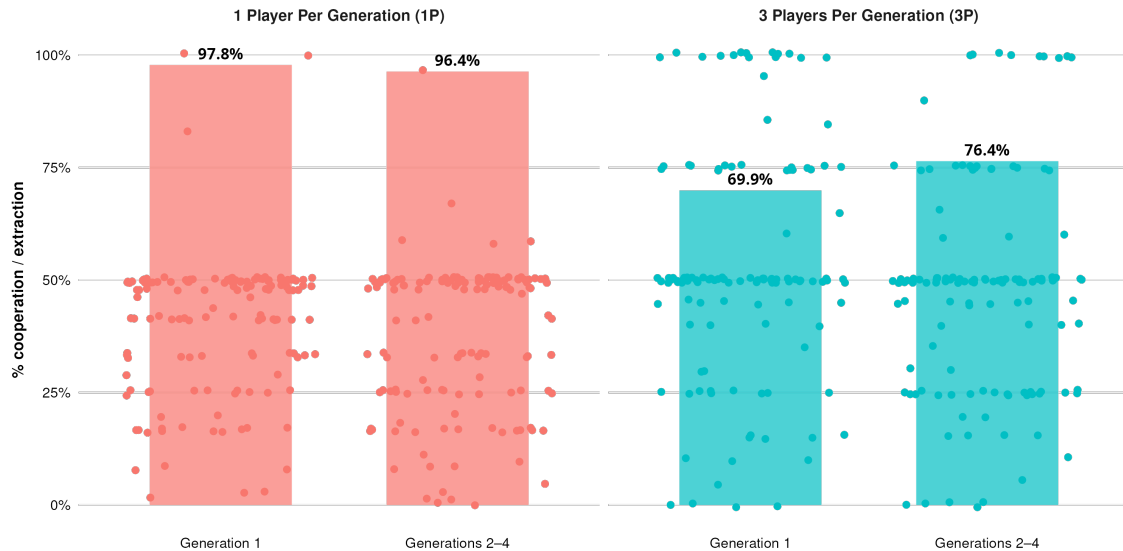
and the extraction decisions of players in previous generations. In this context, the payoff-maximizing strategy is to extract the maximum available resource, whereas the socially optimal strategy involves harvesting only half, thereby leaving the remainder to regenerate for future generations.

In this work, we show that the breakdown in intergenerational cooperation is not primarily due to indifference toward future generations, but to unresolved conflicts among members of the present generation. We show that a key driver of the intergenerational social dilemma lies in intragenerational conflict. Crucially, when this internal conflict is mitigated, individuals are willing to cooperate with the future, even at a cost. In Appendix A, we present a detailed theoretical framework that predicts the issue across various scenarios involving players' altruistic orientations toward future generations, as well as their beliefs about the current generation's altruistic stance. The framework considers both fully rational agents and boundedly rational agents.

## 2 Results and discussion

Cooperation is markedly higher when intragenerational conflict is absent. In the one-player (1P) treatment, cooperation—defined as extracting no more than 50% of the individual capacity (i.e.,  $\leq 30$ )—is rare to fail: 97.8% in the first generation and 96.4% in subsequent generations. In the three-player (3P) treatment, where contemporaries choose simulta-

neously and cooperation requires each to extract  $\leq 50\%$  of their capacity (i.e.,  $\leq 10$ ), cooperation is lower: 69.9% in the first generation and 76.4% thereafter. Differences are large and statistically significant (Fisher’s exact test,  $p < 0.001$  for both first and subsequent generations; Fig. 2).



**Figure 2: Cooperation and extraction by treatment (1P vs 3P).** Bars show total cooperation rates; points show individual extraction as a share of the individual cap. “First generation” refers to decisions for generation 1; “Intermediate generations” pools decisions for generations 2–4. Final-generation decisions are excluded because the resource has no continuation value (see Appendix ?? for details on Generation 5). Renewal in 3P requires all three contemporaries to extract  $\leq 50\%$  of their cap; in 1P it requires the single decision-maker to do so. Sample sizes:  $N_{1P} = 137$ ,  $N_{3P} = 123$ .

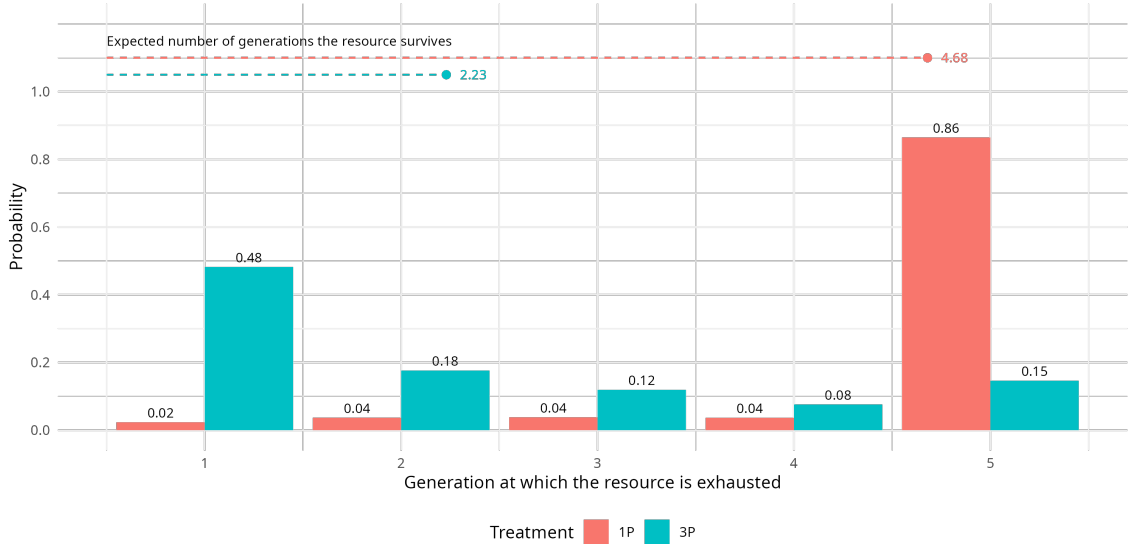
Although a cooperation rate of 69.9% may appear relatively high, it falls short of what is required to ensure long-term resource sustainability. In the 3P treatment, resource renewal necessitates that all three participants in a generation extract no more than 50% of their individual maximum. Under the assumption of independent decisions, the observed cooperation rate translates into a generation-level survival probability of only 0.397. When accounting for subsequent generations, this results in an expected resource survival of just 1.746 generations. This indicates that the resource is frequently depleted in the very first generation due to immediate overextraction. In contrast, the near-universal cooperation observed in the 1P treatment supports an expected survival duration of 4.706 generations (see Appendix C.1 for computational details).

This pronounced sustainability failure in the presence of an intragenerational dilemma highlights a crucial insight: overextraction is driven by contemporaneous strategic interaction within a generation. When this intragenerational conflict is removed, individuals overwhelmingly choose to cooperate with the future, enabling long-term preservation of the resource. In the 3P treatment, this burden is shared across contemporaries, and uncertainty about others’ willingness to restrain extraction depresses cooperation; in 1P the burden is borne unilaterally by a single decision-maker.

## 2.1 Voluntary sacrifices offset aggressive extractions

To move beyond a binary cooperation indicator, we analyse extraction in absolute units and find substantial heterogeneity: many participants restrain extraction well below the 50% cooperation threshold (Fig. 2). We quantify survival using two approaches that rely directly on the decisions elicited for first, intermediate, and final generations (See method and simulations in Appendix C). First, an analytical reconstruction uses average cooperation rates to compute generation-level renewal, assuming independence across contemporaries in 3P, and aggregates these probabilities over five generations. Second, we run 10,000 forward simulations that reassemble generations from the empirical individual decisions within each treatment, sampling without replacement within each trajectory to mirror the experimental structure: for the first transition we draw from first-generation decisions, for transitions 2–4 from intermediate-generation decisions, and we terminate a trajectory as soon as the renewal threshold is exceeded (one decision-maker in 1P; the sum of three in 3P). The latter approach yield higher survival than predicted by average cooperation alone (Fig. 3). The gap is distributional: deliberate restraint, *i.e.* sacrifice, by a sizeable minority offsets higher extractions by others, raising the likelihood that the sum of extractions remains below the threshold. Deliberate restraint emerges in both 1P and 3P settings, yet the distribution of individuals who choose to limit their extraction differs markedly between treatments (Wilcoxon rank-sum,  $p < 0.005$ ). In 1P, most restrained extractions fall between 30% and 50%, whereas in 3P the peak of sacrifice occurs around 25%. This pattern suggests that sacrifice—rather than mere random variation—contributes to the collective outcome in the 3P treatment (see Appendix B.4.1). Such cautious harvesting is consistent with future-oriented social preferences (e.g., intergenerational altruism) and aligns with pro-environmental preferences (see analysis in Appendix B.5).

These results add to a growing literature showing that people are willing to incur current costs to benefit future generations [21, 22, 23, 24, 25], despite the absence of reciprocity or leverage from future individuals. However, the way in which intragenerational conflict undermines this future-oriented behavior remains insufficiently understood. A key explanatory factor may lie in individuals’ beliefs about the preferences of others. Notably, recent large-scale evidence suggests that people systematically overestimate the selfishness of others [48], which could foster expectations of coordination failure. Such beliefs may dampen the effect of future-oriented preferences and thereby weaken cooperation, mechanisms we explore through the two theoretical frameworks introduced below.



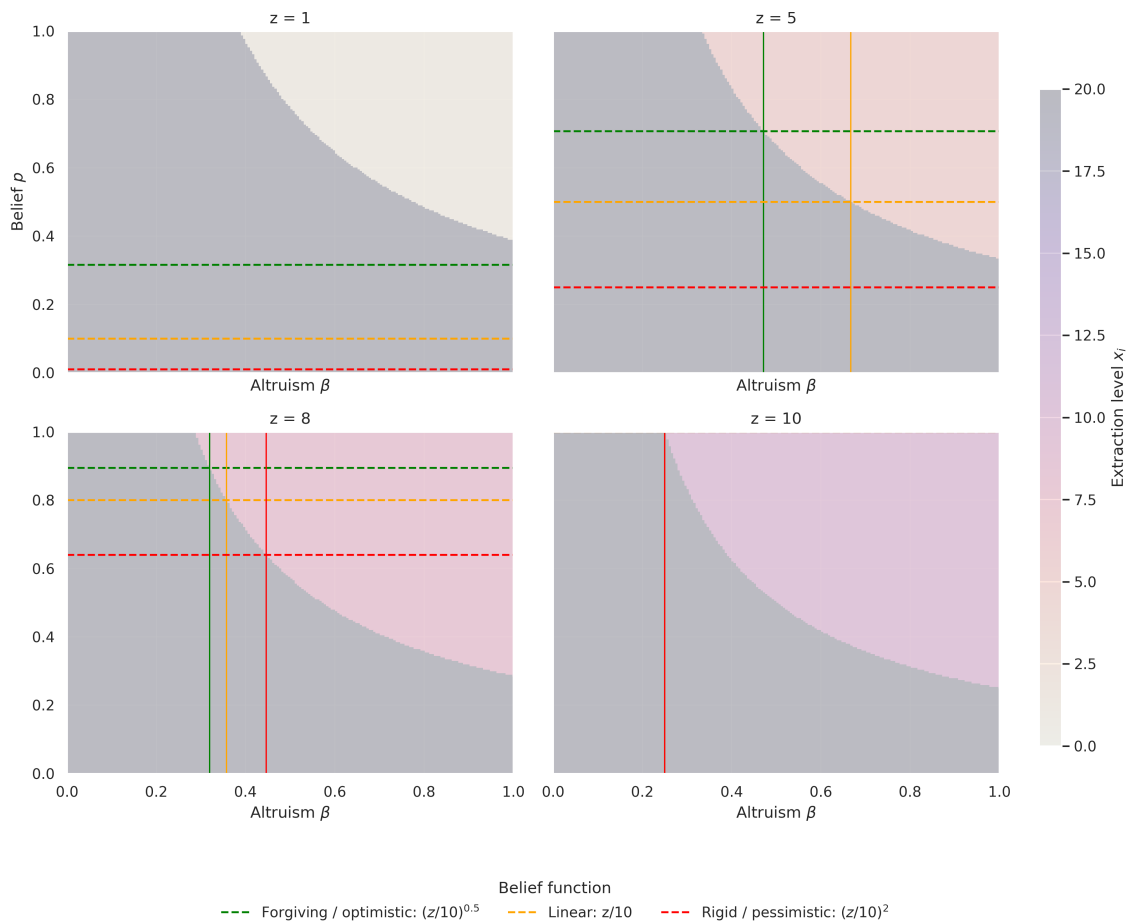
**Figure 3:** Probability that the resource is exhausted at each generation. Horizontal dashed lines indicate the expected lifespan of the resource. The estimates are based on 10,000 bootstrap trajectories, where generations are formed randomly without replacement (an individual cannot belong to more than one generation within a given trajectory). Each trajectory ends once the resource is depleted.

## 2.2 Theoretical foundations: intergenerational altruism and beliefs on coordination jointly shape coordination

To interpret our findings, we introduce a descriptive model that provides a rationale for agents’ decisions according to their generation. The model is based on the hypotheses that individuals evaluate extraction decisions according to (i) an intergenerationally altruistic preference for preserving the resource for future generations and (ii) beliefs about the cooperativeness of their contemporaries. We consider two versions of this model: one that assumes fully rational agents, and another that relaxes this assumption to account for boundedly rational behavior. Formal details and proofs are in Appendix A.

Both versions of the model reproduce the main empirical patterns. In the single-player setting, there is no need for coordination within a generation: beliefs about contemporaries are irrelevant, and cooperation with the future depends solely on the strength of future-oriented preferences. This is consistent with the near-universal restraint observed in the data. In the three-player setting, however, resource preservation becomes a shared responsibility—restraint today yields benefits only if others also choose to restrain. As a result, individuals cooperate with the future when they both value the future and expect sufficient restraint from contemporaries. Heterogeneity in either component naturally generates the observed mix of cooperative and non-cooperative choices, as well as the substantial under-extraction by a subset of participants. Fig. 4 provides a visual summary of the boundedly rational model’s decision regions, according the future-oriented preference parameter ( $\beta$ ), the belief parameter ( $p$ ), and the required sacrifice level ( $z$ ) (an analogous discussion for the variant wit fully rational agents appears in Appendix A). While the

models allow heterogeneity in both components, our data indicate that dispersion in intergenerational altruism is limited, whereas heterogeneity in beliefs is sufficient to mitigate future-regarding motives and generate over-extraction.



**Figure 4: Predicted extraction decisions as a function of intergenerational altruism ( $\beta$ ), belief in others' cooperation ( $p$ ), and required restraint ( $z$ ).** Each panel corresponds to a different level of required sacrifice  $z \in \{1, 5, 8, 10\}$ , i.e., the extraction level a player must not exceed to keep the generation below the renewal threshold, given others' expected behavior. Color shading indicates predicted extraction levels: lighter tones indicate restrained extraction ( $x = z$ ), while gray tone represents full extraction ( $x = 20$ ). Dashed horizontal lines show belief heuristics: forgiving (green,  $\phi(z) = (z/10)^{0.5}$ ), linear (orange,  $\phi(z) = z/10$ ), and rigid (red,  $\phi(z) = (z/10)^2$ ). Vertical lines indicate, for each heuristic, the minimum level of altruism  $\beta$  required to sustain cooperation under that belief. The cooperation condition is  $\beta \cdot p \geq \frac{20-z}{50-z}$ . When  $z = 10$ , cooperation emerges even with low altruism and pessimistic beliefs; lower values of  $z$  require stronger altruistic motivation and/or optimistic expectations.

Two non-exclusive behavioural explanations, both consistent with the evidence of a shift toward over-extraction, may underlie this belief-sensitivity. (i) Altruistic but pessimistic: some participants value the future yet expect contemporaries to over-extract; believing that others will not restrain, they infer that their own restraint would be ineffective and thus take more than they otherwise would. This aligns with broader findings that people often underestimate others' cooperativeness[48]. (ii) Moral wiggle room. Some participants exhibit weaker future-oriented preferences and, in the three-player setting, exploit

the interpretive latitude that preservation will occur “anyway,” assuming that others will exercise restraint. This self-serving belief provides psychological cover to extract more than the equal-sharing (per-person cooperation) benchmark—a latitude unavailable in the single-player setting—and aligns with the observation that some three-player participants over-extract relative to the cooperative norm, without reaching the individual maximum.

The model also explain why some participants are willing to sacrifice. When people believe their own restraint can be decisive—i.e., sufficient to offset the shortfall created by others’ higher extractions—they accept a larger present cost to keep the group below the renewal threshold. Conversely, when they believe their action will not change the outcome (because others will already preserve, or because over-extraction is too large to offset), they are less willing to bear that cost. The boundedly rational variant arrives at the same qualitative conclusions using simple first-order beliefs and projection heuristics, indicating that the model’s predictions do not depend on strong cognitive assumptions.

Together, the two variants of our model provide a compact behavioural lens on our findings: future-regarding motives are present, but their expression depends on beliefs about contemporaries’ restraint; varying these two ingredients reconstructs both the high cooperation in the single-player condition and the heterogeneous, belief-sensitive behaviour in the three-player condition.

### 3 Conclusion

This study contributes to the broader literature on managing social dilemmas, a challenge that increasingly defines many aspects of contemporary society. We show that the conflict between current and future generations is, in large part, driven by tension within the present generation. This finding suggests that when inter- and intragenerational dilemmas coexist, interventions commonly used to address intragenerational social dilemmas, such as institutions that promote cooperation, enable monitoring, or impose sanctions, may also be effective in safeguarding long-term outcomes [10, 12, 49].

Importantly, this does not imply that efforts to foster concern for future generations are unnecessary. On the contrary, our results indicate that intergenerational altruism can lead individuals to adopt self-restraining behaviors that help offset overextraction by others. In such cases, designs that explicitly target future-oriented preferences, such as the Social Learning[26, 27, 28, 20] and Future design[30, 32, 33, 34, 35], can meaningfully enhance cooperation and support the sustainable use of shared resources.

More broadly, our findings underscore the importance of recognizing the layered nature of social dilemmas that unfold over time. While intergenerational challenges are often framed as trade-offs between present and future interests, they are frequently rooted in coordination failures among those alive today. Reducing intragenerational competition or enhancing knowledge about others’ willingness to coordinate may therefore serve as powerful levers to foster long-term sustainability. At the same time, nurturing concern

for future generations remains vital, both as a moral imperative and as a practical buffer against short-termism. Together, these insights point to a dual approach: combining structural mechanisms that align present-day incentives with normative strategies that elevate responsibility to those who follow.

At the same time, our design necessarily involves simplifications and limitations. First, contemporaries' extractions were modeled as independent and without diminishing returns, which weakens the intragenerational dilemma compared to standard common-pool settings. This simplification may bias against detecting coordination failures and thus reinforce our main result. Second, we did not elicit participants' beliefs about others' behaviors, which prevents a direct test of the theoretical mechanisms; incorporating belief elicitation as a proof-of-concept would be valuable in future work. Third, our lab-in-the-field sample was likely more pro-environmental than the general population given the setting of data collection. While random assignment mitigates concerns for internal validity, this composition may have elevated cooperation levels overall and limits external validity.

Our findings have direct implications for climate policy and the governance of natural resources. Climate change epitomizes an intergenerational dilemma[37], where today's emissions and resource use may inflict irreversible harm on those not yet born, including limits to adaptation and displacement pressures[50]. As climate variability increases[? ? ], natural systems are placed under growing stress, and the consequences of mismanagement become more volatile and less predictable. In such a world, fostering cooperation, both within and across generations, is not only ethically urgent but strategically essential. Building institutions that can sustain cooperation under uncertainty, support resilience amid shifting ecological baselines, and embed long-term thinking into present-day decision-making will be a key to navigating the compounding costs of inaction. This work opens new avenues for research on mechanisms and policy designs that address both inter- and intragenerational social dilemmas, and highlights the importance of incorporating uncertainty to better reflect climate variability, its implications for resource management and the need for social and intergenerational justice.

## 4 Method

This research adheres to all relevant ethical guidelines and was approved by the Ethical Committee of the University of Montpellier (the document is available in the OSF project [osf.io/ytjf3](https://osf.io/ytjf3) associated with the pre-registration). Informed consent was obtained from all participants prior to participation.

**Participants** - Participants were recruited voluntarily during the 2024 "Fête de la Science" public event held at multiple venues in Montpellier, including the Village des Sciences, Parc du Lunaret, and Lycée Joffre during the "Nuit Européenne des Chercheuses." Participants used tablets provided by the Laboratory of Experimental Economics of Montpellier (LEEM). A total of 371 participants (40.97% male) participated in this specific

experiment focusing solely on the intergenerational social dilemma hypothesis. The mean age of participants was 32.34 years.

**Experimental Design** - The experiment consisted of two distinct treatments aimed at isolating intragenerational rivalry effects on cooperation in managing intergenerational goods:

**1P Treatment:** In the 1-player (1P) Treatment, participants individually managed a renewable resource starting at 60 units. Each participant represented one generation and decided how many units (0-60) to extract. Extracting over 30 units depleted the resource permanently, eliminating benefits for future generations. Extracting 30 units or fewer ensured full regeneration for subsequent generations. Participants made decisions for three scenarios using the strategy method: as the first generation, as an intermediate generation (assuming resource sustainability from previous generations), and as the last generation.

**3P Treatment:** In the 3-player (3P) Treatment, each generation included three participants independently extracting resources simultaneously. Each participant could extract 0-20 units, maintaining a collective threshold identical to the 1P treatment (30 units total). Extraction exceeding this threshold resulted in resource depletion. This treatment introduced intragenerational rivalry by creating direct competition among contemporaries. Participants also made decisions using the strategy method.

**Incentives and Payment** - Participants were incentivized financially, with payoffs directly proportional to units extracted (€0.15 per unit in the 1P treatment and €0.45 per unit in the 3P treatment). Final payments were determined based on randomly assigning participants' generation positions post-decision-making, ensuring truthful preference revelation. Payments averaged € 2.58 for an average participation duration of 10 minutes.

**Data Collection** - Participants arrived sequentially during the events and were randomly assigned to one of the two treatments. They made decisions on tablets using oTree software in individual sessions lasting about 10 to 15 minutes each. Data were anonymous and collected electronically.

**Statistical Analysis** - Analyses were preregistered and conducted using R statistical software. Differences in cooperation rates between treatments were assessed using Fisher's exact test, with significance established at an alpha level of 0.05 for confirmatory research and 0.005 for exploratory research, following recommendations from [51]. A priori power analyses were conducted to ensure sufficient statistical power (80%) for detecting differences in cooperation rates of at least 15 percentage points between treatments, assuming an alpha of 0.005. Additional robustness checks were performed through simulation methods. Pre-analysis plan is available on OSF (<https://doi.org/10.17605/OSF.IO/2SZYF>).

## 5 Data availability

Raw and processed data will be openly accessible in a public repository with a permanent DOI.

## 6 Code availability

The experimental oTree code, as well as the code used for data analysis and simulations, will be provided as part of a replication package, accessible via a permanent DOI. The authors welcome inquiries and will gladly offer additional information to facilitate replication efforts.

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## 8 Author contributions

Following the recommendation of [52], we want to specify the individual contributions of the authors. **G.B., D.D., V.P., and M.W. are the main contributors to this research project.** G.B. and V.P. managed the research project. G.B., D.D., V.P., and M.W. conceived and planned the experiment. D.D. coded the experiment. G.B. and M.W. respectively modeled the theoretical framework, predictions and interpretations of the bounded rationality and rationality cases. All authors carried out the experiment. G.B., D.D., and V.P. planned and carried out the simulations and data analysis. G.B., D.D., V.P., and M.W. contributed to the interpretation of the results. G.B., and M.W. took the lead in writing the manuscript. All authors provided critical feedback on the manuscript.

## 9 Competing interests

The authors declare no competing interests.

## 10 Extended research credits

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## 11 Additional information

The supplementary materials include the experimental design, instructions, sampling and data collection details, theoretical framework, predictions and interpretations, data cleaning procedures, detailed analysis plan, and other relevant information related to this work.

For additional inquiries regarding this study, please contact: [gabriel.bayle.econ@gmail.com](mailto:gabriel.bayle.econ@gmail.com).

## A Theoretical framework

Our theoretical framework integrates the Intergenerational Goods Game (IGG) with a recursive utility model. We explore two variants of this framework. The first assumes fully rational players with altruistic preferences, while the second incorporates bounded rationality alongside altruistic preferences. Both variants retain the core structure of the IGG and the recursive utility framework. We begin by formally describing these two components before outlining the predictions of each model.

### A.1 Common core features

#### A.1.1 The Intergenerational Goods Game (IGG)

Each generation participates in a resource extraction game. Following Hauser et al. (2014), we model this interaction as an Intergenerational Goods Game (IGG). Each generation consists of  $n$  members and has access to a potential common pool of 60 units resource units. The pool replenishes fully for the next generation only if the current generation extracts no more than the threshold  $T = 30$  units. If a generation withdraws more than  $T = 30$  units, the common pool is fully depleted, resulting in zero resources for all subsequent generations. The IGG presents an intergenerational social dilemma whenever extraction over many generations leads to higher social welfare than the full extraction by the first generation. A simple case of this model is  $u_g = x_g$ , i.e., the level of utility is identical to the level of extraction. Given this simplification, we show that:

$$x_1 = \begin{cases} 30 & \text{if } \beta > 0.5 \\ 60 & \text{if } \beta \leq 0.5 \end{cases}$$

That is, the current generation—and all later generations—extract exactly 30 units if their altruistic preferences are strong enough ( $\beta > 0.5$ ). Assuming  $u_g = x_g$  leads to:

$$V_1 = 30 \times \left( \frac{1}{1 - \beta} \right)$$

if each generation extracts exactly 30 units. On the other hand, if the current generation extracts more than 30 units, the common pool is destroyed for all later generations. In that case, the current generation is better off extracting the total available units, i.e.,  $x_1 = 60$ .

The full depletion outcome arises if

$$60 \geq 30 \times \left( \frac{1}{1 - \beta} \right) \Leftrightarrow 2(1 - \beta) \geq 1 \Leftrightarrow \beta \leq 0.5.$$

Therefore, sustainable exploitation of the common pool arises only if agents are strongly altruistic.

#### A.1.2 Recursive utility

Let  $V_g$  represents the total utility ( $TU$  hereafter) of generation  $g$ , with:

$$V_g = u_g + \beta V_{g+1},$$

where  $V_{g+1}$  is the next generation's  $TU$  and  $\beta$  captures intergenerational altruism, which we assume to be constant. We assume  $0 \leq \beta < 1$ , indicating that the utility of future generations is given less weight than that of the current generation, whose weight is normalized to one. We also assume that  $\beta$  remains constant across generations. This can be interpreted as the current generation projecting its own altruistic preferences onto future generations.

Given this specification of the  $TU$  function, the current generation's  $TU$  is:

$$V_1 = u_1 + \beta V_2,$$

which is equal to:

$$V_1 = u_1 + \beta [u_2 + \beta V_3] = u_1 + \beta [u_2 + \beta [u_3 + \beta V_4]] = \dots = u_1 + \beta u_2 + \beta^2 u_3 + \dots = \sum_{g=1}^{\infty} \beta^{g-1} u_g.$$

Assuming  $u_g = u_{g'} = u, \forall g, g', V_1$  can be rewritten as:

$$V_1 = u + u \sum_{g=2}^{\infty} \beta^{g-1} = u \times \left( 1 + \sum_{g=2}^{\infty} \beta^{g-1} \right) = u \times (1 + \beta + \beta^2 + \beta^3 + \dots) = u \times \left( \frac{1 - \beta^n}{1 - \beta} \right).$$

If  $n \rightarrow \infty$ , then:

$$V_1 = \frac{u}{1 - \beta}.$$

## A.2 Rational players with altruistic Preferences

### A.2.1 Social optimum outcome

We assume a benevolent social planner who aims to maximize intergenerational utility, given by the functional:

$$\widehat{TU} = x_1 + \sum_{g=2}^{\infty} \delta^{g-1} x_{g-1},$$

where:  $x_g$  is the utility or consumption of generation  $g$ , and  $\delta \in (0, 1)$  is the social discount factor, capturing the planner's degree of intergenerational altruism.

This formulation reflects a planner who values both present and future generations, weighting future consumption flows by a declining factor  $\delta^{g-1}$ , similar to time preference in individual decision-making, but applied across generations.

Let us denote  $\widehat{TU}$  the Pareto optimal outcome, and  $\widehat{x}_g$  the Pareto optimal extraction level of generation  $g$ . Since the utility function is the same for each generation, and resource availability requires that each generation does not extract more than 30 units, the socially optimal path depends only on  $\delta$ , the planner's discount factor.

If the planner's discount factor ( $\delta$ ) is large enough, or alternatively, if the planner is sufficiently altruistic with respect to future generations, the optimal path will be sustainable, i.e., each generation enjoys the whole resource.

$$\widehat{TU} = \begin{cases} 30 \times \left(\frac{1}{1-\delta}\right) & \text{if } x_g = 30 \text{ for all } g \\ x_1 & \text{if } x_1 > 30 \end{cases}$$

Indeed,  $\delta$  plays exactly the same role as the altruism parameter of the agent ( $\beta$ ). Therefore, as long as  $\delta > 0.5$ , the social optimum implies that each generation extracts exactly 30 units, ensuring both optimality and sustainability of the resource.

In the sequel we consider two scenarios:  $n = 1$  and  $n = 3$ .

In the first case,  $n = 1$ , the IGG presents only an intergenerational social dilemma.

In the second case, where  $n = 3$ , the IGG involves both an intergenerational social dilemma and an intragenerational social dilemma. We will show that this combination of social dilemmas makes the sustainable outcome more difficult to reach.

## The single player IGG

### IGG with weakly altruistic agents ( $\beta \leq 0.5$ )

Assuming weakly altruistic agents ( $\beta \leq 0.5$ ), the unique equilibrium outcome is  $TU^* = 60$ , i.e., the first generation extracts the entire pool of available resources ( $x_1 = 60$ ), thereby depleting the common pool and leaving nothing for future generations.

On the other hand, the path where each generation extracts exactly 30 units is socially optimal if  $\beta > 0.5$ . This implies that an intergenerational dilemma arises only when agents exhibit weak altruism while the planner is strongly altruistic, i.e.,  $\beta \leq 0.5$  and  $\delta > 0.5$ .

Note that if  $x_1 > 30$ , the current generation maximizes its own utility by extracting the entire resource available to it, i.e.,  $x_1 = 60$ .

### IGG with strongly altruistic agents ( $\beta > 0.5$ )

If  $\beta > 0.5$  the equilibrium path is that each generation extracts exactly 30 units, leaving the common pool intact for the next generation and assuring sustainability. However, the sustainable path is not necessarily optimal, unless  $\delta > 0.5$  as well.

We summarize the predictions of the single player IGG as follows.

**Proposition 1** (for  $n = 1$ ). *Under the recursive utility model with altruistic agents, assuming  $u_g = x_g$ , the equilibrium path coincides with the Pareto optimal outcome if  $\beta = \delta$ . If  $\beta \geq \delta > 0.5$ , the extraction path is sustainable and optimal. If  $\beta \leq 0.5 < \delta$ , the*

extraction path is non-sustainable and sub-optimal. If  $\beta \leq \delta \leq 0.5$  or  $\delta \leq \beta \leq 0.5$ , the extraction path is optimal but unsustainable.

### Multiple-players IGG (n=3)

When  $n = 3$ , the IGG exhibits both an intergenerational social dilemma and an intra-generational social dilemma. Let us assume that each player within a generation has a withdrawal right equal to one third of the available resource, i.e. 20 units. As in the case of a single player per generation, a social dilemma might occur under weak altruistic preferences, i.e.  $\beta \leq 0.5$  and  $\delta > 0.5$ . In addition, we show that if players' types are unknown, miscoordination can lead to unintended depletion of the common pool even if players have strong altruistic preferences; leading to inefficient and unsustainable exploitation.

Assume that there are  $n = 3$  identical agents, each altruistically oriented toward future generations (with the same  $\beta$ ). Their intragenerational utility depends both on their own extraction and on their expectation of the extraction by the two other players. We express this as follows for generation  $g$ :

$$V_g^i = u_g^i(x_g^i, \widehat{x}_g^{-i}) + \beta V_{g+1},$$

where  $x_g^i$  is player  $i$ 's extraction level, and  $\widehat{x}_g^{-i}$  is their belief about the total extraction of the two other players in the same generation.

We consider two cases: (i) common knowledge of players' altruistic types, and (ii) uncertainty about players' altruistic types.

#### Common knowledge of players' altruistic types

Under common knowledge of weak altruism,  $0 < \beta \leq 0.5$ , the first generation extracts the entire pool. Each player  $i$  expects  $\widehat{x}_g^{-i} = 40$  and therefore chooses  $x_g^i = 20$ .

**Proposition 2** (for  $n = 3$  and common knowledge of weak altruism). *Under the recursive utility model with common knowledge of weak altruism, and assuming  $u_g = x_g$ , the equilibrium is unsustainable.*

*It is nevertheless optimal if  $\beta \leq \delta \leq 0.5$  or if  $\delta \leq \beta \leq 0.5$ . However, it is suboptimal if  $\beta \leq 0.5 < \delta$ , because in the latter case, optimality requires sustainability.*

*If altruism is sufficiently strong ( $\beta > 0.5$ ), each player in each generation extracts exactly 10 units, which guarantees sustainability. This extraction path is also the optimal path if  $\delta > 0.5$ .*

#### Uncertainty about players' altruistic types

A key—and more realistic—assumption here is that player  $i$  does not know the types of the other two players in their generation. Three possible configurations are therefore possible: (i)  $\beta \leq 0.5$  for both of them, i.e. both have weak altruistic preferences, (ii)  $\beta > 0.5$  for both of them, i.e. both have strong altruistic preferences, and lastly, (iii) one player's type is  $\beta \leq 0.5$  while the other is of type  $\beta > 0.5$ . We consider two scenarios: myopic agents and farsighted agents.

We define a myopic player as one who assumes that the composition of their current generation will persist unchanged in all future generations. In other words, a myopic player does not anticipate any shift in the distribution of types over time. In contrast, we define a farsighted player as anticipating a potential shift in the distribution of types in any future generation.

### ***Myopic players***

Let us now examine the behavior of a myopic player  $i$  under each of the above configurations. First, note that if player  $i$  is myopic and weakly altruistic, they always choose  $x_{i,g} = 20$ , regardless of the type configuration.

Let us now consider a strongly altruistic type, that is player  $i$ 's type satisfies  $\beta > 0.5$ .

In case (i),  $\widehat{x}_g^{-i} = 40$ , therefore player  $i$  maximizes their utility by choosing  $x_g^i = 20$ .

In case (ii),  $\widehat{x}_g^{-i} = 20$ , so player  $i$  maximizes their utility by choosing  $x_g^i = 10$ .

Finally, in case (iii), the weakly altruistic type  $j$  chooses  $x_g^j = 20$ , leading to player  $i$ 's belief that  $\widehat{x}_g^{-i} \geq 20$ . Since both strongly altruistic types have the same beliefs, they intend to coordinate by extracting no more than 10 units combined.

Therefore, any pair  $(x_g^i, x_g^k) \in \{0, 1, \dots, 10\} \times \{0, 1, \dots, 10\}$  such that  $x_g^i + x_g^k = 10$  constitutes a possible equilibrium.

However, case (iii) involves a coordination issue, and miscoordination is likely to occur. If  $x_g^i + x_g^k < 10$ , the outcome remains sustainable but is sub-optimal. Conversely, if  $x_g^i + x_g^k > 10$ , the outcome is both unsustainable and suboptimal.

We conclude that under the assumption of myopic agents, coordination problems are a key reason for failures to preserve the resource for future generations.

We summarize the case of myopic players as follows.

**Proposition 3** (for  $n = 3$  and common knowledge of weak altruism). *Assuming myopic agents, sustainability is ensured either when all players are strongly altruistic ( $\beta > 0.5$ ) and believe that the others are also strongly altruistic, or when all players believe that there is one weakly altruistic agent and two strongly altruistic types. However, in the latter case, coordination problems may prevent the group from achieving a sustainable and/or optimal outcome.*

### ***Farsighted players***

Consider a farsighted weakly altruistic player, who believes that the next generation will not deplete the resource with probability  $p$  and will deplete it (i.e., extract more than 30 units) with probability  $1 - p$ . We can therefore write their expected utility as:

$$V_1^i = u_1^i(x_1^i, x_1^{-i}) + \beta E[V_2], \quad \text{where} \quad E[V_2] = pV_2^{\text{sust}} + (1 - p) \times 0 = pV_2^{\text{sust}}.$$

Assuming that the same probability of sustainability applies in each generation, we can write:

$$\begin{aligned}
V_1 &= u_1 + \beta p [u_2 + \beta V_3] \\
&= u_1 + \beta p [u_2 + \beta p [u_3 + \beta V_4]] \\
&= u_1 + \beta p u_2 + \beta^2 p^2 u_3 + \dots \\
&= \sum_{g=1}^{\infty} (\beta p)^{g-1} u_g.
\end{aligned}$$

Assuming  $u_g = u$  for all  $g$ , we can simplify  $V_1$  as:

$$V_1 = u \times \left( 1 + \sum_{g=2}^{\infty} (\beta p)^{g-1} \right) = u \times (1 + \beta p + (\beta p)^2 + (\beta p)^3 + \dots) = u \times \left( \frac{1}{1 - \beta p} \right),$$

as the geometric series converges when  $\beta p < 1$ .

As before, assuming  $u = x$ , then:

$$x_1 = \begin{cases} 30 & \text{if } \beta p > 0.5 \\ 60 & \text{if } \beta p \leq 0.5 \end{cases}$$

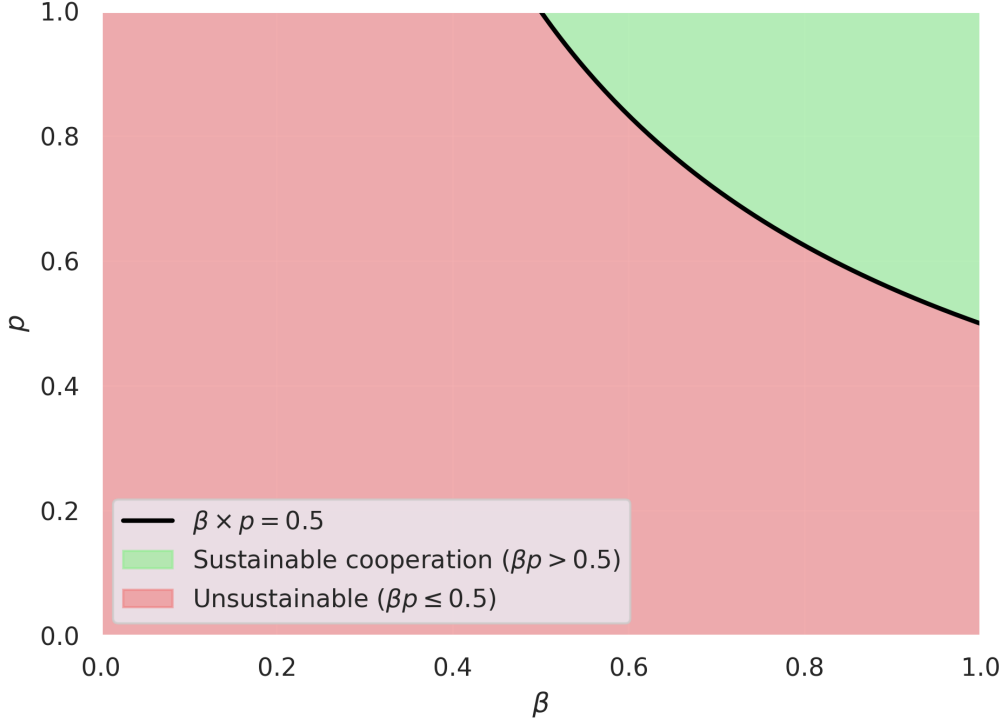
$$60 < \frac{30}{1 - \beta p} \quad \Leftrightarrow \quad 1 - \beta p < \frac{1}{2} \quad \Leftrightarrow \quad \beta p > \frac{1}{2}$$

Satisfying this condition requires stronger altruistic preferences to sustain the extraction path of 30 units per generation. As the probability of sustainability decreases, the altruistic component must increase to compensate (see Figure 5).

**Proposition 4** (for  $n = 3$  and farsighted agents). *Assuming farsighted agents, the current generation extracts the entire available resource, unless the condition  $\beta p > \frac{1}{2}$  is satisfied. Meeting this condition requires stronger altruistic preferences to achieve the sustainable extraction path of 30 units per generation. As the probability of sustainability decreases, the altruistic component must increase to compensate.*

### A.2.2 Conclusions

In settings where intergenerational and intragenerational dilemmas coexist ( $n = 3$ ), uncertainty about others' altruistic preferences substantially undermines the prospects for sustainability. When players lack common knowledge of one another's types, coordination failures and pessimistic beliefs lead to the overexploitation of the common pool. Conversely, when altruistic types are commonly known, sustainability and efficiency can be achieved—but only if a sufficient proportion of agents (at least two out of three) exhibit strong altruistic preferences. Hence, both the transparency of social preferences and their distribution within a generation are critical determinants of sustainable intergenerational



**Figure 5:** Pairs  $(\beta, p)$  satisfying the condition  $\beta p > \frac{1}{2}$

outcomes.

### A.3 Boundedly rational agents

The second variant of the IGG with recursive utility, models intergenerational altruism under bounded rationality. It assumes that agents' beliefs are shaped by cognitive constraints. Specifically, agents: (1) rely only on first-order beliefs about others' actions without modeling their preferences or reasoning, (2) use point estimates instead of full probability distributions to represent strategic uncertainty, and (3) adopt a temporal projection heuristic, assuming that if their generation sustains the resource, future generations will do the same. These heuristics define a cognitively constrained decision-making process in which agents still maximize expected utility, but their reasoning is simplified and lacks the strategic depth of fully rational or Bayesian agents.

The instantaneous utility function of player  $i$  in generation  $g$  is given by:

$$u_{i,g} = \begin{cases} x_{i,g} + \beta_{i,g} \cdot p_{i,g} \cdot V_{g+1}, & \text{if } X_g \leq 30 \\ x_{i,g}, & \text{if } X_g > 30 \end{cases}$$

where:

$u_{i,g}$  is the instantaneous utility of player  $i$  in generation  $g$  that includes the utility of the future generations  $V_{g+1}$ ,

$\beta \in [0, 1]$  is the altruism parameter (also capturing time preferences),

$p_i \in [0, 1]$  is the player's belief that the other players will cooperate with the future and that the resource will survive to the next generation.

The continuation utility,  $V_{g+1}$ , is defined recursively under the assumption that

$$X_{g+m} = 30 \quad \text{for all } m \geq 1.$$

as:

$$V_{g+1} = 30 + \beta_{i,g} \cdot p_{i,g} \cdot V_{g+2}.$$

Assuming an infinite horizon, and optimal resource extraction by future generations, i.e.  $X_{g+m} = 30$  for all  $m \geq 1$ , this recurrence simplifies to:

$$V_{g+1} = \frac{30}{1 - \beta_{i,g} p_{i,g}}$$

We assume that player  $i$  extends their preferences and beliefs to the future generations. Therefore, the instantaneous utility of player  $i$  in generation  $g$ , when  $X_g \leq 30$ , is given by:

$$u_{i,g} = x_{i,g} + \frac{30 \cdot \beta_{i,g} p_{i,g}}{1 - \beta_{i,g} p_{i,g}}.$$

In our discussion of the model's predictions, the expression  $\beta_{i,g} p_{i,g}$  will play a central role. It captures the interaction between player  $i$ 's altruistic preferences and their beliefs about others' cooperativeness. We refer to it as *effective altruism*, as it captures the idea that beliefs moderate the expression of altruistic preferences.

### A.3.1 The single player IGG

When each generation consists of a single individual ( $n = 1$ ), there is no intragenerational dilemma, and beliefs about others' behaviors are irrelevant—hence  $p_g = 1$ . Survival of the resource in generation  $g + 1$  depends solely on whether the player's extraction  $x_g$  remains below the threshold  $T = 30$ . The player faces a binary choice: extract sustainably and preserve future value, or overexploit and forgo all future benefits.

Evaluating the two options at the critical threshold  $x_g = 30$ , the utility from cooperating with future generations is:

$$u_C = 30 \left( 1 + \frac{\beta_g}{1 - \beta_g} \right) = \frac{30}{1 - \beta_g}$$

In contrast, defecting yields:

$$u_D = 60$$

The player prefers to cooperate with the future if  $u_C \geq u_D$ , which holds if and only if  $\beta_g \geq \frac{1}{2}$ . This defines a clear behavioral threshold in terms of the minimum required altruism toward future generations. Note also that this condition aligns fully with the rational player case, as beliefs play no role in this scenario.

This condition highlights that, in the absence of perceived intragenerational competition, cooperation hinges solely on a player's own value placed on future welfare. Notably, this prediction aligns closely with our experimental findings: in the 1P treatment, where players

faced only the intergenerational dilemma, 98% of participants chose to cooperate with the future—consistent with high average levels of  $\beta_g$  in the population.

### A.3.2 Multiple-players IGG (n=3)

While decision-making in the single-player case depends solely on intergenerational preferences, the multi-player setting ( $n > 1$ ) introduces strategic uncertainty. Players must now form beliefs about others' behaviors, making cooperation contingent not only on altruism but also on expectations. We now consider a belief-dependent decision process.

#### Belief about others' cooperation: Definition of $p_{i,g}$ .

We define the belief parameter  $p_{i,g}$  as a function of the perceived distance from the sustainability threshold. Let:

$$z = 30 - \mathbb{E}[X_{-i,g}],$$

denote the expected margin by which others' extraction remains below the threshold, where  $\mathbb{E}[X_{-i,g}] \in \{0, 40\}$  represents player  $i$ 's expectation of their peers' total withdrawal. In the sequel, we refer to  $z$  as the *perceived sustainability*. A higher value of  $z$  reflects a stronger belief in conservative peer behavior. If player  $i$  is altruistically oriented towards the well-being of future generations,  $z$  represents the maximum amount player  $i$  believes they can extract without depleting the resource. To reflect that players may tolerate moderate overuse but not severe free-riding, we let  $p_{i,g}$  depend on  $z$ . Formally,  $p_{i,g} = \phi(z, \alpha)$  is a bounded, increasing function that maps perceived sustainability to the subjective probability that the resource survives to generation  $g + 1$ .

We specify  $\phi(z, \alpha)$  as a piecewise function:

$$\phi(z, \alpha) = \begin{cases} 1, & \text{if } z \geq 30 \\ f(z, \alpha), & \text{if } 0 \leq z < 30 \\ 0, & \text{if } z < 0 \end{cases} \quad \text{with } \alpha > 0,$$

where  $f(z, \alpha)$  is a smooth<sup>1</sup> increasing function (e.g., logistic or linear) that captures how beliefs adjust within the uncertainty range. The parameter  $\alpha$  governs the willingness to make a sacrifice based on perceived deviations from the sustainability threshold. The form of  $\phi(z, \alpha)$  over  $z \in [0, 10)$  critically shapes player  $i$ 's behavior. In this range, player  $i$  believes others extract more than 20 units but sees an opportunity to prevent depletion through personal sacrifice.

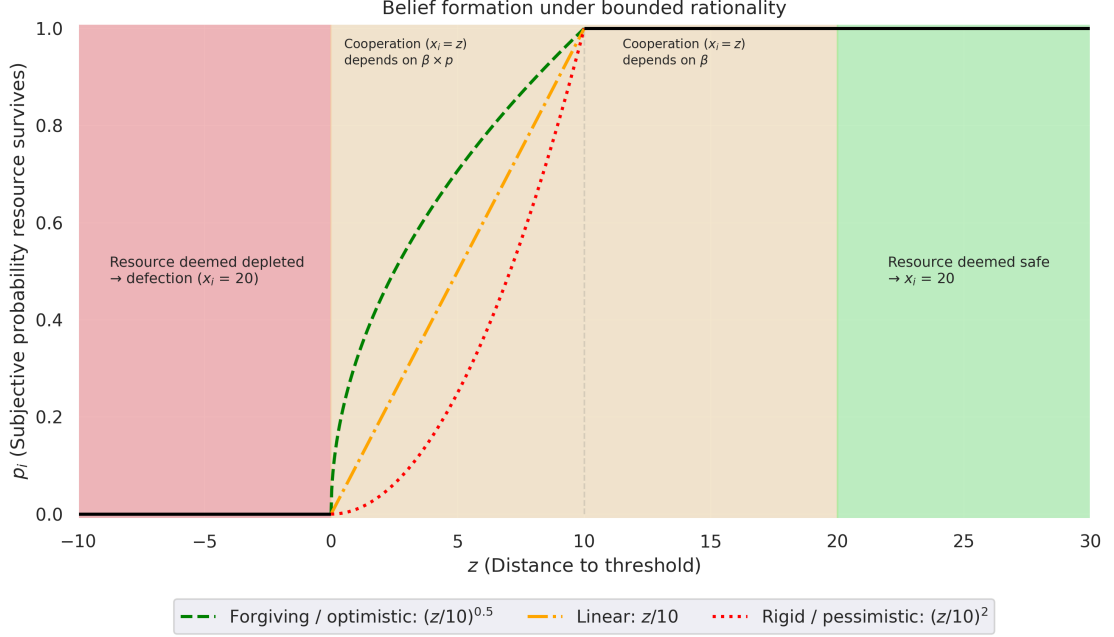
To work on the unit interval, we normalize by defining  $\tilde{z} = \frac{z}{10} \in [0, 1)$ . A convenient specification is:

$$f(\tilde{z}) = \tilde{z}^\alpha,$$

which is strictly increasing for  $\alpha > 0$ .  $f(\cdot)$  is *concave* when  $0 < \alpha < 1$  and *convex* when  $\alpha > 1$ . A concave form reflects a more *forgiving* player—willing to reduce extraction even with modest perceived benefits, signaling tolerance for moderate overuse. Conversely, a

<sup>1</sup>In the sequel, for ease of exposition, we assume that players' choice sets are real intervals. This convenience does not affect the conclusions of the model.

convex form reflects a more *rigid* or *pessimistic* player—cooperating only when benefits are substantial, indicating greater sensitivity to fairness or exploitation.



**Figure 6:** Subjective probability curve over expected distance to the threshold.

**Interpretation of  $p_{i,g}$  through Fig. 6 in Table 1.** Table 1 summarizes the players behaviors corresponding to the different cases described by Fig. 6.

**Table 1:** Decision regions based on belief and required sacrifice ( $z = 30 - \mathbb{E}[X_{-i,g}]$ )

Area	Range of $z$	$p_{i,g} = \phi(z)$	Belief	Player Behavior
A1	$z < 0$	0	Resource collapse	$x_{i,g} = 20$ (myopic defection)
A2	$0 \leq z < 10$	$0 < p < 1$	Can be saved if player sacrifices	<ul style="list-style-type: none"> <li>• If <math>\beta_i</math> high: <math>x_{i,g} = z</math> (cooperate)</li> <li>• If <math>\beta_i</math> low: <math>x_{i,g} = 20</math> (defect)</li> </ul>
A3	$10 \leq z < 20$	1	Others ensure survival	<ul style="list-style-type: none"> <li>• If <math>\beta_i</math> high: <math>x_{i,g} = z</math></li> <li>• If <math>\beta_i</math> low: <math>x_{i,g} = 20</math></li> </ul>
A4	$z \geq 20$	1	Survival guaranteed	Any $x_{i,g} \in [0, 20]$

**Best responses to beliefs** Player  $i$ 's optimal extraction decision depends on their belief about resource survival ( $p_{i,g}$ ), their altruism level ( $\beta_{i,g}$ ), and their perceived sustainability ( $z$ ). We distinguish four cases based on the value of  $z$ :

**A1. Case  $z < 0$**  Player  $i$  believes that total extraction by others exceeds the threshold 30, and that no feasible reduction in their own extraction can prevent resource collapse. Consequently, the belief in survival is null ( $p_{i,g} = 0$ ), and the player behaves purely myopically by maximizing:

$$u_{i,g} = x_{i,g} \text{ leading to } \boxed{x_{i,g} = 20}$$

**A2. Case  $z \in [0, 10)$**  The interval  $[0, 10)$  is a critical region where player  $i$ 's behavior depends on both belief and altruism. In this range, the resource survives only if player  $i$  extracts conservatively, and the subjective probability of survival is  $p_{i,g} = \phi(z) \in (0, 1)$ .

Assuming future generations extract  $X_{g+1} = 30$ , the player evaluates the present value of future welfare as:

$$V_{g+1} = \frac{30}{1 - \beta_{i,g}p_{i,g}}.$$

Player  $i$  then decides whether to sacrifice or free-ride based on the interaction between their altruism, their subjective probability that the resource will survive, and the cost of the sacrifice required to secure it.

In this case, player  $i$  believes that extracting conservatively at level  $x_{i,g} = z$  ensures resource survival ( $X_g \leq 30$ ), whereas extracting more than  $z$  would lead to collapse ( $X_g > 30$ ). The decision therefore hinges on whether the personal cost of restraint is outweighed by the perceived value of preserving the resource for future generations.

The utilities from cooperating and defecting are, respectively:

$$\begin{aligned} u_C &= z + 30 \cdot \frac{\beta_{i,g}p_{i,g}}{1 - \beta_{i,g}p_{i,g}} \quad (\text{cooperation}) \\ u_D &= 20 \quad (\text{defection}) \end{aligned}$$

Player  $i$  prefers to cooperate if  $u_C \geq u_D$ , which simplifies to the condition:

$$\beta_{i,g}p_{i,g} \geq \frac{20 - z}{50 - z} \quad \text{with } \boxed{x_{i,g} = z}$$

This general expression highlights the trade-off for any given  $z$ : the smaller  $z$  is—that is, the greater the required sacrifice—the higher player  $i$ 's altruism, belief, or both (i.e.,  $\beta_{i,g}p_{i,g}$ ) must be to justify cooperation.

*Special case:  $z = 10$  (equal sharing rule optimum).* When the cooperative extraction exactly equals the sustainability threshold per player, the condition reduces to:

$$\beta_{i,g}p_{i,g} \geq \frac{1}{n + 1}$$

with  $p_{i,g} = 1$  because  $i$  believes that others are cooperating, leading to:

$$\beta_{i,g} \geq \frac{1}{n + 1} \quad \text{with } \boxed{x_{i,g} = 10} \quad \text{if the inequality holds, } \boxed{x_{i,g} = 20} \quad \text{otherwise.}$$

This threshold shows that even a moderate level of effective altruism is sufficient to sustain the resource if all players are expected to cooperate equally. The condition becomes stricter as group size  $n$  decreases.

**A3. Case  $z \in [10, 20)$**  We first consider the case where  $z \in (10, 20)$ , before discussing the special case where  $z = 10$ .

Suppose player  $i$  believes that others extract conservatively enough for survival to be possible even with less-than-minimal personal sacrifice. Formally, player  $i$  believes that:

$$\mathbb{E}[X_{-i,g}] < 20,$$

implying that the extraction level required to preserve the resource satisfies  $10 < z < 20$ . In this case, player  $i$  chooses:

$$x_{i,g} = z \in (10, 20),$$

balancing a desire to contribute to sustainability with an interest in minimizing personal cost. This behavior maintains survival without full commitment to the strict cooperative norm.

Consider now the special case where  $z = 10$  (the equal-sharing rule optimum). When cooperative extraction exactly equals the sustainability threshold per player, the condition for player  $i$  to cooperate reduces to:

$$\beta_{i,g} p_{i,g} \geq \frac{1}{n+1}$$

with  $p_{i,g} = 1$  because  $i$  believes that others are cooperating, leading to:

$$\beta_{i,g} \geq \frac{1}{n+1} \text{ with } \boxed{x_{i,g} = 10} \text{ if the inequality holds, } \boxed{x_{i,g} = 20} \text{ otherwise.}$$

This threshold shows that even a moderate level of effective altruism is sufficient to sustain the resource if all players are expected to cooperate equally. The condition becomes stricter as group size  $n$  decreases.

**A4. Case  $z > 20$**  Player  $i$  expects others to behave so conservatively that the resource will survive regardless of their own action. In this case, the belief in survival is maximal ( $p_{i,g} = 1$ ), and the player selects the extraction level that maximizes utility:

$$u_{i,g} = x_{i,g} + \beta_{i,g} \cdot V_{g+1} \text{ leading to } \boxed{x_{i,g} = 20}$$

## A.4 Formal propositions

### A.4.1 Decision without intragenerational dilemma

**Proposition 1** (Threshold for cooperation when  $n = 1$ ). *In the absence of intragenerational conflict ( $n = 1$ ), player  $i$  in generation  $g$  chooses to extract the sustainable amount  $x_g = 30$  (cooperation) if and only if:  $\beta_g \geq \frac{1}{2}$ . Otherwise, player  $i$  extracts the full resource stock,  $x_{i,g} = 60$  (defection).*

### A.4.2 Decision under intragenerational dilemma

**Proposition 2** (General Decision Rule). *Let  $z = 30 - \mathbb{E}[X_{-i,g}]$  denote the expected gap between the sustainability threshold 30 and the expected extraction by all other players.*

*Player  $i$  in generation  $g$  chooses their extraction level  $x_{i,g}$  by comparing:*

- *the cooperative utility:*

$$u_C(z) = z + 30 \cdot \frac{\beta_{i,g} p_{i,g}}{1 - \beta_{i,g} p_{i,g}},$$

with cooperative extraction  $x_{i,g} = z$ ,

- *the defective utility:*

$$u_D = 20, \quad \text{with } x_{i,g} = 20.$$

Player  $i$  cooperates if and only if:

$$\boxed{\beta_{i,g} p_{i,g} \geq \frac{20 - z}{50 - z}}$$

This condition defines the *effective altruism threshold* required for cooperation, given the sacrifice level  $z$ .

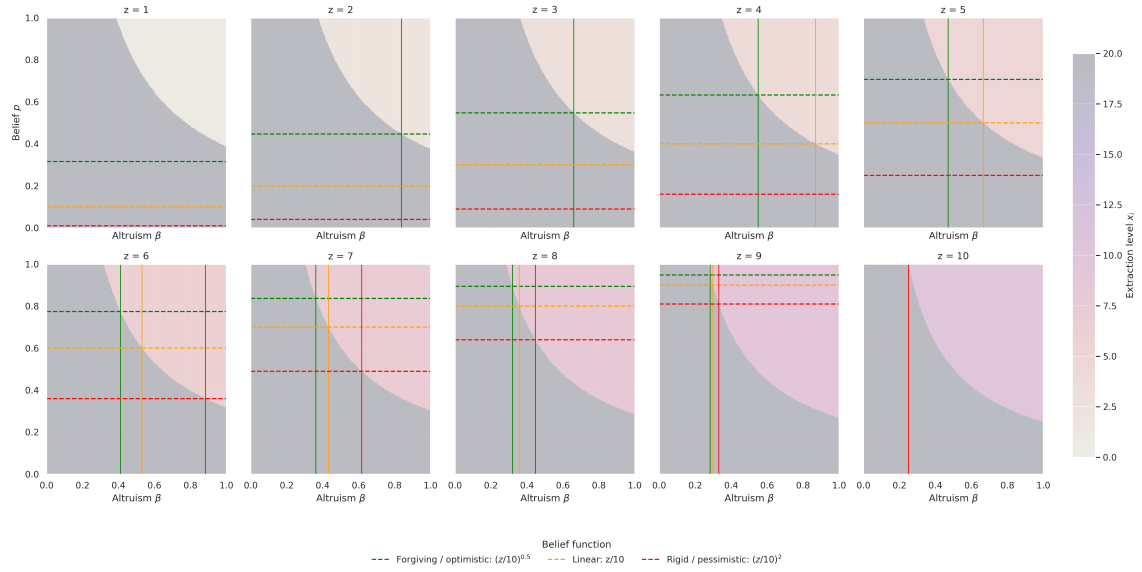
**Corollary 2.1** (No Incentive to Sacrifice). *If the inequality in Proposition 2 fails or the extraction decision of player  $i$  is irrelevant, Player  $i$  defects, i.e., extracts the full amount  $x_{i,g} = 20$ . This may occur under any of the following conditions:*

1. *Player  $i$  is insufficiently altruistic or too pessimistic:  $\beta_{i,g} p_{i,g} < \text{threshold}$ ,*
2. *Player  $i$  believes the resource is already doomed:  $z < 0 \Rightarrow p_{i,g} = 0$ ,*
3. *Player  $i$  believes the resource will survive no matter what:  $z > 20 \Rightarrow p_{i,g} = 1$ .*

**Corollary 2.2** (Minimal Effort Cooperation). *Suppose  $z \in (10, 20)$ , meaning player  $i$  believes others extract so conservatively that survival is possible with a relaxed contribution. If the general condition holds, Player  $i$  extracts  $x_{i,g} = z$ , making a partial but sufficient sacrifice to maintain sustainability.*

## A.5 Simulations and interpretation

### A.5.1 Individual decision: Cooperation and sacrifice



**Figure 7: Extraction decisions as a function of future preference, beliefs, and required sacrifice.** Each panel corresponds to a different level of required sacrifice  $z \in \{1, \dots, 10\}$ , i.e., the extraction level a player must limit themselves to in order to keep the generation below the renewal threshold given others’ expected behavior. The heat map shows predicted extraction levels as a function of intergenerational altruism  $\beta$  and belief  $p$ : lighter tones indicate cooperation ( $x = z$ ), while gray tone represents full extraction\*\* ( $x = 20$ ). Dashed horizontal lines depict belief heuristics: forgiving (green,  $\phi(z) = (z/10)^{0.5}$ ), linear (orange,  $\phi(z) = z/10$ ), and rigid (red,  $\phi(z) = (z/10)^2$ ). For each heuristic and value of  $z$ , the vertical lines identify the minimum altruism  $\beta$  required for cooperation, as defined by the condition  $\beta \cdot p \geq \frac{20-z}{50-z}$ . Forgiving belief functions require lower altruism thresholds, while rigid expectations demand stronger altruistic motivation. As  $z$  increases, the cooperation zone expands: when  $z = 10$ , players expect others to fully cooperate, and even low altruism may suffice to sustain cooperation.

To qualitatively interpret the mechanisms behind cooperation and sacrificial behavior observed in the experiment, we draw on our generalized theoretical model to explore how decisions are shaped by individual-level heterogeneity in beliefs and intergenerational preferences. Using the parameters from the experimental setup—specifically, the sustainability threshold  $T = 30$ , and the extraction choices available to each player—we simulate the extraction behavior of agents as a function of their altruism  $\beta$  and their subjective belief  $p$  that the resource will survive to future generations. For each level of expected sacrifice  $z$  (i.e., the amount an individual must forgo to preserve the resource), we identify the threshold condition under which a player will voluntarily cooperate:  $\beta p \geq \frac{20-z}{50-z}$ . This threshold captures the trade-off between immediate personal benefit and the discounted value of preserving the resource for the future.

Figure 7 illustrates the decision landscape across values of  $\beta$ ,  $p$ , and  $z$ , and includes reference lines corresponding to different belief formations—linear, concave, and convex—representing varying degrees of optimism or pessimism regarding the effectiveness of personal sacrifice. These lines allow us to visually assess, for any given belief structure, the minimal level of altruism required to sustain cooperation. In doing so, the figure highlights the interdependence of social preferences and beliefs in driving future-oriented behavior. The regions of cooperative extraction (in dark colors) emerge only when a player is sufficiently altruistic *and* sufficiently optimistic about the others’ restraint. Thus, the

model provides a framework to identify the psychological and behavioral boundary conditions under which intergenerational cooperation is possible.

## B Data analysis

### B.1 Data

**Implementation** Data were collected in Montpellier (France) over four sessions at various scientific events aimed at the general public and families, held between September 27 and October 26, 2024. The experiment was implemented in Otree and administered on tablets during the events. Participants were members of the general public who expressed an interest in taking part in an economic experiment. They were informed that the study involved monetary incentives, but they were not provided with further details regarding the content of the experiment, the tasks they would be asked to perform, or the objectives of the study. We relied on approximate randomization: session facilitators were instructed to assign each participant to a treatment at random. Individuals aged 10 years and older were eligible to participate in the experiment. To ensure comprehension, control questions were administered prior to the task. All completed responses were retained, and potential mistakes by participants are addressed in the robustness analysis. Subjects participated using the strategy method and were matched ex post into groups. They were asked to keep a personal code and a link in order to reconnect, and were informed that payments would be made available in the following weeks.

**Table 2:** Data collection sessions

session_date	N	N_1P	N_3P	Mean_age	N_male	N_female
2024-09-27	91	61	30	25.01	27	64
2024-10-05	62	40	22	35.42	31	31
2024-10-06	45	36	9	29.24	20	25
2024-10-26	62	0	62	36.47	23	39

For each event, the distribution of participants across treatments, along with basic demographic information, is summarized in Table 2. In the final session, we had a sufficient number of participants in the 1P treatment; therefore, only the 3P treatments were conducted. We observe some differences across sessions: the early sessions included a higher proportion of women. Age distributions also varied: participants tended to be younger in the first and third sessions, while older participants were more represented in the second and fourth sessions. We will test whether demographics influence the outcomes.

**Population specificity** The participants consisted of families, children, and adults with an interest in science and education, who voluntarily attended a scientific event. This implies a degree of selection bias. In particular, during the second and third sessions, the theme of the Fête de la Science was about ocean, with a focus on environmental issues. It is therefore possible that participants were, on average, more educated, more aware of environmental concerns, and more likely to display pro-social preferences. We also observed that several participants were not primarily motivated by monetary rewards, and some were even reluctant to accept payment. Many voluntary participants appeared motivated mainly by curiosity about the study and the opportunity to take part, which may have reduced the relevance of the monetary incentives.

**Data set** The final dataset includes 260 participants, with a mean age of 31 years, comprising 101 males and 159 females. Participants were randomly assigned to one of the treatment conditions. The demographic distribution across treatments is reported in Table 3.

**Table 3:** Experimental Sample

Treatment	N	Mean_age	SD_Age	N_minor	N_male	N_female
All	260	30.99	16.75	100	101	159
1P	137	30.04	16.50	62	52	85
3P	123	32.05	17.03	38	49	74

## B.2 Main Results

### B.2.1 Cooperation in 1P vs 3P

We begin by analyzing cooperation as a binary variable to test our hypothesis. A subject is considered cooperative if they harvest a level of the resource that is equal to or below the sustainable threshold at the individual level in the game, i.e., 30 in the 1P treatment and 10 in the 3P treatment. The cooperation rate is measured as the proportion of cooperators within each treatment. Decisions made in the final generation do not affect subsequent outcomes and are therefore excluded from this analysis. Instead, we focus on the decisions made in the first and intermediate generations.

Our hypothesis is stated as follows:

**Hypothesis 3.** *Introducing an intragenerational dilemma alongside an intergenerational dilemma reduces individuals' cooperativeness in an ICPR.*

This implies that we should observe higher cooperation in the 1P condition, where subjects make decisions alone for the next generation (the next participant), compared to the 3P condition, where the resource survival for future generations depends on the decisions of two other participants, thus introducing an additional intragenerational dilemma.

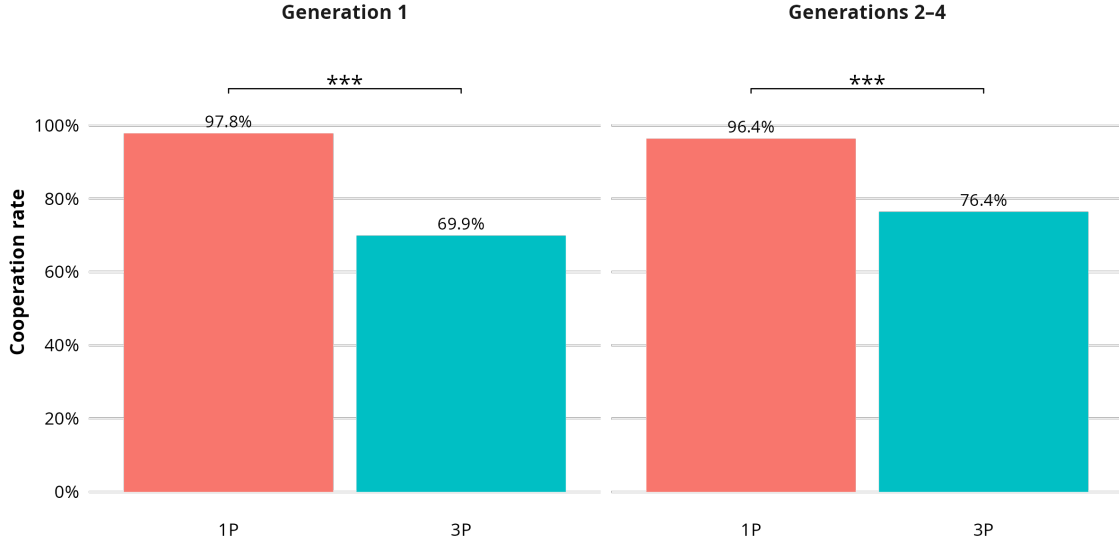
The findings indicate that cooperation in the 1P treatment is substantially higher than in the 3P treatment, with the proportion of cooperators approaching full cooperation under the intergenerational condition. This difference is particularly pronounced for decisions made in the first generation, where the cooperation rate reaches up to 98% in the 1P condition, compared to only 70% in the 3P condition, where an intragenerational dilemma is added.

We employed Fisher's Exact Test to compare the proportion of cooperators between the two treatments. The results confirm a significant difference between 1P and 3P for the first generation (Fisher,  $p < 0.001$ ), as well as for the intermediate generations (Fisher,  $p < 0.001$ ), where the gap is less pronounced, with approximately 96% cooperators in 1P and 76% in 3P. See also Table 4.

### B.3 Effect of Generation

We aim to examine whether there is a difference in cooperation rates between the first and intermediate generations. The first generation refers to participants at the start of the intergenerational line, while intermediate generations are those who can actually harvest from resources sustained by the previous generation.

It can be expected that participants in intermediate generations may be influenced by the behavior of prior generations, potentially through mechanisms such as reciprocity or social norms. If a participant observes that the previous generation cooperated and successfully



**Figure 8: Treatment Effect on Cooperation.** Bars represent average cooperation rates by treatment (1P vs. 3P). Sample sizes:  $N_{1P} = 137$ ,  $N_{3P} = 123$ . Cooperation was significantly higher under the 1P treatment in both generations (Fisher’s exact test; \*\*\* $p < 0.001$ ).

sustained the resource, they may be more likely to cooperate as well. In our data, we observe partial evidence of this pattern.

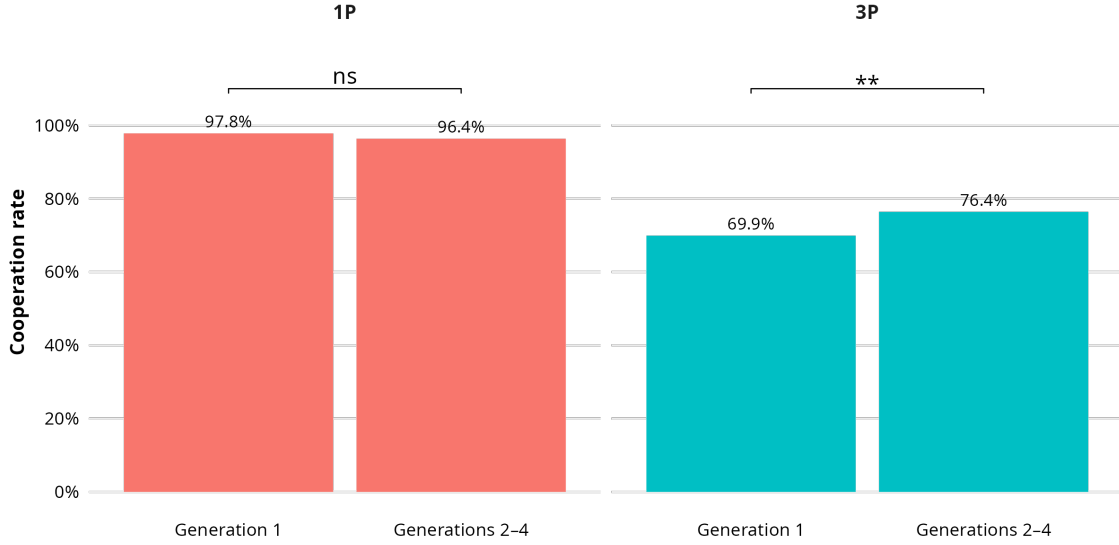
We found no significant differences in the 1P treatment, although cooperation was slightly lower for the intermediate generation (McNemar,  $p > 0.1$ ), likely because the overall level was already very high. In contrast, we found a significant effect in the 3P treatment, where cooperation increased from 70% in the first generation to 76% in the intermediate generation (McNemar,  $p < 0.05$ ). These results are based on McNemar tests, which account for the non-independence of outcomes, as participants provided responses for both the first and intermediate generations. See also Table 4.

This effect is particularly interesting, as it provides an initial insight into how the detrimental impact of an intragenerational dilemma within the context of intergenerational resource use could be mitigated. It suggests a potential lever for policy interventions, for example by highlighting the efforts and successes of previous groups to encourage cooperative behavior in subsequent generations. It should also be noted that, due to the use of the strategy method, being in the intermediate generation and being aware that the previous generation had sustained the resource was not particularly salient, as participants did not know for certain and were unaware of which condition they would face. Therefore, it could be interesting to replicate the experiment in a controlled lab setting, where this effect might be more pronounced.

#### B.4 Extraction Level

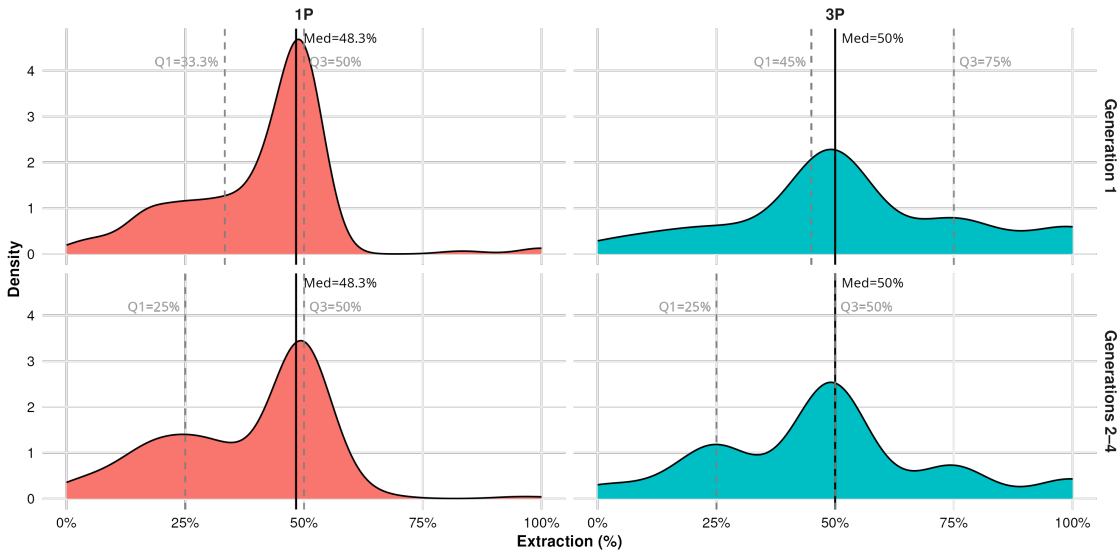
Beyond the binary analysis of cooperation, we examine the distribution of extraction levels, ie. the proportion of the resource harvested by each individual. Distribution of extraction level are represented in Figure 10.

Looking at the 1P treatment, we observe a very similar distribution of extraction levels for both the first and second generations. The level of extraction is concentrated around the threshold, with close to 40% of participants extracting exactly at this level. A small portion (3–4%) harvested above the threshold, either taking the entire resource or an



**Figure 9: Effect of Generation.** Bars represent average cooperation rates for the first and intermediate generations, grouped by treatment (1P vs. 3P). Sample sizes:  $N_{1P} = 137$ ,  $N_{3P} = 123$ . No significant difference was found in the first generation (Fisher’s exact test), while cooperation was significantly higher in the intermediate generation under the 3P treatment (\*\* $p < 0.05$ ).

intermediate amount. The remaining participants extracted below the threshold, with 25% harvesting less than 30% in the first generation and less than 25% in the second generation.



**Figure 10: Distribution of extraction levels.** Kernel density estimates of participants’ extraction decisions (0–100% of the total resource) are shown by treatment and generation. Vertical dashed lines indicate the first and third quartiles, while the solid line marks the median.

This behavior cannot be explained solely by the intention to preserve the resource for the next generation, as extracting at the threshold level would have been sufficient. It may instead reflect intrinsic preferences for resource preservation. We cannot exclude the possibility of miscomprehension, or that some participants were not motivated by the incentives.

In comparison, in the 3P treatment, while we observe a concentration around the threshold

similar to 1P, the overall pattern is different. First, we do not observe as many participants harvesting below the threshold and we observe more participants harvesting above, with spikes at 75% and 100% of the resource. Deviations from the threshold can be explained by strategic behavior: harvesting above the threshold to take advantage of others (free-riders), or harvesting below the threshold to compensate for others' extraction and help sustain the resource (sacrificers).

We also observe slight differences between the first and intermediate generations in the 3P treatment. In the first generation, the spikes around 75% and 100% are higher than in the intermediate generation, while the spike at 25% is lower. A greater proportion of participants harvested below the threshold in the intermediate generation.

	Cooperation	Extraction (%)
1P × Gen 1 (ref.)	13.004***	0.417***
3P vs 1P	-4.863*	0.126***
Gen 2–4 vs Gen 1	-1.814	-0.027
Interaction (3P × Gen 2–4)	4.529*	-0.027
EAI Score	0.860	-0.016
Larson Score	-0.086	0.012
Gender (Male)	-0.342	0.003
Age	-0.298	0.033
Children	-0.065	-0.012
Num. Obs.	520	520
$R^2$ (Marginal)	0.015	0.090
$R^2$ (Conditional)	0.986	0.658
AIC	262.4	-220.7
BIC	304.9	-173.9
ICC	1.0	0.6
RMSE	0.12	0.10

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

**Table 4:** Cooperation: Generalized Linear Mixed Model (GLMM); Extraction: Linear Mixed Model (LMM).

#### B.4.1 Sacrifice behavior in 3P

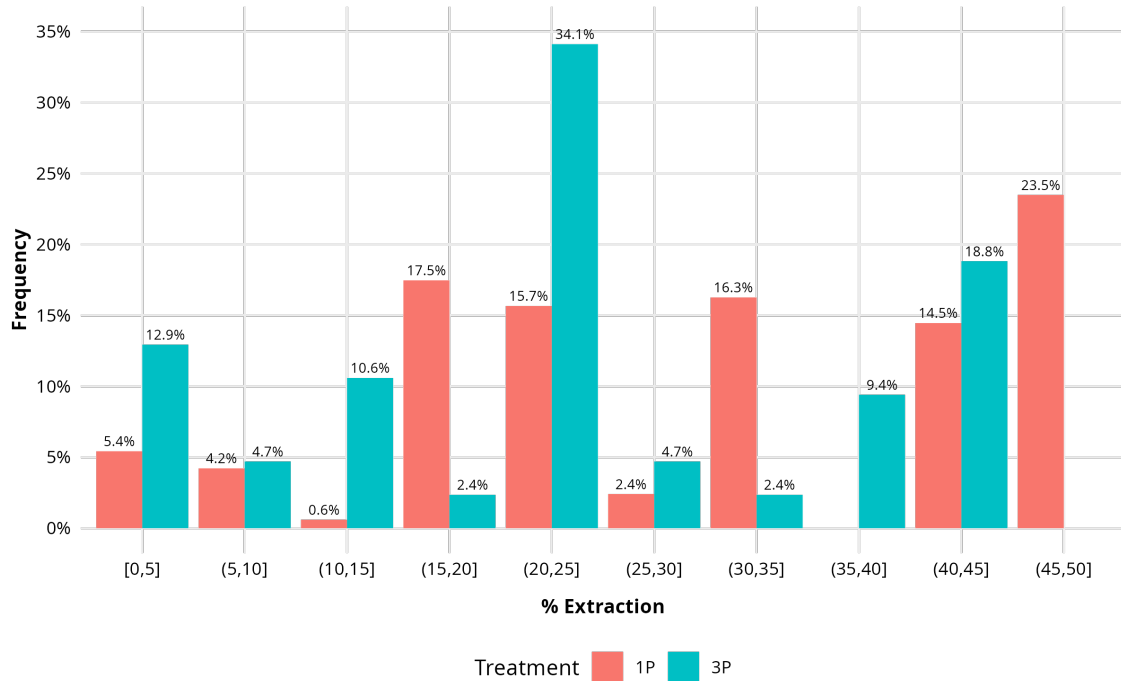
We further examine the behavior of sacrifice in the 3P treatment. In the 1P condition, intrinsic preferences, misunderstanding, or simple errors may have led participants to harvest below the threshold. The same mechanisms may also be at play in 3P, so it is necessary to distinguish between such behaviors and genuinely strategic sacrifice in that setting. To this end, we focus exclusively on cooperators and examine both the proportion and the distribution of participants harvesting below the threshold (hereafter, low extractors).

Looking at the share of participants harvesting below the threshold within the population of cooperators, we observe a significantly higher proportion of low extractors in 1P than in 3P, both in the first (62.04% vs 29.27%) and intermediate (59.12% vs 39.84%) generations (Fisher tests,  $p < 0.001$  and  $p < 0.005$ , respectively).

The distributional patterns differ between 1P and 3P (see Figure 11). While in 1P the proportion of cooperators declines steadily with extraction level, in 3P we observe a pro-

nounced spike at 25%, and a more even distribution around this point. In relative terms, more substantial sacrifices (harvesting  $\leq 25\%$  of the resource) occur in 3P than in 1P. Distributions differ significantly at the pooled level (Wilcoxon rank-sum test,  $p < 0.005$ ); the median extraction is higher in 1P ( $Mdn_{1P} = 0.33$ ) than in 3P ( $Mdn_{3P} = 0.25$ ).

While we cannot clearly disentangle different motivations behind low extraction in 3P, the distinct distributional pattern of cooperation suggests that strategic sacrifice is indeed at play in the 3P treatment.



**Figure 11: Distribution of extraction levels among below-threshold extractors.** Bars represent the proportion of participants extracting at different levels below the threshold, by treatment, pooled across generations.  $N_{1P} = 166$  (85 in Generation 1 and 81 in Generations 2–4),  $N_{3P} = 85$  (36 in Generation 1 and 49 in Generations 2–4).

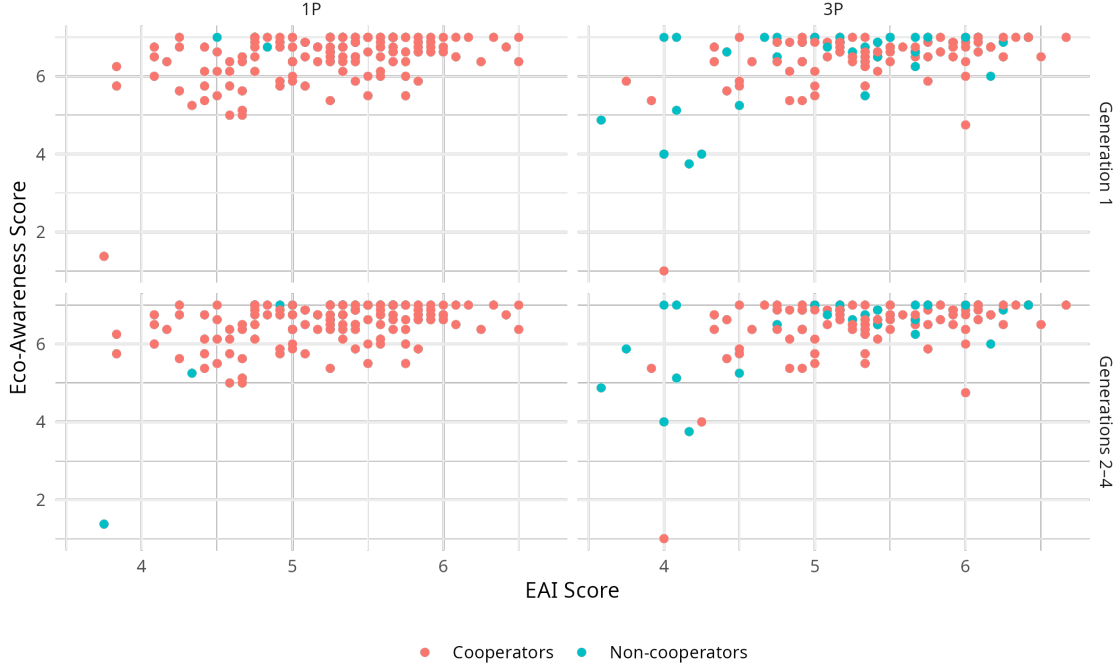
## B.5 Environmental attitude and control variables

After participants made their decisions, we measured their environmental preferences using two scales: the Environmental Attitudes Inventory (EAI, [54, 55]) and the Eco-Awareness scale [56]. Both scores are correlated ( $\rho = 0.450$ ,  $p\text{-value} < 0.001$ ), but none of them seems to influence extraction or cooperation decisions (Table 4 and Figure 12).

## B.6 Robustness

### B.6.1 Sub-sample analysis

**Participants older than 14** Since our sample includes participants as young as 10 years old, we conducted the analysis on a sub-sample of older participants only. During the experiment, we observed that younger children often had difficulty understanding the instructions, sometimes requiring assistance from their parents or accompanying adults. The results remain robust in this sub-sample, with a significant Fisher’s exact test (Fisher,  $p < 0.01$ ) and a significant McNemar test for the generation effect in the 3P treatment (McNemar,  $p < 0.05$ ).



**Figure 12:** Environmental attitudes (EAI) and affective connection to nature (Larson eco-awareness scale) among cooperators (extraction  $\leq 30$ ) and non-cooperators (extraction  $> 30$ ) across treatments and generations.

**Table 5:** Cooperation - Participants over 14 years old

	treatment	N	Overall_Cooperation	Cooperation_First_Gen	Cooperation_Intermed_Gen
1	1P	107	97.20	97.20	97.20
2	3P	103	73.30	69.90	76.70

**Comprehension errors** In the same ways, considering only participants who made no comprehension errors before taking their decision ( $N = 123$ ), the results hold. Fisher’s Exact Test remains significant for both the first and intermediate generations (Fisher,  $p < 0.001$  and  $p < 0.05$  respectively). The McNemar test also shows a significant difference between the first and intermediate generations in the 3P treatment (McNemar,  $p < 0.05$ ). Overall, cooperation is higher in 3P, and the generation effect becomes clearer with 10 percentage point differences between the first and the intermediate generation.

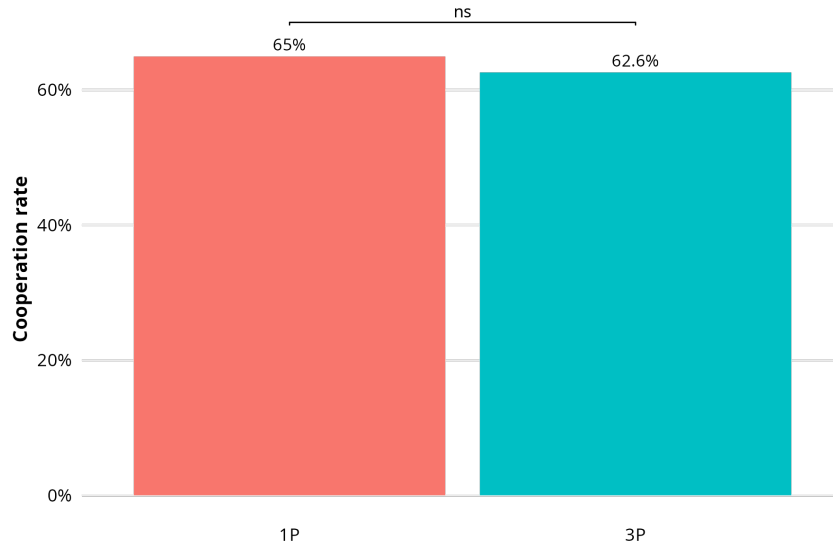
**Table 6:** Cooperation - No comprehension error participants

	treatment	N	Overall_Cooperation	Cooperation_First_Gen	Cooperation_Intermed_Gen
1	1P	67	98.51	98.51	98.51
2	3P	56	80.36	75.00	85.71

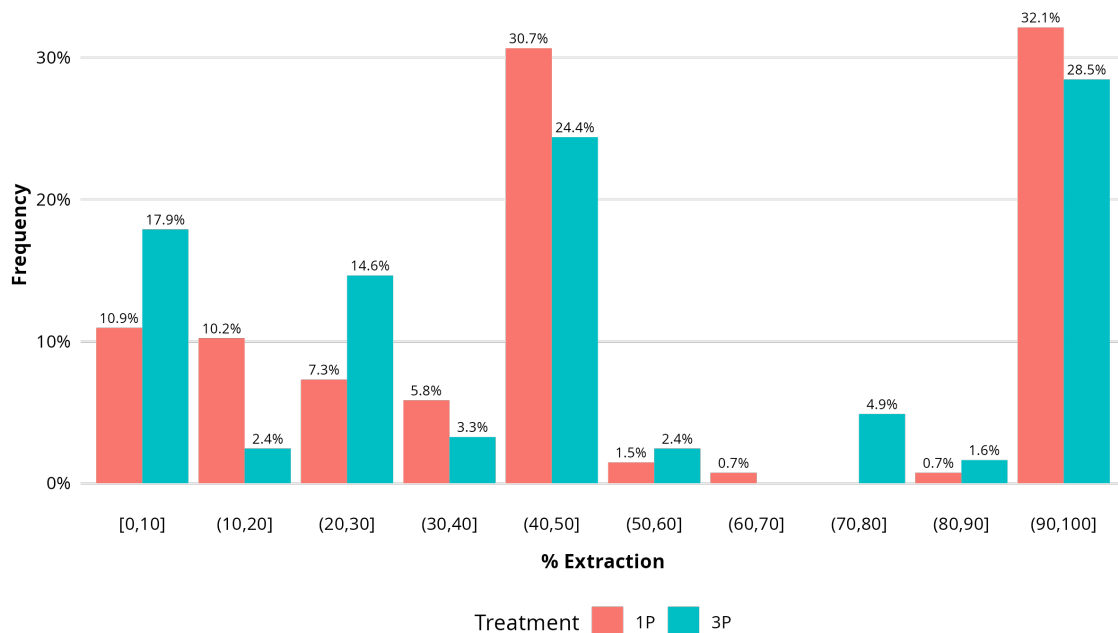
### B.6.2 Last generation

In the chore analysis, we exclude the responses from the last generation, since the decisions made at this stage do not have consequences for others. As the game terminates with the final generation, no one makes use of the remaining resources. For completeness, we nevertheless present the results for this last generation.

In terms of cooperation, we observe no significant differences between treatments 1P and 3P. Cooperation declines to 65% in 1P and to approximately 63% in 3P. The absence of a subsequent generation to benefit from the resource reduces cooperation and eliminates the effects of intra-generational conflict. Nevertheless, cooperation remains above 60% overall, which is still high. This suggests the presence of intrinsic preferences to preserve the resource.



**Figure 13: Cooperation by treatment in the last generation.** Fisher test shows no significant differences between treatment 1P and 3P. Sample sizes:  $N_{1P} = 137$ ,  $N_{3P} = 123$ .



**Figure 14: Distribution of extraction level for the last generation.** Bars indicate the proportion of participants extracting at different levels of resource extraction (0-100% of the total resource) by treatment. Sample sizes:  $N_{1P} = 137$  and  $N_{3P} = 123$ .

Regarding extraction levels, we observe pronounced spikes in both groups at the point of full exploitation of the resource: overall, approximately 30% of participants harvest the

entire resource. A less pronounced spike is also observed at the 50% threshold, while some participants extract at intermediate levels.

We conducted additional regressions to examine whether environmental preferences are related to these intrinsic preferences for preserving the resource. However, neither EAI nor Eco-awareness showed any significant effect on cooperation in the last generation.

## C Simulations

### C.1 Analytical expected number of generations with access to the resource

To analytically estimate the expected number of generations that have access to the resource, we define:

- $p_1$  as the probability that generation 1 (G1) cooperates,
- $p$  as the (assumed constant) probability of cooperation in subsequent generations (G2 to G4).

Because resource renewal requires full cooperation within each generation, access to the resource in a given generation depends on cooperation in all previous ones. Hence, the probability that the resource is still available in:

- generation 2 is  $p_1$ ,
- generation 3 is  $p_1 \cdot p$ ,
- generation 4 is  $p_1 \cdot p^2$ ,
- generation 5 is  $p_1 \cdot p^3$ .

We define the expected number of generations with access to the resource (including G1) as:

$$\mathbb{E} = 1 + p_1 \cdot (1 + p + p^2 + p^3).$$

The term “1” accounts for generation 1, which always receives the initial resource.

In the  $1P$  treatment (one participant per generation), the cooperation probability at the generation level equals the individual cooperation rate. In the  $3P$  treatment (three participants per generation), full cooperation requires all three individuals to act sustainably; under the assumption of independent choices, the generation-level cooperation probability is the cube of the individual cooperation rate. Table 7 reports the resulting cooperation rates, access probabilities, and expected number of generations with resource access.

Treatment	Cooperation rate		Survival probability				Expected generations
	Gen 1	Gen 2–4	Gen 1	Gen 2	Gen 3	Gen 4	
1P	0.978	0.964	0.978	0.943	0.909	0.876	4.706
3P	0.735	0.795	0.397	0.199	0.100	0.050	1.746

**Table 7:** Cooperation rates and survival probabilities per generation, and expected number of generations with access to the resource. In the 3P treatment, generation-level cooperation is calculated assuming independent individual decisions.

## C.2 Empirical expected number of generations with access to the resource

To estimate the sustainability of the resource across generations, we conducted Monte Carlo simulations inspired by the procedure developed in [12]. In each simulation, we constructed a sequence of five successive generations by drawing participants without replacement from the experimental dataset.

In the  $1P$  treatment, each generation was represented by one participant whose extraction decision determined whether the resource was renewed (if extraction  $\leq 30$  units) or permanently depleted. In the  $3P$  treatment, each generation included three participants; the resource was renewed only if their combined extraction did not exceed the same threshold.

To ensure statistical independence and avoid redundancy, we excluded duplicate sequences—defined as identical sets of participants drawn in the same generational order—from the simulation pool. This approach differs from the bootstrap procedure used by [12], which samples with replacement, allowing the same individual to appear multiple times within a single trajectory. While this accounts for random variation in group composition and continuation, it may overweight certain behaviours. Our procedure mirrors the experimental design more closely, in which each participant contributes only once per trajectory (though they may be sampled again in other trajectories).

We then computed, across 10,000 simulated trajectories, the probability that the resource remained available at each generation. The resulting empirical survival curves are directly comparable to those reported in previous IGG studies.

Treatment	Survival probability				Expected generations
	Gen 1	Gen 2	Gen 3	Gen 4	
1P	0.977	0.940	0.902	0.865	4.683
3P	0.518	0.342	0.222	0.146	2.228

**Table 8:** Survival probabilities per generation and expected number of generations with access to the resource, based on 10,000 Monte Carlo-simulated generational sequences.

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