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Abstract

Masuda et al. (2014) showed that the minimum approval mechanism (AM) implements the efficient level of public good theoretically and experimentally in a linear public good game. We extent this result to a two-players common pool resource (CPR) game. The AM adds a second stage into the extraction game. In the first stage, each group member proposes his level of extraction. In the second stage, the proposed extractions and associated payoffs are displayed and each player is asked to approve or to disapprove both proposed extractions. If both players approve, the proposals are implemented. Otherwise, a uniform level of extraction, the *disapproval benchmark* (DB), is imposed onto each player. We consider three different DBs: the minimum proposal (MIN), the maximum proposal (MAX) and the Nash extraction level ($NASH$). We derive theoretical predictions for each DB following backward elimination of weakly dominated strategies ($BEWDS$). We first underline the strength of the AM, by showing that the MIN implements the optimum theoretically and experimentally. The sub-games predicted under the $NASH$ are Pareto improving with respect to the Nash equilibrium. The MAX leads, either to Pareto improving outcomes with respect to the free access extractions, or to a Pareto degradation. Our experimental results show that the MAX and the $NASH$ reduce the level of over-extraction of the CPR. The MAX leads above all to larger reductions of (proposed and realized) extractions than the $NASH$.

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1 Introduction

This paper addresses the effectiveness of the approval mechanism (AM) in reducing or avoiding over-extraction of a common pool resource (CPR). We consider the case of a two-players non-cooperative game. In the absence of regulation, selfish rational agents will be reluctant to sacrifice their private benefits in order to achieve a greater group benefit. Therefore, whenever private interests dominate the group interest, the group extraction level from the CPR will usually be inefficient.

The general principle of the AM can be thought as a two-stage game. In stage 1 players submit proposals. In stage 2 submitted proposals become common knowledge and each player is asked to approve or to disapprove them. If all players approve, the first stage decisions are implemented. If at least one player disapproves[1], a uniform action is imposed on all players. For instance, the court where the conciliation is required before the trial is a good illustration for the AM. If the conciliation fails the verdict of the trial depends on the interpretation of the law, i.e. the standard decision.

Mechanisms that introduce an additional stage to an original game were previously studied by Varian (1994a,b), Andreoni and Varian (1999), Falkinger (1996) and Falkinger et al. (2000). Falkinger (1996)'s mechanism was designed for public goods dilemma. In stage 1 of the contribution game, each player chooses a level of contribution. In stage 2, individual contributions are compared to the group's average contribution. A player whose contribution is larger (lower) than the average, receives a subsidy (pays a tax) in a way that is budget balanced. Falkinger et al. (2000) studied this mechanism experimentally and showed that it leads to a significant increase of the contributions, approaching the efficient level. However, Falkinger (1996)'s mechanism implements the efficient contribution only under specific conditions. Varian (1994a) and Andreoni and Varian (1999) implemented a mechanism that introduces a pre-commitment stage, allowing each player to compensate his counterpart if he or she cooperates. Such mechanism leads to a socially optimum outcome, theoretically. Saijo et al. (2018) tested the compensation mechanism and observed a

[1]The unanimity approval rule is a particular case. One may consider other rules, such as the majority rule.

low performance in early periods. As an alternative to Falkinger (1996)'s mechanism, Saijo et al. (2015, 2016, 2018) proposed the approval mechanism. An interesting property of the AM is that it is carried out endogenously (i.e. by the group members themselves). In the second stage, all group members are involved in its implementation by choosing to approve or disapprove others' proposals. In addition, the AM is a simple and easy-to-implement mechanism that can restore optimality by inducing players to choose collectively the efficient level of contribution in a public good game. Applied to a CPR game, the AM provides a non-monetary incentive that can limit extractions to levels which are compatible with the Pareto level of extraction, independently of the players' preferences[2].

Prior empirical research showed that the adverse outcomes in social dilemma games [3] can be mitigated or avoided. In the case of voluntary contributions to a public good Falkinger (1996), Davis and Holt (1999), Andreoni and Varian (1999) and Masuda et al. (2014) proposed mechanisms that are effective at increasing cooperation. Equivalently, in the case of extractions from a CPR, Walker et al. (2000) showed that over-harvesting can be prevented through a collective action mechanism such as a sharing rule.

In the CPR game, the AM transforms the initial simultaneous extraction game, into a two-stage game in which the extraction stage is followed by the approval stage. In case of approval the first stage extractions are implemented, otherwise a common extraction level is enforced. We will call this uniform extraction level, the disapproval benchmark (DB). There are many possibilities to define the disapproval benchmark. It can be exogenously set, for instance as the symmetric Nash extraction level of the unregulated CPR game ($NASH$), or endogenously from the stage 1 extraction vector. For instance, the endogenous DB could be the minimum extraction level (MIN), the maximum extraction level (MAX), the average level, the median level or any combination of the first stage submitted extraction proposals.

[2]A pro-social player aims at maximizing the joint payoff of himself and the other party, as the benevolent social planner. On the other hand, a selfish rational player maximizes only his own payoff without regard to the other payoff. Therefore if the AM induces a social optimum level of extraction for a selfish player, it also does so for any player whose preferences support pro-social behavior.

[3]Low contributions to public goods, over-extraction from CPRs or high levels of emission of pollutants.

Saijo et al. (2015, 2018) investigated the effectiveness of the AM in the prisoners' dilemma. In stage 1 players had to choose between "cooperate" and "defect". In stage 2, in case of disapproval, the NASH DB, i.e. "defect", was implemented. Saijo et al. (2015, 2018) showed that the $NASH$ implements the cooperative outcome in the prisoners dilemma. An obvious extension of this game is the linear public good. The AM transforms the voluntary contribution mechanism into the two-stage game previously described. Masuda et al. (2014) showed experimentally that the $NASH$ and the MIN contributions are both effective in providing the efficient level of public good. However, the $NASH$ implements the Pareto efficient level of public good provision as a sub-game perfect equilibrium, only when the set of voluntary contribution levels is restricted to zero and full contribution. In contrast, the MIN implements the optimum level of public good without requiring such a restriction.

Our aim is to study the effectiveness of the AM in the case of a CPR game. The AM was never considered for a CPR dilemma, but only for the prisoner dilemma and the linear public good game. Our objective was to investigate whether the AM can also solve the social dilemma in the CPR game. We do this in two ways. First, we show theoretically that the MIN implements the socially optimal level of extraction by backward elimination of weakly dominated strategies ($BEWDS$). Second, we provide experimental evidence that this is indeed the case.

The CPR game represents another canonical example of social dilemma. However, there are some key differences with the voluntary contribution mechanism for public goods provision. It is therefore useful to provide feedback about the relevance of the AM for different types of dilemmas. In the standard linear public good game, payoffs are linearly determined by contributions. Therefore, the Nash equilibrium and the Pareto optimum level of contribution lie at the corners of the set of strategies. The Nash equilibrium is also a dominant strategy equilibrium and there is no rivalry in the provision of the public good. In contrast, in the CPR game, payoffs depend non-linearly on extractions, both the Nash equilibrium level of extraction and the Pareto optimum level of extraction are interior in the strategy space, and extractions are rival.

Considering the DB, the MIN may be perceived differently in the CPR game than in the public good game. While in the public good game it might be considered as a sanction, in the CPR game it could be interpreted as a reward. The MIN was initially studied by Masuda et al. (2014) in the context of the provision of a linear public good. The idea underlying the choice of the MIN in this context, is that no player is liable for more than he offered to contribute in the first stage. This property was called "voluntariness" by Masuda et al. (2014). It is therefore tempting to consider a DB that satisfies the same property in the CPR context. Although the MAX seems to be a possible candidate, it does not always satisfy voluntariness because of the non-linearity of the payoff function in the CPR game.[4] From a deeper point of view, in a population of heterogeneous players, voluntariness is difficult to justify, as it appears to be discriminatory in favour of selfish players. For instance, in the context of the linear public good game, altruistic players or Kantian players who follow a categorical imperative, would suffer a utility loss with any mechanism that does not implement their most preferred contribution. If one such player proposed more than the MIN in stage 1, forcing him to contribute the MIN in stage 2 would entail a utility loss that is not necessarily compensated by the material refund that he receives by contributing the MIN. Therefore, in a population of players with heterogeneous preferences the AM will usually violate voluntariness. This is the reason why we relax this principle and consider DBs that are not necessarily compatible with it.

Our experimental design involves three test treatments corresponding to three different DBs: the $NASH$, the MIN and the MAX contributions. The control treatment is the standard one-stage CPR game. 146 subjects, split into 73 two-player groups, participated in the experiment which relied on a partner pairing. Each pair of subjects played the CPR game over 20 periods, broken into two sequences of 10 periods. In test treatments, subjects played the unregulated CPR game in sequence 1 and the CPR game under the AM in sequence 2. The control groups played the unregulated CPR game over the two sequences. We rely on panel data analysis, using a Difference in Differences (DiD) approach, to estimate treatment effects.

[4]Under the MIN, voluntariness is satisfied only if total group extraction is above the threshold $X = (a - p)/b$. However, it is not satisfied under the MAX as mentionned in appendix 6.7.

We report four main finding. First, all DBs reduce significantly the level of group extraction. Second, the MIN is more effective at reducing the level of extraction than the MAX and the $NASH$. Third, only the MIN allows to implement the optimum extraction level. Finally, the MAX is more effective at reducing the level of extraction than the $NASH$.

The rest of the paper is organized as follows. Section 2 derives the theoretical predictions. Section 3 presents the experimental design and section 4 exhibits the summary statistics and the results. Section 5 discusses the results and section 6 concludes.

2 Predictions

2.1 Unregulated CPR game

We consider a simple two-players CPR dilemma. Each player ($i \in \{1, 2\}$) simultaneously chooses his level of extraction from the CPR, noted x_i such as $x_i \in [0, w]$. The total group extraction noted X is equal to the sum of extractions of the 2 players: $X = x_i + x_j$. Let $w > 0$ be the endowment of the two homogeneous players. Player i invests $w - x_i$ in a private activity which has a constant return $p > 0$. The payoff $\pi_i(x_i, x_j)$ of player i is the sum of the payoff from the CPR extraction and that from the private activity.

- If $x_i > 0$,

$$\pi_i(x_i, x_j) = \frac{x_i}{x_i + x_j}[a(x_i + x_j) - b(x_i + x_j)^2] + p(w - x_i) \tag{1}$$

- If $x_i = 0$,

$$\pi_i(x_i, x_j) = pw \tag{2}$$

$$\pi_i(x_i, x_j) = \frac{x_i}{X}[F(X)] + p(w - x_i) \tag{3}$$

$$F(X) = a(X) - b(X)^2 \tag{4}$$

a and b are positive constants and $\frac{x_i}{x_i+x_j}$ is the fraction of the group payoff from the CPR extraction captured by player i. $p > 0$ can be interpreted as an opportunity cost.

We denote by $\pi \equiv (\pi_1, \pi_2)$ the payoff vector corresponding to the extraction vector $x \equiv (x_1, x_2)$ of the group members. Under the selfish rational agent hypothesis, player i maximizes $\pi_i(x_i, x_j)$. The unique Nash equilibrium leads to the individual extraction level $x^* = \frac{1}{3}\frac{a-p}{b}$ with associated payoff $\pi^* = \frac{(a-p)^2}{9b} + pw$. The corresponding group extraction is $X^* = \frac{2}{3}\frac{a-p}{b}$. Assuming pro-social agents, each player maximizes the group payoff, which leads to the individually socially efficient extraction level $\hat{x} = \frac{a-p}{4b}$ *, with associated individual payoff* $\hat{\pi} = \frac{(a-p)^2}{8b} + pw$ and group extraction $\hat{X} = \frac{a-p}{2b}$. In the experiment we adopt the parameters proposed by Walker et al. (1990): $a = 23$, $b = 0.25$, $p = 5$ and $w = 10$ tokens. With these parameters we obtain, $\hat{x} = 6$, $\hat{X} = 12$, $\hat{\pi} = 312$, $x^* = 8$, $X^* = 16$ and $\pi^* = 294$. In the experiment extraction units were defined as tokens[5] and payoffs were expressed in ecus.

Without regulation, the extractions from the CPR lead to over-extraction, i.e. a level of extraction above the efficient extraction. Although the predicted level of over-extraction corresponds to the Nash extraction, empirical findings showed that over-extraction could be even worse than predicted by the Nash equilibrium (Hardin, 1968; Lindahl et al., 2016). The possible extractions and associated payoffs ($\pi(x_i, x_j)$) are summarized in Table 1. The first line (column) indicates the possible extraction levels of the mate (self). They were restricted in the experiment to integers between 0 and 10. Each cell shows two values separated by a semicolon. The values in bold correspond to the payoff of the mate (player j) and the other values correspond to the payoff of player i. At the Nash equilibrium each player extracts 8 units from the CPR and gets a payoff of 294 ecus.

Proposition 1 (Nash equilibrium): *In the unregulated CPR game with selfish rational players, the unique symmetric Nash Equilibrium is given by:* $x^* = \frac{1}{3}\frac{a-p}{b}$, $\pi^* = \frac{(a-p)^2}{9b} + pw$ *and* $X^* = \frac{2}{3}\frac{a-p}{b}$. *With the parameters of the experiment we have:* $x^* = 8$ *tokens,* $\pi^* = 294$ *ecus and* $X^* = 16$ *tokens.*

[5] 1 token is equal to 3 units of CPR extraction level

2.2 The CPR game with the approval mechanism

We now introduce the Approval Mechanism (AM). The CPR game with approval involves 2 stages. Stage 1 is the same as in the CPR extraction game without regulation. In stage 2, the players' extraction levels and their resulting payoffs are publicly revealed. Once informed, each player is asked to approve or disapprove his group mate's proposed extraction. The proposed extractions are implemented if both players approve. If at least one of them disapproves, the DB is imposed on each one.

We consider three DBs as mentioned above (MIN, MAX and NASH). There is a fundamental difference between the MIN and the MAX on one hand, and the $NASH$ on the other hand. MIN and MAX are endogenously determined while $NASH$ is exogenously set. That is why we discuss them separately. Furthermore, in the CPR context the AM does not always satisfy voluntariness, a key property introduced by Masuda et al. (2014). The violation of this property has important implications, both for the implementation of the mechanism and from a behavioral point of view as mentionned in the introduction.

We use backward elimination of weakly dominated strategies to identify the equilibrium solution for each version of the AM.

2.2.1 The CPR game with the MIN disapproval benchmark

Under the CPR game with MIN, the minimum of stage 1 proposed extractions is the DB. Consider extractions, x_i and x_j proposed in stage 1 by player i and j, respectively. Let x_i and x_j belong to the strategy set $S = [\ 0, w]$. By simplification, the payoff of both players for the proposals can be written as follows: $\pi_i(x_i, x_j) = ax_i - bx_i(x_i + x_j) + p(w - x_i)$ and $\pi_j(x_i, x_j) = ax_j - bx_j(x_i + x_j) + p(w - x_j)$. Suppose that $x_i < x_j$, i.e., $xi = min(x_i, x_j)$. Thus, $\pi(x_i, x_i) = ax_i - 2bx_i^2 + p(w - x_i)$. Under the MIN, in stage 2, player i approves/disapproves by comparing his payoff $\pi_i(x_i, x_j)$ to $\pi(x_i, x_i)$. Thus, player i approves if and only if $\pi_i(x_i, x_j) \geq \pi(x_i, x_i)$ and disapproves for $\pi_i(x_i, x_j) < \pi(x_i, x_i)$.

Proposition 2: *The MIN implements the symmetric Pareto-efficient outcome by $BEWDS$.*

Proof: The proof of proposition 1 is divided into 2 parts.

- Firstly, we show that only symmetric sub-games survive to $BEWDS$ in stage 2.
  Suppose that $x_i < x_j$. Thus, $\pi(x_i, x_i) - \pi_i(x_i, x_j) = bx_i(x_j - x_i) \geq 0$. Therefore, the player who proposes the minimum (x_i) always disapproves asymmetrical proposals. For this reason, the proposed extractions (x_i, x_j) such that $x_i < x_j$ and (x_i, x_i) have the same payoff for both players. In other words, $\pi_i(x_i, x_j) = \pi_j(x_i, x_j) = \pi(x_i, x_i) = ax_i - 2bx_i{}^2 + p(w - x_i)$ if $x_i < x_j$. Consequently, only the sub-games for which both players propose the same extraction level survive to $BEWDS$ in stage 2.

- We now address the second part of the proof by showing that $\hat{x}$ weakly dominates all strategies $x_1 \in [0, \hat{x}) \cup (\hat{x}, \bar{x}]$ by following Masuda et al. (2014, p. 76)[6]
  a) Consider the case $x_2 \in [0, x_1]$. We have $\pi_1(x_1, x_2) = \pi_1(x_2, x_2) < \pi_1(x_1, x_1)$. Now, consider that $x_2 \in (x_1, \hat{x}]$, then, $\pi_1(x_1, x_2) = \pi_1(x_1, x_1) < \pi_1(x_2, x_2) = \pi_1(\hat{x}, x_2) < \pi_1(\hat{x}, \hat{x})$. It proves that $\hat{x}$ weakly dominates all strategies $x_1 \in [0, \hat{x})$.
  b) Consider $x_1 > x_2 > \hat{x}$. Thus, $\pi_1(x_1, x_1) < \pi_1(x_1, x_2) = \pi_1(x_2, x_2)$. Moreover, consider that $x_2 \in [\hat{x}, x_1)$, $\pi_1(x_1, x_2) = \pi_1(x_2, x_2) < \pi_1(\hat{x}, x_2) = \pi_1(\hat{x}, \hat{x})$. Therefore, $\hat{x}$ weakly dominates all strategies $x_1 \in (\hat{x}, \bar{x}]$, where $\bar{x}$ is the highest extraction level.

2.2.2 The CPR game with the MAX disapproval benchmark

The MAX means that the maximum of stage 1's proposed extractions is implemented in case of disapproval. Suppose $x_i = max(x_i; x_j)$. Thus, player i approves the proposed extraction levels if and only if $\pi_i(x_i, x_j) \geq \pi(x_i; x_i)$ and disapproves if $\pi_i(x_i, x_j) < \pi(x_i; x_i)$.

[6]Secondly, we show that Pareto-efficient sub-game $(\hat{x}, \hat{x})$ weakly dominate others symmetrical sub-games. The two players determine the outcome of the DB in the set of a uniform extraction vectors. To do so, player i maximizes his payoff under the constraint of uniform extraction vector: **maximize** $\pi_i(x_i, x_j)$ **wrt** $x_i = x_j$. The solution of this problem is Pareto-efficient extraction level $\hat{x} = \frac{a-p}{4b} = 6$ tokens , $\hat{\pi} = \frac{(a-p)^2}{8b} + pw = 312$ ecus and $\hat{X} = \frac{a-p}{2b} = 12$ tokens.

Table 1: Both players payoff Table when $a = 23$, $b = 0.25$ and $p = 5$

		mate										
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
self	0	150 ; **150**	150 ; **201.75**	150 ; **249**	150 ; **291.75**	150 ; **330**	150 ; **363.75**	150 ; **393**	150 ; **417.75**	150 ; **438**	150 ; **453.75**	150 ; **465**
	1	201.75 ; **150**	199.5 ; **199.5**	197.25 ; **244.5**	195 ; **285**	192.75 ; **321**	190.5 ; **352.5**	188.25 ; **379.5**	186 ; **402**	183.75 ; **420**	181.5 ; **433.5**	179.25 ; **442.5**
	2	249 ; **150**	244.5 ; **197.25**	240 ; **240**	235.5 ; **278.25**	231 ; **312**	226.5 ; **341.25**	222 ; **366**	217.5 ; **386.25**	213 ; **402**	208.5 ; **413.25**	204 ; **420**
	3	291.75 ; **150**	285 ; **195**	278.25 ; **235.5**	271.5 ; **271.5**	264.75 ; **303**	258 ; **330**	251.25 ; **352.5**	244.5 ; **370.5**	237.75 ; **384**	231 ; **393**	224.25 ; **397.5**
	4	330 ; **150**	321 ; **192.75**	312 ; **231**	303 ; **264.75**	294 ; **294**	285 ; **318.75**	276 ; **339**	267 ; **354.75**	258 ; **366**	249 ; **372.75**	240 ; **375**
	5	363.75 ; **150**	352.5 ; **190.50**	341.25 ; **226.5**	330 ; **258**	318.75 ; **285**	307.5 ; **307.5**	296.25 ; **325.5**	285 ; **339**	273.75 ; **348**	262.5 ; **352.5**	251.25 ; **352.5**
	6	393 ; **150**	379.5 ; **188.25**	366 ; **222**	352.5 ; **251.25**	339 ; **276**	325.5 ; **296.25**	312 ; **312**	298.5 ; **323.25**	285 ; **330**	271.5 ; **332.25**	258 ; **330**
	7	417.75 ; **150**	402 ; **186**	386.25 ; **217.5**	370.5 ; **244.5**	354.75 ; **267**	339 ; **285**	323.25 ; **298.5**	307.5 ; **307.5**	291.75 ; **312**	276 ; **312**	260.25 ; **307.5**
	8	438 ; **150**	420 ; **183.75**	402 ; **213**	384 ; **237.75**	366 ; **258**	348 ; **273.75**	330 ; **285**	312 ; **291.75**	294 ; **294**	276 ; **291.75**	258 ; **285**
	9	453.75 ; **150**	433.5 ; **181.5**	413.25 ; **208.5**	393 ; **231**	372.75 ; **249**	352.5 ; **262.5**	332.25 ; **271.5**	312 ; **276**	291.75 ; **276**	271.5 ; **271.5**	251.25 ; **262.5**
	10	465 ; **150**	442.5 ; **179.25**	420 ; **204**	397.5 ; **224.25**	375 ; **240**	352.5 ; **251.25**	330 ; **258**	307.5 ; **260.25**	285 ; **258**	262.5 ; **251.25**	240 ; **240**

In stage 2, if player i, proposes the highest extraction level, he always approves sub-game (x_i, x_j), because $x_i \geq x_j$ implies that $\pi(x_i, x_i) - \pi_i(x_i, x_j) = bx_i(x_j - x_i) \leq 0$.

We now look at the best response of player j, proposing the lowest extraction level. We show that $\pi(x_i, x_i) - \pi_j(x_i, x_j) = (x_i - x_j)(a - p - b(2x_i + x_j))$. Since $x_i \geq x_j$, we only look at the sign of the expression $a - p - b(2x_i + x_j)$.

Proposition 3:*Under the MAX, players following $BEWDS$ propose and approve the sub-game (x_i, xj) if $x_i + \frac{1}{2}x_j < \hat{X}$ and $x_i \geq x_j$; where $\hat{X} = \frac{a-p}{2b}$ is the group optimal extraction level.*

2.2.3 The CPR game with the exogenous ($NASH$) disapproval benchmark

The Nash extraction level, $x^* = \frac{1}{3}\frac{a-p}{b}$, with associated payoffs $\pi^* = \frac{(a-p)^2}{9b} + pw$, is implemented if at least one member of the group disapproves. Thus, player i approves if only if $\pi_i(x_i, x_j) > \pi^*$. For the set of sub-games with extraction levels between $\frac{1}{2}x^*$ and x^*, players make higher payoffs than by choosing Nash extraction levels.

Proposition 4: *In the CPR game with the $NASH$, there exists a non-empty set of approved sub-games, including the efficient extraction vector, which are Pareto improving with respect to the Nash equilibrium.*

With our parameters ($a = 23$, $b = 0.25$ and $p = 5$ and $w = 10$ tokens) the individual optimal extraction level is 6 tokens. This corresponds to the sub-game (6.6), with the associated payoff vector $(312, 312)$. The Nash extraction level is 8 tokens per player, which corresponds to the sub-game $(8, 8)$ and associated payoff vector $(294, 294)$. Figures 1, 2 and 3 presents the set of extraction levels mutually approved in stage 2, using $BEWDS$.

In stage 2, under $BEWDS$, the MIN implements symmetric extraction levels. However, in addition to the symmetric extraction levels, the MAX leads to asymmetric extraction levels, that are higher than the Nash extraction level (see fig. 2). Furthermore, The $NASH$ forces players to extract amounts of resource that are less or equal to the Nash extraction level, and which are distributed around the optimum (see fig. 3). With the MIN, $BEWDS$ leads to the optimum in stage 1 because sub-game $(6,6)$ weakly dominates any other symmetrical sub-game. Nevertheless, under the MAX or under the $NASH$, each player has an incentive to deviate from the optimum by over-extracting, for example, 10 or 7 tokens. Indeed, the sub-games $(10,6)$ and $(7,6)$ have been approved in stage 2 under the MAX and the $NASH$, respectively. The payoffs in sub-games $(10,6)$ and $(7,6)$ are $(352.5, 251.25)$ and $(323.25, 298.5)$, respectively. They provide a higher payoff to the player who deviates from the optimum extraction.

Figure 1: Approved extractions in stage 2 under MIN

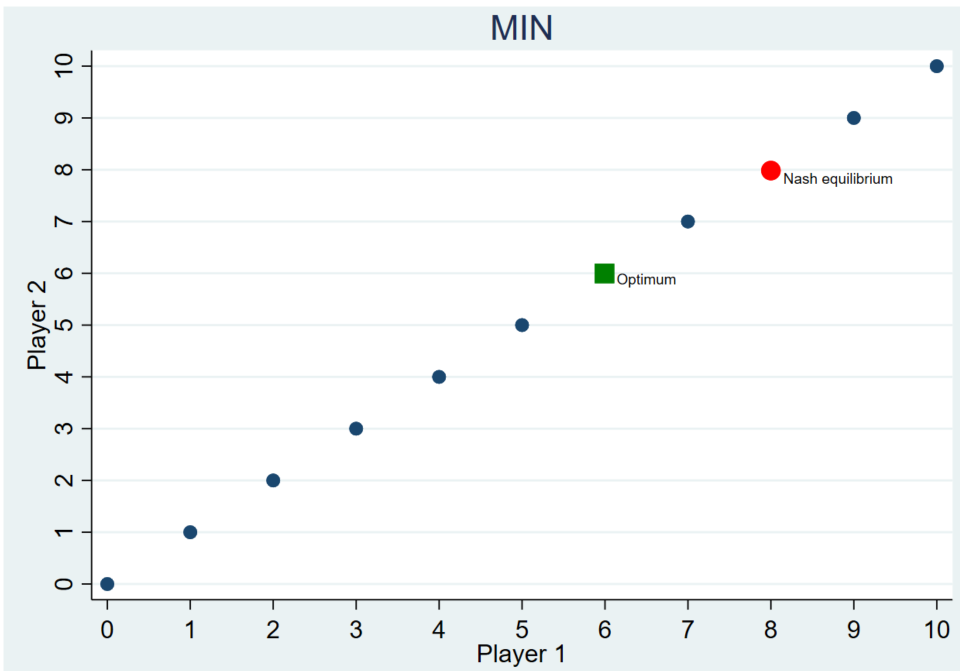


Figure 2: Approved extractions in stage 2 under MAX

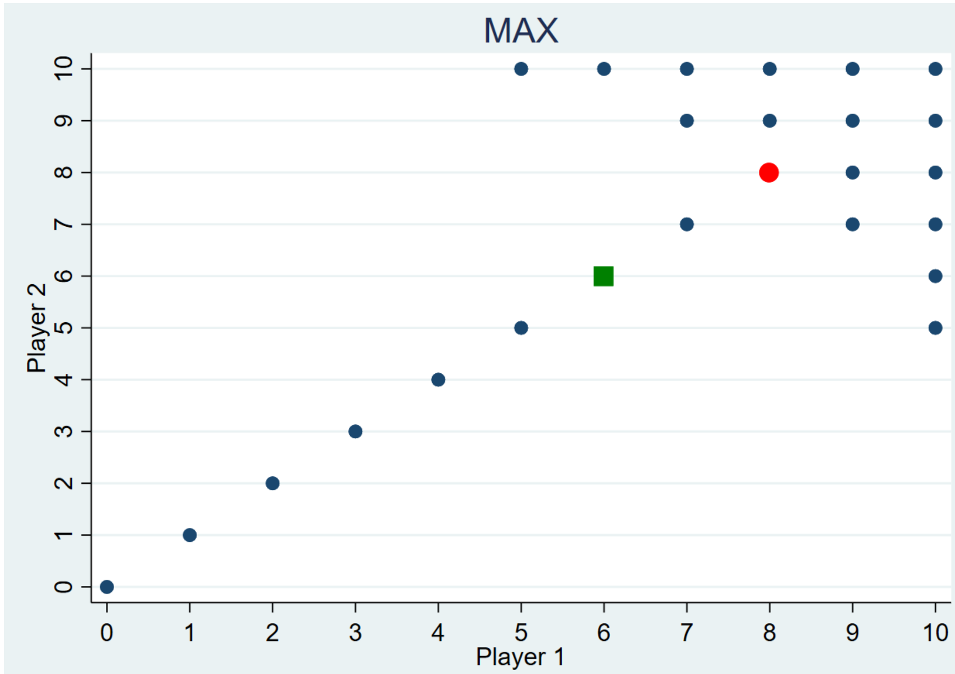
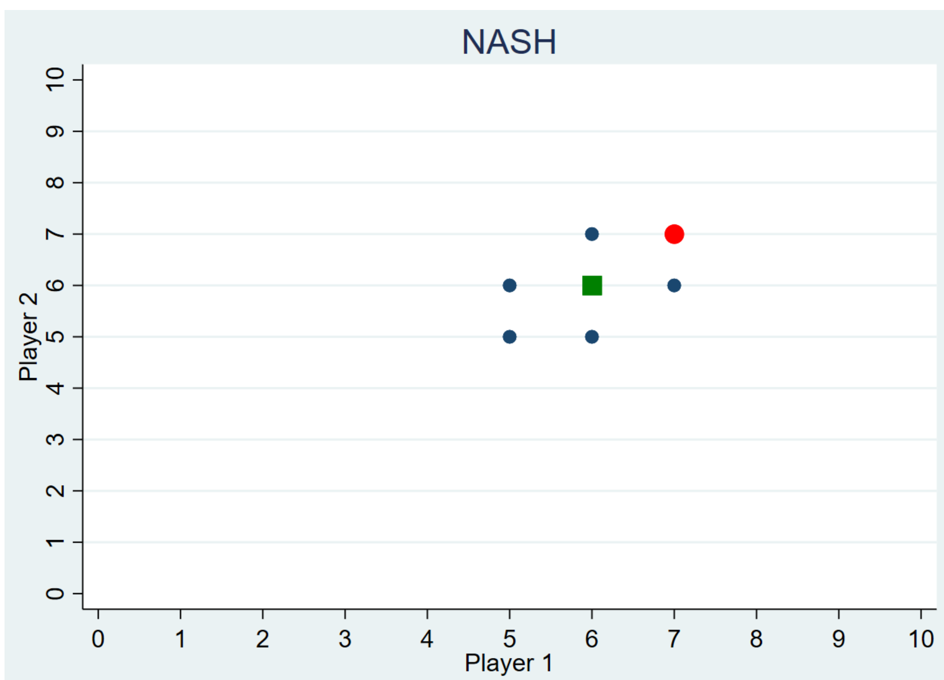


Figure 3: Approved extractions in stage 2 under NASH



3 Methodological issues

In this section, we discuss the experimental design and the experimental procedure as well as the empirical strategy.

3.1 Experimental design

We set up an experimental design to test the theoretical predictions presented in Section 2 (see propositions 1-3) based on a partner setting. The main reason for choosing the partner pairing is that we wanted to study the effectiveness of the AM conceived as an instrument to promote cooperation at the group level, which means that we wanted to carry the statistical analysis at the group level, rather than at the individual level. By choosing a stranger matching we could only conduct the analysis at the individual level which would have changed somehow the focus and the message of the paper. To control for potential reputation and beliefs effects, we implement a DiD analysis. Indeed, the partner pairing is not only in the treated groups but also in the baseline groups. Hence, the difference in difference model assumes that reputation effects, if they exist, are captured before the introduction of the AM. The first sequence of 10 periods, played both in treatment groups and in baseline groups, allows to control for repeated game effects. More generally, unobserved factors that are common to both types of groups are controlled by the DiD analysis. We are able to isolate the effect of the AM on the level of group extraction as long as the only change in the 11th period is the availability of the AM. Everything else is already captured before the introduction of AM thanks to the baseline. The DiD model thus infers the causal impact of AM on the level of extraction of the group.

We consider four treatments: a control treatment and three AM treatments, involving three DB: $NASH$, MIN and MAX. The $NASH$ and MIN were already investigated by Masuda et al. (2014) in the case of a linear public good game. In this paper, we test the robustness of $NASH$ and MIN in the CPR game. Furthermore, we also consider the AM treatment based on the MAX. The MIN (respectively the MAX) could induce different perceptions by the participants in the CPR game compared to the linear public good game. Indeed, the payoff function has a positive slope in the public good game. In contrast, in the CPR game, the payoff function is bell-shaped. Beyond the optimal extraction level, the payoff function is negatively sloped. The MAX (MIN) is therefore likely to trigger high (low) contributions. The opposite holds behind the optimal extraction level. Therefore, we conjecture that the MAX in the CPR game, has a similar impact than the MIN in the linear public good game, because each DB is likely to be perceived as a sanction in the corresponding game. Furthermore, both the implementation of the DB and the optimum outcome share the common property of equalizing players' payoffs. This particularity is likely to create an attraction effect for inequality averse players as they end up with equal payoffs.

Note that we deliberately chose not to control for the ordering of the treatments because our main question, as the title of the paper shows, is: "does the AM help avoiding group over-extraction in 2 player CPR games?" This requires to establish first that in the absence of any regulation (sequence 1) groups tend to over-harvest the CPR. This is indeed what we observed: in sequence 1 over-harvesting arises, even beyond the Nash extraction. Once established that over-harvesting occurs in all groups, we wanted to demonstrate that the AM curbs the extractions towards the optimal level as predicted. We therefore chose a within-group design, keeping constant the group composition and with a specific treatment ordering. Of course, reversing the treatments raises an interesting issue: do groups who experienced the AM behave in a more cooperative way (preserving more the resource) than baseline groups, once the mechanism is removed? This issue is among our future projects as it raises an interesting behavioral question. However, this question is not directly relevant for the issue of the effectiveness of the AM which is the main reason why we did not consider it for this project.

3.2 Practical procedures

Data were collected at the LEEM[7] of the CEEM[8] in Montpellier. Participants were predominantly bachelor and master degree students from various disciplines, e.g. economics, life science,

[7]Author would like to thank the Experimental Economic Laboratory of Montpellier (LEEM) for technical support

[8]Center for environmental economics - Montpellier

management, computer science, and others. All participants were volunteers recruited from the LEEM[9] database.

8 sessions were organized, involving between 16 and 20 participants. A total of 146 subjects, split into 73 groups of two players, participated in the experiment which relied on a partner pairing. Each pair of subjects played the CPR game over 20 periods, split into two sequences of 10 periods, with the AM being implemented from the11^{th} period. In the treated groups (with AM), subjects played the unregulated CPR game in sequence 1 and the CPR game under the AM in sequence 2. The control groups played the unregulated CPR game over the two sequences.

Once participants arrived at the LEEM, they were seated in a cubicle in front of a computer. They received general instructions for the whole experiment, as well as specific instructions for sequence 1. After the 10 periods of sequence 1, they received new instructions for sequence 2. In the general instructions, participants were informed that they will be in groups of two and that the composition of their group would be unchanged for the duration of the experiment. They were also informed that only one of the 20 periods would be randomly selected to be paid at the end of the session at the exchange rate of 1 euro for 15 ecus. In each period, each participant was endowed with 10 tokens, and had to decide how many of them to invest in CPR extraction. Extraction decisions were made simultaneously and no communication was allowed. At the end of each period, the extraction of each member of the group and the associated payoffs were displayed. In sequence 2, when the AM was implemented, subjects were informed about the two stages. In stage 1, each participant proposed his level of extraction. In stage 2, after displaying the stage 1 extractions and their corresponding payoffs, each member of the pair had to approve or to disapprove the other participant's proposal. They were aware that in case of mutual approval, the proposed extractions would be implemented. In case of disapproval, the minimum (MIN), the maximum (MAX) or the Nash ($NASH$) contribution was imposed onto each group member. Each participant was assigned to only one of the 4 treatments. Table 2 summarizes our experimental design.

[9]http://leem.umontpellier.fr/

Table 2: Summary of treatments

	AM Treatments			Control
	NASH	MAX	MIN	
Sequence 1 : Periods 1-10	Unregulated	Unregulated	Unregulated	Unregulated
Sequence 2 : Periods 11-20	AM	AM	AM	Unregulated
Number of groups and participants	20 groups 40 participants	19 groups 38 participants	17 groups 34 participants	17 groups 34 participants

3.3 Empirical strategy

Our goal is to assess the impact of the implementation of an AM on the extraction level. We estimate difference in differences model using the implementation of the AM as an exogenous control change. We rely on both temporal and group variation. Group extractions are observed under unregulated CPR in sequence 1 and after the introduction of the AM in sequence 2. In addition, we compare the level of group extraction in both sequences in treatment groups where the AM is implemented and in control groups where the AM remains absent. Using a panel data set, we implement this by estimating the following equation :

$$Y_{it} = \alpha_0 + \alpha_1[seq \times AM]_{it} + \zeta_t + \mu_i + \epsilon_{it} \tag{5}$$

Where Y_{it} is the extraction level of group i in period t. Turning to the independent variables, seq is an indicator variable for sequence 2 when the AM is activated and AM is an indicator variable for whether an AM is implemented. α_1 is our coefficient of interest. The interaction variable $seq \times AM$ corresponds to the causal effect of the AM on the extraction level . ζ_t corresponds to period and sequence fixed effects and acts as a control for temporal patterns[10]. To control for time invariant characteristics of the group we include group fixed effect (μ_i). ϵ_{it} corresponds to the error term. A key assumption in difference in differences model is that trends should not

[10]The period dummy corresponds to twice 10 periods in order to take into account the 10 periods timing of the game

be significantly different between the two groups in the pre-treatment sequence, i.e. sequence 1. Figure 4 provides support to this assumption. The average group extraction for all treatments do not differ significantly in sequence 1 (Kruskal-Wallis, p-value > 0.05).

As explained in previous sections, we consider various types of AM. It leads us to empirically evaluate various combination of DB. Equation 5 first captures the magnitude of the overall effect of the AM on group extractions whatever the DB. We then want to compare endogenous DB (MIN and MAX) to exogenous DB ($NASH$) to finally compare the two endogenous DB. Thus, we respectively regress the following equations:

$$Y_{it} = \alpha_0 + \alpha_2[seq \times AM \times ENDO]_{it} + \alpha_3[seq \times AM]_{it} + \zeta_t + \mu_i + \epsilon_{it} \quad (6)$$

and

$$Y_{it} = \alpha_0 + \alpha_4[seq \times AM \times ENDO \times MIN]_{it} + \alpha_5[seq \times AM \times ENDO]_{it} + \alpha_6[seq \times AM]_{it} + \zeta_t + \mu_i + \epsilon_{it} \quad (7)$$

where Y_{it} is the extraction level of group i in period t. seq is an indicator variable for sequence 2. It equals 1 for sequence 2 (where the AM is activated) and 0 for sequence 1. AM is equal to 1 for groups for which an AM is activated and is equal to 0 otherwise. $ENDO$ is equal to 1 for endogenous DB (MIN or MAX) and 0 for exogenous DB, i.e. NASH. Finally, in order to distinguish between MIN and MAX, we create an indicator variable, MIN, that takes value 1 when MIN is implemented in sequence 2 and 0 otherwise. ζ_t and μ_i corresponds respectively to our temporal and group fixed effect. ϵ_{it} corresponds to the error term. In equations 6 and 7 the coefficients of interest are α_2 and α_4. α_2 is the additional effect of $ENDO$ on the global effect of AM, i.e., α_1 (see Equation 5). α_2 allows to compare the effectiveness of the endogenous DB with respect to the exogenous DB. In equation 7, α_4 is the additional effect of he MIN on the effect of $ENDO$ (α_2). Then, α_4 allows the comparisons of both endogenous DB (MIN vs MAX).

In the results section, we compare separately the effectiveness of the $NASH$ and the MAX on one hand, and on the $NASH$ and the MIN on the other hand. To do so, we measure the additional marginal effect of the $NASH$ with respect to the MAX and the additional effect of the $NASH$ with respect to the MIN (see Tables 6 and 7). Thus, we alternatively remove MAX (Panel A) and MIN (Panel B) from the sample[11]. Indeed, in the first column (see Panel A) of the Tables 6 and 7, the variable AM is coded 1 for the MIN and the NASH DBs and 0 for the control groups. seq remains 1 for sequence 2 and 0 for sequence 1. $NASH$ is coded 1 for the NASH and 0 for the MIN DB and the control groups. Therefore, $seq \times AM$ is the average combined reduction due to the NASH and the MIN and $seq \times AM \times NASH$ represents the additional effect of NASH which allows the comparison between the $NASH$ and the MIN. In the same way, in the second column (see panel B) of both of Tables 6 and 7, the variable AM is coded 1 for the MAX and the NASH DB and 0 for the control groups. seq remains 1 for sequence 2 and 0 for sequence 1. NASH is coded 1 for the NASH and 0 for the MAX DB and the control groups. Therefore, $seq \times AM$ is the average reduction due to the $NASH$ and the MAX and $seq \times AM \times NASH$ represents the additional effect of the NASH, which allows the comparison between the NASH and the MAX.

4 Results

We aim to assess the efficiency of the AM for reducing group extraction. We focus on one dimension of the AM: the DB, i.e. the default extraction level implemented in case of disapproval. More specifically, we compare the MIN, the MAX and the $NASH$. To do so, we separately analyze the stage 1 group extractions (proposed extractions) and the implemented group extractions after stage 2 (realized extractions). In sub-section 4.1 we present the summary statistics and in subsection 4.2 the results of the difference in differences (DiD) estimation approach.

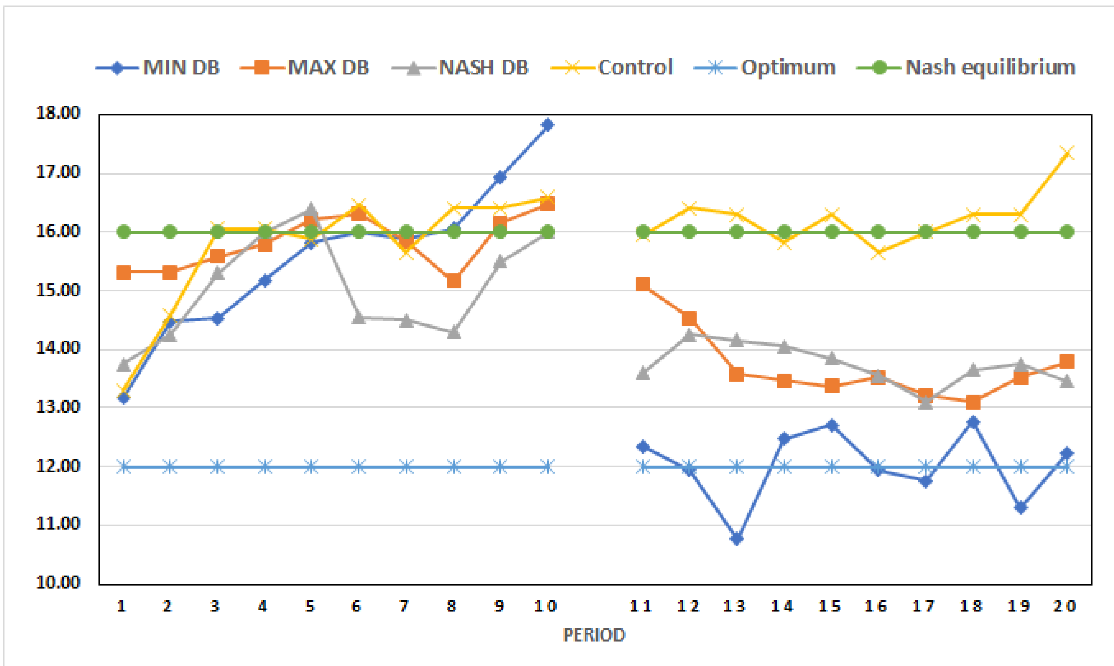
4.1 Summary statistics

Figure 4 presents the trend of the average group extraction over the 20 periods for each of the treatments. Periods 1-10 relate to sequence 1, i. e. the unregulated CPR game. Periods 11-20 (sequence 2) refer either to the regulated CPR under AM DB or to the unregulated CPR game

[11]the comparison between $NASH$ and MAX versus MIN as well as $NASH$ and MIN versus $NASH$ is not of interest that is why there are alternatively removed from the sample

in the case of control groups. The Nash equilibrium and the optimum correspond to 16 and 12 tokens, respectively. Thus, in sequence 1, the average group extraction per period is higher than the optimum for all treatments. According to the Kruskal-Wallis test, the average group extractions in sequence 1 do not differ across treatments (p-value= 0.092) [12]. As shown in Table 3, the average group extractions are quite close to the Nash equilibrium extraction level.

Figure 4: Average realized extraction over periods



Note : Periods 1-10 (sequence 1) relate to the unregulated CPR game. Periods 11-20 (sequence 2) refer to the regulated CPR game under the AM for the treated groups, and to the unregulated CPR game for the control groups. The Nash equilibrium is at 16 tokens and the optimum at 12 tokens.

Let us consider first the control groups. According to figure 4, in sequence 2, the average group extraction per period does not differ from the Nash equilibrium extraction level, except towards the end of the sequence where extractions increase. The average group extraction of sequence 1 does not differ from that of sequence 2 (see Table 3), (signed-rank, p-value=0.167) [13]. Finally, average group extraction in sequence 1 (sequence 2) does not differ from the Nash equilibrium

[12]This test is based on 40 independent observations.
[13]This test is based on 20 independent observations (10 observations per sequence).

extraction level (rank-sum, p-value=0.375) [14] .

Considering realized extractions, from figure 4 it seems that MAX and $NASH$ do not differ, while MIN seems to converge to the optimum (12 tokens). We can also see that the MAX and the $NASH$ implement a Pareto-improving level of extraction compared to the control (16.24 tokens). We conclude that the AM reduces (over)extraction, following its introduction in period 11 (Figure 4).

Table 3: Average group extraction (by sequence) and AM treatment effects

	Sequence 1 (S1) Periods 1 – 10	Sequence 2 (S2) Periods 11 – 20		Within-group difference		
	(1)	proposed (2)	realized (3)	(2)-(1)	(3)-(1)	(3)-(2)
Control	15.74	16.24	16.24	0.49	0.49	0.00
NASH	15.06	13.20	13.74	-1.86	-1.32	0.54
MAX	15.82	13.14	13.72	-2.67	-2.09	0.58
MIN	15.59	13.34	12.02	-2.25	-3.56	-1.32

We finally compare the differences between sequence 2 and sequence 1 extractions (S2-S1: see column 5 in Table 3). S2-S1 measures the reduction of group extraction under each DB. Column 5 of Table 3 shows that the reduction of the realized group extraction is larger under the MIN than under the MAX and under the NASH. Finally, MAX reduces the group extraction more than NASH. These observations suggest that the reduction of group extraction is larger with endogenous than with exogenous DB.

We now turn to the analysis of stage 1, i.e. the extraction proposal. As for realized extractions, the AM leads to a reduction of over-extraction, with a larger reduction for endogenous DB. In fact, in sequence 2, under the AM, the proposed group extractions are lower on average than in sequence 1 where the CPR is unregulated. The average proposed group extractions do not

[14] This test is based on 20 independent observations (10 observations per sequence).

differ for the three DB (see column 2, Table 3). The average (proposed) group extraction under each DB is larger than or equal to the optimum but smaller than the average extraction under unregulated CPR (sequence 1). Column 4 emphasizes that all DBs reduce the proposed group extraction on average. Under the MIN, the proposed group extractions are quite close to those of the NASH and the MAX (NASH=-1.86, MIN=-2.25 and MAX=-2.67). However, the reduction is larger under the MAX than under the NASH.

Column 5 also emphasizes that all DB reduce the realized group extraction on average and that the reduction is larger under the MAX than under the NASH. Concerning the MIN and since the payoff function is bell shaped, and over-extraction arises in the negatively sloped portion of the curve, imposing the MIN tends to promote the optimum. Column 6 highlights this mechanical and negative effect of the MIN comparing proposed and realized extraction.

4.2 Detailed results

In the summary statistics, we compare the average group extraction in sequence 1, in sequence 2 and the difference between both sequences (S2-S1), respectively. The DiD allows the comparison of the differences in group extractions, before and after the implementation of a DB, between treatments by controlling for bias from unobserved variables that remain fixed over time. The estimates from equations 5, 6 and 7 are respectively presented in columns 1, 2 and 3 of Table 4 for the realized group extraction, and of Table 5 for the proposed group extraction. We first analyze whether AM reduce the level of group extraction in general, whatever the DB (MIN, MAX and $NASH$) with respect to the control group (see column 1) as presented in equation 5. Second, we compare the effectiveness of endogenous DB (MIN and MAX) with respect to exogenous DB ($NASH$) (see column 2) as presented in equation 6. Third, we compare the effectiveness of MIN with respect to MAX (see column 3) as presented in equation 7.

Result 1:*The introduction of the AM reduces significantly the level of proposed and realized group extraction.*

Support for result 1: We estimated the DiD model of equation 5. The regressions are reported in column 1 of Tables 4 and 5, for realized and for the proposed group extractions, respectively. The regressions were done on the overall data set, i.e. by taking into account all groups (MIN, MAX, NASH and the control groups). Thus, ***Result 1*** reports the overall effect of AM on group extractions. The DiD regression shows that on average the AM reduces the realized (proposed) group extraction by 2.75 (2.74) tokens. The effectiveness of the AM at reducing group extraction is therefore strong and significant.

Table 4: Impact of the AM and compared effectiveness of DBs on realized group extractions

VARIABLES	AM $overall$ (1)	$endogenous/$ $exogenous$ (2)	MIN/MAX (3)
$seq \times AM$	-2.757^{***}	-1.809^{***}	-1.809^{***}
	(0.290)	(0.341)	(0.341)
$seq \times AM \times ENDO$		-1.474^{***}	-0.780^{***}
		(0.309)	(0.348)
$seq \times AM \times ENDO \times MIN$			-1.470^{***}
			(0.397)
Constant	16.23^{***}	16.23^{***}	16.23^{***}
	(0.218)	(0.216)	(0.212)
seq	yes	yes	yes
$Group\ FE$	yes	yes	yes
$Period\ FE$	yes	yes	yes
Observations	$1,460$	$1,460$	$1,460$
R-squared	0.377	0.387	0.394
$F-test$	23.83^{***}	22.82^{***}	22.20^{***}

Note: Robust standard errors are in parentheses. * denotes significance at the 10-percent level, ** at the 5-percent level and *** at the 1-percent level. The regressions contain period, sequence and group fixed effect. All AM treatments (MIN, $NASH$ and MAX) are pooled in AM. The variable AM equals 1 for the MIN, the MAX and the $NASH$ DBs and 0 for the control groups. The variable seq equals 1 for the sequence 2 and 0 for the sequence 1. The variable $ENDO$ is coded 1 for the MAX and the MIN (both endogenous) DBs and 0 for the $NASH$ and the control groups. The variable MIN is coded 1 for the MIN and 0 otherwise. Finally, the variables $seq \times AM$, $seq \times AM \times ENDO$ and $seq \times AM \times ENDO \times MIN$ are the interaction variables. These regressions have been ran with (realized) group extractions. FE stands for "fixed effect".

Result 2*: The endogenous DB reduce significantly more proposed and realized group extractions than the exogenous DB.*

Support for result 2: We estimated the DiD model of equation 6. The coefficients are reported in column 2 of Tables 4 and 5. The coefficients of interest ($seq \times AM \times ENDO$) which captures the additional effect of endogenous DBs on the combined reduction of group extraction are negative (-1.47 tokens for the realized group extraction and -0.61 tokens for the proposed group extraction) and highly significant. Therefore, the endogenous DB reduce significantly more the realized and the proposed group extractions than the exogenous DB.

Result 3: *Proposed extractions do not differ across endogenous DB.*

Result 4: *The MIN reduces significantly more the realized group extractions than the MAX .*

Support for result 3 and for result 4: We estimated the DiD model of equation 7. Coefficients reported in column 3 of Table 4 support result 4 and coefficients in column 3 of Table 5 support result 3. The coefficient of interest ($seq \times AM \times ENDO \times MIN$), which captures the additional effect of the MIN on the overall reduction of group extractions due to endogenous DB, is negative (-1.47 tokens) and highly significant only for realized group extractions (see column 3 of Tables 4 and 5, respectively). Therefore, the MIN reduces significantly more the realized group extractions than the MAX while proposed group extractions do not differ across both endogenous (MIN and MAX) DB.

We already observed that, overall, endogenous DB perform better than the exogenous DB. However, as we find a difference in effectiveness between the MAX and the MIN, it is not obvious whether each of the endogenous DB performs better than the exogenous DB. We therefore need to compare the MAX and the MIN to the $NASH$ separately. To do so, we alternatively remove MAX and MIN from the sample.

Result 5: *The MAX reduces significantly more the realized and the proposed group extractions* than the $NASH$.

Table 5: Impact of the AM and compared effectiveness of DBs on proposed group extractions

VARIABLES	*AM overall* (1)	*endogenous/ exogenous* (2)	MIN/MAX (3)
$seq \times AM$	-2.746^{***}	-2.349^{***}	-2.349^{***}
	(0.285)	(0.346)	(0.346)
$seq \times AM \times ENDO$		-0.617^{**}	-0.819^{**}
		(0.303)	(0.336)
$seq \times AM \times ENDO \times MIN$			0.427
			(0.364)
Constant	16.32^{***}	16.32^{***}	16.32^{***}
	(0.197)	(0.196)	(0.197)
seq	yes	yes	yes
Group FE	yes	yes	yes
Period FE	yes	yes	yes
Observations	1,460	1,460	1,460
$R - squared$	0.393	0.395	0.397
$F - test$	28.34^{***}	26.31^{***}	24.85^{***}

Note: Robust standard errors are in parentheses. * denotes significance at the 10-percent level, ** at the 5-percent level and *** at the 1-percent level. The regressions contain period, sequence and group fixed effect. All AM treatments (MIN, $NASH$ and MAX) are pooled in AM. The variable AM equals 1 for the MIN, the MAX and the $NASH$ DB and 0 for the control groups. The variable *seq* equals 1 for the sequence 2 and 0 for the sequence 1. The variable $ENDO$ is coded 1 for the MAX and the MIN (both endogenous) DBs and 0 for the $NASH$ and the control groups. The variable MIN is coded 1 for the MIN and 0 otherwise. Finally, the variables $seq \times AM$, $seq \times AM \times ENDO$ and $seq \times AM \times ENDO \times MIN$ are the interactions variables. These regressions have been ran with proposed group extractions. FE stands for "fixed effect".

Support for result 5: The regressions are reported in columns 2 (panel B) of Tables 6 and 7. In column 2 of these two Tables the data corresponding to the MIN DB has been removed. Therefore, the variable AM is equal to 1 for the MAX and the NASH DB and 0 for the control groups. We replace the former variable $seq \times AM \times ENDO$ by $seq \times AM \times NASH$ which captures the additional effect of the NASH on the reduction of group extraction due to the AM, i.e both the NASH and the MAX. The variable $seq \times AM \times NASH$ can be interpreted as the reduction of group extraction of the NASH compare to the MAX. Our regressions show that the additional effect of the NASH is positive and significant (0.78 tokens for the realized extraction and 0.82 for the proposed extraction). Thus, the MAX DB reduces the group extraction more than the NASH.

Table 6: Comparison of the effectiveness of the DBs on realized group extractions

VARIABLES	MIN **vs** $NASH$ **Panel A** (1)	MAX **vs** $NASH$ **Panel B** (2)
$seq \times AM$	-4.059***	-2.589***
	(0.389)	(0.355)
$seq \times AM \times NASH$	2.250***	0.780**
	(0.384)	(0.347)
Constant	16.25***	16.06***
	(0.244)	(0.226)
seq	yes	yes
Group FE	yes	yes
Period FE	yes	yes
Observations	1,080	1,120
$R-squared$	0.416	0.373
$F-test$	19.99***	10.60***

Note: Robust standard errors are in parentheses. * denotes significance at the 10-percent level, ** at the 5-percent level and *** at the 1-percent level. The regressions contain period, sequence and group fixed effect. The treatments MIN and $NASH$ are pooled in AM of Panel A. The treatments MAX and $NASH$ are pooled in AM of Panel B. The variable *seq* equals 1 for sequence 2 and 0 for sequence 1. $seq \times AM$ is the interaction between the variables *seq* and AM. These regressions have been ran with (realized) group extractions. FE stands for "fixed effect"

Result 6*: The MIN reduces significantly more the realized group extractions than the NASH.*

Support for result 6: We have already shown that the MIN reduces more the group extraction than the MAX and the MAX reduces more the group extraction than the NASH. Therefore, by transitivity, the MIN should reduce more the group extractions than the NASH. This is confirmed by regression in column 1 (panel A) in Table 6. The additional effect of the NASH DB, that allows to compare the NASH and the MIN, is positive and highly significant (2.25 tokens). This result reinforces result 6. However, there is no significant difference between the NASH and the MIN in term of proposed group extraction (see column 1 of the Table 7).

Table 7: Comparison of the effectiveness of the DBs on proposed group extractions

VARIABLES	MIN **vs** $NASH$	MAX **vs** $NASH$
	Panel A	**Panel B**
	(1)	(2)
$seq \times AM$	-2.741***	-3.168***
	(0.371)	(0.338)
$seq \times AM \times NASH$	0.392	0.819**
	(0.371)	(0.335)
Constant	16.36***	16.19***
	(0.230)	(0.213)
seq	yes	yes
$Group\ FE$	yes	yes
$Period\ FE$	yes	yes
$Observations$	1,080	1,120
$R-squared$	0.394	0.413
$F-test$	16.19***	19.83***

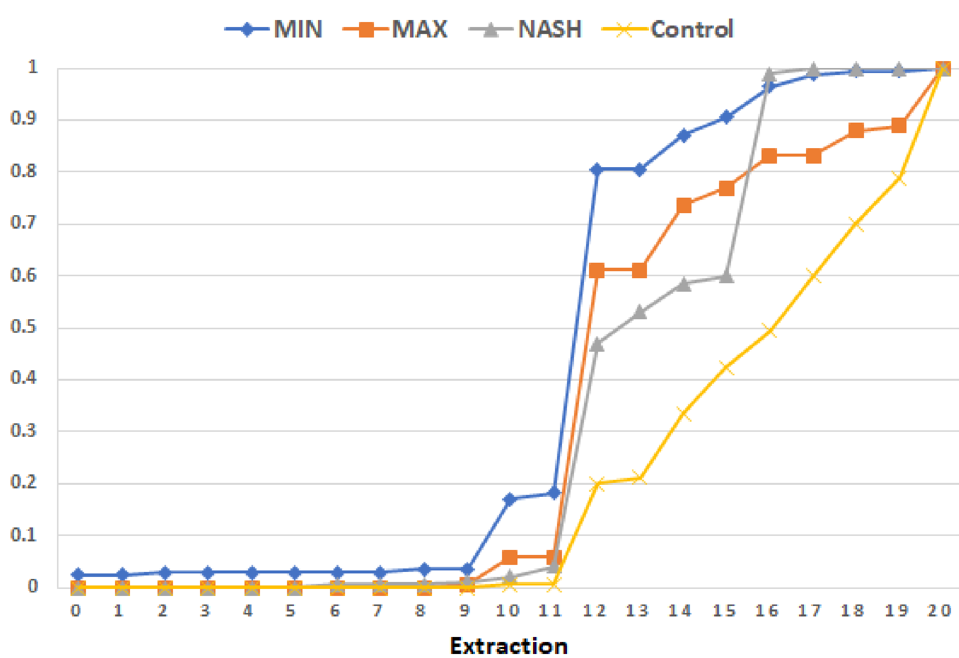
Note: Robust standard errors are in parentheses. * denotes significance at the 10-percent level, ** at the 5-percent level and *** at the 1-percent level. The regressions contain period, sequence and group fixed effect. The treatments MIN and $NASH$ are pooled in AM of Panel A. The treatments MAX and $NASH$ are pooled in AM of Panel B. The variable seq equals 1 for sequence 2 and 0 for sequence 1. $seq \times AM$ is the interaction between the variables seq and AM. These regressions have been ran with proposed group extractions. FE stands for "fixed effect".

5 Discussion and conclusion

Our results show that the AM reduces significantly group extraction (Result 1) and that endogenous DBs are more effective at reducing extractions compared to the exogenous DB (Result 2). The MIN is the most efficient DB: it leads to lower realized group extractions than the MAX and the NASH (Results 4 and 6). The MAX is also better than the NASH (Result 5).

We observed that the effectiveness of the AM depends on the particular DB that is implemented, i.e. the uniform extraction level in case of disapproval. Endogenous benchmarks, such as the MIN or the MAX have a mechanical effect in case of disapproval. Since the payoff function is bell shaped, and over-extraction arises in the negatively sloped portion of the curve, imposing the MIN tends to promote the optimum while imposing the MAX tends to favor extractions above the optimum. In other words, the MIN is akin to a collective reward while the MAX resembles to a collective sanction. Interestingly, proposed extractions do not differ between the MIN and the MAX (Result 3). Moreover, as shown in Table 8, average approved extractions are quite similar (12.74 for the MAX and 12.98 for the MIN) and only slightly above the optimum extraction (12). However, after the approval stage, they differ however substantially (16.78 for the MAX and 11.05 for the MIN).

Figure 5: Cumulative distribution function by treatment for the sequence 2



The comparison between the NASH and the MAX supports our conjecture that the proposed group extraction is higher under the NASH than under the MAX. Under the MAX no one can know the level of extraction implemented in case of disapproval before making the first stage decision. In contrast, under the NASH every group member knows the uniform extraction that will be implemented in case of disapproval. Therefore, participants had a clear reference point on which to anchor their first stage proposal. The realized extraction level was therefore lower or equal to the Nash extraction level. In contrast, under the MAX, the extraction level could be higher, lower or equal to the Nash extraction level (see Figure 5). It is no surprise that the average group extractions under the MAX and under the NASH do not differ (sequence 2 : 13.74 and 13.72, see Table 3). According to the theoretical predictions, the accepted extractions are between $\frac{1}{2}x^*$ and x^* for the NASH. For the MAX, approved extractions may be greater than the Nash extractions. Figure 3 shows that in 80% of the cases, the extractions under the MAX were lower than under the NASH even though they had the same mean. By controlling the period effects and the effects specific to each group (which makes it possible to isolate the true effect of each DB), the DiD estimates show that MAX reduces more over-extraction than the NASH. However, the DiD estimation shows a significant difference between the two DBs. The reason is that DiD controls for bias from unobserved variables that remain fixed over time. Despite the negative mechanical effect of the MAX, it leads to a stronger reduction of over-extraction of the CPR better than the threat of the Nash extraction. This result highlights the fact that there is sharp difference between endogenous and exogenous DBs that affect their effectiveness.

Table 8: Proportion of approval and average extractions approved/disapproved

	Mean of extractions		proportion of approval
	approval	disapproval	
Control	*16.23*		−−
NASH	*12.44*	*16*	63.5%
MAX	*12.74*	*16.78*	75.79%
MIN	*12.98*	*11.05*	50%

Note: approval corresponds to group mutual approval and disapproval corresponds to group disapproved.

We found that the MIN disapproval benchmark is the best instrument for implementing the level of optimal extraction. This instrument has a positive mechanical effect (which is the force of the approval mechanism) that explains the difference in the reduction of extraction compared to the MAX and the NASH. An important question is whether the MIN is also efficient in larger groups. Considering larger groups, raises however the question of the aggregation rule of the approval votes. For instance, in the case of a three-players CPR game, one can choose the unanimity rule (every single player can approve the stage 1 extraction vector) or the majority rule (the stage 1 extraction vector is approved if at least two players approve it). Studying the performance of the MIN under these two rules, will provide a robustness check for its performance.

In this paper we applied the approval mechanism to a CPR game. Our results showed that the approval mechanism is robust to the nature of the social dilemma. However, we also showed that the effectiveness of the approval mechanism depends on benchmark that is implemented in case of disapproval. We suggest several research directions that would be worth exploring: considering other social dilemmas, analyzing other types of disapproval benchmarks, investigating the long term effect of the AM, and considering a larger number of players.

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6 Appendix

6.1 Welcome

We thank you for agreeing to participate in this decision-making experiment. This experiment will be paid. Your earnings will depend on your decisions as well as those of the other participants in this experiment. Your identity and decisions will be kept anonymous. You will have to indicate your choices on the computer in front of which you are seated, and the computer will notify your earnings (in points) as the experiment progresses.

From now until the end of the experiment we ask you to stop all communication. If you have any questions, please raise your hand, an instructor will answer you privately.

6.2 General procedure

At the beginning of the experiment you will be randomly assigned to a group of two players. The composition of your group remains unchanged until the end of the experiment. Each member of your group (including you) will have an ID 1 or 2.

The experiment is divided into 2 parts. Each part consists of a series of ten periods. The rest of the instructions concern only part 1. At the end of part 1, you will receive new specific instructions for part 2. At the end of the experiment, one of the 20 periods will be drawn and your earnings (in points) for that period will be converted into euros according to a rule defined at the end of the instructions.

Once all participants have read the instructions, an experimenter will read them out loud again. After reading the instructions, you will be asked to complete a questionnaire to verify your understanding of the experiment. When all participants have completed this questionnaire, the experiment will begin.

6.3 Types of investments

In each period, each player of your group has 10 tokens, which he has to split between two activities: activity A and activity B. activity A is common to both players. Activity B is specific to each player. Each token must be invested, either in activity A or in activity B. Earnings associated with your investment in each activity and the total earnings are described as follows.

6.3.1 Earnings activity A

Your earnings from activity A depend on your investment in activity A and the investment in the activity A of the other player in your group.

6.3.2 Earnings from the investment in activity B

Your earnings from activity B depend solely on your own investment in that activity. Each token invested in activity B earns you 15 points. Similarly, each token that the other player invests in his activity B earns him 15 points.

6.3.3 Total earnings

Your total earnings in each period are equal to your earnings from activity A + your earnings from activity B.

We present the different possibilities of total earnings. They are described in the earnings Table (see sheet "Table of total earnings") (see Table 1.1). The first column corresponds to your investment in activity A (between 0 and 10). The other columns correspond to the other player's investment in activity A (between 0 and 10). Your total earnings and the other player's earnings are measured in points. There are two values in each cell of the Table: Your total earnings in points (in blue) and the other player's total earnings in points (in black). For example, you decide to invest 8 tokens in activity A and therefore 2 tokens in your activity B. The other player decides to invest 6 tokens in activity A and therefore 4 tokens in his activity B. Your total earnings for the period are 330 points. The total earnings of the other player of your group are 285 points.

6.4 Part 1

In each period, you must split your 10 tokens between your investment in activity A and your investment in your activity B. You are free to choose how you want to allocate your 10 tokens. For example, you can decide whether to allocate all your tokens in activity A or all your tokens in activity B.

In practice, the computer will ask you to indicate the number of tokens you want to invest in activity A. The rest of your 10 tokens will automatically be invested in your activity B. The sum of these two investments is exactly equal to your 10 tokens for this period. As a result, you cannot transfer a part or all of your tokens from one period to another.

You and the other player make your decisions simultaneously. Once the investment decisions have been made, the computer calculates your total earnings, as well as the earnings of the other player for the current period. It will tell you how many tokens you have invested in each of the two activities and your total earnings in points. The same information about the other player will also be displayed on your screen. The next period can then begin. Before each new period, you will be informed about your total earnings from each of the previous periods. When the 10^{th} period will be over, the computer will summarize the amount of your earnings for each of the 10 periods.

6.5 Part 2 [AM treatments]

As in part 1, there are 10 periods in part 2 in which you will interact with the same person as in part 1. You and the other player in your group must decide how much you will invest in activity A. The earnings in activity A and activity B are exactly the same as in part 1, so you will use the same "Table of total earnings" as in part 1.

In part 2, each period consists of two stages: Stage 1 and Stage 2. Stage 1 corresponds to the investment decision: you and the other player will each have to decide how much to invest in activity A. Stage 1 corresponds exactly to the same investment decision as in part 1. Stage 2 is new. Once the two members of your group have chosen their amount to invest in activity A, these decisions and their associated total earnings are published on the screens of all members (including yourself) and submitted for approval. If the two members of your group approve the proposed investment decisions, they will be applied and everyone will earn the corresponding earnings. If at least one player in your group disapprove, the computer will apply an identical investment level as explained in the following instructions.

In practice, in stage 1, the computer will ask you to indicate the amount of your investment in activity A. In stage 2, the computer will tell you how many tokens you proposed for both activities and how many tokens the other player proposed in the current period. It will also tell you your total earning as well as the total earning of each other player. In addition, the computer will inform you about the minimum **(under the MIN)** or the maximum **(under the MAX)** of the proposed investments in activity A and the total associated earnings if all members Of your group invest this amount in activity A. Then, the computer will ask you whether you approve or reject the proposals from the other members of your group. You will click YES if you agree with the proposals, or NO if you disagree with the proposals. At the same time, the other player also has to approve or reject the proposals for the current period.

As aforementioned, if they approve, the computer implements the proposals. Otherwise, it imposes a uniform level of investment in activity A :

- the minimum of proposals [**under MIN** DB]
- the maximum of proposals [**under MAX** DB]
- always 8 tokens [**under NASH** DB]

and the rest of the 10 tokens is invested in activity B. Then the computer will display the investments (tokens in activities A and B respectively) and the total earnings.

At the end of stage 2, the computer displays the final total earnings of each group member for that period. The next period can then start. Before each new period you will know your earnings for each of the previous periods. When the 10^{th} period is over, the computer will summarize the amount of your total earnings for each of the 10 periods.

The exchange rate is 1 euro for 15 points. One of the 20 periods will be randomly chosen to be paid out for real.

6.6 Part 2 [Baseline treatment]

As in part 1, there are 10 periods in part 2 in which you will interact with the same persons as in part 1. You and the other player in your group must decide how much you will invest in activity A. The earnings in activity A and activity B are exactly the same as in part 1, so you will use the same "TTable of total earnings" as in part 1.

You and the other player(s) make your investment decisions simultaneously. Once the investment decisions have been made, the computer calculates your total earnings, as well as the earnings of the other player in your group for the current period. It will show you how many tokens you invested in each of the two activities and your total earnings in points. The same information about the other player will also be displayed on your screen. The next period can then begin. Before each new period, you know your total earnings from each of the previous periods. When the 10^{th} period is over, the computer will summarize the amount of your winnings for each of the 10 periods

The exchange rate is 1 euro for 15 points. One of the 20 periods is randomly drawn to be remunerated.

6.7 CPR Properties

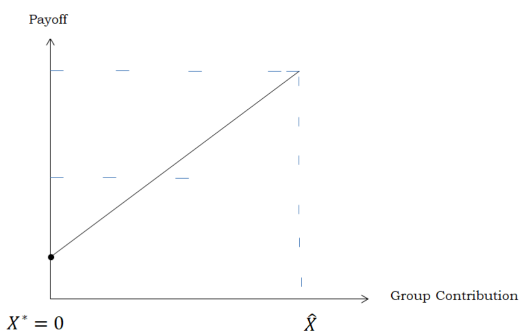
- Linear public good

  1. Non-rivalry
  2. $x_j < x_i \implies \pi_i(x_i, x_j) < \pi_j(x_i, x_j)$

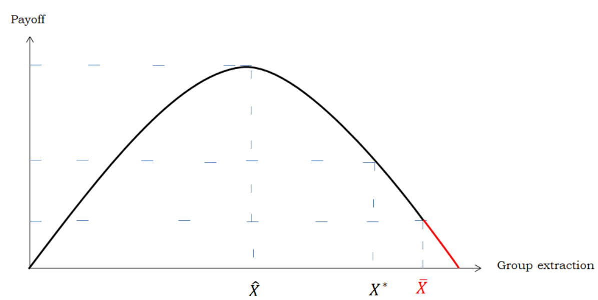
- CPR

  1. Rivalry
  2. The comparison of payoffs depends on a threshold $\overline{X} = \frac{a-p}{b}$
  3. $x_j < x_i \implies \pi_i(x_i, x_j) > \pi_j(x_i, x_j)$ if only if $X < \overline{X}$
  4. $x_j < x_i \implies \pi_i(x_i, x_j) < \pi_j(x_i, x_j)$ if only if $X > \overline{X}$

(a) Linear public good



(b) CPR



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