Ecological Economics 206 (2023) 107730

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Resource booms and group punishment in a coupled social-ecological system

Anna Lou Abatayo [a,*], John Lynham [b]

[a] Environmental Economics and Natural Resource Group, Wageningen University and Research, Hollandseweg 1, 6706KN, Wageningen, Netherlands
[b] Department of Economics and UHERO, University of Hawaiʻi at Mānoa, 2424 Maile Way, Honolulu, HI 96822, USA

ARTICLE INFO

JEL classification:
D70
Q22
Q57

Keywords:
Resource curse
Common pool resources
Social ostracism

ABSTRACT

Climate change is altering the dynamics of common pool resources around the world. We design an experimental game that varies both the flow of natural resources and the group punishment mechanisms available to resource users. Our experiments show that subjects are more likely to over-harvest when resource flows are high. But group punishment mechanisms that rely on social ostracism (as opposed to fines or fees) are more effective at mediating the desire to over-harvest when resources are booming. This suggests that collective management systems based on social norms, exclusion, and ostracism may be more resilient to unexpected changes in resource dynamics and supports bottom-up, as opposed to top-down, management of common pool resources.

1. Introduction

The work of Elinor Ostrom and colleagues explores how small, often remote, communities successfully manage common pool resources with little external management or interference. One of the guiding principles that emerges from Ostrom's work is the frequent use of group punishment mechanisms for sanctioning rule violators (Ostrom, 1990). The types of sanctions often vary, depending on context, and include social ostracism or more financial forms of punishment (such as fines).

Both theoretically and empirically, the effectiveness of social punishment mechanisms tends to break down as group size increases (Yang et al., 2013; Carpenter, 2007). But what if the resource itself increases (either physically or in terms of its market value)? How do social punishment mechanisms respond to fluctuations in resource abundance? We build on the work of Janssen et al. (2010), Tavoni et al. (2012) and specifically Lade et al. (2013) to design a social-ecological laboratory experiment that tests how resource inflows affect the extractive behavior of resource users. We also test how this behavior is moderated by different forms of group punishment, and how group punishment is itself influenced by changes in resource flows.

The experiment is a Common Pool Resource (CPR) game that varies both the inflow of resources (high and low) and the group punishment mechanisms available to harvesters (social ostracism and financial punishment). In a departure from similar experiments (Janssen et al., 2010; Cason and Gangadharan, 2015; Ostrom, 2006), punishment is costless for the punisher.[1] We find that resource booms lead to less cooperation and more resource extraction. This is largely in line with the theory underlying the experimental design (Lade et al., 2013). The most interesting departure from the Lade et al. (2013) theory is our finding that social ostracism is more effective at encouraging cooperation (especially under high resource flow conditions) compared to purely financial punishment. This suggests that communities that rely on social ostracism and norms to enforce cooperation (as opposed to fines or taxes) may be more resilient to future resource shocks.

In the next section of the paper, we explain the design of the experiment in detail. Section 3 summarizes the results of the experiment. In Section 4, the Conclusion section, we discuss what our results imply for community management of common pool resources subject to dynamic resource flows (that may be exacerbated by climate change).

2. Experimental design

We follow the setup in Lade et al. (2013) very closely. The main difference is that our experiments have groups of 10 people, instead of 50. The overall experimental design follows the 2 × 2 design in

---

* Corresponding author.
E-mail address: anna.abatayo@wur.nl (A.L. Abatayo).

[1] The reason for this design decision was to match the motivating theory of Lade et al. (2013), where punishment is costless for the punishers. We recognize that this is a deviation from the standard design in the experimental literature and could be viewed as a confound when comparing our findings to similar studies. Although punishment is costless in the sense that it does not deduct from the punisher's earnings in the experiment, it most likely still involves some psychic cost for the punisher, much like many forms of social punishment in real-world settings. Another feature of the Lade et al. (2013) theory that led to a design departure from most existing studies is that we do not allow for anti-social punishment (Herrmann et al., 2008); in other words, only cooperators are allowed to punish and they can only punish defectors.

https://doi.org/10.1016/j.ecolecon.2022.107730
Received 9 September 2021; Received in revised form 18 July 2022; Accepted 15 December 2022

Table 1
2 × 2 experimental design.

		Resource inflow	
		Low inflow	High inflow
Punishment	Social	Social, Low	Social, High
	Financial	Financial, Low	Financial, High

Table 1, with two levels of resource inflow – high and low – and two forms of punishment — social and financial. Each of the ten resource users can extract resources by choosing an individual effort level, e_i. This individual effort level can either take the value of e_c or e_d, with $e_c < e_d$; e_c represents the cooperative or sustainable level of effort and e_d represents the "defect" or selfish level of effort. The combined effort of all users results in total production, $F(E, R)$, where E is the sum of the community's extractive effort and R is the resource level currently available to the community. $F(E, R)$ is assumed to be Cobb–Douglas:

$$F(E, R) = \gamma E^a R^b, \tag{1}$$

where $0 < b < a < 1$. Production is therefore increasing in effort and resource abundance, but at a decreasing rate. Further, the higher the resource level, the higher the marginal increase in production from an extra unit of effort.

Total production is shared among users according to their relative share of total effort. A user's total profit is their share of the total production minus their cost of harvesting per unit effort, w. When financial punishment is allowed, those choosing effort levels of e_d may lose some of their profits. The magnitude of the financial punishment depends on the number of cooperators who choose to punish, specifically:

$$\tilde{\omega}(f_c) = h e^{t e^{g f_c}} \left(\frac{e_d - e_c}{e_d} \right) \tag{2}$$

where f_c is the fraction of individuals with effort levels of e_c who choose to punish anyone with effort levels of e_d. This is a departure from Lade et al. (2013) who assume that all cooperators will automatically choose to punish defectors. Hence, the profits of individuals choosing effort levels of e_c and e_d are:

$$\pi_c = e_c \left(\frac{F(E, R)}{E} - w \right) \tag{3}$$

$$\pi_d = e_d \left(\frac{F(E, R)}{E} - w \right) - \tilde{\omega}(f_c). \tag{4}$$

The amount of resources available for harvest is dynamic. Resource extraction is given by ER. In the absence of resource extraction, we are left with the constant resource inflow, c, and a function that captures resource decay. Hence, we have:

$$\dot{R} = c - d \left(\frac{R}{R_{max}} \right)^k - ER \tag{5}$$

where $\dot{R}$ indicates the time derivative of the resource stock, R_{max} is the upper limit or carrying capacity, and d is a decay parameter. Following Lade et al. (2013), we set $\gamma = 10$, $a = 0.6$, $b = 0.2$, $h = 0.34$, $t = -150$, $g = -10$, $w = 15$, $d = 50$, $R_{max} = 200$, $k = 2$, $e_c = 0.048$, and $e_d = 0.183$ so that:

$$\pi_c = \frac{0.48 R^{0.2}}{E^{0.4}} - 0.73 \tag{6}$$

$$\pi_d = \frac{1.83 R^{0.2}}{E^{0.4}} - 2.79 - 0.34 e^{-150 e^{-10 f_c}} \left(\frac{0.183 - 0.048}{0.183} \right) \tag{7}$$

$$\dot{R} = c - 50 \left(\frac{R}{200} \right)^2 - ER \tag{8}$$

In groups of 10 that we call a match, participants decide whether to exert an effort level of 4.8% (low effort level) or an effort level of 18.3% (high effort level) to extract tokens from a shared token pool. This corresponds to e_c and e_d. Effort level choice affects profit for the round, the profits of the other people in the group, and the number of tokens available in the shared token pool for the next round. Within a match, participants repeatedly make decisions on how much effort to exert in extracting resources for an infinite number of rounds. To make this experimentally feasible, we follow the procedures of Frechette and Yuksel (2013) for infinitely repeated games in a lab. Following their design, we program the experimental software to generate a random number between 1 and 100 (inclusive of 1 and 100).[2] If the number generated is lower than or equal to 75, the match continues for another round. Otherwise, it ends. The random number generated is the same for all participants within a session.

Importantly, participants are not informed whether a match had ended until the end of a "block". Participants played every match in blocks of 9 rounds. At the end of each block, they were told whether the match had already ended in any of the previous 9 rounds or not. If it has, they were told which round it ended. If it has not, they played another block of 9 rounds. Once a match ends, participants were randomly rematched and placed in another group of 10. In this new match, they played the exact same game with the exact same rules. Participants were unable to identify which individuals in their new match were part of their old match. Participants were paid the sum of their profits from both matches for all the rounds that did not end.

The amount of resources available for extraction after every round is equal to the sum of the change in the amount of resources for that round and the resource inflow. The change in the amount of resources within a round is given by Eq. (5). Resource inflows, on the other hand, can either be low or high. Under a low resource inflow treatment, 10 tokens are added to the token pool at the end of each round while under a high resource inflow treatment, 60 tokens are added to the token pool at the end of each round.

Within each round, participants who chose low effort levels were asked whether they want to punish those who chose high effort levels.[3] This happened right after participants chose effort levels and right before participants were shown their profits, the amount of resources left for extraction in the next round, and the number of individuals in their group who decided to pick low and high effort levels. Depending on the treatment, punishment could either be social or financial. Social punishment sends the message "You have extracted too much! You're being greedy!" while financial punishment is a profit loss equivalent to $\tilde{\omega}(f_c)$. Both social and financial punishments are "increasing" in the number of members who decide to punish. Under social punishment, the message appeared multiple times on the screen of the punishee, one time for each punisher. Under financial punishment, profits decreased by $\tilde{\omega}(f_c)$, where f_c is the fraction of punishers. It is important to note that both social and financial punishments are not automatic. Those who chose lower effort levels can choose whether or not to punish those exerting higher effort levels. Both the social and financial punishments are costless in monetary terms for the punishers.

There are obviously a number of possible Nash equilibria in a complex infinitely-repeated game of this nature. We highlight what we think are number of interesting possible outcomes. First, the social optimum under both low and high resource inflows is for all participants to cooperate by choosing to exert low effort levels. This social optimum, however, is not a stable equilibrium. When resource inflows are high ($c = 60$), the strict Nash equilibrium predictions for this game are the same with and without punishment: all participants do not cooperate. When resource inflows are low ($c = 10$), the strict Nash equilibrium depends on whether financial punishment exists (8 out of 10 players

---

[2] We use the random number generator recommended in Park and Miller (1988). It is the same random number generator that Frechette and Yuksel (2013) use.

[3] As noted in the introduction, this essentially precludes antisocial punishment (Herrmann et al., 2008). Again, the motivation for this design choice was to match the theory of Lade et al. (2013) as closely as possible. Allowing for the possibility that defectors can punish cooperators does not change the equilibrium predictions of the model since discouraging cooperators from cooperating only makes defectors worse off.

Table 2
Session summary.

Session	Punishment	Inflow	Match 1		Match 2	
			Blocks Played	Round Ended	Blocks Played	Round Ended
1	Financial	Low	1	1	1	6
2	Financial	High	1	5	1	4
3	Financial	High	1	4	1	5
4	Financial	Low	1	4	1	7
5	Social	Low	1	9	1	2
6	Social	High	1	4	1	8
7	Social	Low	2	8	1	7
8	Social	High	1	8	1	1

Notes: In Session 7, the round ended in the 8th round of the second block. Participants in Session 7 were paid for their summed earnings for the first 17 rounds.

Table 3
Average number of high effort choices.

	Match 1		Match 2	
	Low	High	Low	High
Social	5.28 (1.47) ≪	6.33 (1.55)	5.36 (1.64) ≈	6.64 (1.38)
	⩔	⩓	≀	≀
Financial	5.06 (1.78) ≪	6.86 (1.50)	5.47 (1.61) ≈	7.19 (1.27)

Notes: Match 1 and Match 2 refer to observations belonging to the first and second matches, respectively. Standard deviations in parenthesis. ≈, <, ≪, and ⋘ refer to $p > 0.10$, $p < 0.10$, p<0.05, and p<0.01, respectively; p-values refer to two-tailed Wilcoxon–Mann–Whitney tests. Non-parametric tests were conducted at a group level for Match 1 ($n = 4$ for each treatment) and the session level for Match 2 ($n = 2$ for each treatment). The second block for the first match under the low inflow social punishment treatment is included in the computation of the mean and standard deviation. Excluding this increases the mean to 4.81, with a standard deviation of 1.31.

Table 4
Effect of inflow and punishment type on effort choices.

Dependent variable: Effort choice (1 = High, 0 = Low)			
	All (1)	Social (2)	Financial (3)
HighInflow	0.6159***	0.4855***	0.7618***
	(0.0945)	(0.1361)	(0.0264)
Constant	0.3972*	0.428	0.3536**
	(0.158)	(0.2856)	(0.1203)
Observations	3,060	1,620	1,440
Pseudo R2	0.0220	0.0177	0.0315
	All (4)	Low (5)	High (6)
SocialPunish	−0.123	0.029	−0.2482**
	(0.2419)	(0.0495)	(0.1268)
Constant	0.7248***	0.6598***	0.7854***
	(0.2022)	(0.1028)	(0.1044)
Observations	3,060	1,620	1,440
Pseudo R2	0.0062	0.0146	0.0045

Notes: Logit regressions ran with robust standard errors clustered at the session level in parenthesis. $HighInflow$ is a dummy variable that take on the value of 1 if the observation belongs to a high inflow treatment, 0 otherwise. $SocialPunish$ is a dummy variable that takes on the value of 1 if the observation belongs to a social punishment treatment, 0 otherwise. Match and round fixed effects included. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

cooperate) as opposed to when financial punishment is set equal to zero (6 out of 10 participants cooperate). These predictions imply that we expect the highest level of cooperation under the low inflow treatment with financial punishment and the lowest level of cooperation under either high inflow treatment. Thus, our design allows us to measure whether the participants perceive the social ostracism as more or less costly than the financial punishment.

Participants were recruited via the Online Recruitment System for Experimental Economics (ORSEE) (Greiner, 2015). Most of our participants were freshmen and sophomore undergraduate students in engineering and the natural sciences. 41.88% of our participants were male and 58.12% were female. All experiment sessions were conducted using z-Tree (Fischbacher, 2007) and each participant was assigned a computer station with partitions blocking their view of all other stations. Participants were not allowed to verbally communicate with one another for the duration of the experiment. After giving participants the experiment instructions, they were required to answer a quiz to test their understanding. All participants were successfully able to answer the quiz. Experiment instructions are provided in the appendix.

3. Results

We conducted a total of 8 experimental sessions, two for each of our four treatments, on the campus of a North American university. Each experimental session had exactly 20 participants, divided into two groups of 10. Groups are independent of each other in the first match but are no longer independent after rematching. Hence, non-parametric tests are conducted on the group level for the first match ($n = 4$ for each treatment) and the session level for the second match ($n = 2$ for each treatment).[4] All in-text results below come from two-tailed Wilcoxon–Mann–Whitney (WMW) tests, unless otherwise stated. Table 2 provides a summary of the number of blocks and rounds played in each session. All sessions, except the first match of Session 7, ended after one block. On average, games ended after 3 rounds.

3.1. Low vs. high inflow treatments

Looking at individual choices within each group, we find that those in low inflow treatments are more likely to choose low effort levels compared to those in high inflow treatments (see Table 3 and Columns (1)–(3) of Table 4, as well as Figures 1 and 2 in the appendix.). This is true in both the social and financial treatments (Match 1, Low vs High Inflow: Social, $p < 0.05$ and Financial $p < 0.05$ in Table 3) and is akin to a resource curse effect: abundant resources encourage greedier, more extractive, behavior (Al-Ubaydli et al., 2014; Leibbrandt and Lynham, 2018). Logit regressions in Table 4 support our visual and non-parametric results: a high inflow leads to an increase in the number of high effort choices. Overall, the marginal effect of high inflows on effort choice is 0.62 (Column (1) of Table 4). The marginal effect of high inflows on effort choice is 0.49 under the social punishment treatment (Column (2) of Table 4) and 0.76 under the financial punishment treatment (Column (3) of Table 4).

Why do high inflow treatments lead to high effort choices? The answer seems to lie on a combination of two things: the amount of resources available for extraction at the beginning of each round and an individual's effort choice in the previous round. Columns (1)–(4) of Table 5 show the effect of these two things on effort choice for each of our four treatments. The results for $HighEffort(t-1)$ show that individuals are consistent with their type: previously uncooperative behavior is correlated with current uncooperative behavior. The coefficients for $ResAmount$, on the other hand, show that, even with a particular inflow regime, more resources are correlated with higher effort choice. Hence, we have the following results:

Result 1 (*Low vs. High Resource Inflow*). *High resource inflows lead to higher resource abundance, which, in turn drives higher effort levels.*

3.2. Social vs. financial punishment treatments

We also examine whether the type of group punishment affects a participant's choice of effort level. Results show varying effect of the

---

[4] It is difficult to get statistical significance with just 2 independent observations per treatment.

Table 5
Effect of resource abundance and punishment on effort choices.

Dependent variable: Effort choice (1 = High, 0 = Low)				
	Social, Low (1)	Social, High (2)	Financial, Low (3)	Financial, High (4)
ResAmount	0.1922***	0.0327***	0.0228	0.0355***
	(0.0359)	(0.0031)	(0.1238)	(0.0047)
HighEffort(t-1)	0.8869***	1.2836***	1.3882***	1.1056***
	(0.1991)	(0.0915)	(0.3669)	(0.2815)
Constant	−0.7133***	−1.7057**	−0.8005	−1.6188***
	(0.0749)	(0.6009)	(0.6244)	(0.2333)
Observations	800	640	640	640
Pseudo R2	0.0477	0.0672	0.0891	0.0550
	Social, Low (5)	Social, High (6)	Financial, Low (7)	Financial, High (8)
Punisher(t-1)	−0.5151	0.1664	−1.4126***	−1.5492***
	(0.4547)	(0.2933)	(0.2323)	(0.1765)
Punished(t-1)	0.2759	1.0790***	−0.4556	−1.3783***
	(0.1589)	(0.1914)	(0.6465)	(0.0489)
Constant	0.0687	0.0088	0.8190*	1.8816***
	(0.2428)	(0.5079)	(0.3769)	(0.3508)
Observations	800	640	640	640
Pseudo R2	0.0288	0.0456	0.0689	0.0644

Notes: Logit regressions ran with robust standard errors clustered at the session level in parenthesis. All variables labeled with $(t-1)$ refer to previous round observations. $ResAmount$ is the amount of resources available for extraction at the start of the round. $HighEffort$ is a dummy variable that take on the value of 1 if an individual chose a high effort level. $Punisher$ is a dummy variable that equals 1 if the individual punished others, 0 otherwise. $Punished$ is a dummy variable that equals 1 if the individual was punished, 0 otherwise. Since observations in the first round do not have previous round observations, they are dropped from the regression. Match and round fixed effects included. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

type of group punishment in levels of inflow (see Table 3 and Columns (4)–(6) of Table 4, as well as Figures 1 and 2 in the appendix). When inflows are low, those under financial punishment pick lower effort levels on average than those under social punishment. This is statistically significant using non-parametric tests (Table 3: $p < 0.10$ under Match 1), but loses its significance in logit regression (see Column (5) of Table 4). On the other hand, when inflows are high, those under social punishment pick lower effort levels on average than those under financial punishment. This result is statistically significant using non-parametric tests (Table 3: $p < 0.10$ under Match 1) as well as in a logit regression (see Column (6) of Table 4). The marginal effect of a social punishment regime on effort choice is −0.25 under the high inflow treatment.

Hence, the following result:

Result 2 (*Social vs. Financial Punishment*). *Social punishment works just as well as financial punishment to deter selfish behavior. In fact it outperforms financial punishment when resource flows are high.*

3.3. Exploring punishments

In this section, we want further investigate two things: (1) the effect of being punished in the previous round on effort choices in the current round and (2) what drives an individual's decision to punish. We discuss each of these in turn below.

3.3.1. Punishment and effort choices

Fig. 1 shows the number of individuals selecting low effort per round for each treatment and how many of these individuals are punishing those selecting high efforts. The highest amount of punishment occurs in the Social Punishment, Low Inflow treatment. For a given inflow level, punishment tends to be bigger for social rather than financial punishment. Recall that both forms of punishment are costless (at least in monetary terms) for the punishers.

How does being punished affect future behavior? For our low inflow treatments, the graphs do not seem to indicate a correlation between being socially or financially punished in the previous round and the current round's effort choice. This visual result is supported by regression results in Columns (5) and (8) in Table 5. The coefficients for $Punished(t-1)$ are statistically insignificant for both the low inflow treatments. Our high flow treatments, on the other hand, show statistically significant results for $Punished(t-1)$. In the social treatment, those who were punished in the previous round are correlated with higher effort choices in the current round (Column (6) of Table 5). The opposite is true in the financial treatment, those who were punished in the previous round are correlated with lower effort choices in the current round (Column (8) of Table 5). This result for the high inflow social treatment can be clearly seen in Fig. 1: when the number of punishers in the previous round is high, the number of individuals picking low effort levels in the current round falls.

Another result that we see in Table 5 is the effect of previously punishing on current choice of effort. In the financial treatment, those who previously exercised their right to punish defectors are more likely to pick lower effort levels in the current round. The marginal effect of being a punisher in the previous round is −1.41 for the low inflow financial treatment and −1.55 for the high inflow financial treatment. Hence, the following result:

Result 3 (*Punishment and Effort Choices*). *When resource inflows are high, social punishment increases the likelihood of an individual picking a higher effort level while financial punishment decreases the likelihood of an individual picking a lower effort level. Individuals who previously financially punished are more likely to continue picking lower effort levels.*

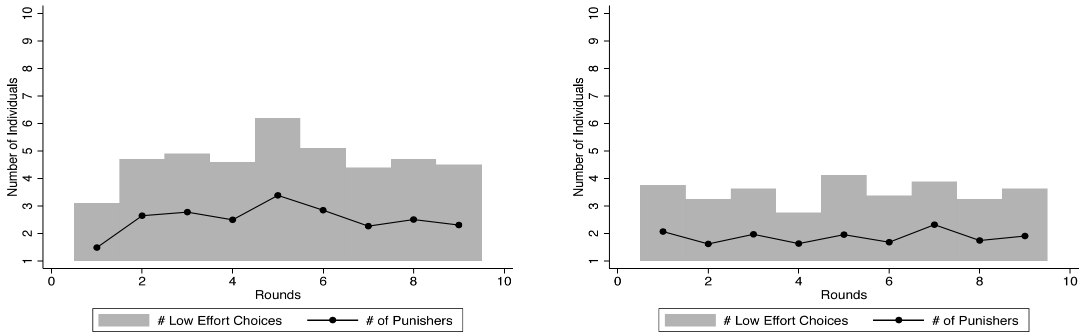
3.3.2. Decision to punish

Our experimental design deviates from that of Lade et al. (2013) in that those who choose lower effort levels do not automatically punish those who choose higher effort levels. In our experiment, cooperative individuals get to decide whether or not to exercise their right to punish defectors in that round. We conjecture that there are three main types of individuals who maintain their type: cooperators who always punish, cooperators who never punish, and defectors. We also conjecture that an individual who switches type (i.e., from defector to cooperator) is more likely to punish (i.e., they were affected by the punishment and may see punishment as a way to convince others to do as they did). Hence, in Table 6 we look at the correlation of previous effort choices and punishing behavior with current decisions to punish. We also conjecture that individuals are less likely to punish when resources are abundant (i.e., there is no competition in resource extraction).

Regression results in Table 6 show support in favor of our conjecture on individual types. Across treatments, those who punish in the previous round are more likely to punish in the current round. The coefficients for $Punisher(t-1)$ is positive and statistically significant across all treatments. We also find the coefficients for $HighEffort(t-1)$ is positive and statistically significant across all treatments. Those who picked higher effort levels in the previous round are also statistically significantly more likely to punish in the current round. A reason for this could be that previous round defectors who are now cooperators are punishing current defectors to manipulate them to cooperate, especially if too many defectors in the previous round depleted resources. Our results show that out of 179 previous defectors turned cooperators who punished, approximately 59% reverted to being defectors in the round right after. This conjecture is supported by our results for $ResAmount$. While it is only statistically significant for the "Financial, Low" treatment, it is in favor of the conjecture that when there is no competition for resources, individuals are less likely to punish.

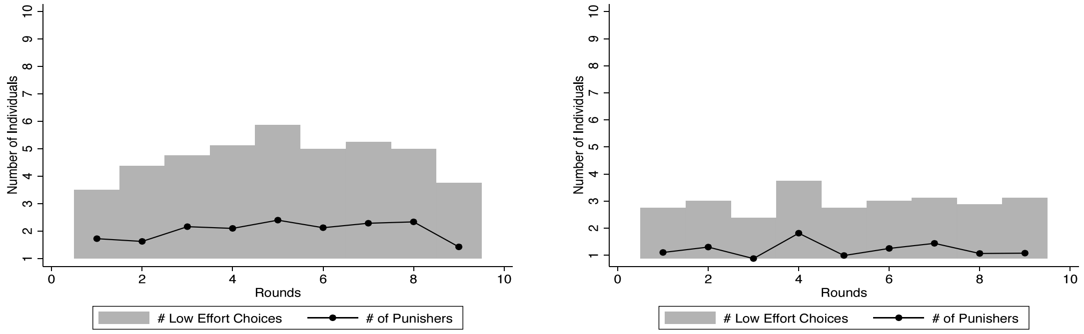
Hence, the following result:

Result 4 (*Decision to Punish*). *An individual's decision to punish is correlated with outcomes in the previous round. An individual is likely to decide to punish if (1) the individual punished in the previous round and (2) the individual was punished in the previous round and picked a lower effort in current round. Resource abundance decreases financial punishment when inflow is low but has no effect on other treatments.*



(a) Social Punishment, Low Inflow

(b) Social Punishment, High Inflow



(c) Financial Punishment, Low Inflow

(d) Financial Punishment, High Inflow

Fig. 1. Number of possible and actual punishers by treatment.

Table 6
Causes for punishment.

Dependent Variable: Decision to Punish (1 = Yes, 0 = No)

	Social, Low (1)	Social, High (2)	Financial, Low (3)	Financial, High (4)
HighEffort(t-1)	0.6649***	1.2739**	1.1950**	1.4055**
	(0.0867)	(0.3938)	(0.4254)	(0.4764)
Punisher(t-1)	1.8392***	2.3236***	1.6936***	1.5796***
	(0.066)	(0.2323)	(0.2799)	(0.3582)
ResAmount	−0.0101	0.0056	−0.0663*	0.0376
	(0.0614)	(0.0256)	(0.0352)	(0.0242)
Constant	−0.3991*	−1.1824	0.1823	−0.4788
	(0.1914)	(02.0616)	(0.8996)	(01.7149)
Observations	391	223	313	192
Pseudo R2	0.0955	0.1156	0.0695	0.0992

Notes: Logit regressions ran for the subset of individuals who picked low effort levels in the current round. Robust standard errors clustered at the session level in parenthesis. All variables labeled with $(t-1)$ refer to previous round observations. $HighEffort$ is a dummy equal to 1 if the individual picked a high effort level, 0 otherwise. $Punisher$ is a dummy variable that equals 1 if the individual punished others, 0 otherwise. $Punished$ is a dummy variable that equals 1 if the individual was punished, 0 otherwise. $ResAmount$ is the amount of resources available for extraction at the start of the round. Since observations in the previous round do not have previous round observations, they were dropped from the regression. Match and round fixed effects included. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

4. Conclusion

Our interest in resource booms and busts arises from the observation that climate change is altering the dynamics of common pool resources around the world. Harvestable fish species are appearing in some communities and disappearing from others (Free et al., 2019). Growing seasons are shortening in some parts of the world and lengthening in others (Mora et al., 2018). We know that the state of natural resource stocks is a crucial factor for the emergence of successful local institutional arrangements in the commons (Ostrom, 2009). How will different forms of collective management be affected by changes in the dynamics of natural resource stocks? This is an important question because experimental studies have typically been more successful in incorporating the social context than the ecological context (Anderies et al., 2011).

To answer this question, we conducted a laboratory experiment to test how resource booms interact with social punishment mechanisms to sustain cooperation in a coupled social-ecological system. The experiment was motivated by theoretical work by Lade et al. (2013) but the results departed from theory predictions in a number of interesting ways. In line with theory, high resource inflows led to less cooperation and more resource extraction. This appears to be triggered by higher resource abundance, in and of itself. For example, even with low inflows, there was a positive correlation between current resource abundance and choosing the high extraction option. A possible mechanism is that resource users believe the resource can “handle” more extraction when it is more abundant. But, in a departure from theory, cooperation levels were much higher across all treatments, relative to the predicted equilibria.

The second noticeable departure from theory was that the threat of non-financial social punishment (negative messages from fellow group members) was more effective at encouraging cooperation (especially under high resource flow conditions) compared to the threat of purely financial punishment. In other words, aggregate levels of cooperation in social punishment treatments were as high (or higher) than aggregate levels of cooperation in financial punishment treatments. This suggests that communities that rely on social ostracism and norms to enforce cooperation (as opposed to fines or taxes) may be more resilient to future resource shocks. We also find that resource users react very differently to social versus financial punishment. Being punished socially does not cause defectors to switch to cooperating but being punished financially does lead defectors to be more cooperative. This does not imply that social punishment is poor mechanism for regulating behavior in the commons (in fact, we find the exact opposite). The threat of future social punishment appears to lead to preemptive cooperation among some players (resulting in similar aggregate levels of cooperation as the financial punishment treatments). But, if someone chooses to defect when social punishment is available as a tool to cooperators, and this defector is subsequently punished, the act of punishing them does not cause them to switch to cooperating. If the threat of social punishment does not work as a deterrent for some individuals, it also does not seem to work as behavior-adjusting mechanism for those individuals. This suggests that a hybrid mechanism might be ideal: social punishments for first-time or small infractions and financial punishments for repeat offenders.

It should be emphasized that our experimental setup, along with the theoretical work of Lade et al. (2013), is a simplification of reality. This simplification is necessary to be able to examine important relationships that may be confounded when looking at real-world data. Hence, care should be taken in interpreting and generalizing our results. Lade et al. (2013) also departs from the standard punishment setup in the experimental economics literature by making punishment costless. Since we follow closely the setup of Lade et al. (2013), we have also implemented a costless financial and social punishment. In reality, punishment is not costless. There are financial, reputation, and retaliation costs that are associated with individual decisions to punish others that we do not consider in our design. A possible effect of our design choice could be an increase in the number of punishers. We, however, have no reason to believe that this is the case. The number of individuals deciding to punish in every round for all treatments is always less than the number of individuals who could punish for that round.

Our results should hopefully prove insightful for communities looking to design rules to manage common pool resources subject to dynamic resource flows (perhaps exacerbated by climate change). In particular, in line with the work of Ostrom and colleagues, our lab experiments again demonstrate the strength of social forms of punishment compared to prices or taxes. This suggests that small remote communities attempting to build resilience to external top-down stressors should focus on bottom-up forms of resource management (Cardenas et al., 2000).

Declaration of competing interest

The authors acknowledge financial support provided by the National Science Foundation [GEO-1211972]. The authors declare no competing interests.

Data availability

The research data and code is available via Mendeley Data. DOI: 10.17632/c2z95m5gty.1.

Appendix A. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.ecolecon.2022.107730.

References

Al-Ubaydli, O., McCabe, K., Twieg, P., 2014. Can more be less? An experimental test of the resource curse. J. Exp. Political Sci. 1 (1), 39–58.

Anderies, J.M., Janssen, M.A., Bousquet, F., Cardenas, J.-C., Castillo, D., Lopez, M.-C., Tobias, R., Vollan, B., Wutich, A., 2011. The challenge of understanding decisions in experimental studies of common pool resource governance. Ecol. Econom. 70 (9), 1571–1579.

Cardenas, J.C., Stranlund, J., Willis, C., 2000. Local environmental control and institutional crowding-out. World Dev. 28 (10), 1719–1733.

Carpenter, J.P., 2007. Punishing free-riders: How group size affects mutual monitoring and the provision of public goods. Games Econom. Behav. 60 (1), 31–51.

Cason, T.N., Gangadharan, L., 2015. Promoting cooperation in nonlinear social dilemmas through peer punishment. Exp. Econ 18 (1), 66–88.

Fischbacher, U., 2007. z-Tree: Zurich toolbox for ready-made economic experiments. Exp. Econ 10 (2), 171–178.

Frechette, G.R., Yuksel, S., 2013. Infinitely Repeated Games in the Laboratory: Four Perspectives on Discounting and Random Termination. In: SSRN Electronic Journal. pp. 1–36. http://dx.doi.org/10.2139/ssrn.2225331.

Free, C.M., Thorson, J.T., Pinsky, M.L., Oken, K.L., Wiedenmann, J., Jensen, O.P., 2019. Impacts of historical warming on marine fisheries production. Science 363 (6430), 979–983.

Greiner, B., 2015. Subject pool recruitment procedures: organizing experiments with ORSEE. J. the Econ Sci Assoc 1 (1), 114–125.

Herrmann, B., Thoni, C., Gachter, S., 2008. Antisocial punishment across societies. Science 319 (5868), 1362–1367.

Janssen, M.A., Holahan, R., Lee, A., Ostrom, E., 2010. Lab experiments for the study of social-ecological systems. Science 328 (5978), 613–617.

Lade, S.J., Tavoni, A., Levin, S.A., Schlüter, M., 2013. Regime shifts in a social-ecological system. Theoretical Ecology 6 (3), 359–372.

Leibbrandt, A., Lynham, J., 2018. Does the paradox of plenty exist? Experimental evidence on the curse of resource abundance. Exp. Econ 21 (2), 337–354.

Mora, C., Spirandelli, D., Franklin, E.C., Lynham, J., Kantar, M.B., Miles, W., Smith, C.Z., Freel, K., Moy, J., Louis, L.V., et al., 2018. Broad threat to humanity from cumulative climate hazards intensified by greenhouse gas emissions. Nature Clim. Change 8 (12), 1062–1071.

Ostrom, E., 1990. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press.

Ostrom, E., 2006. The value-added of laboratory experiments for the study of institutions and common-pool resources. J. Econ. Behav. Organ. 61 (2), 149–163.

Ostrom, E., 2009. Understanding Institutional Diversity. Princeton University Press.

Park, S.K., Miller, K.W., 1988. Random number generators: good ones are hard to find. Commun. ACM 31 (10), 1192–1201.

Tavoni, A., Schlüter, M., Levin, S., 2012. The survival of the conformist: social pressure and renewable resource management. J. Theoret. Biol. 299, 152–161.

Yang, W., Liu, W., Viña, A., Tuanmu, M.-N., He, G., Dietz, T., Liu, J., 2013. Nonlinear effects of group size on collective action and resource outcomes. Proc. Natl. Acad. Sci. 110 (27), 10916–10921.