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Can Violence Harm Cooperation? Experimental Evidence*

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Abstract

In this paper we argue that natural resource conservation is jeopardised by the ability of users to resort to violence to appropriate resources when they become scarce. We provide evidence from a lab experiment that participants interacting in a dynamic game of common pool resource extraction reduce their cooperation on efficient levels of resource extraction when given the possibility to appropriate the resource at some cost, i.e. through conflict. Theoretically, cooperation is achievable via the threat of punishment strategies, which stop being subgame perfect in the presence of conflict. Accordingly we argue that the observed reduction of cooperation in the game's early stages in the lab is a consequence of participants (correctly) anticipating the use of appropriation when resources become scarce.

Keywords: Natural Resource Exploitation, Experiment, Dynamic Game, Cooperation

JEL classification: Q20; C72; C73; C91; D74

1 Introduction

The over-exploitation of commonly-managed renewable natural resources (CPR), exacerbated by the familiar "tragedy of the commons", has become increasingly concerning (Hardin 1968, Homer Dixon 1999, Stern 2007). Infinitely repeated models of resource management show that efficient resource extraction rates can be sustained among users under the threat of a general reversion to over extraction in case of noncompliance by some users (Cave 1987, Dutta 1995, Sorger 2005, Dutta and Radner 2009). This class of models, however, entirely disregards the fact that scarcities could push resource-users to seek alternative ways of securing access to the resource, like using violence.

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The collapse of Easter Island's society, as documented by Diamond (2005) is one case in point. According to Diamond, the society of Easter Island plunged into chaos because of resource depletion that was provoked by their clans' permanent quest for prestige. The society was organised in hierarchical clans that peacefully competed with each other for power supremacy by erecting stone statues weighing up to 80 tons. To that end, the island's tallest trees needed to be cut down, as a result of which a rapid deforestation occurred.[1] The exhaustion of this valuable natural resource implied an incapacity to build new large canoes permitting high sea fishing, as a consequence of which the rate of consumption of on-land food necessarily increased. In 1680, amidst dramatic levels of deprivation, a prolonged period of internecine wars started. By the time the first European expedition reached the island in 1722, deforestation was almost complete. Brander and Taylor generalise this argument stating that "[r]ather than being the cause of decline, violent conflict is commonly the result of resource degradation and occurs after the civilisation has started to decline, as on Easter Island" (Brander and Taylor 1998: 132). The "Cod Wars", in which Iceland and United Kingdom confronted each other in the 1950s-1970s over fishing rights in the Atlantic, represents another salient example (Barston and Hannesson 1974, Glantz 1992). Perhaps even more strikingly, some of the most cruel violence in recent history, like the Rwandan and the the Sudanese genocides, have been interpreted in light of natural resource pressure (André and Platteau 1998, Prunier 2009, Verpoorten 2012, Olsson and Siba 2013).

Starting from this simple observation, Sekeris (2014) amended a standard dynamic model of natural resource conservation by explicitly empowering players with the ability to violently appropriate resources. As a result, rational agents never choose to cooperate on the efficient level of extraction, with the tragedy of the commons unfolding at equilibrium. The intuition behind this can be summarised as follows: since conflict will eventually occur over scarce resources, the threat of a collective reversion to over-extraction (i.e. punishment) "for ever after" to deter deviations from the efficient extraction level is no longer credible since strategic interaction is bound to stop once conflict is initiated. Reasoning backward from the point at which conflict is a rational response, there is no incentive to cooperate at the point in time just before the moment of conflict, or at any earlier time period – the game becomes finite at the moment of conflict and unravels like a finite prisoner's dilemma problem.

Given the far-reaching potential implications of this finding for resource conservation, we reproduce the setting of Sekeris (2014) and study the extraction rates of resource users in a controlled lab environment. This leads to the main contribution of the present paper: we provide the first experimental evidence that the option to violently appropriate resources reduces the incentives to cooperate on the conservation of natural resources.

We first adapt the model in Sekeris (2014) so it can be used in an experimental setting. We then design two treatments and compare cooperation rates across them. Each treatment involves 58 participants for a combined total of 116 students from the University of York (UK). In both treatments participants are randomly matched into pairs and then called to decide on the amount of 'points' to extract from a pool of points (resources) at each 'round' of the game, and given a pre-defined regeneration rate of the CPR. In the first treatment, which we label the 'conflict' treatment, participants get to choose between three options during each 'round'. Participants can either extract a 'low' level of points – corresponding to the theoretical prediction of a cooperative extraction –, or extract a 'high' level of points –

[1] A controversy on the real causes of the Island's deforestation is still open among scientists (Hunt and Lipo 2011).

corresponding to the theoretical prediction of a non-cooperative (Markov-perfect) extraction –, or to opt for resource appropriation, denoted by 'chance'.[2] If chance is chosen, the CPR is split equally between the two paired subjects, at some cost which is increasing in the stock of the CPR.[3] If at some time period 'chance' is played, the optimal extraction path is imposed on participants from the subsequent time period and thereafter.

The second treatment, named 'control', is identical to the conflict treatment, except for the cost of opting for resource appropriation, which is substantially increased, such that playing chance is theoretically suboptimal. So, we offer participants the same three options as in the conflict treatment (i.e. low, high extraction rates and chance), but if 'chance' is chosen, 60% of the CPR is destroyed, thus making this choice suboptimal for any level of resources.

To emulate the infinite horizon environment required for folk theorems to be applicable, we follow the methodology in Vespa (2014), which was first introduced by Roth and Murnighan (1978), and later applied by Cabral et al. (2014). The technique introduces an uncertain time horizon by allowing the software to terminate the game at any 'time period' with some predetermined probability. This practice – which in theory is equivalent to an infinite time horizon, if individuals are risk neutral – has been shown not to be innocuous in practice (Dal bó 2005, Frechette and Yuksel 2017). Since both our control and treatment groups are subject to the same random termination rule, however, the validity of our experiment is not jeopardised.

Our experimental findings support our theoretical predictions. In the initial rounds of the game (or alternatively for high levels of the CPR), where conflict is unlikely to have been selected in either treatment, the level of cooperation is lower in the conflict treatment compared to the control treatment, and non-cooperation is higher. Hence, the expectation of a higher likelihood of chance being played in later stages of the game in the conflict treatment seems to reduce cooperation in favour of non-cooperation in the early stages of the game.

We find that participants who experienced violence in a specific game were more likely to behave according to predictions in the subsequent game. This evidence lends additional intuitive support to our conjecture that a higher *expectation* of chance being played in later rounds induces participants to substitute cooperation for non-cooperation. Furthermore, we show that participants in a slightly amended treatment, in which chance is imposed for low resource stocks, also reduce their cooperation level, which once more supports our interpretation of the results. Lastly, we track individual paths of play by participants, and find that in 24% of the games played in the conflict treatment, participants behave according to theoretical predictions. In the control treatment, however, no single participant made these same choices. This constitutes suggestive evidence that our experimental findings are indeed driven by individual participants behaving as predicted by the theory.

The rest of the paper is organised as follows. In the next section we discuss the related literature. We then lay out the theoretical model in Section 3. In Section 4 we describe the experimental design, in Section 5 we present our experimental results, and Section 6 concludes.

[2] We deliberately chose a neutral tag to denote the conflict action in our experiment to avoid any framing bias. In particular, had we named our resource appropriation 'conflict' or 'violence', changes in cooperation rates across treatments may have been the consequence of different moral/ethical values among participants.

[3] Notice that this assumption is an endogenous feature in Sekeris (2014), where conflict is modelled as a standard contest success function.

2 Related literature

Over the recent past, game theoretic predictions on the management of the commons have received extensive attention by experimental economists.[4] The early experimental literature focused on testing the equilibrium behaviour generated by repeated games (Palfrey and Rosenthal 1994, Dal Bó 2005), or finite dynamic games (Herr et al. 1997). In general, findings tend to concur with theoretical predictions, suggesting that free riding, and therefore inefficiencies, do arise, and that dynamics help fostering the cooperative equilibrium through reputation mechanisms and the existence of latent punishment schemes (Fehr and Gaechter 2000, Casari and Plott 2003). Further experimental work provides evidence that repeated interactions foster the development of social capital which, in turn, favors cooperation (Pretty 2003, Bouma et al. 2008).

Exploring whether cooperation can be sustained in dynamic games of resource exploitation is a more challenging question, which has only been tackled recently (Kimbrough and Vostroknutov 2015, Dal Bó and Fréchette 2016). Since the cooperative extraction level can be sustained with several different subgame perfect punishments, experimental economists need to limit their experimental tests to a (some) specific strategy(ies). Vespa (2014) shows that individuals tend to cooperate in a dynamic renewable common pool resource (CPR) game if they are given the options of "cooperating" or "defecting" to the non-cooperative Markovian strategy. Yet such cooperation is jeopardised when participants are offered the choice of a "highly profitable" deviation. These findings nevertheless seem to suggest that individuals do cooperate under the threat of some punishment strategies.[5] In contrast with this literature, Sekeris (2014) demonstrates that in a dynamic renewable CPR game where property rights can be enforced at a cost, cooperation along the equilibrium path may be impossible to achieve. In this paper we therefore investigate experimentally whether, in settings comparable to Sekeris (2014), participants act as predicted by the theory.

A growing experimental literature on conflict has emerged in recent years.[6] While the initial contributions subjected static theories of conflict to experimental validation, more recent studies have focused on the dynamic considerations we are concerned with (Abbink and de Haan 2014, Lacomba et al. 2014, McBride and Skaperdas 2014). Yet, whereas these contributions perceive conflict as an appropriation of private goods and/or production potential, our approach conceives the status quo as a CPR game. Cooperation in experimental conflict settings has also received some attention, but the focus of the existing literature has mostly been on alliance formation and group fighting as opposed to cooperation in the production process (Abbink et al. 2010, Ke et al. 2015, Herbst et al. 2015).

[4] See also Ostrom (2006) for a review on the role of laboratory experiments for the study of institutions and common-pool resources.

[5] Lindahl et al. (2016) enrich this setting by showing that the expectation of a drastic depletion of the CPR can increase communication among participants and can favor within-group cooperation, eventually leading to a more efficient management of the resource.

[6] See Dechenaux et al. (2015) for a recent review of this literature.

3 Theory

3.1 The setting

We consider a dynamic common pool resource game featuring a renewable resource, r_t, initially owned commonly by two players labeled 1 and 2. Time is discrete and denoted by $t = \{0, 1 \ldots \infty\}$. At any time period t the two players take two sequential decisions: first, a conflict decision, $(w_{1,t}, w_{2,t})$, with $w_{i,t} = v$ if player i opts for violence, and $w_{i,t} = p$ otherwise, and second, a resource extraction decision where players simultaneously decide the extraction technology to use at any time period t, a low extraction technology $k^l_{i,t}$, or a high one $k^h_{i,t}$. If either player opts for conflict, part of the resources get destroyed and the remaining stock is immediately shared equally among the players forever after, thus making conflict an absorbing state. If no player opts for conflict, the resources remain commonly owned. Hence, in deciding the resources to extract, players either deplete their privately owned resources (under conflict), or else they deplete the common pool resources (no conflict).

The initial resource endowment is given by r_0 and the resource regenerates at some linear rate $\gamma < (1-\delta)/\delta$, where δ designates the players' common discount rate.[7] Players costlessly select their extraction technology at each time period, and choose their resource-use effort. If conflict has not taken place and player i opts for the low extraction technology $k^l_{i,t}$, his period extraction in time t equals $e^p_{i,t}(k^l_{i,t}, k^x_{j,t}) = \frac{1-\delta}{2} r_t$ irrespective of player j's technology choice $x = \{l, h\}$. On the other hand, when player i opts for the high extraction technology $k^h_{i,t}$, his period extraction in time t depends on the other player's action so that $e^p_{i,t}(k^h_{i,t}, k^h_{j,t}) = \frac{1-\delta}{2-\delta} r_t$ and $e^p_{i,t}(k^h_{i,t}, k^l_{j,t}) = \frac{(1-\delta)(1+\delta)}{2} r_t$.[8] In case of conflict in time t the resources' resilience is described by function $\phi(r_t)$, with $\phi(r_t)' \leq 0$. The common pool is then split up in two private stocks of resources, and out of the r_t resources in the common pool, the actual resources that become player i's private property equal $r_{i,t} = \phi(r_t) r_t / 2$. If conflict has taken place, the choice of the low extraction technology is imposed on players, which emulates the first best solution, and the period extraction of player i is then given by $e^v_{i,t} = (1-\delta) r_{i,t}$. The above information is summarised in a normal form (game) capturing the period extraction levels of players in Figure 1.

Dynamics

We sequentially describe the players' dynamic payoffs under conflict and no conflict, respectively, before proceeding with the equilibrium analysis.

Under conflict, at any time period t player i privately controls resources $r_{i,t}$. Given the assumed resources' regeneration rate, the law of motion of resources is given by:

[7] This restriction on the regeneration rate is meant to avoid scenarios where the resource grows dynamically along the equilibrium path since the mechanism we uncover in this paper relates to resource scarcities.

[8] These seemingly *ad hoc* extraction levels are the ones obtained when solving the unconstrained problem in Appendix A.1.1. Our ultimate goal being the construction of a self-contained model that we can test in the lab, we have deliberately restricted the players' extraction levels to the fewest necessary configurations required to characterise two potential equilibria, the *non-cooperative subgame perfect Nash equilibrium*, and the *cooperative subgame perfect Nash equilibrium* that we describe in detail in the Appendix.

		Player 2		
		$e^p_{2,t}(.,k^l_{2,t})$	$e^p_{2,t}(.,k^h_{2,t})$	$e^v_{2,t}$
Player 1	$e^p_{1,t}(k^l_{1,t},.)$	$\frac{1-\delta}{2}r_t,\ \frac{1-\delta}{2}r_t$	$\frac{1-\delta}{2}r_t,\ \frac{(1-\delta)(1+\delta)}{2}r_t$	$(1-\delta)r_{1,t},(1-\delta)r_{2,t}$
	$e^p_{1,t}(k^h_{1,t},.)$	$\frac{(1-\delta)(1+\delta)}{2}r_t,\ \frac{1-\delta}{2}r_t$	$\frac{1-\delta}{2-\delta}r_t,\ \frac{1-\delta}{2-\delta}r_t$	$(1-\delta)r_{1,t},(1-\delta)r_{2,t}$
	$e^v_{1,t}$	$(1-\delta)r_{1,t},(1-\delta)r_{2,t}$	$(1-\delta)r_{1,t},(1-\delta)r_{2,t}$	$(1-\delta)r_{1,t},(1-\delta)r_{2,t}$

Figure 1: Period extraction levels

$$r_{i,t+1} = (1+\gamma)(r_{i,t} - e_{i,t}) \tag{1}$$

The instantaneous utility of any player i is assumed to be logarithmic in consumption levels so that player i's instantaneous utility in time t is given by:

$$u_{i,t} = \ln((1-\delta)r_{i,t}) \tag{2}$$

If conflict takes place in period τ, then the discounted life-time (indirect) utility of player i in time period τ can be shown to equal:

$$V^c_i(r_\tau) = \frac{1}{1-\delta}\ln\left((1-\delta)r_{i,\tau}\right) + \frac{\delta}{(1-\delta)^2}\ln((1+\gamma)\delta) \tag{3}$$

where δ designates the discount rate, and $r_{i,\tau} = \phi(r_\tau)r_\tau/2$

If conflict did not take place in time period t or at any earlier time period, the law of motion of resources is given by:

$$r_{t+1} = (1+\gamma)(r_t - e_{1,t} - e_{2,t}) \tag{4}$$

And the discounted life-time utility of player i in time period t equals:

$$U_{i,t}(r_t) = \ln(e_{i,t}) + \delta U_{i,t+1}(r_{t+1}) \tag{5}$$

We denote a strategy for player i by $(\mathbf{w_i}, \mathbf{k_i}) = \{w_{i,t}, k^j_{i,t}\}^\infty_{t=0}$, $j = \{l, h\}$. Our equilibrium concept is subgame perfect Nash equilibrium (henceforth SPE).

3.2 Equilibrium with costly conflict

We first consider the game's equilibria if conflict is highly damaging. More specifically, we assume that the resilience function is defined by $\phi(r_t) = \phi$, with $\phi \leq 0.40$.

We first demonstrate that with such costly conflict technology neither player finds it optimal to choose violence along the equilibrium path. To establish this we begin by defining as the "non-cooperative path" the extraction path such that both players choose a high extraction technology at any time period. We then demonstrate that the strategies supporting the "non-cooperative path" constitute a SPE since they are robust to the One Shot Deviation Principle. Denote by $V_i^h(r_t)$ the discounted expected payoff of player i from both players playing their "non-cooperative strategies" from time t onwards. The total share of resources being extracted at any time period then equals $2(1-\delta)/(2-\delta)$, thus implying that for any stock of resources r_t, the available stock in $t+1$ equals $(1+\gamma)\frac{\delta}{2-\delta}r_t$. Accordingly, $V_{i,t}^h$ can be shown to equal:

$$V_{i,t}^h = \frac{1}{1-\delta}\left[\ln\left(\frac{(1-\delta)r_t}{2-\delta}\right) + \frac{\delta}{1-\delta}\ln\left(\frac{\delta(1+\gamma)}{2-\delta}\right)\right] \tag{6}$$

A unilateral deviation from this play path generates an instantaneous utility of $\ln\left(\frac{1-\delta}{2}\right)$, which is smaller than the instantaneous utility from conforming to the non-cooperative play path, $\ln\left(\frac{1-\delta}{2-\delta}\right)$. On the other hand, the resources available in $t+1$ under this unilateral deviation amount to $r_{t+1} = \frac{(1+\gamma)\delta(1+\delta)}{2}r_t$, an amount larger to the one obtained under the non-cooperative play-path where $r_{t+1} = \frac{(1+\gamma)\delta}{2-\delta}r_t$. Comparing the discounted expected utility under these two play-paths reveals that a deviation is not profitable if:

$$\ln\left(\frac{2}{2-\delta}\right) \geq \delta\ln(1+\delta) \tag{7}$$

An expression which is always true for $\delta \in [0,1]$, as demonstrated in Appendix (A.1.2).

We next consider the deviation whereby player i chooses chooses $w_{i,t} = v$. We demonstrate that the non-cooperative strategy strictly dominates the conflict one by showing that the following inequality is verified for the conflict technology considered in this section:

$$V_i^c(r_t) < V_i^h(r_t) \tag{8}$$

Replacing for the appropriate values and simplifying yields:

$$(1-\delta)\ln(\phi/2) + \ln(2-\delta) < 0 \tag{9}$$

And we demonstrate in Appendix A.1.4 that this inequality is always satisfied, both for $\phi \leq 0.4$ and for any $\delta \in [0,1)$.

The above results allow us to state the following Lemma:

Lemma 1. *When the resilience function is described by $\phi(r_t) = \phi$, with $\phi \leq 0,4$, both players forever opting for the high extraction technologies is a subgame perfect equilibrium.*

Define next the extraction path such that both players choose a low extraction technology at any time period as the "cooperative path". We seek for the conditions making the cooperative strategies sustaining the cooperative extraction path a SPE. It can easily be shown that players *unconditionally* choosing the low extraction technology cannot be an equilibrium. To sustain cooperation, therefore, punishment strategies should be considered. A widespread strategy that supports the cooperative extraction path as a SPE is the Grim-trigger strategy, whereby any deviation from the 'low' extraction technology by either player implies that both players revert to the non-cooperative SPE forever after. One interesting route is therefore to derive the conditions that induce play of the cooperative path in equilibrium.

We denote the discounted expected payoff of both players always opting for the low extraction technology as $V^l_{i,t}$. For the cooperative path to be sustained as a SPE, it is necessary that the following condition be satisfied:

$$\ln\left(e^{dev}_{i,t}\right) + \delta V^h_i\left((r_t - e^{dev}_{i,t} - e^l_{j,t})(1+\gamma)\right) < V^l_i(r_t) \tag{10}$$

In the above inequality we are thus comparing a player's life-time utility from the path where both players would always cooperate ($V^l_i(r_t)$), to the path where the player considered would deviate in time period t ($\ln(e^{dev}_{i,t})$), before both players revert to the Grim-trigger strategy where both players choose the high extraction technologies forever after (δV^h_i). In other words, we are inspecting the condition for the cooperative path of play to be an equilibrium, where player i considers the deviation in time period t given player j's 'low' extraction technology in time period t, and given the reversion to the non-cooperative SPE in period $t+1$ (i.e. Grim-trigger strategy).

It is shown in the on-line Appendix A.1.4 that, after replacing for the appropriate terms, this expression can be written as:

$$\delta \ln(2-\delta) > (1-\delta)\ln(1+\delta) \tag{11}$$

In Appendix A.1.5 we show that this condition is true for any $\delta \in (1/2, 1)$.

Recalling that the cooperative extraction levels are the ones solving the central planner's problem (see Appendix A.1.1), it follows that $V^l_{i,t} > V^h_{i,t}, \forall i, t$. Having already shown that $V^h_{i,t} > V^c_{i,t}$, we can then state the following proposition.

Proposition 1. *In a renewable resource exploitation game where the resilience function is described by $\phi(r_t) = \phi$, with $\phi \leq 0,4$, 'low' extraction technologies are supported as a subgame perfect equilibrium by a Grim-trigger strategy of reversion to the non-cooperative subgame perfect Nash strategy, for any $\delta \in (1/2, 1)$.*

Notice that this is not the only punishment supporting 'low' extraction rates forever, nor is it the only play path which may be sustained as an equilibrium and which yields higher payoffs than under non-cooperation. The essential finding for our experimental implementation is that with costly conflict technologies there exist equilibria such that players improve their payoffs as compared to choosing the non-cooperative extraction technologies at any time t, and that one such equilibrium involves eternal cooperation. The conflict option does not play any role in this setting (i.e. the same outcome would be obtained in the absence of the conflict action). It is nevertheless important for the subsequent experimental design to demonstrate that cooperation can be sustained in such settings, and that the conflict option should never be chosen by players.

3.3 Equilibrium with varying cost of conflict

We now consider the game's equilibria when the resources' resilience $\phi(r_t)$ is a function of the stock of resources such that $\phi(r_t) \in [0,1]$, $\phi(r_t)' \leq 0$, and $\exists \bar{\bar{r}} > \bar{r} > 0$, whereby $\phi(r) = 1, \forall r \leq \bar{r}$ and $\phi(r) = 0, \forall r \geq \bar{\bar{r}}$. The function $\phi(r_t)$ is continuous on the interval $]\bar{r}, \bar{\bar{r}}[$.[9]

[9]Notice that this set of simplifying assumptions about the conflict technology is meant to produce numerical results that can easily be mapped in the lab, while also capturing the essence of Sekeris (2014) where the players' conflict effort, and therefore the associated damage to the resource, are endogenous. In Appendix A.2 we develop a slightly more elaborate model with endogenous armaments and a Contest Success Function conflict technology, which results in conflict being the players' best response in the presence of low resource stocks.

To understand how this conflict technology affects the game's equilibria, we proceed in two steps. We first demonstrate that playing 'low' eternally is not achievable because, (i) 'low' itself is sustained as an equilibrium via the off-the-equilibrium path threat of permanently reverting to 'high', and (ii) through the dynamic depletion of the resource, the game reaches a point where both players prefer deviating from 'high' to conflict, thus making the threat of eternal reversion to 'high' non-credible, and thereby not subgame perfect. In a second step, we demonstrate that playing 'low' in the short run alone is not implementable either.

To demonstrate that 'high' cannot be played forever at equilibrium, it is sufficient to establish that Inequality (9) is violated when the stock of resources falls below some threshold. For any $r_{t+1} \leq \bar{r}$, $\phi(r_{t+1}) = 1$ and Inequality (9) is violated for any value of δ. For any $r_{t+1} \geq \bar{\bar{r}}$, $\phi(r_{t+1}) = 0$, and the inequality is then satisfied for any value of δ. Moreover, since $\phi(r_t)$ is continuously defined on $]\bar{r}, \bar{\bar{r}}[$, there exists some $\hat{r} \in [\bar{r}, \bar{\bar{r}}]$ such that the inequality is violated for any $r_{t+1} < \hat{r}$.

Having shown that playing 'high' forever is not an equilibrium, we deductively prove that playing 'low' forever cannot be sustained as an equilibrium either. The only threat that can be wielded against players deviating from the cooperative play path is the threat of temporarily playing 'high' before reverting to conflict (i.e. until Inequality (9) becomes violated). Yet, it is straightforward to observe that since along the cooperative path play the resources are dynamically depleted, there exists some t such that $r_{t+1} \leq \bar{r}$, and thus $\phi(r_{t+1}) = 1$. As a consequence in period $t + 1$ conflict will certainly be played if it has not been played earlier. Moreover, with $\phi = 1$, $\ln(e_i^l) = \ln(e_i^v)$, so that in period t there is no credible punishment for disincentivising players from deviating from the 'low' extraction technology. As both players follow the same reasoning, in t they will both play 'high'. This mutual non-cooperation is due to the fact that in time $t+1$ players have no punishment scheme to support 'low'. Applying the argument backwardly implies that players never play 'low', which leads to the following proposition.

Proposition 2. *In a renewable resource exploitation game where resources are increasingly resilient to conflict as they become scarcer, the unique equilibrium is such that players choose the 'high extraction technology' if $r > \hat{r}$ and they declare conflict if $r \leq \hat{r}$.*

The intuition of this result is that, as the stock of resources is expected to dynamically decrease as a consequence of the players' use of the CPR, the cost of conflict is also expected to fall dynamically, so that at some point in the future conflict will become optimal for both players. In expectation of conflict taking place in the future, however, the Folk theorem logic breaks, and both players find it optimal to choose the high extraction technology in earlier time periods. It is important to mention at this stage, that our result is conditional on the parameter restriction $\gamma < (1 - \delta)/\delta$ that guarantees the dynamic depletion of resources along the cooperative path of play. In settings with high enough regeneration rates, γ, the stock of resources would grow dynamically, and conflict would therefore never be profitable.

Combining the results of Propositions 1 and 2, we can enunciate the following corollary, which will be tested in the experimental section of the paper:

Corollary 1. *In a renewable resource exploitation game where resources can be violently appropriated at some cost, replacing a highly costly conflict technology by a technology making resources increasingly resilient to conflict when resources are scarcer implies that,*

1. *The 'high' extraction technology is optimal (and the 'low' extraction technology is suboptimal) when resources are sufficiently abundant.*
2. *Conflict is chosen when the resources are sufficiently depleted.*

4 Experimental design

The theory developed in the previous section establishes two results. First, playing 'low' forever may be supported as a subgame perfect equilibrium of the game provided the conflict technology is sufficiently costly (and hence never optimal). Second, if conflict becomes optimal along the equilibrium path, the unique equilibrium involves players playing 'high' when the stock of resources is large, and opting for conflict when the stock of resources drops below some threshold level.

4.1 Parametrisation

For the experimental game, we fix the parameters of the model such that (i) cooperation is supported as a SPE in the costly-conflict version of the game, and (ii) conflict is the players' preferred option when resources are sufficiently depleted in the version of the game where resources' resilience to conflict increases with scarcity, therefore verifying Proposition 2.

For (i) to hold we require that $\delta > 1/2$ and $\phi \leq 0.4$. Denote next by s_i^l, s_i^h, and s_i^{dev} the extraction rates corresponding, respectively to $e_{i,t}^p(k_{i,t}^l, .)$, $e_{i,t}^p(k_{i,t}^h, k_{i,t}^h)$, and $e_{i,t}^p(k_{i,t}^h, k_{i,t}^l)$. Setting the discount rate in the lab to $\delta = 0.7$, we obtain that the values of s^l, s^h, and s^{dev} are fixed at 0.15, 0.23, and 0.255, respectively.[10] We equally set $\phi = 0.4$.

For (ii) to hold, we consider the following function:

$$\phi(r_t) = \begin{cases} 1 & \text{if } r_t < 25 \\ 2 - 0.04 r_t & \text{otherwise} \end{cases} \tag{12}$$

which implies that the threshold value of the CPR, below which conflict is theoretically optimal, is given by $\hat{r} = 29.15$.

We set the initial stock of points to $r_0 = 40$, and set the regeneration rate to $\gamma = 0.3$.

4.2 Design

The experiment was programmed in zTree and participants were recruited among the student pool of the University of York using hroot (Bock et al. 2014). We conducted two different treatments capturing the two different "resilience functions" identified in the theory: the conflict treatment with a variable resilience of resources to conflict, and the

[10]Notice that one of the advantages of adopting a logarithmic utility function lies in the invariability of s^h and s^l with respect to changes in the expected future outcomes of the game. Changes in future outcomes typically alter expected marginal utilities, which in turn imply an adjustment of current consumption to restore the Euler equation commanding inter-temporal optimality. With logarithmic utilities players extract a constant share of the available resources under all scenarios. Consequently, the Euler equation remains unaffected by whether conflict will occur or not, hence allowing us to focus on unique values of s^h and s^l.

control treatment where the resources' resilience is fixed to $\phi = 0.4$. Each treatment involved 58 participants, and each treatment consisted of 20 identical games (10 practice games and 10 "real" games with a lottery payment of two out of the 10 "real" games).[11] For each game, participants were randomly matched into pairs, whereby each game ran for a randomly determined number of rounds. Random rematching at the end of each game occurred using zTree's matching-stranger option. To implement an infinitely dynamic game in the laboratory, we followed the methodology of Vespa (2014), building on Roth and Murninghan (1978) and the recent application of Cabral et al. (2014). Like Vespa (2014), we imposed that the first six rounds of each game were played with unit probability, but that the earned payoff was discounted at a constant rate of 0.7. From round 7 onwards, the software randomly terminated the game with a probability of $(1 - \delta) = 0.3$. The rationale for adopting such a hybrid termination rule was that, without such a rule in place for the entire game (i.e. such that after each round the game would terminate with probability 0.3), the average length of a game would approximately equal 3.3 periods, thus potentially inducing players not to play 'low' despite the Pareto-superiority of playing 'low' forever. Indeed, *if both players were to always play 'low'*, this strategy would start dominating the strategy of playing 'high' forever after round 6, as shown in Figure 1, where we depict cumulated payoffs under both players opting for 'low' and both players opting for 'high', respectively. Imposing 6 rounds of certain play increases the average number of rounds played to 9.3, without affecting players' expected payoffs.

FIGURE 1 HERE

In both treatments, participants begin each game with a common pool of 40 'points'. In both treatments, participants are given three extraction choices, a 'high' extraction rate, a 'low' one, and the 'chance' option. In accordance with our theoretical setting, the (constant) shares of points that were extracted for each combination of choices of paired participants are given as follows:

- If both participants play 'high', each extracts 23% of the remaining points.
- If a participant opts for 'low', he/she extracts 15% of the remaining points, irrespective of the other participant's extraction.
- If a participant plays 'high' and his/her match plays 'low', he/she extracts 25.5% of the remaining points.
- If either participant plays chance, he/she retains the control of $\phi(r_t)r_t/2$ resources, and extracts 30% of the resources in this and all remaining rounds.

If chance was selected, the CPR was subjected to a loss described by $(1 - \phi(r_t))r_t$ with the resilience function given by (12) in the conflict treatment, or by $(1 - \phi)r_t = 0.6r_t$ in the control treatment. In both treatments the remaining stock of points was shared equally among both players, on whom, from then on, the (optimal) 'low' level of extraction for the current and all subsequent rounds was imposed upon. Consistent with the theoretical findings, the expectation was that, when confronted with the conflict treatment, participants should substitute 'low' by 'high' in a game's early rounds, while chance should be selected whenever the stock of points dropped below 29.15 (i.e. when inequality (9) was satisfied).

[11] This payment method was chosen to prevent participants from adapting strategies with regards to accumulated payoffs obtained during earlier games.

In addition to the instructions that were handed out to participants (see on-line Appendix), the screen indicated the amount of points that would be available in the next time period for each potential choice participants could make, as well as those for all respective choices of the opponent. This information was available during each round of the game. Participants could pre-select an option, in which case a red frame would appear around their choice. When chance was pre-selected, a box visualised the amount of resources which would be lost in case chance was chosen. Participants then had to confirm their selection by pressing "OK", which let them proceed to the next round. A screenshot of the conflict treatment is provided in Figure 2. It illustrates the functionality of the software.

FIGURE 2 HERE

Each experimental session lasted approximately 120 minutes. We paid a show-up fee of £3, and, given our two-out-of-ten rounds lottery, the average payment per participant was £17.56, with an earnings' variance of £1.20.

Based on the results in section 3 we formulate the following Hypothesis:

Hypothesis 1. *Participants play 'high' ('low') more (less) frequently in early rounds (when conflict is suboptimal) in the conflict treatment as compared to the control treatment.*

5 Empirical analysis

The entire empirical analysis is focused on the games played for money. Before presenting the empirical results, we provide some descriptive statistics to facilitate the inspection of the participants' behaviour. In Figure 3 we depict the cumulative share of participants who opted for 'low' across the two treatments. It shows a marked difference between treatments, where 'low' was played at a higher rate – at any given round – in the control treatment (discontinuous curve). This very preliminary result concurs with our theoretical expectations: the anticipation of chance being played in the conflict treatment did reduce the players' propensity to opt for 'low'.

Our theoretical predictions suggest that 'low' should be substituted by 'high' when the CPR is relatively abundant. To see that this is indeed the case, consider Figure 4, where we have plotted the cumulated share of participants who opted for 'high' across the two treatments. Interestingly, we observe a trend which seems to mirror the 'low' rates in the *game's initial rounds*, so that it is the participants in the conflict treatment who played 'low' the least.

To show that this preliminary evidence is indeed persuasive, we have plotted the proportion of participants who played chance for both treatments in Figure 5. This figure shows that the differences between the proportion with which 'low' and 'high' were played are intimately linked to the participants' propensity to resort to chance during later rounds of the game. There is a notable difference in the proportion with which chance was played in the conflict (solid line) and the control (dotted line) treatments. In the former treatment, participants were more willing to play chance during any round of the game, but perhaps more importantly, there is a striking difference between the chronological evolution depicted in the separate lines. In the conflict treatment we observe a sharp increase in round 3, which corresponds to the round where the level of points is – on average – in the range where chance becomes optimal in theory. Since chance is never optimal in the control treatment, we should expect no similar pattern in the latter treatment, which seems to be confirmed by Figure 5. Under both treatments we do, however, observe an increase in the proportion of participants who played chance in later rounds, and more specifically around round 14. Bearing the imposed random termination rule in mind, the probability that any game would have reached round 14 equals 0.057, which makes it a very unlikely event. One reason that could explain this behaviour could be that participants resorted to some sort of protection mechanism by attempting to put an end to the depletion of the CPR. Other psychological mechanisms could be invoked to explain these observations, but irrespective of the cause of this behaviour, a prominent explanation for the differences in the higher propensity to play 'high' in the game's early rounds are the differential expectations of such behaviour in the future (i.e. higher such expectations in the conflict treatment).

FIGURE 3 HERE

FIGURE 4 HERE

FIGURE 5 HERE

The patterns presented in Figures 3-5 are consistent with Hypothesis 1 and our proposed mechanism: in the conflict treatment, where the depletion of resources makes the chance option optimal after rounds 2-3, there is a clear substitution of 'low' by 'high' in the early rounds of the game. On the other hand, no such substitution seems to be occurring in the control treatment, where chance was only played in the later rounds of the game. Bearing in mind that rounds 2 and 3 were always reached, while round 14 was only reached in around 5% of the games, the expectation of chance being played in any game ought to have been higher in the conflict treatment, thus explaining the manifest difference in the substitution of 'low' by 'high' in the game's early rounds. Visual correlations alone, however, cannot be interpreted as causal evidence. We thus turn to a regression analysis, estimating the following model:

$$Low_{igt} = \alpha + \beta\, Game_i + \gamma\, Round_{ig} + \delta\, Conflict_i + X_i'\zeta + \epsilon_{igt} \tag{13}$$

where Low_{igt} is a dummy variable capturing whether participant i in game g and round t opted for the efficient extraction of points. $Game_i$ is the number of 'real' games played by participant i, whereas $Round_{ig}$ captures the number of rounds played by participant i in the current game. Both controls are meant to capture potential trends or learning effects across and within games. $Conflict_i$ is a dummy variable equal to one for all participants of the conflict treatment.[12] The vector X_i controls for individual characteristics and includes study subject and gender. Regarding the study program, we create dummies for hard sciences (*science*) and for social sciences (*social*), with the residual group being humanities. As for gender, since it may influence the attitude of participants, both towards extraction levels and towards the chance option, we include a dummy variable for *male*. Finally, ϵ_{igt} is the standardised error term clustered at the individual level. The coefficient of interest is δ, which captures the impact of having the chance option on the level of cooperation.

We then estimate equation (13) by replacing the dependent variable by a dummy $High_{igt}$ equal to one when the participant chooses the 'high' extraction level.

Table 1 contains the descriptive statistics.

[12] We do not include the stock of points left in our empirical model, as it is endogenous to the choice of 'low' *vs* 'high', and highly collinear with the variable Round. Substituting Round with the level of stock of points, however, produces qualitatively identical results.

5.1 Baseline results

In Table 2 we report the results of estimating model (13).[13] In other words, we are evaluating the effect of the presence of a conflict technology, which makes conflict a profitable choice on the propensity to play 'low'. The first column of Table 2 reports the results of the benchmark specification. Compared to the control treatment, participants in the conflict treatment tend to play 'low' by 12.1 percentage points less on average, thus lending support to our theoretical findings. Given that the average propensity of 'low' in the control treatment equals 23.3%, this implies that the introduction of the chance option reduces the likelihood of 'low' being played by about 50%. Consistently with previous findings, the *Game* coefficient, which captures the learning effect across games, implies that the propensity of 'low' decreases on average by 1.2 percentage points from one game to another (Dal Bó and Fréchette 2011). Moreover, 'low' is decreasing on average by 1.9 percentage point from one round to another within a game. As will become clear later, the latter result is mainly driven by participants' increasingly frequent choice of chance, on the one hand, and by the participants' increasingly frequent reversion to 'high' when the stock of points starts to run very low. Lastly, the gender and studies coefficients take signs compatible with earlier findings: male participants tend to cooperate less (Eckel and Grossman 1998), and the same holds true for non-humanities students (Frank et al. 1993).

Giving participants the option to play chance (resort to conflict) had a negative effect on the play of 'low'. This effect could, however, not be completely counterbalanced by an increase in the play of 'high', as it could partially be driven by an increase in the use of the third option, chance, which is sub-optimal in the control treatment. Proposition 2 stipulates that, for high levels of the stock of points (i.e. $r > 29.15$ given our parametrisation), the optimal decision is to choose 'high', with the chance option being used only when the stock of points is sufficiently depleted. To verify therefore that we indeed observe a substitution of 'low' by 'high' in the game's early rounds, as suggested by Hypothesis 1 – and that we can exclude a selection bias –, we restrict our estimation in multiple ways. In the second and third columns of Table 2, we restrict the sample to the first and the first two rounds of the game – where chance is unlikely to have been chosen in either treatment – to see whether 'low' does decrease. The coefficients remain positive and significant at the 1% level, thus implying that 'low' decreases as compared to the control treatment, when resorting to chance is theoretically sub-optimal.

Given that all games begin with a stock of 40 points, the stock of points would equal 28 in round 2 if both players played 'high' in the game's first rounds, making participants roughly indifferent between playing chance and not in the conflict treatment. Cooperation is significantly lower under the conflict treatment, by 11.9 percentage points, further confirming our expectations.

Specification (13) considers a linear effect of *Round* and *Game* on the dependent variable. To allow for non-linear effects, we reproduce the specifications of columns 1 – 3 in columns 4 – 6, now introducing *round* and *game* fixed effects instead of linear trends. The results remain quantitatively almost unchanged.

In Table 3 we present the results of the same specifications as in Table 2 by replacing the dependent variable with 'high'. The benchmark regression yields a negative coefficient, which is significant at the 1% level: adding the

[13] All model specifications are estimated by OLS. Replicating our estimates with probit and multinomial logit does not affect our results qualitatively. Results are available upon request.

chance option reduces 'high' on average by 27.3 percentage points compared to the control treatment. As mentioned earlier, one may be tempted to conclude that in the chance option, when playing chance becomes optimal, we observe a reduction of *both* 'low' and 'high' in favour of chance, thus possibly contradicting Proposition 2. Such an interpretation would be mistaken, however, since the benchmark model captures the average effects of the introduction of chance in a standard CPR exploitation game, while Proposition 2 clearly identifies two distinct optimal choices depending on the stock of points: when points are abundant, 'high' should increase, whereas when points are scarce, chance is the optimal choice and both "low" and "high" are accordingly expected to decrease. We therefore proceed in columns 2-3 with the same sample restrictions as in Table 2. If Proposition 2 is to be confirmed, we should expect 'high' to increase only when the stock of points is abundant, or alternatively in the early rounds of the game. Our results do confirm this prediction: according to the results reported in column 3, 'high' increases by 16.3 percentage points in the game's first round compared to the control treatment. Hence, the availability of a "profitable" conflict technology induces participants to substitute 'low' with 'high' when the stock of points is sufficiently large.[14]

One potential concern could be that, since playing chance implies that participants stop making choices in subsequent rounds of the same game, the decision to play chance could be driven by non-pecuniary motivations, such as putting an early end to the game (playing chance too early), or deferring chance to future rounds, because participants may simply enjoy playing the game (playing chance too late). Since our theoretical mechanism identifies a critical resource threshold triggering conflict (i.e. chance), we reproduce Tables 2 and 3 by adding as a control variable the level of resources. The results are contained in Tables 4 and 5. Our results are strongly robust to this additional test.

As explained earlier, the substitution of 'low' by 'high' in the conflict treatment is explained by the sharp increase of chance being played in rounds $3-6$. Indeed, as can be seen in Figure 3 virtually no participant opts for chance in the first 2 rounds of the game. Secondly, we observe a surge of chance being chosen in rounds 3 to 6, rising from it being played by 1.5% to 66% of the pairs. This coincides roughly with our expectation that chance becomes optimal when the stock of points drops below 29, since the *average* stock of points in rounds 2 and 3 is equal to 29 and 21.1 points, respectively. Bearing in mind the relatively low proportion of participants opting for chance in the control treatment, as well as the low probability of the game lasting long enough (i.e. after round 13) for there to be a real risk of chance being played, this graph supports our narrative. Combined with the results of Tables 2 and 3, we can confidently state that our empirical results are consistent with Hypothesis 1. The introduction of a profitable (for low levels of resources) appropriation option in an experimental game of renewable CPR exploitation induces participants to become more non-cooperative in the presence of abundant resource stocks, thus precipitating their depletion, and eventually opting for the partition of the resource.

[14] In the on-line Appendix Tables A1-A2 replicate the same tests keeping the whole sample and adding interaction terms to identify the effect of chance in early rounds. The interpretation is sometimes less straightforward but the pattern of our findings is identical.

5.2 Exploring the mechanism

5.2.1 The expectation of chance

To further convince the reader that it is indeed the expectation of chance play in later rounds that triggers 'high' in the early rounds of a game, we propose two alternative strategies.

First, we explore whether a higher expectations of chance being played does in fact reinforce the behaviour patterns that are compatible with our theory. If the substitution of 'low' by 'high', as we observe it in the early rounds of the conflict treatment, rests in the expectation of chance being played in later rounds, we should expect participants who choose chance ('attackers'), and those matched with them ('victims') in the previous game, to increase their expectation that chance will be played later. While the attackers' behaviour may be driven by the unobserved characteristics that explain also their initial decision to opt for chance, the potential alteration of the victims' behaviour should reveal some information updating, since they should expect chance play to be more likely after experiencing chance. This implies that past attackers, and even more so past victims, should more markedly reduce 'low' and increase 'high' in the early rounds of a game.

To implement this test we create two additional variables: a dummy capturing whether a participant has played chance in the previous game (*lagged attacker*) and another dummy capturing whether a participant was matched with an attacker in the previous game (*lagged victim*). We then re-estimate our models, including these two additional controls. The results of this test are reported in Table 6. Columns $1-2$ and $5-6$ replicate columns $2-3$ of Tables 2 and 3, respectively.

The results in column 1 of Table 6 suggest that, in the first round of the game, previous game attackers play 'low' by 8 percentage points less than the average participant in the conflict treatment. The equivalent figure for victims in the previous game equals 6.7 percentage points. The equivalent values for 'high' as contained in column 5 equal 7.3 and 6.5 percentage points, respectively. This suggests that both lagged victims and attackers fully substitute their reduced propensity to play 'low' by 'high' when resources are abundant. This considerable difference between participants who did not experience chance in the previous game, and those who did, further supports the conclusion that the expectation of chance is the mechanism driving the substitution of 'low' by 'high'. Results in columns 2 and 6 follow a similar pattern, thus further strengthening our interpretation. In columns $3-4$ and $7-8$ we substitute round and game trends by round and game fixed effects. The results remain unaffected.[15]

Finally, we replicate the same exercise, but restricting the analysis to participants in the conflict treatment only. We therefore test whether participants that have experienced chance in the previous game, as an attacker or as a victim, are more likely to play 'high' and less likely to play 'low' in the early periods of the game. The results, reported in Table 7, broadly confirm our previous results. We can thus confidently deduce that participants who have experienced chance in the previous game are more likely to expect chance to be chosen in the current game, therefore substituting 'low' by 'high' in the game's early rounds.

[15]Replicating the estimations in Tables 6 when including also interaction terms between $conflict$ and *lagged attacker* and *lagged victim* reveals that the expectation mechanism is operating in both treatments (as both interaction terms are not significant).

The second strategy proposed relies on a slightly modified experiment.[16] We amend the conflict treatment to impose chance on participants whenever the resource stock decreases below 25, which occurs concomitantly with the cost of chance decreasing to 0. This minor change implies that participants now know that chance will occur with certainty later in the game. If the expectation of chance is the reason driving the substitution of 'low' with 'high' in early rounds of the game, as we are arguing, then we should observe the same substitution also in this modified treatment, which we name 'sure conflict'. The results, based on two sessions involving 42 participants are reported in Tables 8 and 9, which follows the same structure of Tables 2 and 3.[17] Even though columns 3 and 6 are not statistically significant at the conventional levels, overall the results in Tables 8 and 9 suggest that participants did substitute 'low' with 'high' in the early rounds of the game, thereby lending further support to our interpretation.

5.2.2 Tracking individual paths of play

To show that the mechanism identified in our theoretical framework is actually the one driving our experimental results, we provide some additional supportive evidence based on the individual play-paths of our participants. Notice first that the timing according to which chance has been played by participants is consistent with the theory proposed. Figure 6 reports the distribution of actions in the conflict treatment across rounds for the first five and the last five real games, separately. It shows that right after the 10 training games (solid line), the majority of participants who played chance, did so in round 3, when the cost is nil. It also shows that in the last five games chance players are even more concentrated around the optimal behaviour (dashed line).

FIGURE 6 HERE

In Table 10 we report the 5 most frequent sequences chosen in the first five rounds by participants in the conflict and control treatments, respectively. The top sequence is $\{h, h, h, h, h\}$ in both treatments, where h stands for high.

The theory predicts that in the conflict treatment participants should play h for two rounds, before opting for chance (c). In the control treatment, on the other hand, no similar pattern should be observed since conflict is theoretically suboptimal. Interestingly, out of 580 participant-game play paths (i.e. 58 participants each playing separate 10 games), 77 perfectly match the theoretical expectations. In other words, in 13.3% of the participant-games the participants opted for the sequence $\{h, h, c\}$.

Computing the precise optimal round where conflict should be played in the conflict treatment may, however, involve a significant level of sophistication on behalf of the participants. Table 10 shows that in almost a quarter of participant-games in the conflict treatment play paths, chance was chosen either in rounds 4 or in round 5, following a continuous sequence of h choices. In the control treatment none of these sequences was ever adopted. These findings constitute strong evidence that our results do not merely reflect behaviour compatible with the theoretical results on average, but instead that the mechanism is verified for a large share of participants at the individual level.

[16] We thank an anonymous referee for proposing this test.

[17] Tables A3 and A4 in the on-line Appendix replicate the same test by including the stock of resources as an additional control.

6 Conclusion

Folk theorems permit cooperation to arise in equilibrium in dynamic common pool renewable resource games, both theoretically and experimentally. Allowing the players to revert to violence to split the resource (and to thereafter manage efficiently what has become a private resource) breaks the logic of folk theorems. In our theoretical section we propose a simple version of the CPR management model of Sekeris (2014), where players can opt for potentially costly conflict to permanently split resources. In the presence of a highly destructive conflict technology, violence is never optimal, and thus cooperation is sustainable. With conflict technologies that make conflict profitable under some circumstances (i.e. when resources are sufficiently depleted), infinite horizon dynamic games endogenously become finite horizon strategic games up to the moment when conflict emerges, after which the game reduces to a decision-theoretic problem. This deprives players of the required punishment strategy for sustaining cooperation, thereby leading to the collapse of cooperation. In this paper we inquire experimentally whether participants respond to such incentives that should lead to (i) less cooperation in the presence of high stocks of resources, and to (ii) conflict after the resource stock is sufficiently depleted. We find a strong and highly significant effect of conflict on the choices of cooperation and non-cooperation. In the game's first round, participants reduce their cooperation by 16 percentage points and increase non-cooperation by 16.3 percentage points. Given that the average rates of cooperation and non-cooperation in the game's first round are around 24.1% and and 75.7%, respectively, this equates to a 66% decrease of cooperation, and to a 21% increase of non-cooperation.

To provide further evidence of the theoretical mechanism proposed in this paper, we included two additional verification tests. We explored whether having experienced chance in the previous game being played as an attacker (initiator of conflict) or a victim increases the participants' inclination to play according to the theoretical results. The findings unambiguously point towards an increased substitution of cooperation by non-cooperation among both lagged attackers and lagged victims. This confirms that the experience of conflict in a previous game increases the expectation among these participants of conflict occurring in the ongoing game, in turn leading to less cooperative behaviour. The second verification exercise was to organise a treatment where players were certain that chance would occur since we experimentally imposed it below a certain threshold level of resources. Observing the same substitution of cooperation by non-cooperation in the game's early rounds as in the benchmark regressions further supports our interpretation of cooperation decreasing in expectation of chance. Lastly, we tracked the sequence of choices made by participants in games. We find that in the conflict treatment more than a third of the participant-game play paths match the sequence of actions compatible with our theory, compared with none in the control treatment. We interpret these results as strong evidence that our experimental findings are driven by the participants' individual behaviour rather than by average effects, thus allowing us to confidently conclude that participants behave as predicted by our theory.

This contribution constitutes the first evidence for the theory that the expectation of (possibly distant) conflicts over shared resources can break cooperation in the short run. In equilibrium, the depletion of resources occurs more rapidly when conflict is an option. Our findings may help comprehend the failure to reach agreements over such matters as the conservation of the environment. This, in turn, would imply that one crucial dimension for promoting cooperation would be the strengthening of institutions and international bodies able to contain such violence.

Figures

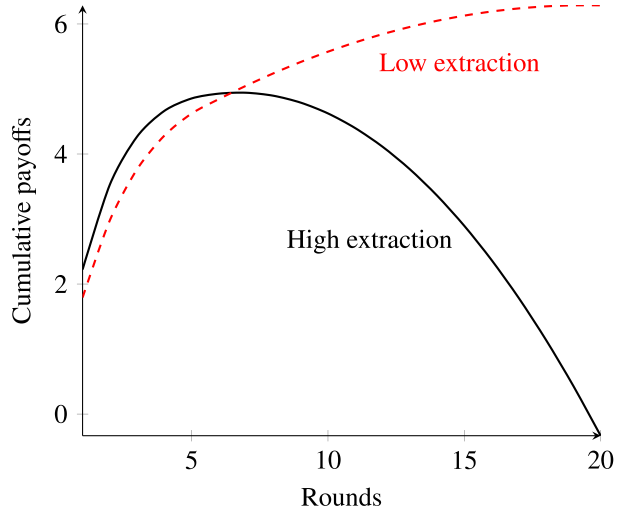


Figure 1: Cumulative payoffs under both players opting for ‘low’ and for ‘high’

Figure 2: Screenshot of ‘conflict’ treatment with 28 points

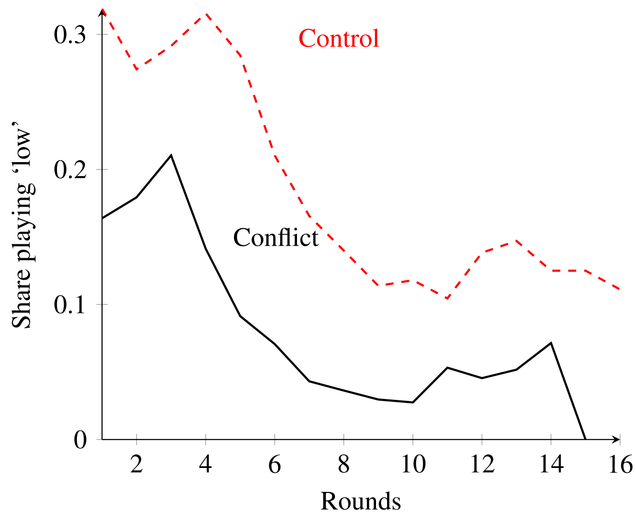


Figure 3: Share of participants opting for 'low'

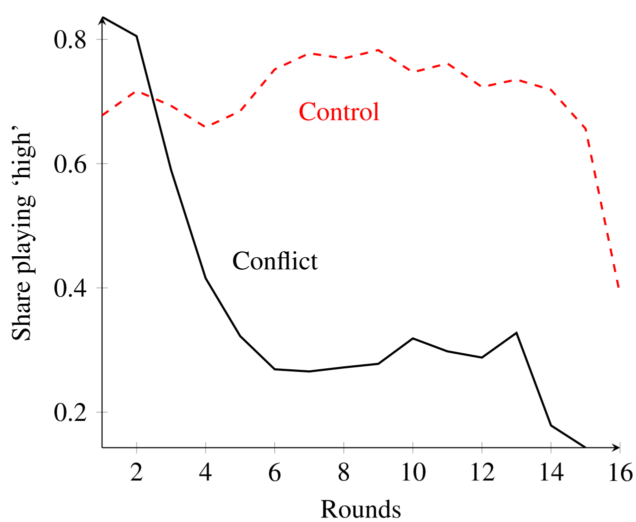


Figure 4: Share of participants opting for 'high'

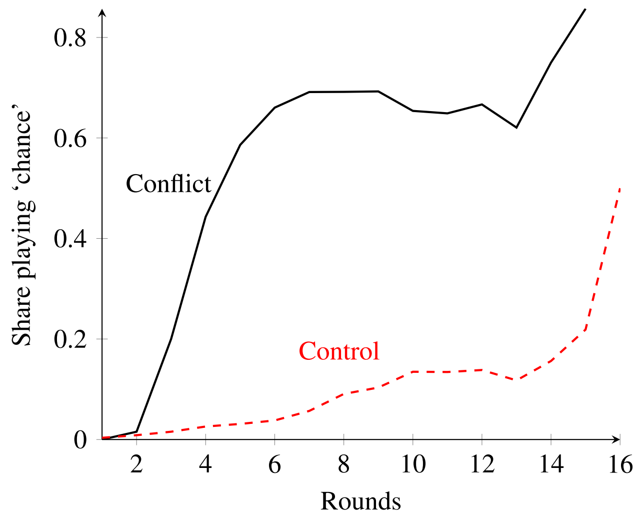


Figure 5: Share of participants opting for 'chance'

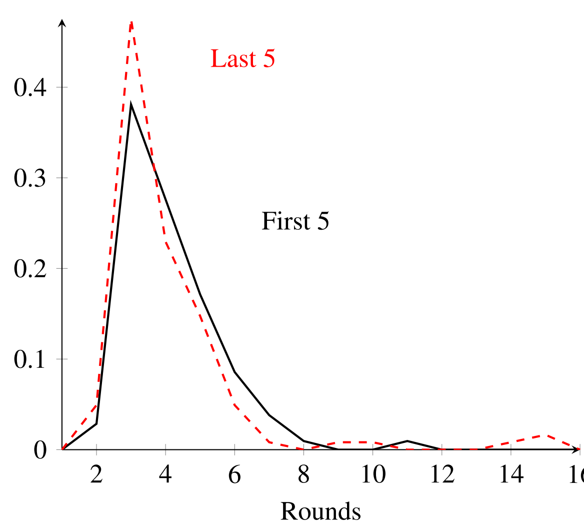


Figure 6: Distribution of 'chance' in the first five and last five games

Tables

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Conflict treatment:					
Low	5172	0.109	0.311	0	1
High	5172	0.453	0.498	0	1
Chance	5172	0.438	0.496	0	1
Control treatment:					
Low	5292	0.233	0.423	0	1
High	5292	0.719	0.450	0	1
Chance	5292	0.048	0.213	0	1
Game	10464	5.563	2.846	1	10
Round	10464	5.293	3.119	1	16
Male	10464	0.468	0.499	0	1
Stock of points	10464	16.901	11.484	0.121	40
Science	10464	0.138	0.345	0	1
Social	10464	0.499	0.500	0	1

Table 2: Effect of ‘conflict’ on the choice of Low

Dependent variable:	Low					
	(1)	(2)	(3)	(4)	(5)	(6)
Conflict	-0.121***	-0.160***	-0.119**	-0.121***	-0.160***	-0.119**
	(0.030)	(0.053)	(0.048)	(0.030)	(0.059)	(0.048)
Round	-0.019***		-0.015			
	(0.003)		(0.028)			
Game	-0.012***	-0.016***	-0.015***			
	(0.002)	(0.004)	(0.003)			
Male	-0.034	0.012	0.002	-0.035	0.012	0.002
	(0.029)	(0.061)	(0.049)	(0.028)	(0.061)	(0.049)
Science	-0.085**	-0.203***	-0.213***	-0.085**	-0.203***	-0.213***
	(0.042)	(0.068)	(0.055)	(0.042)	(0.068)	(0.056)
Social	-0.057*	-0.019	-0.077	-0.056*	-0.019	-0.077
	(0.033)	(0.068)	(0.056)	(0.033)	(0.069)	(0.056)
Rounds 1		✓			✓	
Rounds 1-2			✓			✓
Game & Round FE				✓	✓	✓
Observations	10,464	1,160	2,320	10,464	1,160	2,320
R-squared	0.071	0.069	0.058	0.079	0.071	0.060

Notes: Standard errors clustered at the individual level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. FE=fixed effects.

Table 3: Effect of ‘conflict’ on the choice of High

Dependent variable:	High					
	(1)	(2)	(3)	(4)	(5)	(6)
Conflict	-0.273***	0.163***	0.119**	-0.272***	0.163***	0.119**
	(0.035)	(0.059)	(0.049)	(0.035)	(0.059)	(0.049)
Round	-0.025***		0.004			
	(0.005)		(0.027)			
Game	0.005	0.016***	0.014***			
	(0.003)	(0.004)	(0.003)			
Male	-0.006	-0.009	-0.004	-0.007	-0.009	-0.004
	(0.035)	(0.061)	(0.051)	(0.035)	(0.061)	(0.051))
Science	0.044	0.204***	0.217***	0.044	0.204***	0.217***
	(0.045)	(0.068)	(0.056)	(0.045)	(0.068)	(0.056)
Social	0.040	0.019	0.070	0.040	0.019	0.070
	(0.039)	(0.068)	(0.057)	(0.039)	(0.069)	(0.057)
Rounds 1		✓			✓	
Rounds 1-2			✓			✓
Game & Round FE				✓	✓	✓
Observations	10,464	1,160	2,320	10,464	1,160	2,320
R-squared	0.099	0.070	0.055	0.120	0.072	0.057

Notes: Standard errors clustered at the individual level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. FE=fixed effects.

Table 4: Effect of 'conflict' on the choice of Low - controlling for the resource stock

Dependent variable:	Low					
	(1)	(2)	(3)	(4)	(5)	(6))
Conflict	-0.129***	-0.160***	-0.100**	-0.150***	-0.160***	-0.100**
	(0.029)	(0.059)	(0.044)	(0.029)	(0.059)	(0.044)
Round	0.001		0.426***			
	(0.005)		(0.069)			
Game	-0.011***	-0.016***	-0.013***			
	(0.002)	(0.004)	(0.003)			
Resource stock	0.006***		0.042***	0.021***		0.041***
	(0.002)		(0.007)	(0.003)		(0.007)
Male	-0.037	0.012	-0.002	-0.043*	0.012	-0.002
	(0.027)	(0.061)	(0.046)	(0.025)	(0.061)	(0.046)
Science	-0.082**	-0.203***	-0.198***	-0.077*	-0.203***	-0.198***
	(0.041)	(0.068)	(0.052)	(0.039)	(0.068)	(0.052)
Social	-0.055*	-0.019	-0.070	-0.052*	-0.019	-0.070
	(0.032)	(0.068)	(0.052)	(0.030)	(0.069)	(0.052)
Rounds 1		✓			✓	
Rounds 1-2			✓			✓
Game & Round FE				✓	✓	✓
Observations	10,464	1,160	2,320	10,464	1,160	2,320
R-squared	0.080	0.069	0.083	0.107	0.071	0.084

Notes: Standard errors clustered at the individual level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. FE=fixed effects.

Table 5: Effect of 'conflict' on the choice of High - controlling for the resource stock

Dependent variable:	High					
	(1)	(2)	(3)	(4)	(5)	(6)
Conflict	-0.261***	0.163***	0.103**	-0.185***	0.163***	0.103**
	(0.034)	(0.059)	(0.047)	(0.025)	(0.059)	(0.047)
Round	-0.057***		-0.353***			
	(0.006)		(0.096)			
Game	0.004	0.016***	0.012***			
	(0.003)	(0.004)	(0.003)			
Resource stock	-0.010***		-0.034***	-0.065***		-0.034***
	(0.002)		(0.010)	(0.004)		(0.010)
Male	-0.001	-0.009	-0.001	0.018	-0.009	-0.001
	(0.033)	(0.061)	(0.048)	(0.024)	(0.061)	(0.048)
Science	0.039	0.204***	0.205***	0.017	0.204***	0.205***
	(0.043)	(0.068)	(0.053)	(0.034)	(0.068)	(0.053)
Social	0.037	0.019	0.064	0.027	0.019	0.064
	(0.037)	(0.068)	(0.054)	(0.028)	(0.069)	(0.054)
Rounds 1		✓			✓	
Rounds 1-2			✓			✓
Game & Round FE				✓	✓	✓
Observations	10,464	1,160	2,320	10,464	1,160	2,320
R-squared	0.113	0.070	0.071	0.277	0.072	0.072

Notes: Standard errors clustered at the individual level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. FE=fixed effects.

Table 6: The impact of experiencing chance in the past

Dependent variable:	Low				High			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Conflict	-0.114*	-0.082	-0.112*	-0.080	0.121*	0.089*	0.119*	0.087
	(0.062)	(0.052)	(0.063)	(0.052)	(0.063)	(0.053)	(0.063)	(0.053)
Lagged attacker	-0.080	-0.059	-0.084	-0.062	0.073	0.036	0.076	0.039
	(0.052)	(0.042)	(0.052)	(0.043)	(0.053)	(0.049)	(0.054)	(0.049)
Lagged victim	-0.067**	-0.070***	-0.070**	-0.072***	0.065*	0.070***	0.067**	0.072***
	(0.033)	(0.026)	(0.033)	(0.026)	(0.034)	(0.026)	(0.034)	(0.027)
Round		-0.013				0.002		
		(0.029)				(0.028)		
Game	-0.013***	-0.012***			0.013***	0.012***		
	(0.004)	(0.003)			(0.004)	(0.003)		
Male	0.014	0.003	0.014	0.003	-0.010	-0.003	-0.010	-0.003
	(0.060)	(0.047)	(0.060)	(0.047)	(0.060)	(0.049	(0.060)	(0.049)
Science	-0.193***	-0.204***	-0.193***	-0.203***	0.196***	0.209***	0.195***	0.209***
	(0.065)	(0.052)	(0.066)	(0.052)	(0.065)	(0.053)	(0.066)	(0.053)
Social	-0.023	-0.079	-0.023	-0.079	0.022	0.071	0.022	0.071
	(0.067)	(0.054)	(0.068)	(0.054)	(0.067)	(0.056)	(0.068)	(0.056)
Rounds 1	✓		✓		✓		✓	
Rounds 1-2		✓		✓		✓		✓
Game & Round FE			✓	✓			✓	✓
Observations	1,044	2,088	1,044	2,088	1,044	2,088	1,044	2,088
R-squared	0.069	0.058	0.072	0.061	0.070	0.055	0.073	0.057

Notes: Standard errors clustered at the individual level in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 7: The impact of experiencing chance in the past - conflict treatment only

Dependent variable:	Low				High			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged attacker	-0.071	-0.083*	-0.072	-0.082*	0.071	0.062	0.072	0.062
	(0.060)	(0.046)	(0.060)	(0.046)	(0.060)	(0.052)	(0.060)	(0.053)
Lagged victim	-0.056	-0.077***	-0.054	-0.076**	0.056	0.077***	0.054	0.076**
	(0.037)	(0.029)	(0.036)	(0.029)	(0.037)	(0.029)	(0.036)	(0.029)
Round		0.015		0.015		-0.033		-0.033
		(0.038)		(0.038)		(0.034)		(0.034)
Game	-0.012**	-0.014***			0.012**	0.014***		
	(0.006)	(0.004)			(0.006)	(0.004)		
Male	-0.058	-0.056	-0.058	-0.056	0.058	0.048	0.058	0.048
	(0.070)	(0.058)	(0.071)	(0.058)	(0.070)	(0.063)	(0.071)	(0.063)
Science	-0.098	-0.134**	-0.097	-0.134**	0.098	0.144**	0.097	0.144**
	(0.072)	(0.061)	(0.073)	(0.062)	(0.072)	(0.065)	(0.073)	(0.065)
Social	0.027	-0.042	0.027	-0.042	-0.027	0.033	-0.027	0.033
	(0.081)	(0.071)	(0.082)	(0.071)	(0.081)	(0.073)	(0.082)	(0.073)
Rounds 1	✓		✓		✓		✓	
Rounds 1-2		✓		✓		✓		✓
Game & Round FE			✓	✓			✓	✓
Observations	522	1,044	522	1,044	522	1,044	522	1,044
R-squared	0.038	0.048	0.045	0.050	0.038	0.041	0.045	0.043

Notes: Standard errors clustered at the individual level in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 8: Effect of 'sure conflict' on the choice of Low

Dependent variable:	Low					
	(1)	(2)	(3)	(4)	(5)	(6)
Sure Conflict	-0.179***	-0.137**	-0.078	-0.184***	-0.135**	-0.078
	(0.029)	(0.064)	(0.055)	(0.030)	(0.064)	(0.055)
Round	-0.021***		-0.008			
	(0.004)		(0.031)			
Game	-0.009***	-0.019***	-0.015***			
	(0.003)	(0.005)	(0.005)			
Male	-0.002	0.017	0.021	-0.003	0.017	0.021
	(0.034)	(0.071)	(0.058)	(0.034)	(0.071)	(0.058)
Science	-0.048	-0.120	-0.139**	-0.048	-0.120	-0.139**
	(0.045)	(0.087)	(0.067)	(0.045)	(0.088)	(0.067)
Social	-0.023	0.000	-0.025	-0.023	0.001	-0.025
	(0.037)	(0.077)	(0.064)	(0.038)	(0.077)	(0.064)
Rounds 1		✓			✓	
Rounds 1-2			✓			✓
Game & Round FE				✓	✓	✓
Observations	7,700	888	1,776	7,700	888	1,776
R-squared	0.073	0.039	0.025	0.083	0.041	0.029

Notes: Standard errors clustered at the individual level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. FE=fixed effects.

Table 9: Effect of 'sure conflict' on the choice of High

Dependent variable:	High					
	(1)	(2)	(3)	(4)	(5)	(6)
Sure Conflict	-0.516***	0.140**	0.070	-0.508***	0.138**	0.071
	(0.029)	(0.064)	(0.055)	(0.030)	(0.064)	(0.055)
Round	-0.017***		-0.005			
	(0.005)		(0.031)			
Game	0.014***	0.018***	0.014***			
	(0.003)	(0.005)	(0.005)			
Male	0.000	-0.013	-0.016	-0.001	-0.013	-0.016
	(0.036)	(0.071)	(0.059)	(0.036)	(0.071)	(0.059)
Science	0.063	0.122	0.141**	0.064	0.122	0.141**
	(0.045)	(0.087)	(0.067)	(0.045)	(0.088)	(0.068)
Social	0.043	-0.001	0.017	0.043	-0.001	0.018
	(0.040)	(0.077)	(0.064)	(0.040)	(0.077)	(0.065)
Rounds 1		✓			✓	
Rounds 1-2			✓			✓
Game & Round FE				✓	✓	✓
Observations	7,700	888	1,776	7,700	888	1,776
R-squared	0.252	0.040	0.023	0.288	0.042	0.026

Notes: Standard errors clustered at the individual level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. FE=fixed effects.

Table 10: Top sequences for the first 5 rounds

Sequence	Participant-games	%
Conflict treatment		
hhhhh	106	18.28
hhhcc	85	16.38
hhccc	77	13.28
hhhhc	43	7.42
hhhhl	14	2.41
Control treatment		
hhhhh	211	36.38
lhhhh	37	6.38
llllll	29	5
hhhhl	26	4.48
hhhll	24	4.14

Notes: h, l, c stand for high, low and chance, respectively.

A Appendix

A.1 Proofs

A.1.1 Unconstrained optimisation

Instead of constraining the players' extraction rates to pre-determined values, we now consider the same game to the one presented in Section 3 without the restriction on extraction technologies. We are thus considering the game where any player i can choose any extraction effort $e_{i,t} \in \mathcal{R}^+$ at any time period t.

Derivation of the "conflict" extraction rates, $e^c_{i,t}$:

We denote by $V_i^c(r_{i,t})$ the value function of this problem given the resource stock $r_{i,t}$, meaning that the indirect aggregate utility can be expressed as a Bellman equation:

$$V_i^c(r_{i,t}) = \arg\max_{e_{i,t}} \left[\ln(e_{i,t}) + \delta V^c(r_{i,t+1})\right] \tag{14}$$

Given the assumed regeneration rule, the above expression can be written as:

$$V_i^c(r_{i,t}) = \arg\max_{e_{i,t}} \left[\ln(e_{i,t}) + \delta V_i^c\left((1+\gamma)(r_{i,t} - x_{i,t})\right)\right] \tag{15}$$

Differentiating (22) with respect to $e_{i,t}$, we obtain the following equation:

$$\frac{\partial V_i^c(r_{i,t})}{\partial e_{i,t}} = \frac{1}{e_i^c(r_{i,t})} - \delta(1+\gamma)V_i^{c'}\left((1+\gamma)\left(r_{it} - e_i^c(r_{i,t})\right)\right) = 0 \tag{16}$$

We next inquire whether $e_{i,t}(r_{i,t})$ can be a linear in the stock of resources so that $e_{i,t}(r_{i,t}) = s^c r_{i,t}$. This assumption implies that the stock of resources in time $t+1$ equals $r_{i,t+1} = (1+\gamma)(1-s^c)r_{i,t}$ so that the player's indirect utility now reads as:

$$V_i^c(r_{i,t}) = \left[\ln(s^c r_{i,t}) + \delta\ln\left(s^c r_{i,t}(1+\gamma)(1-s^c)r_{i,t}\right) + \delta^2\ln\left(s^c r_{i,t}(1+\gamma)^2(1-s^c)^2 r_{i,t}\right) + \dots\right] \tag{17}$$

Factoring yields:

$$V_i^c(r_{i,t}) = \frac{\ln(s^c r_{i,t})}{1-\delta} + \sum_{t=0}^{\infty}\delta^t\ln\left((1+\gamma)^t(1-s^c)^t\right) \tag{18}$$

Thus implying that:

$$V_i^{c'}(r_{i,t}) = \frac{1}{(1-\delta)r_{i,t}} \tag{19}$$

This is turn allows to re-write (16) as:

$$\frac{1}{s^c r_{i,t}} - \frac{\delta(1+\gamma)}{(1-\delta)(1+\gamma)(r_{i,t} - s^c r_{i,t})} \Leftrightarrow s^c = 1-\delta \tag{20}$$

And we therefore conclude that $e^c_{i,t} = (1-\delta)r_{i,t}$.

Derivation of the "low" extraction rates, $e^p_{i,t}(k^l_{i,t}, .)$:

The extraction rates defined in the paper as "low" correspond to the extraction rates the social planner would impose on the players. Proceeding as above, and denoting by $V^l(r_t)$ the value function of this problem given the resource stock r_t, the indirect aggregate utility can be expressed as a Bellman equation:

$$V^l(r_t) = \arg\max_{e_{1,t},e_{2,t}} \left[\sum_{i=1,2} \ln(e_{i,t}) + \delta V^l(r_{t+1}) \right] \tag{21}$$

Given the assumed regeneration rule, the above expression can be written as:

$$V^l(r_t) = \arg\max_{e_{1,t},e_{2,t}} \left[\sum_{i=1,2} \ln(e_{i,t}) + \delta V^l((1+\gamma)(r_t - e_{1,t} - e_{2,t})) \right] \tag{22}$$

Differentiating (22) with respect to the two decision variables, $e_{1,t}$ and $e_{2,t}$, we obtain the following system of equations:

$$\begin{cases} \frac{\partial V^l(r_t)}{\partial e_{1,t}} = \frac{1}{e_1^l(r_t)} - \delta(1+\gamma)\sum_{i=1,2} V_i^{l'}\left((1+\gamma)\left(r_t - e_1^l(r_t) - e_2^l(r_t)\right)\right) = 0 \\ \frac{\partial V^l(r_t)}{\partial e_{2,t}} = \frac{1}{e_2^l(r_t)} - \delta(1+\gamma)\sum_{i=1,2} V_i^{l'}\left((1+\gamma)\left(r_t - e_1^l(r_t) - e_2^l(r_t)\right)\right) = 0 \end{cases} \tag{23}$$

Where these equations hold because the constraint $e_{1,t} + e_{2,t} \le r_t$ will never be binding, as $\lim_{r_t \to 0} V_i^{l'} = +\infty$.

From (23) we deduce that $e_1^l(r_t) = e_2^l(r_t) = e^l(r_t)$. To derive the efficient equilibrium, we inquire whether $e^l(r_t)$ may be a linear function of its argument so that $e^l(r_t) = s^l r_t$. This assumption implies that the stock of resources in time period $t+1$ can be expressed as $r_{t+1} = (1+\gamma)\left(1-2s^l\right)r_t$. Replacing in V_i^l, together with using the regeneration rule gives us:

$$V^l(r_t) = 2\left[\ln\left(s^l r_t\right) + \delta\ln\left(s^l(1+\gamma)(1-2s^l)r_t\right) + \delta^2\ln\left(s^l(1+\gamma)^2(1-2s^l)^2 r_t\right) + \ldots\right] \tag{24}$$

Rearranging the terms of (24) gives us:

$$V^l(r_t) = \frac{2\ln\left(s^l r_t\right)}{1-\delta} + 2\sum_{\tau=0}^{\infty} \delta^\tau \ln\left((1+\gamma)^\tau(1-2s^l)^\tau\right) \tag{25}$$

Thus implying that $V^{l'}(r_t) = \frac{2}{(1-\delta)r_t}$. Substituting in (23) for $V^{l'}(.)$ yields:

$$\frac{1}{s^l r_t} - \frac{2\delta(1+\gamma)}{(1-\delta)(1+\gamma)(1-2s^l)r_t} \Rightarrow s^l = \frac{1-\delta}{2}$$

And we therefore conclude that $e_{i,t}^l = \frac{1-\delta}{2} r_{i,t}$.

Derivation of the "high" extraction rates, $e_{i,t}^p(k_{i,t}^h, k_{i,t}^h)$ and $e_{i,t}^p(k_{i,t}^h, k_{i,t}^l)$:

We begin by focusing on the extraction rates that prevail at the Markov-Perfect equilibrium of this game, namely at the equilibrium where strategies cannot be conditioned on the game's history. Denote these strategies by N. Proceeding as above, we have:

$$V_i^N(r_t) = \arg\max_{e_{i,t}} \ln(e_{i,t}) + \delta V_i^N(r_{t+1}) \tag{26}$$

From which we deduce:

$$\frac{\partial V^N(r_t)}{\partial e_{i,t}} = \frac{1}{e_i^N(r_t)} - \delta(1+\gamma)V_i^{N'}\left((1+\gamma)\left(r_t - e_1^N(r_t) - e_2^N(r_t)\right)\right) = 0$$

And following the above steps we easily obtain that $e_{i,t}^N = \frac{1-\delta}{2-\delta} r_{i,t}$. The extraction rates imposed in the paper when both players opt for a "high" extraction technology, $e_{i,t}^p(k_{i,t}^h, k_{j,t}^h)$, therefore emulate the Markov Perfect equilibrium extraction rates.

Lastly, we consider the optimal "deviation" from the social planner's solution, namely the optimal extraction rate when facing a player who follows the social planner's instructions, and in expectation that any subgame will involve "high" extraction rates. Player i's optimisation problem reads as:

$$\max_{e_{i,t}} \ln(e_{i,t}) + \delta V^N\left(\left(r_{t+1} - e_{i,t} - \frac{1-\delta}{2}\right)(1+\gamma)\right)$$

Replacing for the appropriate values and optimising yields the optimal extraction rate $e_{i,t}^{dev}$ given by:

$$e_{i,t}^{dev} = \frac{(1-\delta)(1+\delta)}{2} r_t \tag{27}$$

And lastly we set $e_{i,t}^{dev} = e_{i,t}^p(k_{i,t}^h, k_{j,t}^l)$.

A.1.2 Proof of Condition (7)

Proof. We want to prove that $f(\delta) = \ln\left(\frac{2}{2-\delta}\right) - \delta\ln(1+\delta) \geq 0, \forall\delta \in [0,1]$.

We have

$$f'(\delta) = \frac{1}{2-\delta} - \frac{\delta}{1+\delta} - \ln(1+\delta) \tag{28}$$

$$f''(\delta) = \frac{1}{(2-\delta)^2} - \frac{1}{(1+\delta)^2} - \frac{1}{1+\delta}. \tag{29}$$

$f''(\delta)$ is increasing in $[0,1]$ and $f''(1) < 0$. Hence, $f''(\delta) < 0, \forall\delta \in [0,1]$. This implies that $f'(\delta)$ is decreasing $[0,1]$. It is easy to see that $f'(0) > 0 > f'(1)$. Hence, $\min_{\delta\in[0,1]} f(\delta) = \min(f(0), f(1)) = 0$. We therefore conclude that $f(\delta) \geq 0$ $\forall\delta \in [0,1]$.

□

A.1.3 Proof of Condition (9)

Proof. We want to prove that $f(\delta) = (1-\delta)\ln\left(\frac{\phi}{2}\right) - \ln(2-\delta) < 0, \forall\delta \in [0,1)$, and $\phi \leq 0,4$.

We have

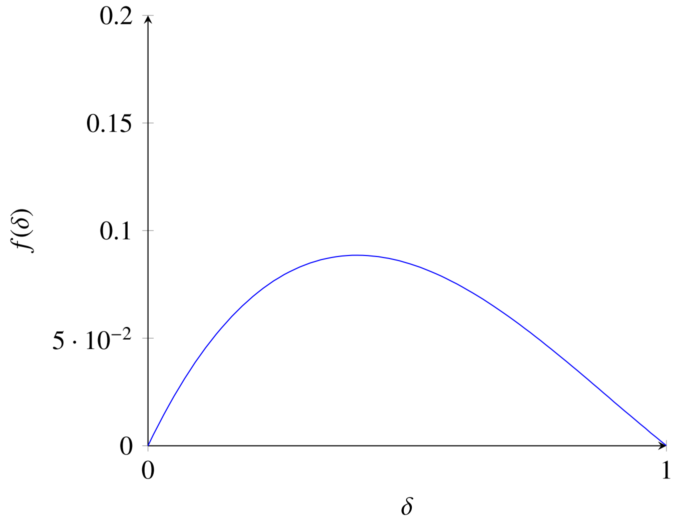
$$f'(\delta) = -\ln(\phi/2) + \frac{1}{2-\delta} > 0 \tag{30}$$

Fix next $\phi = 0,4$. We then have that $f(1) = 0$. It thus follows that $\forall\delta < 1$ and $\forall\phi \leq 0,4$, Condition (9) is satisfied. □

A.1.4 Derivation of expression (11)

Plugging $e_{i,t}^{dev}(r_t)$ and $e_{j,t}^l(r_t)$ in the law of motion of resources gives:

$$r^{t+1} = \frac{\delta(\delta+1)(1+\gamma)}{2}$$



Replacing in expression (10) yields:

$$\ln\left(\frac{(1-\delta)(1+\delta)}{2}r_t\right)+\frac{\delta}{1-\delta}\ln\left(\frac{(1-\delta)(1+\gamma)\delta(1+\delta)}{2(2-\delta)}r_t\right)+\frac{\delta^2}{(1-\delta)^2}\ln\left(\frac{\delta(1+\gamma)}{2-\delta}\right)$$
$$<\frac{1}{1-\delta}\ln\left(\frac{1-\delta}{2}r_t\right)+\frac{\delta}{(1-\delta)^2}\ln\left(\frac{1-\delta}{2}\right) \quad (31)$$

Simplifying yields:

$$(1-\delta)\ln(1+\delta)+\delta\ln\left(\frac{1}{2-\delta}\right)<0$$

which straightforwardly gives expression (11).

A.1.5 Proof that Condition (11) holds for any $\delta \in (1/2)$

For Expression (11) to hold for $\delta \in (1/2, 1)$, we require that for that range of parameters:

$$f(\delta)=\delta\ln(2-\delta)-(1-\delta)\ln(1+\delta)>0$$

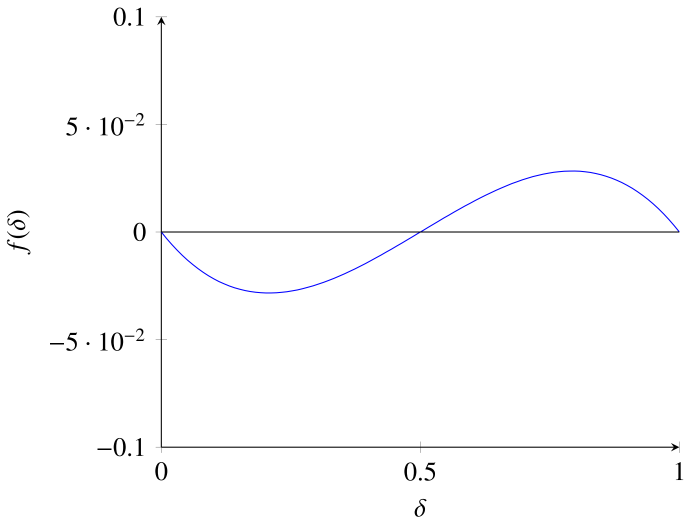
We can first easily verify that $f(1/2)=f(1)=0$.

We next compute $f^{'}(\delta)$ and $f^{''}(\delta)$ which equal, respectively:

$$f^{'}(\delta)=\ln(2-\delta)+\ln(1+\delta)-\frac{\delta}{2-\delta}-\frac{1-\delta}{1+\delta}$$
$$f^{''}(\delta)=\frac{3+\delta}{(1+\delta)^2}-\frac{4-\delta}{(2-\delta)^2}$$

From these expressions we can obtain that $f^{'}(1/2)=2\ln(3/2)-2/3>0$ and $f^{'}(1)=\ln(2)-1<0$. Since $f^{''}(1/2)=0$ and $f^{''}(1)=-2<0$, to complete the proof it is sufficient to establish that $f^{'''}(\delta)<0$ over $\delta\in[1/2;1]$ so that $f^{''}(\delta)<0$, $\forall\delta>1/2$. And this last condition is verified since:

$$f'''(\delta) = -\frac{4-\delta}{(2-\delta)^2} - \frac{5+\delta}{(1+\delta)^3} < 0 \qquad , \forall \delta \in [1/2, 1]$$



A.2 Model with no destruction and endogenous conflict efforts

In this Appendix, we consider exactly the same setting as in Section 2, with the difference that (i) $\phi(r_t) = 1, \forall t$, (ii) in case of conflict players equally decide the amount of resources g_i, $i \in \{1, 2\}$ to devote to conflict, and (iii) the stock of resources is share by players according to the following technology instead of being split up in two:

$$\sigma_i(g_i, g_j) = \frac{g_i + \alpha/2}{g_i + g_j + \alpha}$$

with $\alpha > 0$.

For the results of Proposition 2 to hold, it is thus sufficient to show that there exists a $\bar{r}$ such that $g_i, g_j = 0, \forall r < \bar{r}$.

Re-writing the discounted expected utility under conflict as expressed in (3), taking into account the new assumptions of this section, we can write:

$$V_i^c(r_t) = \frac{1}{1-\delta} \ln\left((1-\delta)\frac{g_i + \alpha/2}{g_i + g_j + \alpha}\left(r_t - g_i - g_j\right)\right) + \frac{\delta}{(1-\delta)^2} \ln((1+\gamma)\delta)$$

Optimising this expression with respect to g_i yields:

$$\frac{(1-\delta)\left(\frac{g_j+\alpha/2}{(g_i+g_j+\alpha)^2}(r_t - g_i - g_j) - \frac{g_i+\alpha/2}{g_i+g_j+\alpha}\right)}{(1-\delta)\frac{g_i+\alpha/2}{g_i+g_j+\alpha}\left(r_t - g_i - g_j\right)} = 0$$

Imposing symmetry, observing that $r_t > g_i + g_j$ at equilibrium, and denoting equilibrium conflict efforts by g^*, we obtain:

$$\frac{g^* + \alpha/2}{(2g^* + \alpha)}(r_t - 2g^*) - (g^* + \alpha/2) = 0$$

$$\Leftrightarrow g^* = \frac{r_t - \alpha}{4}$$

And since $\alpha > 0$, it follows that there exists $\bar{r} > 0$ such that $g^* = 0, \forall r \leq \bar{r}$.

A.3 Instructions to the conflict treatment

In this section we present the instruction handed to the conflict treatment alone. The control group received the same instructions, with the difference that the cost of chance was maintained equal to 60% of the resources throughout.

Welcome,

You are about to participate in an experiment on decision-making. You will be paid for your participation in cash, privately, at the end of the session. What you earn depends partly on your decisions, partly on the decisions of others, and partly on chance.

Please turn off all electronic devices now.

The entire experiment will take place through computer terminals. Please do not talk or in any way try to communicate with other participants until everybody has been told that the experiment is over and that you can leave the room.

We will now give you some time to carefully read the following instructions. If you have any questions, please raise your hand and your question will be answered so everyone can hear.

Overview & Payment

In this experiment you will play **the same game 20 times**. Each time you play, the computer will randomly pair you up with someone else in the room (but you don't know with whom). So, in each game you are paired with a random person in the room. The **first 10 games** you play will be for **practice**. The **remaining 10 games will be for real**.

Each game lasts for at least 6 rounds. After the 6^{th} round, you will enter each next round with a probability of 70% (so with a 30% probability the game ends). So, if you happen to enter round 7, there is a 70% share that you will enter round 8 and so on and so forth.

When you have played the game 10 times, each game lasting 6 or more rounds, you will be paid. Your payment has two components, an **initial endowment of** £5 and **a payment of** £1.50 **per point won**. To establish how many points you have won, we will randomly **draw 2 of the last 10 games (the for-real games)** you played and pay you according to the amount of points you won in those games. So, your final payment will be ***your initial endowment*** plus ***your points payment***.

> Here is an example:
> Say, the random draws were games 4 and 6, and you won **5.6 points** and **2.4 points** in those games respectively.
> Then your final payment would be: **3 + (5.6 + 2.4) x 1.50 = £15**.

Depending on how you play and for how many rounds the game continues, it is possible that you will get negative points, though this is unlikely.

Here is another example:

Say, the random draws were games 4 and 6, and you got **-2.4 points** and **1.2 points** in those games respectively.

Then your final payment would be: **3 + (-1.2 + 2.4) x 1.50 = £4.80**.

So, to conclude, the choices you make really matter.

Playing a game

At the beginning of each game, you and your opponent both start with a joint stock of 40 points. Each round, you can choose how much of this stock of points you want to take. Whatever you and your opponent choose each round will affect how much stock there will be left next round.

The game continues like this. In the second round you choose how much to take of the remaining stock and that will affect how much stock will be left in round 3, and so on and so forth, until the game ends.

So, there are two things to understand: **choice** and **stock**.

Your choices are:

- **Low**
- **High**
- **Chance**

Low:

If you choose **low** and your opponent chooses **low** too, you **each take 15%** of the points in stock (e.g. 15% of 40 points = 6 points).

If you choose **low** and your opponent chooses **high**, **you take 15%** of the points (**e.g. 15% of 40 points = 6**) and your **opponent takes 25.5%** of the points (25.5% of 40 points = 10.2).

If you choose **low** but your opponent chooses **chance**, then you are in **chance mode**. What this means is described below.

High:

If you choose **high** and your opponent chooses **low**, **you take 25.5%** of the points (25.5% of 40 points = 10.2) and **your opponent takes 15%** of the points (15% of 40 points = 6).

If you choose **high** and your opponent chooses **high** too, you **each take 23%** of the points (23% of 40 points = 9.2 points).

If you choose **high** but your opponent chooses **chance**, then you are in **chance mode** (described below).

Chance:

If either **you or your opponent pick chance**, then **both of you** will be in **chance mode**.

If one of you has played **chance**, (so that you are both in **chance mode**) you will each take **15% of the stock** in all of the remaining rounds. As explained more in detail below, the total number of points you will collect is entirely left to *chance* under this scenario since you will not be making any more decisions after picking this option.

Playing **chance** is **costly**. Once chance is chosen, a cost will be taken away from your joint stock. The **cost** is a **one-off loss of points**, so it will **only be applied once** when you enter chance mode, but not in subsequent rounds of chance mode. Depending on the size of the current stock, this is how much playing chance would cost:

Stock:	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	...	0
Cost:	24	21.8	19.8	17.8	15.8	14	12.2	10.6	9	7.4	6	4.6	3.4	2.2	1	0	0	...	0

There is more to know about your choices:

The **points that you take** from the current stock each round are not exactly the **points that you get to keep**. There is a **formula**, which describes how many points you get to keep each round.

This will involve some mathematics, i.e. the natural logarithm. If you don't like maths, don't worry about understanding what logarithm means. All you need to know is that the **natural logarithm** of ***something*** is quite a bit **less** than that ***something***.

Anyway, the following table shows how this works. In **round 1** you **get to keep the natural logarithm of the points you decide to take**. In **round 2** you get **70%** of the **natural logarithm of the points you take**. In round 3, you get to keep **70% of 70%** of the natural logarithm of the points you took, and so on and so forth. (Note that "ln" just means natural logarithm.)

Round	**Points you get to keep**
1	ln(points you take)
2	70% × ln(points you take)
3	70% × 70% × ln(points you take) =49% × ln(points you take)
4	70% × 49% × ln(points you take) =34% × ln(points you take)
5	70% × 34% × ln(points you take) =24% × ln(points you take)
6	70% × 24% × ln(points you take) =17% × ln(points you take)

Here are two examples:

Suppose you are in round 1, where your current stock is 40. If you both chose **low**, the points you would take would be 15% of 40 points (i.e. 6 points) each. But you would only get to keep ln**(points you take)**, which is ln(**6**) ≈ **1.79**.

Suppose again that you are in round 1, where your current stock is 40. If you chose **low** and your opponent chose high, you would again take 15% of 40 points (i.e. 6 points) and your opponent would take 25.5% of 40 points (i.e. 10.2 points). Here you would only get to keep ln(points you take), which is ln(6) ≈ 1.79 and your opponent would get to keep ln(10.2) = 2.32.

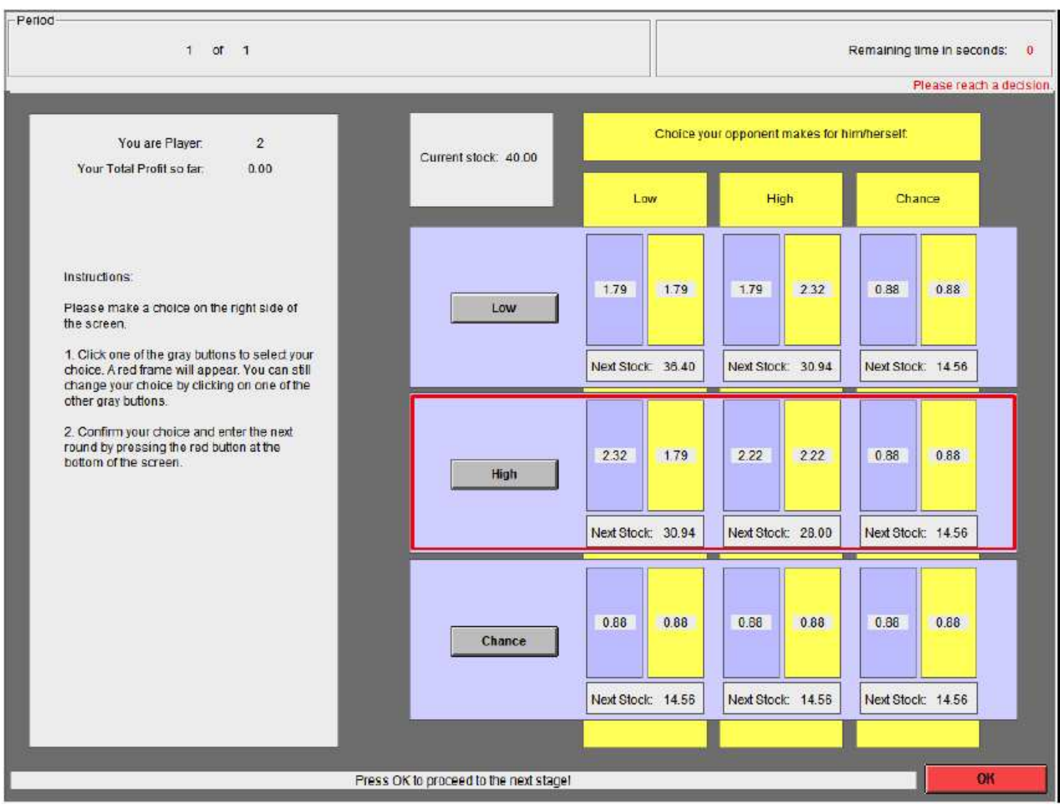
Now, if you remember, **after round 6 there is only a 70% probability** of getting into each subsequent round. To be precise, at the end of each round **after round 6** the computer software will roll a virtual, 100-sided dice and will end the game if a number higher than 70 comes up on that virtual dice.

This has an **effect on** the **points you get to keep from round 7 onwards**. From Round 7 onwards, you and your opponent can make the same choices as previously but now **you continuously get to keep 17% of the natural logarithm of the points you take** for each additional round played. The following table illustrates this:

Round	Shares of playing the round	Points you get to keep
7	70%	$=17\% \times \ln(\text{points you take})$
8	70%	$=17\% \times \ln(\text{points you take})$
9	70%	$=17\% \times \ln(\text{points you take})$
10	70%	$=17\% \times \ln(\text{points you take})$
11	70%	$=17\% \times \ln(\text{points you take})$
...	...	...

This is what your screens look like:

The following picture shows you what your first screen will look like. The **grey buttons** are your **choices**. The **purple boxes** display the **points you get to keep**, the **yellow boxes** display the **points your opponent gets to keep**. The **little grey boxes** show you what your **next stock** will be if you were to make that choice. The **big grey boxes** show you what either player **would get** if you were to choose chance.



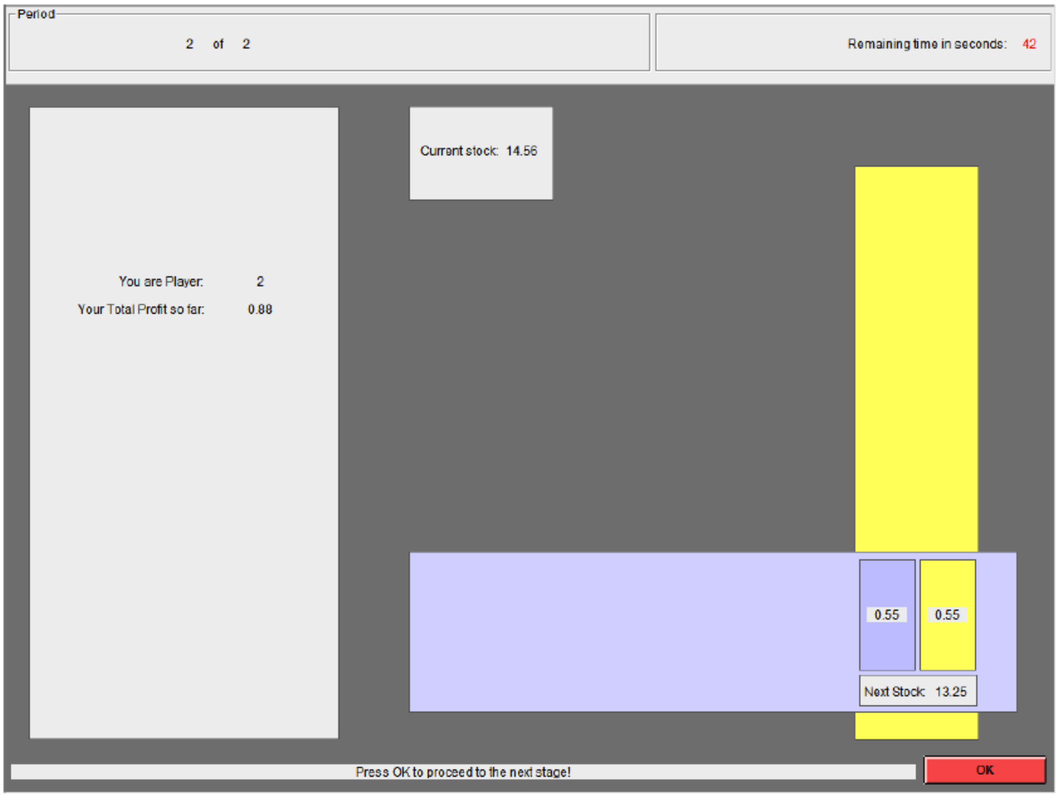
If you click a **choice button**, a red frame will appear around the choice that you have picked (see image).

If you click on the **"chance" choice-button**, a **box will appear** next to it. It tells you what the **cost of choosing chance** would be, if you chose it in your **current round**. The following screenshot gives an example:

Of course, you do not know what your opponent's choice will be until the next round, so do not wait for him/her.

At the bottom of the screen there is a **red OK button**. You ought to **press it** in order to **confirm your choice and enter the next round**.

Finally, the following picture shows the screen you would get if either of you were to choose chance; it shows you what **chance mode** looks like:



Stock:

Now, there is a little more to know about the stock of points. First, depending on the choices made, the stock decreases in size. But second, it also replenishes. It regrows by 30% each round. This is how the next stock of points is calculated:

1. Current stock - points you take - points opponent takes = remaining stock

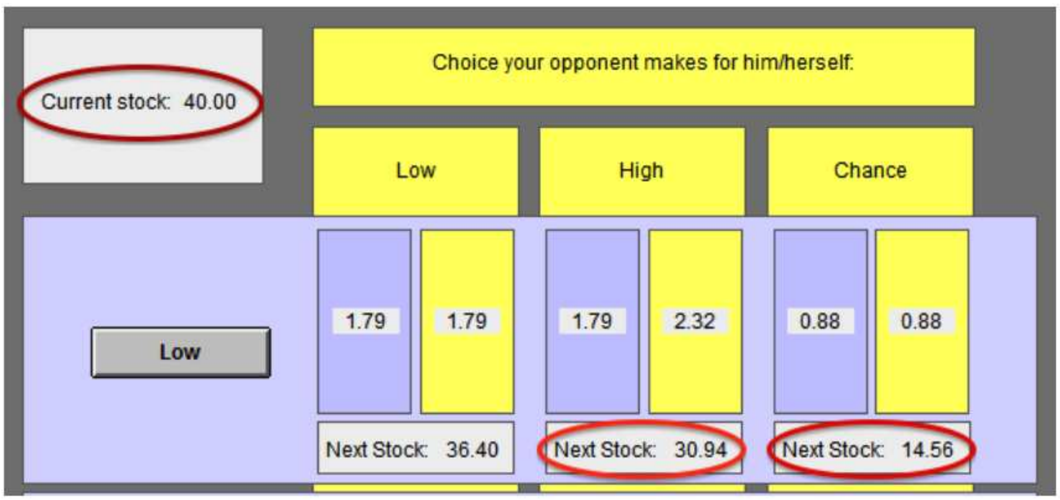
2. Remaining stock + 30% = next stock

Here are two examples:

Suppose the **current stock** is **40** and **you choose low** and your **opponent chooses high**. Then we calculate: (**40** − **6** − **10**.**2**) × **1**.**30** = **30**.**94** points.

Suppose the **current stock** is **40** and **you choose low** and your **opponent chooses chance**. Then we calculate: (**40** − **24** − **3**.**2** − **1**.**6**) × **1**.**3** = **14**.**56** points. Here the 24 is the cost of playing chance, if you remember from above.

This picture highlights your **current stock** and **next stock** if **you choose low** and if **your opponent** chooses either **high** or **chance**:



This is it. Good luck!

Table A1: Effect of 'conflict' on the choice of Low - interaction terms

Dependent variable:	Low					
	(1)	(2)	(3)	(4)	(5)	(6)
Conflict	-0.121***	-0.119***	-0.126***	-0.121***	-0.118***	-0.126***
	(0.030)	(0.030)	(0.029)	(0.030)	(0.030)	(0.029)
Rounds 1		-0.004			0.219***	
		(0.043)			(0.075)	
Rounds 1 × Conflict		-0.027			-0.028	
		(0.054)			(0.055)	
Rounds 1-2			-0.030			-0.035
			(0.027)			(0.034)
Rounds 1-2 × Conflict			0.040			0.040
			(0.040)			(0.040)
Full set of controls	✓	✓	✓	✓	✓	✓
Game & Round FE				✓	✓	✓
Observations	10,464	10,464	10,464	10,464	10,464	10,464
R-squared	0.071	0.071	0.071	0.079	0.079	0.079

Notes: Standard errors clustered at the individual level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Rounds 1 and Rounds 1-2 are dummies equal to one for the first round and the first two rounds, respectively. FE=fixed effects. Full set of controls includes Male, Science and Social, Game and Round.

Table A2: Effect of 'conflict' on the choice of High - interaction terms

Dependent variable:	High (1)	(2)	(3)	(4)	(5)	(6)
Conflict	-0.273***	-0.326***	-0.317***	-0.272***	-0.326***	-0.317***
	(0.035)	(0.037)	(0.036)	(0.035)	(0.037)	(0.036)
Rounds 1		-0.145***			0.239**	
		(0.046)			(0.116)	
Rounds 1 × Conflict		0.480***			0.480***	
		(0.060)			(0.060)	
Rounds 1-2			-0.078***			-0.196***
			(0.029)			(0.042)
Rounds 1-2 × Conflict			0.400***			0.400***
			(0.050)			(0.050)
Full set of controls	✓	✓	✓	✓	✓	✓
Game & Round FE				✓	✓	✓
Observations	10,464	10,464	10,464	10,464	10,464	10,464
R-squared	0.099	0.125	0.121	0.120	0.143	0.136

Notes: Standard errors clustered at the individual level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Rounds 1 and Rounds 1-2 are dummies equal to one for the first round and the first two rounds, respectively. FE=fixed effects. Full set of controls includes Male, Science and Social, Game and Round.

Table A3: Effect of 'sure conflict' on the choice of Low - controlling for the resource stock

Dependent variable:	Low (1)	(2)	(3)	(4)	(5)	(6)
Sure Conflict	-0.223***	-0.137**	-0.055	-0.294***	-0.135**	-0.056
	(0.029)	(0.064)	(0.050)	(0.029)	(0.064)	(0.050)
Round	0.016***		0.564***			
	(0.005)		(0.078)			
Game	-0.009***	-0.019***	-0.012***			
	(0.002)	(0.005)	(0.004)			
Resource stock	0.012***		0.056***	0.032***		0.055***
	(0.002)		(0.007)	(0.003)		(0.007)
Male	-0.008	0.017	0.011	-0.013	0.017	0.011
	(0.032)	(0.071)	(0.052)	(0.028)	(0.071)	(0.052)
Science	-0.041	-0.120	-0.131**	-0.031	-0.120	-0.131**
	(0.042)	(0.087)	(0.060)	(0.038)	(0.088)	(0.060)
Social	-0.019	0.000	-0.014	-0.012	0.001	-0.014
	(0.035)	(0.077)	(0.058)	(0.031)	(0.077)	(0.058)
Rounds 1		✓			✓	
Rounds 1-2			✓			✓
Game & Round FE				✓	✓	✓
Observations	7,700	888	1,776	7,700	888	1,776
R-squared	0.103	0.039	0.072	0.144	0.041	0.074

Notes: Standard errors clustered at the individual level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. FE=fixed effects.

Table A4: Effect of 'sure conflict' on the choice of High - controlling for the resource stock

Dependent variable:	High (1)	(2)	(3)	(4)	(5)	(6)
Sure Conflict	-0.507***	0.140**	0.053	-0.365***	0.138**	0.054
	(0.030)	(0.064)	(0.052)	(0.023)	(0.064)	(0.052)
Round	-0.025***		-0.445***			
	(0.006)		(0.104)			
Game	0.014***	0.018***	0.011***			
	(0.003)	(0.005)	(0.004)			
Resource stock	-0.002		-0.043***	-0.041***		-0.043***
	(0.002)		(0.011)	(0.003)		(0.010)
Male	0.002	-0.013	-0.008	0.013	-0.013	-0.008
	(0.035)	(0.071)	(0.054)	(0.029)	(0.071)	(0.054)
Science	0.061	0.122	0.135**	0.042	0.122	0.135**
	(0.044)	(0.087)	(0.062)	(0.038)	(0.088)	(0.063)
Social	0.042	0.013	0.009	0.028	-0.001	0.009
	(0.040)	(0.077)	(0.060)	(0.033)	(0.077)	(0.060)
Rounds 1		✓			✓	
Rounds 1-2			✓			✓
Game & Round FE				✓	✓	✓
Observations	7,700	888	1,776	7,700	888	1,776
R-squared	0.253	0.040	0.050	0.350	0.042	0.052

Notes: Standard errors clustered at the individual level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. FE=fixed effects.