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Back to the future: An experiment on ecological restoration

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ABSTRACT

The urgency of climate, biodiversity, and pollution crises has prompted international and national institutions to move beyond the prevention and mitigation of damages and to design policies aimed at promoting ecological restoration. In this paper, we address this emerging policy challenge by presenting experimental evidence on individuals' propensity to contribute to restoration activities. Specifically, our design links a common pool resource game to a public good game to investigate how previous resource exploitation influences restoration decisions. We find that history matters since subjects who participate in resource depletion show a different behavior as compared to subjects who are only called to restore it. Specifically, while the former are subject to behavioral lock-ins that influence the success of restoration, the latter are more prompt to restore the more the resource is depleted.

1. Introduction

Traditionally, environmental policies and regulations have mainly focused on preventing and mitigating damage to minimize the negative effects of human activities on the environment. However, the global and local threats posed by climate change, biodiversity loss, and pollution crises are soliciting a profound revision of environmental regulation and resource management. It is now evident that preservation alone is insufficient, and widespread restoration efforts are urgently needed on a global scale (Suding et al., 2015). According to the Society of Ecological Restoration, the practice can be defined as "the process of halting and reversing degradation, resulting in improved ecosystem services and recovered biodiversity" (Gann et al., 2019). Essentially, it involves returning a degraded ecosystem to its original functioning, structure, and diversity, making it more resilient to changing external conditions (Harris et al., 2006). Although nature has an extraordinary ability to recover its functions even after deep negative interferences, the engagement of human societies in restoration activities delivers a decisive boost and this is why such activities are increasingly studied and implemented. Not only is humanly-induced restoration more successful in most cases (Benayas et al., 2009), but social factors significantly influence the effectiveness of restoration projects (Löfqvist et al., 2022), and greater community participation enhances their long-term sustainability (Swart and Zevenberg, 2018).

At the policy level, significant initiatives have been developed in recent years, including the United Nations Decade on Ecosystem Restoration launched in 2021, aimed at stimulating community-led restoration practices worldwide (United Nations Environmental Programme, 2021). At the European level, in June 2024 the Council of the EU has adopted the Regulation on Nature Restoration, a landmark and innovative legal instrument part of the Green Deal. This Regulation introduces obligations for the recovery of nature, the mitigation of climate change, and the adaptation to changing environmental scenarios.[1] To achieve these objectives, it sets forth an overarching target of restoring 30% of its land and sea areas by 2030, along with a commitment to restore all degraded ecosystems by 2050. Additionally, the general target is supplemented with ecosystem-specific objectives, encompassing areas such as forests, urban ecosystems, agricultural lands, rivers, and marine areas. The obligations stemming from the Regulation fall directly on Member States, which are called upon to draft National Restoration Plans; public authorities are thus obliged to plan how they intend to achieve the specified restoration objectives, detailing the types of funds they plan to utilize and the administrative levels they intend to involve. It should be emphasized that the path of the Restoration Law has been particularly tumultuous, given that the first version of the Regulation was subject to many objections (Cliquet et al., 2024). Indeed, while the initiative received praise from various stakeholders, including scientists, organizations, and various companies, there was

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[1] Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869.

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also strong opposition, especially from representatives of the primary sector (agriculture, forestry, and fisheries).

Now that an agreement on the objectives of the Law has been reached, it remains very relevant to understand if and how States will be able to secure political support for such costly policies, as well as to evaluate the specific contributions that can be made by citizens, both individually and through non-governmental associations. To this end, this study aims to experimentally investigate the behavioral and psychological drivers that influence individuals' willingness to participate in collective restoration efforts. Our focus is on analyzing the conditions that create incentives for restoration beyond legal mandates, providing deeper insight into its underlying dynamics for effective policy interventions. Therefore, we examine the combined impact of strategic interaction and ecosystem characteristics on both individual and collective motivations to restore depleted goods and resources.

We propose a novel design that connects a Common Pool Resource game to a Public Good game to represent the concatenation between an *exploitation* and a *restoration* phase involved in ecological restoration. In more detail, our *Restoration Game* requires subjects to face an exploitation decision - where they choose how much to extract from a common environmental resource - and a restoration decision - where they decide how much to invest in the regeneration of the same resource. The main conditions differ based on subjects' participation in both decisions or only one of them. Accordingly, we have subjects making both decisions in sequence and subjects who make only the restoration decision, while inheriting the resource from other subjects who only made the extraction decision.

These design features are motivated by two fundamental aspects of ecological restoration crucial for understanding its behavioral drivers. Firstly, the decision to restore occurs within a specific time-frame: more precisely, the need to *re-store* inevitably follows resource exploitation. Therefore, we can assert that the intensity of prior degradation or the types of extraction choices made in the past can influence both individual and collective restoration decisions in the present - in other words, history matters. Secondly, the action of restoring an environmental resource implies a transformation in the perception and use of the resource itself. Indeed, when an environmental resource is exploited, there is a progressive depletion of its availability, which brings out the typical characteristic of rivalry in consumption. On the contrary, the action of restoration has the opposite effect: it intervenes to multiply the functionality of the resources and thus increases their availability. A classic example is forests: while excessive timber extraction leads to a reduction in available ecosystem services, restoration practices such as afforestation projects reactivate ecological functions and produce non-rival benefits that are accessible to all. This typical characteristic of resource regeneration affects both the perception people have of a given ecosystem and the behavior they then adopt in using the resources.

Using common-pool resource games and public good games to explore environmental resource management is not new in behavioral ecological economics (Cardenas, 2000; Ostrom, 2008; Calzolari et al., 2018; Gächter et al., 2022). However, while both frameworks have been employed in repeated (Schill and Rocha, 2023) or intergenerational (Fischer et al., 2004) settings, the concatenation of the two represents an element of novelty. To our knowledge, only Boldrini et al. (2024) have applied a similar approach to investigate behavioral impacts of a restoration technology. However, while their main focus lies on the potential crowding out of motivation towards mitigation of environmental damages, we specifically address behavioral and psychological drivers of voluntary restoration activities. To this purpose, our between-subject design aims at disentangling the specific role played by subjects' participation in environmental resource degradation and their propensity towards restoration.

The paper is organized as follows: Section 2 describes the experimental design, illustrating the underlying model and the research questions; Section 3 presents the main results, discussing the treatment and condition effects as well as a first analysis of the behavioral traits in the restoration scheme. Section 4 concludes with the synthesis of the results and a discussion of the relevant insights for policy and practice.

2. Methods

2.1. The design

Our experiment consists of two main and two auxiliary conditions.[2] The first main condition is the Baseline (BL), where subjects perform in sequence an exploitation decision in a Common Pool Resource game (CPR) and then are asked to restore the resource in a Public Good game (PG). The second main condition is the Only Restoration condition (OR), where subjects only make the PG restoration decision while inheriting the resource from another group of participants who exploited it in the CPR. We focus on these two conditions to specifically analyze restoration decisions.

The two auxiliary conditions are then functional for the implementation of the two main conditions. Specifically, in the Strategy Method condition (SM) subjects make the CPR and the PG decisions in sequence, but they perform the latter conditional on every possible state of the resource after the CPR decision. The data from this condition are used to compute the final payoffs of subjects in the BL, as explained below. The second auxiliary condition is the Only Extraction (OE), where subjects are only asked to make CPR decisions and are informed that another group of participants will be asked to restore it (i.e. the subjects in the OR). In other words, OE serves the purpose of providing subjects in the OR with real input about exploitation decisions made by others.

To enhance the realism and emphasize the narrative of restoration, the decisions are framed in terms of the management of a forest: during the exploitation decision, participants choose the number of trees to cut and earn monetary payoffs from timber; in the restoration decision, they choose how much money to invest in the re-forestation. This approach imposes constraints on the generalizability of our findings, which may not accurately represent restoration decisions involving other types of environmental resource, as further discussed Section 4. However, within the online setting where our experiment was conducted, the framing is intended to enhance comprehension of the decision at hand while facilitating identification (Alekseev et al., 2017).

To motivate the main features of our design, we focus on the main conditions and first describe the steps taken by subjects in the BL condition, and then outline the key distinctions of the OR condition. The analysis of the payoffs of these two conditions is provided in the next Section 2.2.

Subjects in the BL are informed from the very beginning that they will face in sequence both the exploitation phase (i.e., the CPR decision) and the restoration phase (i.e., the PG decision) and that feedback is provided between the two. In the exploitation phase, participants are randomly and anonymously matched in groups of three and share a forest made of six trees. Each participant begins with an initial endowment of 40 points per person and is informed that these points are converted into GBP at the end of the experiment, with a conversion rate of 100 points per 1 GBP. The exploitation decision involves determining the number of trees to cut and convert into timber from a forest containing six trees. Each participant is presented with three extraction options: extracting 0, 1, or 2 trees. Cutting down a tree yields an individual benefit of 20 points. Participants make their decision privately by selecting the corresponding radio-button displayed in Fig. 1. The counter instantaneously displays the points earned from timber associated with each option.

Following their extraction decision, subjects receive feedback about the state of the forest post-extraction. This feedback entails information about the behavior upheld by the other participants in their group, but does not detail individual extraction choices. Information is conveyed

[2] All the conditions were preregistered on AsPredicted.org (#127629). The pre-registration, along with the instructions, datasets, and replication files, can be accessed through an OSF repository (https://osf.io/g82fs/).

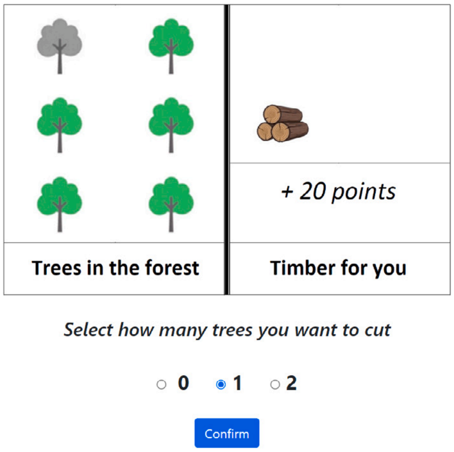

Fig. 1. Example of screen for CPR decision.

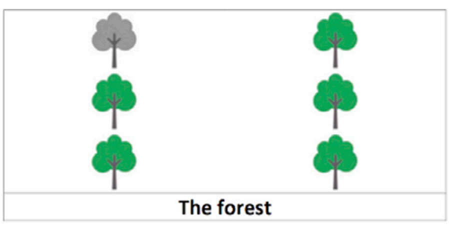

Fig. 2. Feedback screen.

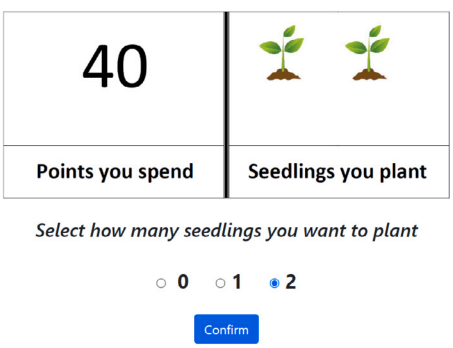

Fig. 3. Example of screen for PG decision.

through a graphical representation, as depicted in Fig. 2. The graphical representation of the overall forest condition provides subjects with a stimulus that potentially activates subjects' considerations and feelings concerning the resource as a whole.

In the restoration phase (i.e., the PG), the subjects' decision is about replanting trees: they can choose to plant either 1 or 2 trees or decide not to plant any, with each tree costing 20 points. The assumption that the cost of restoring one tree equals the earnings from extracting one tree in the CPR is admittedly bold. However, this parametrization is essential to ensure isomorphism between CPR and the PG decisions, thus keeping the same incentive to free-ride (see Fig. 3).

To investigate whether the efficiency of restoration technology impacts decisions, we manipulate the returns from contribution in restoration (the marginal per capital returns *MPCR* of the PG) with two further treatments. Accordingly, we compare between-subjects the restoration decisions made by subjects who have the possibility of replanting trees with a higher return (H treatment) and of replanting seedlings with a relatively lower return (L treatment). We account for the difference in return from reforestation in terms of fresh air generated by the forest.

These returns from the PG contribution are then paid off in points at the end of the experiment. Specifically, a tree planted in the H treatment generates 12 points in fresh air for each participant, whereas a seedling planted in the L treatment generates 9 points in fresh air for each group participant.

To compute payoffs for the BL we perform an *ex-post* matching strategy using observations from the SM. Specifically, each subject in BL is randomly matched with two subjects in the SM to compute both the returns from the CPR (i.e. the returns from trees overall left in the forest) and the PG (i.e. the returns from trees replanted into the forest). This procedure is necessary considering the difficulties associated with simultaneous interactions in online experiments (Arechar et al., 2018; Zhou and Fishbach, 2016), primarily because of attrition. Subjects in the BL were unaware of this matching strategy. However, we consider that this omission does not affect the outcomes in the BL or compromise the accuracy of our payment procedure, since the payoffs in the BL and the SM are identical.

In the OR condition, only the restoration phase is involved and subjects are informed that they are dealing with the forest left after exploitation by another group of three subjects in the OE. After receiving the information about the trees left in the forest, subjects are asked to determine the number of trees (or seedlings) they wish to replant. To ensure compatibility in payoffs with the BL, individuals are endowed with either 40, 60, or 80 points, representing all possible endowments individuals in the BL could possess after exploiting the forest for their benefit.

In both the BL and OR conditions, we included a brief comprehension test before the decision task to ensure understanding. After the decision task, we elicited, only for exploratory purposes, social expectations based on the incentivized method proposed by Cristina Bicchieri and coauthors (e.g.Bicchieri and Xiao, 2009; Bicchieri and Chavez, 2010). Social expectations in this case encompass subjects' expectations about the level of restoration by other individuals (*empirical expectations*) as well as subjects' expectations regarding the average belief within the group concerning how much one ought to restore (*normative expectations*). Both questions were incentivized, and subjects knew they could earn 20 additional points for each correct guess. Moreover, at the end of the experiment, we administered two further questions to measure altruism and risk attitudes, following the methodology introduced and validated in Falk et al. (2023) and Dohmen et al. (2011), respectively.

2.2. The restoration game: model and theoretical predictions

We analyze the payoffs of the designed decision problem by using a simple model that we call the *Restoration Game* (RG). In the RG, players interact in two stages: the CPR stage and the PG stage. In CPR, each player i decides how much to extract (e_i) from a common pool of size P, where each unit of resource extracted yields δ (in our set up $P = 6$, $e_i = \{0, 1, 2\}$ and $\delta = 20$). In the second stage, PG, the choice concerns the voluntary contribution to restoring the common pool (c_i), with each unit of resource restored costing γ (in our set up $c_i = \{0, 1, 2\}$ and $\gamma = 20$). After the PG stage, two marginal per capita returns (*MPCR*) factors come to play: one pertains to what remains from the previous stage ($\alpha_{CPR} \in (0, 1)$), while the other concerns only what is restored ($\alpha_{PG} \in (0, 1)$).

The payoff function for a generic i player in a group of n is illustrated by Eq. (1),

$$\pi_i(BL) = Y_i + \delta e_i - \gamma c_i + \alpha_{CPR}(P - \sum_{j=1}^{n} e_j) + \alpha_{PG}(\sum_{j=1}^{n} c_j) \quad (1)$$

where Y_i is player i's endowment (in our set up $Y_i = 40$), δ is the earning from one unit extracted from the common pool, and γ is the cost of restoring one unit of the common resource. In the *BL*, what remains of the common resource after extraction by the j players – given by $P - \sum_{j=1}^{n} e_j$ – is multiplied by the *MPCR* $\alpha_{CPR} \in (0, 1)$, while what is restored by the same j players – represented by $\sum_{j=1}^{n} c_j$ – is multiplied by the MPCR $\alpha_{PG} \in (0,1)$. Accordingly, the i's final payoffs result from the sum of the personal endowment which is increased by the earnings from extraction and decreased by the cost of restoration, as well as the returns from what remains in the common pool after the group's extraction, and the returns of overall restored resource.

Notice that in the BL version of the RG, the n players remain the same across both game stages. In the OR version, the n players make only the restoration decision, with other p players extracting from the common resource in the OE condition (in our set up $n, p = 3$). The i's payoff function is represented by Eq. (2)

$$\pi_i(OR) = Y_i - \gamma c_i + \alpha_{CPR}(P - \sum_{k=n+1}^{n+p} e_k) + \alpha_{PG}(\sum_{j=1}^{n} c_j) \quad (2)$$

where Y_i is player i's endowment (with $Y_i = 40, 60, 80$ due to the randomization procedure illustrated above for our set up), δ is again the same earning from one unit extracted from the common pool, and γ is the cost of restoring one unit of the common resource. In the *OR*, what remains of the common resource after extraction by the p players – given by $P - \sum_{k=n+1}^{n+p} e_k$ – is multiplied by the *MPCR* $\alpha_{CPR} \in (0,1)$, while what is restored by the other j players, represented by $\sum_{j=1}^{n} c_j$, is multiplied by the MPCR $\alpha_{PG} \in (0,1)$. Accordingly, the i's final payoffs result from the sum of the personal endowment that is decreased by the cost of restoring, and of the returns from what remains in the common pool after extraction by the other group in OE, and the returns of the overall restored resource.[3]

Independently on the condition, everyone benefits from the returns of overall restoration in the PG, thus creating an incentive to free-ride in both stages of the RG. The theoretical predictions concerning both the BL and the OR are as follows: full extraction ($e_i = max$) whenever $\alpha_{CPR} < 1$ (and $e_i = 0$ otherwise), and full free riding ($c_i = 0$) whenever $\alpha_{PG} < 1$ (and $c_i = max$ otherwise). As we are interested in the social dilemma aspects of restoration, we impose $\alpha_{CPR} < 1$ and $\alpha_{PG} < 1$, in addition to $n \times \alpha_{PCR} > 1$ and $n \times \alpha_{PG} > 1$. Specifically, in our design $\alpha_{PG} = 0.45$ in the L treatment and $\alpha_{PG} = 0.6$ in the H treatment.

2.3. Research questions and behavioral hypotheses

Our design enables us to investigate two main research questions. The first one explores the impact of participation in resource extraction on subsequent restoration behavior, while the second one focuses on the potential drivers of restoration within the BL condition. As for the first question, following a purely rational decision-making process, no differences should be observed. However, when comparing restoration decisions between the BL and the OR behavioral and psychological factors could emerge. Even if happening just a few seconds after their initial choice, participants in the BL have the opportunity to reconsider it, and may be influenced by sentiments such as guilt (Wyss et al., 2021) or a sense of loss for the depleted natural environment (Bartczak et al., 2015; Holland, 2015).

In contrast, decisions in the OR condition are influenced by the extraction levels maintained by another group. Participants inheriting a forest previously utilized by others may choose to conform and mimic their behavior (Cialdini et al., 1990), or they may opt to deviate from the norm, particularly in cases of heavy extraction, driven by a desire to distinguish themselves as more responsible or pro-social (as described in social tipping dynamics initiated by pro-environmental behaviors of minorities, see Berger et al., 2023).

Moreover, the salience of the potential benefit of restoration differs between conditions. While subjects in the OR focus on restoration as their only decision, subjects in the BL view restoration as a future, second occasion. Boldrini et al. (2024) find that the possibility of restoring in the future negatively affects extraction decisions in their first stage. Contrarily, we investigate whether being involved in the first-stage decision conditions the restoration decision in the second stage by comparing the BL and the OR. In this regard, we consider that subjects in the BL could be focused on their first decision and be comparatively less concerned about all the implications involved in restoration, compared to subjects in the OR.

The second research question concerns the potential drivers of restoration behavior within the BL condition. In particular, being exposed to both decisions and sharing them stably with the same group can condition restoration decisions in two ways. Firstly, subjects could be influenced by the feedback from the group extraction, deciding to either reciprocate or punish cooperative behavior upheld by others (Bowles and Gintis, 2011; Gächter et al., 2017), or they could decide to cooperate conditionally on others' behavior (Fischbacher et al., 2001; Fischbacher and Gächter, 2010; Ackermann and Murphy, 2019). Indeed, the feedback can update priors held by subjects, influencing their restoration behavior based on their expectations of others' behavior. Secondly, subjects' own extraction decision can condition their restoration decision (Gunnthorsdottir et al., 2007). For instance, they may tend to replicate the kind of behavior (more or less pro-social/pro-environmental) they adopted in the first stage without considering possible changes. Alternatively, a sense of consistency may drive them to reapply the same decision criteria without updating them to the new decision situation. We will discuss this hypothesis in terms of a behavioral lock-in binding subjects' decisions in the BL.

3. Results

The experimental sessions were coded using oTree (Chen et al., 2016) and conducted on Prolific, a crowdsourcing platform for online experiments (Palan and Schitter, 2017), throughout April 2023. Prolific provides researchers with a large and diverse pool of registered participants, allowing for efficient and reliable data collection. We recruited an average of 135 subjects per condition. This sample size was computed using the software G*Power 3.1 (Faul et al., 2009) through an *ex ante* power analysis to detect effect sizes of 0.25 at a significance level of 5% with a power of at least 0.8. The experiment was restricted to participants located in the UK, aged between 18 and 40, who had previously completed at least 10 studies on Prolific with an approval rate of at least 90%. This means that the participants were experienced with the platform and had a history of providing high-quality responses. An approval rate of at least 90% indicates that their submissions were accepted by researchers in at least 9 out of every 10 studies they participated in. No sample restriction was applied *ex post* and only observations relative to subjects not concluding the experiment were excluded. On average, subjects took 6 min to complete the experiment. The participants had an average age of 31, with 49% identifying as female. Additionally, 62% reported having a full-time job at the time of the experiment, while 16% were students. They were paid a 0.50 GBP show-up fee to complete the experiment and received an average bonus of 0.56 GBP for the incentivized part. Therefore, on average, they received a total payment of 10.60 GBP per hour.

In this section, we analyze the evidence gathered in the experiment. In the first part, we focus on comparing extraction and restoration behaviors across the different conditions to which subjects are assigned. These conditions include the BL, where subjects make both decisions, and two other conditions where participants make only one decision (OE or OR). We also differentiate by restoration efficiency level, which is exogenously manipulated in our design.

Moving to the second part, our focus shifts to a detailed analysis of restoration behavior. Initially, we examine behavioral patterns in the BL, linking individual extraction decisions to restoration choices. Then, we investigate restoration behavior in relation to the state of integrity of the resource, considering the forest conditions in the BL and the OR treatment.

[3] Payoff function and theoretical predictions for subjects in the OE treatment are provided in Appendix A.

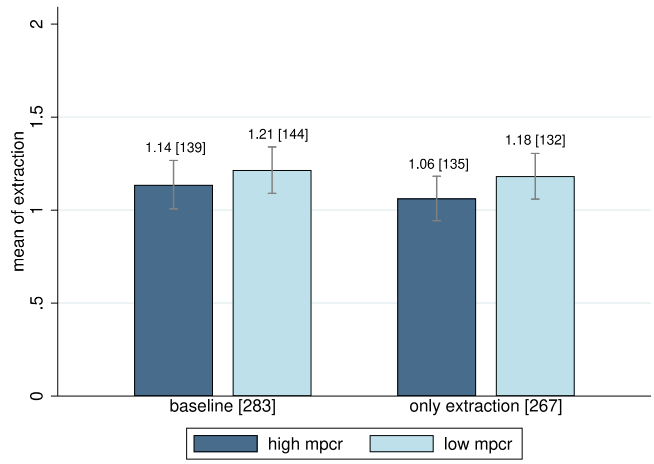

Fig. 4. Means of extraction by condition and over *mpcr*.
Note. Number of observations is in brackets.

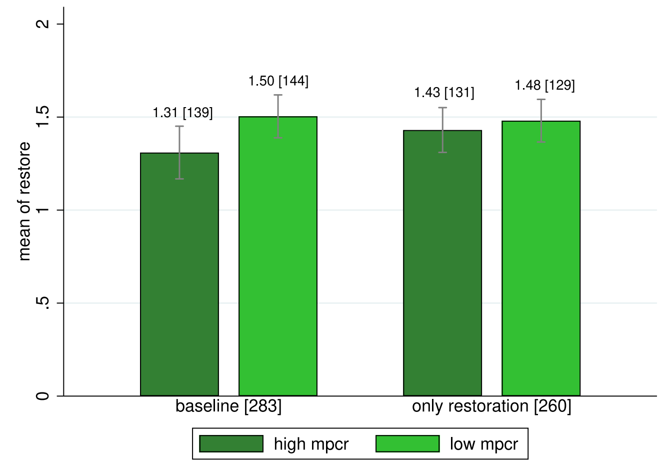

Fig. 5. Means of restoration by condition and over *mpcr*.
Notes. Number of observations is in brackets.

Finally, we ensure the robustness of our findings through regression analyses, controlling for the effects of demographics and self-assessed validated measures of altruism and proneness to risk.[4]

3.1. Condition and treatment effects

In Fig. 4 we present evidence from the extraction stage, corresponding to the CPR decision, where participants could choose to cut 0, 1 or 2 trees from the forest. This decision was made by participants in the BL, who later also participated in the PG decision on the same forest, and by participants in the OE condition, who only made this choice, and then left the forest to other groups who could, in turn, restore it. Overall, we do not observe any significant difference in results between the two groups. Specifically, while pooling conditions by *MPCR* value, extraction levels show no differences in subjects' behavior between the BL and the OE condition (Mann–Whitney test, $p = 0.127$). The same holds when combining the two conditions and comparing the two *MPCR* levels (Mann–Whitney test, $p = 0.331$). Moreover, we find no significant evidence when comparing the BL and the OE condition for the same level of *MPCR* (Mann–Whitney tests, with *high MPCR* $p = 0.435$, with *low MPCR* $p = 0.174$), or vice versa, when examining the effect of a change in the *MPCR* on extraction within the same condition (Mann–Whitney tests, BL $p = 0.373$, OE $p = 0.673$).

In Fig. 5, we present findings from the restoration stage, corresponding to the PG decision, where participants could decide whether to plant 0, 1 or 2 trees (high *MPCR*) or seedlings (low *MPCR*). This decision was made by participants in the BL who had already taken part also in the CPR decision on the same forest, and by participants in the OR condition who only made this choice, receiving the forest from another group. Overall, once again, we do not observe significant differences between groups when considering our experimental manipulations. Specifically, while aggregating conditions by *MPCR* value, restoration levels show no differences in subjects' behavior between the BL and the OR condition (Mann–Whitney test, $p = 0.175$). The same holds when pooling over the two conditions and assessing the effect of the *MPCR* (Mann–Whitney test, $p = 0.672$). Additionally, no significant effect emerges when contrasting the BL and the OR condition for the same *MPCR* level (Mann–Whitney tests, with high *MPCR* $p = 0.115$, with low *MPCR* $p = 0.746$), or vice versa, when evaluating the impact of a change in the *MPCR* on restoration within the same condition (Mann–Whitney tests, BL $p = 0.345$, OE $p = 0.702$).

3.2. Exploring restoration behaviors

The analysis conducted so far reveals no treatment effects on restoration decisions. However, this lack of evidence must be further investigated to rule out the possibility that underlying factors are canceling out these effects. Indeed, these underlying factors – e.g., the condition of the forest left in both the BL and t OR and one's own extraction decision in the BL – are present before the restoration decision and can potentially influence it. In the next subsection, we perform a series of parametric analyses to account for these factors as *explanans* of restoration decisions. All the variables used in the regression analyses that follow are explained in Table 1.

To examine how resource integrity and extraction choices affect restoration behaviors, we first merge data collected from the BL and OR conditions. This approach allows for comparisons of restoration behavior based on whether a subject participates in the extraction of the resource, the state of the forest she inherits, and the two different levels of MPCR concerning restoration returns. The average levels of restoration concerning forest conditions encountered by subjects upon entering stage 2 of the game are depicted in Fig. 6. Forest condition is determined by the number of trees, ranging from 0 to 6, based on the decisions made by group participants in the CPR stage. Our observations indicate a significant impact stemming from involvement in resource exploitation during the first stage: in the BL, where participants took part in the extraction phase in CPR decision, we note a positive correlation between restoration levels and the number of trees remaining in the forest. Conversely, within the OR condition, a negative trend is observed. So, the history of the resource matters, despite theoretical predictions suggesting otherwise (namely, that nobody should restore the forest regardless of who exploited it or how many trees are still there).

To test this, we conducted a regression analysis which is presented in Table 2.

In Model 1, we consider as regressors the variables related to the impact of the MPCR *(low mpcr)*, the difference between the BL and OR

[4] In Appendix B, our analysis shows that, despite the low attrition levels in the online experiment, some dropouts may be attributed to asymmetries between treatments in control questions presented to subjects, potentially leading to self-selection. However, we clarify that this issue is confined to the experiment's section related to control questions, even though subjects were allowed to continue with the experiment after failing the control questions twice by being provided with the correct answers. Importantly, in the segment involving subjects' decisions, the attrition rate becomes negligible. We also establish that attrition has minimal impact on the composition of samples across the three conditions. Additionally, we confirm the robustness of our results by incorporating subjects' responses to control questions into our analysis.

Table 1
Description of variables.

Name	Description	Value
low mpcr	the treatment corresponds to planting trees ($\alpha_{PG} = 0.6$) or seedlings ($\alpha_{PG} = 0.4$)	0 = no (high mpcr = trees) 1 = yes (low mpcr = seedlings)
only restoration	players face both stages (BL) or only the second stage (OR)	0 = no (BL) 1 = yes (OR)
forest left	trees left after the extraction phase	from 0 to 6
own extraction	subject's choice in CPR decision (number of trees cut)	0, 1, 2
others extraction	sum of the other two group members' decisions in CPR	0, 1, 2, 3, 4
altruism	self-assessed willingness to donate to a good cause after receiving 1,000 GBP (Falk et al., 2023)	$0, 100, \dots, 1000$
self-assessed risk	self-assessed willingness to take risk (Dohmen et al., 2011)	from 0 (not at all willing) to 10 (very willing)

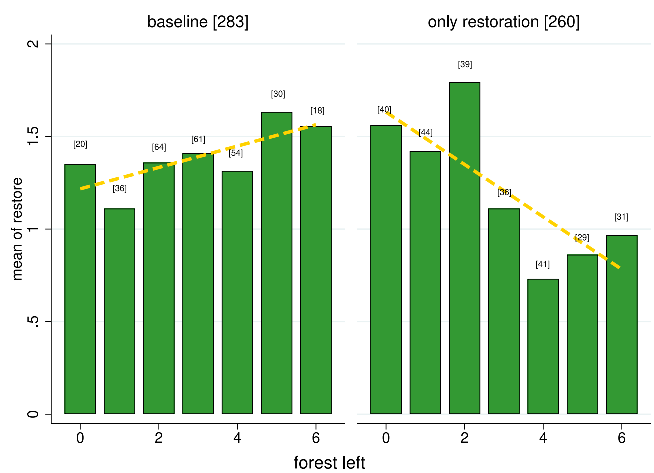

Fig. 6. Means of restoration by condition and over forest left.
Notes. Number of observations is in brackets.

Table 2
Tobit regressions with standard errors in parentheses.
$^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$.
Sample: baseline + only restoration.
Notes. A table with complete regressions is in Appendix C. Appendix D reports the correlation matrix for the regressors and the Variance Inflation Factor (VIF) for each independent variable included in the regression. This analysis excludes any potential multicollinearity issues. Three subjects revoked consent on Prolific for the use of personal data, one in the BL and two in the OR.

DV: restore	(1)	(2)	(3)	(4)
low mpcr	0.153 (0.232)	0.166 (0.230)	0.210 (0.227)	0.184 (0.227)
only restoration	0.128 (0.078)	1.656*** (0.453)	1.683*** (0.448)	1.638*** (0.448)
forest left	−0.040 (0.063)	0.217** (0.101)	0.217** (0.100)	0.215** (0.100)
only restoration X forest left		−0.444*** (0.131)	−0.446*** (0.129)	−0.443*** (0.130)
altruism			0.002** (0.001)	0.002*** (0.001)
self assessed risk			0.115** (0.050)	0.133*** (0.050)
controls				✓
Pseudo R^2	0.0029	0.0123	0.0235	0.0337
N	543	543	543	540

(only restoration), and the number of trees left in the forest after CPR decision *(forest left)*, but with no interactions between them. We find that none of these variables has a significant impact on restoration behavior, consistently with the non-parametric analysis. However, significant effects emerge once we introduce interaction terms in subsequent models. Specifically, the positive (negative) trend displayed in Fig. 6 is supported by the significant coefficient of the forest left regressor (interaction between forest left and only restoration). Moreover, the positive and significant coefficient regarding the OR indicates that in this condition subjects tend to restore more when the forest is in poor conditions compared to the BL.

Since participants in the BL are engaged in both stages of the game, the positive correlation between individual restoration contributions and the number of trees present in the forest (as shown in the left panel of Fig. 6) could be associated with their extraction decisions and/or the behaviors of others regarding the exploitation of the common resource. To disentangle these two potential determinants of restoration decisions, our investigation now focuses on the significance of prior decisions in shaping restoration choices, specifically within the BL condition.

Fig. 7 illustrates subjects' average levels of restoration contributions (trees or seedlings planted in the PG decision) in the BL as related to their choice during the extraction stage (trees cut in the CPR decision). Independently from the *MPCR* level, subjects' behavior is consistent across the two stages. This means that when they show stronger pro-environmental behavior in the first stage (extracting less), they tend to restore more in the second stage, and vice versa. To test this relationship and understand if others' extraction decisions influence restoration decisions in the BL, we conduct a regression analysis.

The results of this regression analysis, presented in Table 3, reveal a positive effect of subject's extraction decisions on restoration choices, confirming the pattern displayed in Fig. 7, and a non-significant effect of the actions of other players in CPR decision. Additionally, we corroborate the non-parametric analysis findings regarding the negligible effect of the *MPCR* on restoration choices. This evidence aligns with Struwe et al. (2023), where exogenously manipulating the returns of the public good does not affect contributions in one-shot games.[5]

[5] Appendix C shows the results of regression models that include further control variables in order to investigate their role in both extraction and restoration decisions. It is worth pointing out that while the positive (negative) effect of being female on restoration (extraction) decisions is in line with the evidence collected in the pro-environmental behavior literature (Zelezny et al., 2000; Xiao and McCright, 2015), the negative correlation between environmental concern and restoration is puzzling. However, based on the circumstance that the correlation between environmental concern and extraction is also negative, a potential – albeit speculative and requiring further investigation – explanation can be advanced. Actually, environmental concern is a specific attitude that typically connects with negative emotions, such as fear or anxiety (Kurth and Pihkala, 2022). Accordingly, we could conjecture that this kind of negative attitude is affecting the decision process by inducing

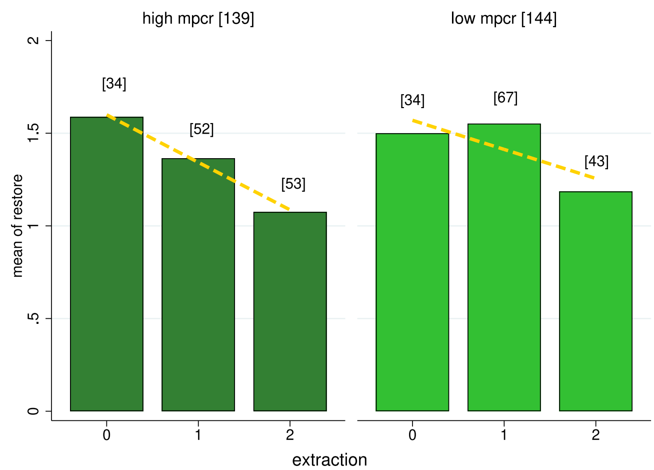

Fig. 7. Means of restoration by extraction in first stage and over *MPCR* (baseline).
Notes. Number of observations is in brackets. Pooling observations from the two MPCR levels: 68 extracted "0", 119 extracted "1", and 96 extracted "2".

Table 3
Tobit regressions with standard errors in parentheses.
$^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$.
Sample: baseline.
Notes. A table with complete regressions is in Appendix C. Appendix D reports the correlation matrix for the regressors and the Variance Inflation Factor (VIF) for each independent variable included in the regression. This analysis excludes any potential multicollinearity issues. One subject revoked consent on Prolific for the use of personal data.

DV: restore	(1)	(2)	(3)
low mpcr	0.374	0.389	0.365
	(0.398)	(0.392)	(0.390)
own extraction	−0.957***	−0.978***	−1.021***
	(0.279)	(0.271)	(0.281)
others extraction	−0.060	−0.054	−0.064
	(0.141)	(0.137)	(0.137)
altruism		0.003**	0.004**
		(0.001)	(0.002)
self assessed risk		0.135	0.136
		(0.087)	(0.088)
controls			✓
Pseudo R^2	0.0229	0.0389	0.0452
N	283	283	282

Finally, in both sets of regressions presented in Tables 2 and 3, we find a positive and significant impact of altruism on restoration, suggesting a correlation between pro-sociality and pro-environmental behaviors. Additionally, we observe a positive correlation between willingness to take risks and restoration levels, although this correlation is significant only in the specifications of Table 2.

4. Concluding remarks

We devised an experiment in which subjects can restore a common pool resource after it has been exploited in a previous stage. In our Baseline, the group exploiting the resource and the group restoring it coincide, whereas in the Only Restoration treatment, the restoring group inherits the resource from another group. This setup enables us to explore to what extent previous exploitation of a resource influences restoration decisions. We find that subjects in the Only Restoration condition that received the resource fully depleted exhibited a higher propensity to restore. This behavior starkly contrasted with that of subjects in the Baseline condition, who restored after extracting the resource themselves. Notably, in the Only Restoration condition, the more depleted the received resource was, the more it was restored, while the opposite trend was observed in the Baseline condition. From our results, it appears that the history of resource exploitation burdens those who engaged in it, leading them to act less responsibly towards restoration compared to those who are free from this burden.

In exploring potential explanations for this behavioral difference, we observed that subjects in the Baseline were locked in the behavior they exhibited in the extraction phase. Those who were more aggressive in exploitation continued to opportunistically free-ride on others' contributions during the restoration phase, while those who initially displayed more pro-environmental behavior were more proactive in restoration. Furthermore, the two decisions appear to be taken independently of others' decisions, ruling out other *explanans* such as reciprocity or conditional cooperation (Fischbacher et al., 2001; Fischbacher and Gächter, 2010; Ackermann and Murphy, 2019), and confirming the behavioral lock-in hypothesis. Moreover, the statistical significance of our control for altruism does not rule out the behavioral lock-in hypothesis. The personal propensity for pro-social behavior does not eliminate the observed hysteresis effect in the Baseline.

Overall, these results suggest that targeting individuals who are not responsible for resource depletion or who do not have conflicts of interest in its exploitation may be more effective in motivating citizen participation in restoration initiatives. However, some limitations of our experiment must be acknowledged to demarcate the scope of applicability of its results and to suggest possible avenues for further research.

The main limitation concerns external validity. Indeed, inferring insights from preferences and behavior expressed in experimental settings to real-world situations is a common issue in experimental and behavioral economics (Schram, 2005; Kessler and Vesterlund, 2015). In our case, the findings should be considered only as *stilized facts*, which are useful to highlight factors whose relevance in real-person decision processes should be further tested, for instance in the field. However, we believe that the online experiment we developed could potentially provide insights into citizens' behavioral attitudes, allowing to reach wider and more varied samples than standard lab experiments. Moreover, they could be devised to complement survey methodologies and link the collected experimental evidence to the elicitation of further individual characteristics, propensities, and habits. To this purpose, the very simple design we proposed can facilitate remote administrations and easily be adapted to collect more detailed and geolocalised data.

A second limitation concerns the framing used to provide subjects with a relatively familiar decision context. While grassroots initiatives pursuing reforestation are becoming increasingly popular, including through online crowdfunding, they represent only a specific case of possible restoration actions which include a broader range of ecosystems, such as rivers, meadows, peatlands, and others. The robustness of our results could be tested by simply substituting the forest framing to embrace a wider range of environments and relative exploitation and restoration initiatives. However, it must be acknowledged that these different environments may require both a different modelization of the choice and other experimental features.

Moreover, considering the current challenges that the development of legal obligations for ecological restoration faces at the institutional level, there is potential for further developing our experimental design to capture key features of the agreement-making process. Ultimately, such a design could offer valuable insights into how to design institutions more effectively to overcome existing interlocks and conflicts of interest and to pursue the common interest in ecological restoration.

inaction. In other words, subjects concerned about the environment might be restrained from acting in both the extraction and restoration stages, thus affecting negatively both the aggregate averages.

Replication files

The preregistration document, the screens of the experiment and the data and code for replicating the results of this paper are available at https://osf.io/g82fs/. All files are licensed under a Creative Commons Attribution 4.0 International (CCBY4.0) license.

Use of human subjects

The authors declare that all procedures were performed in compliance with relevant laws and institutional guidelines. Informed consent was obtained from all subjects in the experiment.

CRediT authorship contribution statement

Virginia Cecchini Manara: Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Conceptualization. **Eleonora Ciscato:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Pietro Guarnieri:** Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Conceptualization. **Lorenzo Spadoni:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

A link to the dataset and the replication files is included in the manuscript.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.ecolecon.2024.108386.

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