CEE-M
CENTER FOR ENVIRONMENTAL ECONOMICS - MONTPELLIER

# Information sharing is not always the right option when it comes to CPR extraction management: experimental findings


Dimitri Dubois
Stéfano Farolfi
Phu Nguyen-Van
& Juliette Rouchier


CEE-M Working Paper 2018-11

# Information sharing is not always the right option when it comes to CPR extraction management: experimental findings*

Dubois, D.† Farolfi, S.‡ Nguyen-Van, P.§ Rouchier, J.¶

June 5, 2018

**Abstract**

We experimentally investigate the impact of information sharing in a common pool resource game. More precisely, we test whether the voluntary disclosure of the decision by a player has a positive impact on the extraction level exhibited by the group compared to the level observed when decisions are compulsory disclosed. We design an experiment composed by three treatments: a mandatory disclosure treatment and two treatments where players are free to choose whether or not to disclose their decisions. The latter differ by the degree of freedom given to players. In the treatment "Voluntary Free Disclosure" players are also free to choose the extraction level that is displayed, while in the treatment "Voluntary Binary Disclosure" if the player discloses h(is)er decision the value displayed is the effective extraction level. We observe that the voluntary disclosure has a positive effect in the social dilemma, measured by lower average extraction levels. However the disclosure mechanism should not allow to self-declare extraction: here it reveals a large tendency to lie leading to an increase in extraction.

*This research benefited from CNRS's financial support (Project PEPS-DIPP: Decision, Indicator and Public Policy).

†CEE-M, Univ. Montpellier, CNRS, INRA, SupAgro, Montpellier, France

‡UMR G-eau, CIRAD, Montpellier, France

§BETA, CNRS, INRA, Univ. Strasbourg, Strasbourg, France

¶LAMSADE, CNRS, PSL-Univ. Dauphine, Paris, France. Corresponding author. E-mail: juliette.rouchier@dauphine.fr

# 1 Introduction

In recent years, the use of collective resources, whatever their form of appropriation, has been transformed by new technics of information sharing. Indeed it is now possible for consumers to declare or make public their consumption in real-time so that there is a possibility for others to adapt or for public service to provide more resource at certain time. For example, it has become very common for the general public in the electricity provision case: a permanent surveillance is nowadays introduced in many countries. The initial aim is not to change behaviors but to integrate the consumption within the smart grid, so that a decentralized production of electricity can fit the demand more precisely. In the case of the use of water, many communities tend to coordinate by asking members to declare their intake: here the aim is to see others adapt to the global extraction. In South-West France, for instance, the local water management company (CACG) is introducing a system of remote reading for irrigation water consumption. This system allows the company to have a more precise and timely information about the irrigators' water consumption with a double objective of an improved effectiveness in the water allocation and a stricter control on the respect of the quotas allocated to the users in the respect of the environment. Two regimes are being introduced following the location of the irrigators in the area under the jurisdiction of CACG: a compulsory introduction of the remote reading system and a system based on the choice of the irrigator. In this second case, water users can either decide to accept the instalment of the remote reading system or refuse it. It is not so clear, however, how individuals use the information that circulates about the complex system of resource that they depend on.

This has led to a specific interest for the role of voluntary information sharing in experimental literature dealing with social dilemma (Dawes 1980), with the notion of social norms of behaviors that could emerge through imitation (Goldstein et al. 2008). Indeed, the modification of behavior that can take place thanks to the sharing of information could be used not just to better provide resource, but also to better coordinate and restraint its use. In particular, studies are based on the observation that individuals are in majority conditional cooperators and that they care a great deal about others' behavior while choosing their own actions (Janssen et al. 2010). However, there is to date no definitive and univocal answer to the question on which structure of information circulation can enhance the apparition of pro-social behaviors for example, the heterogeneity of initial behaviors can create a counter effect (called boomerang effect) that creates a collective increase of the resource use (Ostrom & Walker 2003).

Recent experimental findings show that voluntary disclosure of information can have a positive impact on cooperative behavior in a context of resource provision (Kreitmair 2015). However, this original research has never been applied to an extraction context, where the pro-social behavior is not defined as the provision of a larger share of a private endowment but rather as the avoidance of overexploitation by choosing a reasonable extraction of the shared resource. Considering the importance of framing on the behaviors observed in public good experiments (Willinger & Ziegelmeyer 1999), it seems necessary for us to adapt the structure of the game that we test in an experiment to our practical questions.

In the type of setting we think about, the organization of information sharing, be it voluntary or not, can be based on different protocols that can result in very different costs of implementation, and this is why, as Kreitmair (2015) does, we test several ways to disclose information in our protocol and in particular we add one technic of disclosure that would be the least costly in terms of ability to measure the extraction: self-declaration. Contrary to Kreitmair (2015) who wonders how much agents try to induce others in well-behaving through signaling, encouraging reciprocity, our protocol relies on the assumption of reinforced commitment in action (Becker 1960): participants who commit to disclose their information might be more willing to behave cooperatively regarding the group after they accept to display their information. This is why we test three behavioral information sharing devices in the case of the consumption of a common resource (extraction), where subjects in experiments are more or less constrained in their disclosure, and observe the effect of the device on resource use. We produce three treatments:

**Mandatory Disclosure (MD)** : subjects are informed of each extraction decision made by the other members of their group. This implies that information is compulsorily made available by the agency to all the subjects.

**Voluntary Binary Disclosure (VBD)** : subjects must decide whether or not they want to share the information about how much they extract from the common resource. If they choose to share, the information shared will correspond to the real one. This implies that the agency has full knowledge of the extractions, and will provide this information to all once the subjects allow it.

**Voluntary Free Disclosure (VFD)** : like in the previous device, subjects can choose whether or not to share information about resource extraction. However, subjects that decide here to share must also provide the amount extracted. This implies that a) the agency does not know the extraction levels, and b) subjects can trick in a strategic way, indicating false extraction levels.

Results show that mandatory disclosure is the set-up conducting to the higher extraction level (consistent with previous studies by Villena & Zecchetto (2011)), while voluntary binary disclosure is the information sharing set-up conducting to the lower extraction level. In our setting, we add one more degree of freedom with the VFD, and observe that the subjects actually did use this freedom to be more strategic. This is indeed the clearest result of our experiments: we allow subjects to lie in terms of extraction declarations, and this induces more free-riding and a level of extraction close to the mandatory disclosure set-up. In fact the VFD protocol shows the appearance of two types of free-riders: those who do not share information and those who share false information, the latter extracting even more than those who do not share.

The paper is organized as follows: a literature review about information sharing and social dilemmas is provided in Section 2. Section 3 is dedicated to explain the experimental design and our conjectures, Section 4 to the lab results, which are discussed in Section 5.

# 2 Information sharing and social dilemmas

The use of renewable resources is often modeled as social dilemma around a CPR, be it a provision model or an extraction model, expressing the tensions between individual and collective interests in a group (Gardner & Walker 1990, Apesteguia & Maier-Rigaud 2006). It has been shown that coordination around these resources is not trivial for groups of individuals, who tend to destroy the resource (Olson 1965, Hardin 1968), although many examples of long-term sustainable use can also be found (Ostrom 1990).

This is why lab experiments have been designed to study more precisely the factors that can influence the behavior of individuals in social dilemma situations. In the seminal paper by Walker et al. (1990) it is revealed that subjects tend to indeed overexploit when they are in a situation where they alone face an abstract social dilemma. However, several factors can increase trust in the group, and thus have been shown to help establish more cooperation, such as the sharing of information, communication, framing of the context (Ostrom 2010, Poteete et al. 2010, Janssen 2013). The information sharing issue is particularly studied experimentally but its effects on subjects' choices when facing social dilemmas are not easy to generalize. Generally this information can be the payoff or the behavior of others, in an aggregate form, as a distribution of behavior or related to each precise individual.

Some experimental results show that the addition of information about other's payoff in a situation of extraction does not improve the resource use: knowing about other's payoff, subjects still overexploit (Apesteguia 2006). The main impact of the sharing of information is the reduction of the learning effect, which make subjects' behavior converge quicker. In Villena & Zecchetto (2011), it is however shown that some individual learning effect can take place that leads subjects to Nash (overexploitation) quicker when information about payoffs is shared. And this is in line with Huck et al. (2017), who show the same feature for a game that puts subjects in a long-run context (subjects must take short-term choices -8s/period- for 600 repeated interactions) where they know the other agents' payoffs and efforts. It has even shown that the type of information about others (payoffs vs contributions in a provision game) changes the impact of the information on subjects' cooperation attitude (reduced vs increased cooperation) (Nikiforakis 2010). In a different setting, it has been shown that when subjects are in an asymmetric situation, the addition of information does not necessarily improve the efficiency of the collective behavior, but reduces inequality of payoff among subjects (Pfaff et al. 2013). In a two-step game, reducing the asymmetry of information about the resource state can improve efficiency (reduce overexploitation) (Espinola-Arredondo & Munoz-Garcia 2011).

All these former experiments were conducted in a context where information was not voluntarily provided by subjects. In a study about public good contribution, Kreitmair (2015) shows that individuals tend to disclose their contribution information when given the opportunity, and that voluntarily revealed contributions are significantly higher that contributions under mandatory disclosure. In her paper, there are three different treatments on top of the basic treatment without contribution disclosure: (i) mandatory, (ii) choose to reveal ex-post, (iii) engage ex-ante to reveal the contribution, which is then revealed after the choice. In this setting, a certain share of subjects does choose to communicate their information and this leads to a slight increase in cooperation. The third treatment, where participants declare in advance that they will reveal their contribution, and thus try to induce others to well-behave through signaling, does not change results in a significant way, but reduces the boomerang effect. As in our case, Kreitmair (2015)'s setting can be seen as a double social dilemma, one about resource provision and one about information sharing, and seems to show that the introduction of this second dilemma has a positive impact on the first. This can be related to the idea of commitment in action (Becker 1960): after displaying a certain type of behavior, individuals feel committed to the kind of person they think would do this action, and thus feel bound to their first behavior. Our idea was that people choosing to reveal contribution before acting (pro-social behavior) commit towards others and are pushed to behave again in a pro-social manner.

We also test this hypothesis about the influence of voluntary disclosure of information on social dilemmas in an extraction context. This, to the best of our knowledge, has never been explored so far. We also change a bit the information-sharing dilemma by introducing a different option. In the Kreitmair (2015)'s experiment, voluntary provision is binary: subjects either reveal (true) information or not. We do not explore the situation where individuals can declare ex-ante that they will disclose their behavior, but in one treatment we let them choose the amount they declare, our hypothesis being that adding one more degree of freedom to their engagement will make them even more cooperative.

# 3 Experimental design and conjectures

## 3.1 Experimental game

In a Common Pool Resource game (thereafter CPR), each player $i$ in a group of $N$ players can extract from $y_i = 0$ to $y_i = E$ tokens from a common resource that contains $N \times E$ tokens. For each extracted token, player $i$ earns 3 ECUs[1], but it creates a negative externality for each one of the other group members. In our experimental game the payoff function of player $i$ is given by $\pi_i(y_i, Y) = 3y_i - 0.01875Y^2$ where $Y = \sum_i y_i$ and $y_i$ is the individual amount extracted by player $i$.

To avoid corner solutions, we adapt an existing model (Cox et al. 2013) by transforming the linear payoff functions into a quadratic one. Figure 1 shows, on the left, that (i) whatever the amount extracted by the other group members player $i$ has a higher payoff when (s)he extracts the maximum 10, and (ii) that whatever the amount extracted by $i$ her payoff is higher when the other group members do no extract any amount from the common resource. In other words, the dominant strategy is to extract the maximum possible (10). On the right side the figure shows the evolution of the collective payoff, computed as the sum of individual payoffs, depending on the total amount extracted by the group. As it can be seen from the graph, the social optimum refers to a global extraction of 20 tokens, with a symmetric issue where each player extracts exactly five tokens. The game is therefore a social dilemma, where individual and collective interests are divergent.

[1]Experimental Currency Unit

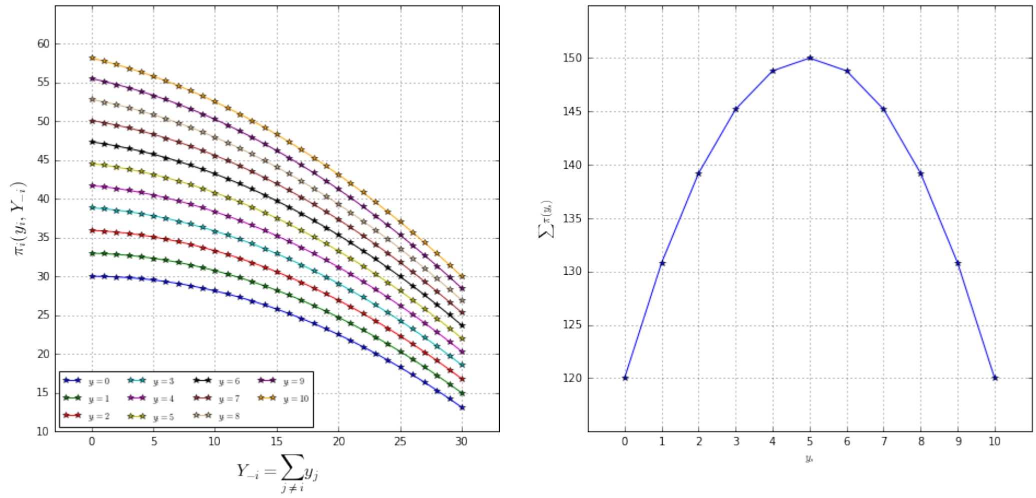


Figure 1: The game of our experiment

## 3.2 Treatments

We run three treatments, in which the game is identical in terms of parameters but differs by the nature and quantity of information provided to decision makers (Table 1). The game played is the one described in the previous section, with fixed groups of size 4 randomly formed at the beginning of the experiment. In the group each player is player A and the other group members are players B, C, and D. These id are unchanged during the 20 repetitions of the game. Each of the 20 periods of the game is divided into two or three steps depending on the treatment: (i) a step where players decide how much they extract from the CPR, (ii) a step where players decide whether or not they want to inform the other members of their group about their extraction decision, and (iii) the summary of the period. From each of the corresponding screen players can access a history screen that displays the informations about past periods (decisions, payoffs and so on). The rest of the subsection is dedicated to a more precise description of each of the implemented treatment.

**Mandatory Disclosure (MD)**
This is our baseline treatment. In this treatment players are informed of each extraction decision made by the other members of their group, besides its id (B, C or D). This information is given in the summary, so that there are only two steps in this treatment (extraction decision and summary).

**Voluntary Binary Disclosure (VBD)**
In this treatment each player must decide, in the second step of the period, whether (s)he wants or not to share the information about how much she extracted from the common resource in step 1. If she does, her extraction decision is displayed in the summary screen of each member of her group besides her id. Conversely, if she refuses the information is not displayed. Compared to treatment MD the player chooses whether her extraction decision is displayed or not on the screen of her group members.

**Voluntary Free Disclosure (VFD)**
As in treatment VBD the player has to decide whether she shares or not the information about her extraction level. The difference is however that if the player decides to share her extraction decision with the other group members then she must also enter the value that will be displayed. In other words, compared to MD or VBD, the player is free to choose the extraction level that is displayed on the others' screen, meaning that she has the possibility to lie by entering a value different from her effective decision.

Table 1: Overview of treatments

| Treatment | Nb. of periods | Group size | Voluntary information sharing | Choice of declaration |
|---|---|---|---|---|
| MD | 20 | 4 | No | No |
| VBD | 20 | 4 | Yes | No |
| VFD | 20 | 4 | Yes | Yes |

## 3.3 Practical procedure

The experiment took place at the experimental economics lab of Montpellier (LEEM) in France. A total of 104 subjects participated in the experiment, some students from various disciplines of the university randomly selected from a subject pool of almost 5000 volunteers[2]. We ensured that none had previously participated to a common pool resource game. The experiment was computerized, using the LE2M software[3]. Terminals were separated by lateral partitions to ensure complete anonymity. Sessions lasted about an hour and a half, including initial instruction and payments.

[2]The pool of volunteers is handled with ORSEE (Greiner 2015)
[3]LE2M is the software dedicated to economic experiments developed by the engineers of the LEEM.

## 3.4 Conjectures

We make our conjectures on the basis of the literature cited in Section 2.

**Conjecture 1** : Voluntary disclosure of information will be chosen by agents.

**Conjecture 2** : The voluntary disclosure of information increases the level of cooperation among the group's members, which results in lower levels of extraction of the CPR than the mandatory disclosure.

**Conjecture 3** : When allowed to choose whether to disclose information or not (VBD and VFD), free-riders will not share their extraction decision. We build on the findings of several experiments about CPR showing that users of a CPR include "pure" free-riders, conditional cooperators, and "pure" altruists (Ostrom et al. 1999), and want to find a connection between free-riding and information-sharing.

**Conjecture 4** : The more freedom is given to agents in the disclosure of their behavior, the more cooperative they behave.

# 4 Results

Table 2: Statistics

| Treatment | Nb of Groups | Av. Extraction Period 1 | Av. Extraction Periods 1-10 | Av. Extraction Periods 1-20 |
|---|---|---|---|---|
| MD | 8 | 8.06 | 9.00 | 9.23 |
| VBD | 9 | 7.31 | 7.84 | 8.35 |
| VFD | 9 | 8.03 | 8.26 | 8.66 |

Table 2 provides statistics about the average level of extraction depending on the treatment and Figure 2 displays the evolution of the average extraction by treatment. Since the first period of play, which is without any prior information about the other members' behavior in the group, the VBD treatment leads to a lower average level of extraction compared to MD and VFD. This initial effect is observed in the whole repetition, even if with the repetitions the three treatments converge in the average amount extracted in the game. The increasing dynamic observed in the three treatments is typical in this kind of game because the dominant strategy (maximum extraction) has a powerful attraction force.

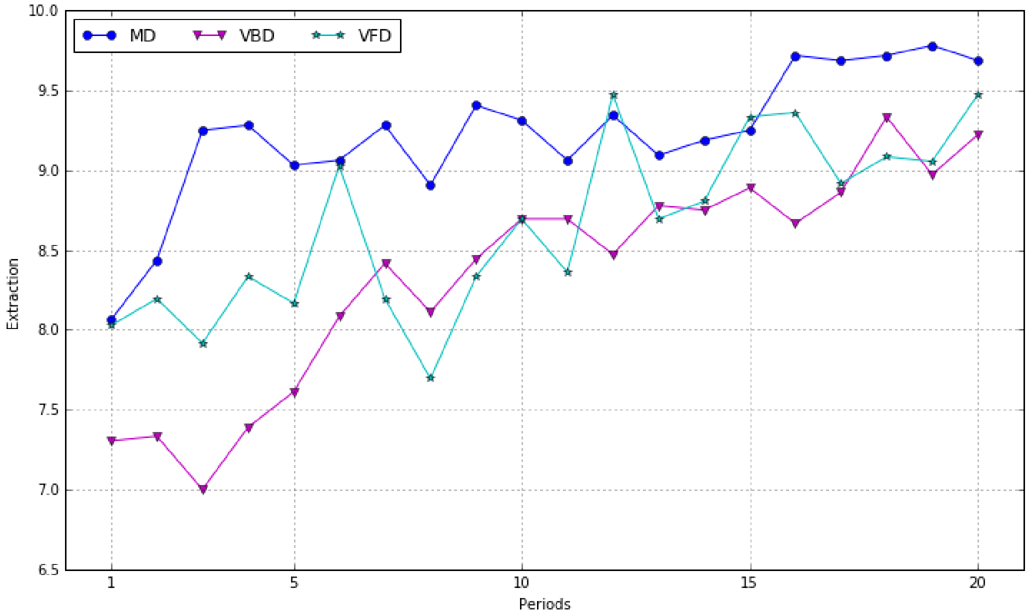


Figure 2: Evolution of the average extraction

We now analyze the determinants of individual resource attraction. Let $y_{it}$ the amount of extraction of player $i$ at period $t$. This amount is both left- and right-censored, i.e. $0 \leq y_{it} \leq 10$. We propose to study the dynamic model for panel data given in (1) below

$$y_{it} = \rho y_{i,t-1} + x'_{it} b + \mu_i + \epsilon_{it};\ i = 1, 2, \dots, N;\ t = 1, 2, \dots, T \tag{1}$$

where $y_{i,t-1}$ is the extracted amount of player $i$ at the previous period, $x_{it}$ corresponds to the whole set of explanatory variables including both time-variant variables (total amount of extraction at $t-1$ of the group to which player $i$ belongs, decision-making time, information-related variables such as dummy of information sharing, number of individuals who shared in the previous period their extracted amounts) and time-invariant variables (treatment dummy variables). The dynamic structure of the model allows us to account for persistence in individual decisions over time. The error term is composed of two parts, an idiosyncratic error $\epsilon_{it}$ and an individual-specific effect $\mu_i$.

The dynamic structure is at the origin of the well-known problem of initial observations in econometrics, leading to the inconsistency of traditional estimators. Following Wooldridge (2005), this problem can be fixed by specifying a more general model where $\mu_i$ are defined as correlated random effects with the following assumption:

$$\mu_i | y_{i1}, z_i \sim N(\alpha_0 + \alpha_1 y_{i1} + z'_i \gamma, \sigma_\mu^2). \quad (2)$$

This assumption appears to be general enough as it suggests that individual-specific effect depends not only on the initial attracted amount $y_{i1}$ but also on a set of values of explanatory variables ($z_i \equiv (x_{i1}, \ldots, x_{iT})$). The model with assumption given in (2) corresponds therefore to a dynamic Tobit model for panel data with correlated random effects. Estimation of the latter model, compared to the original model in (1), implies two additional sets of variables: initial decision ($y_{i1}$) and a set of auxiliary variables ($z_i$). A likelihood-ratio (LR) test is performed to compare model (1) to the model with the general assumption in (2). The null hypothesis corresponds to $\alpha_1 = \gamma = 0$. For the whole sample (all treatments included), the test statistic is 275.93 and the $p$-value of the chi-squared distribution with 58 degrees of freedom is almost 0, leading to the rejection of the model given in (1) in favor of the dynamic Tobit model with correlated random effects. This test shows the importance of the initial observation problem which has to be controlled for. The significance (at the 10% level) of this coefficient ($\alpha_1$, Table 3) provides an illustration of this result.

Table 3 also reports estimation results for other coefficients. We observe that subjects are sensitive in a positive way to the total amount extracted by their group in the previous period. In other words, this result reveals the existence of a positive externality in an individual's decision with respect to her group. Moreover, an increase in the decision-making time can reduce the individual amount of resource attraction, suggesting that decision-making time was used to resource protection. The positive and significant coefficient of time trend shows the upward trend in individual resource attraction. Finally, it is shown that both treatments, VBD and VFD, lead to a lower extraction level when compared to the reference treatment (MD) thanks to their negative coefficients. The coefficient of VBD seems to be higher than that of VFD. However, this difference is not significant at the 5% level as a chi-squared test does not reject the equality between the two coefficients (i.e. the $\chi^2$ statistic is equal to 0.10, with a $p$-value of 0.755).

Figure 3 reports for both treatments with voluntary sharing (VBD and VFD), the dynamic over twenty periods of the average amount extracted by those who share and by those who don't. The first observable fact is that players who voluntarily share their decision with their group members, at least in the first periods, extract less than those who do not disclose their decision, and this difference is larger in VBD than in VFD (Wilcoxon bilateral

Table 3: Estimation results, whole sample

| Variable | Coefficient | Standard errors |
|---|---|---|
| Initial individual decision | 0.178* | 0.095 |
| Individual decision in previous period | 0.006 | 0.061 |
| Group decision in previous period | 0.133** | 0.030 |
| Decision-making time | -0.049** | 0.010 |
| Treatment VBD | -1.830** | 0.563 |
| Treatment VFD | -2.171** | 1.040 |
| Time trend | 0.163** | 0.019 |
| Intercept | -8.229 | 5.148 |
| Log-likelihood | -2129.767 | |
| Wald test $\chi^2(63)$, for the model's significance | 902.19 | $p$-value=0 |
| Number of observations | 1976 | |
| Number of individuals | 104 | |
| Number of uncensored observations | 672 | |
| Number of left-censored observations | 26 | |
| Number of right-censored observations | 1278 | |

Notes: Regression of the dynamic Tobit model with correlated random effects with individual extraction decision ($y_{it}$) as dependent variable. Regression also contains auxiliary regressors ($z_i$) but their coefficients (without much interest) are not reported here.

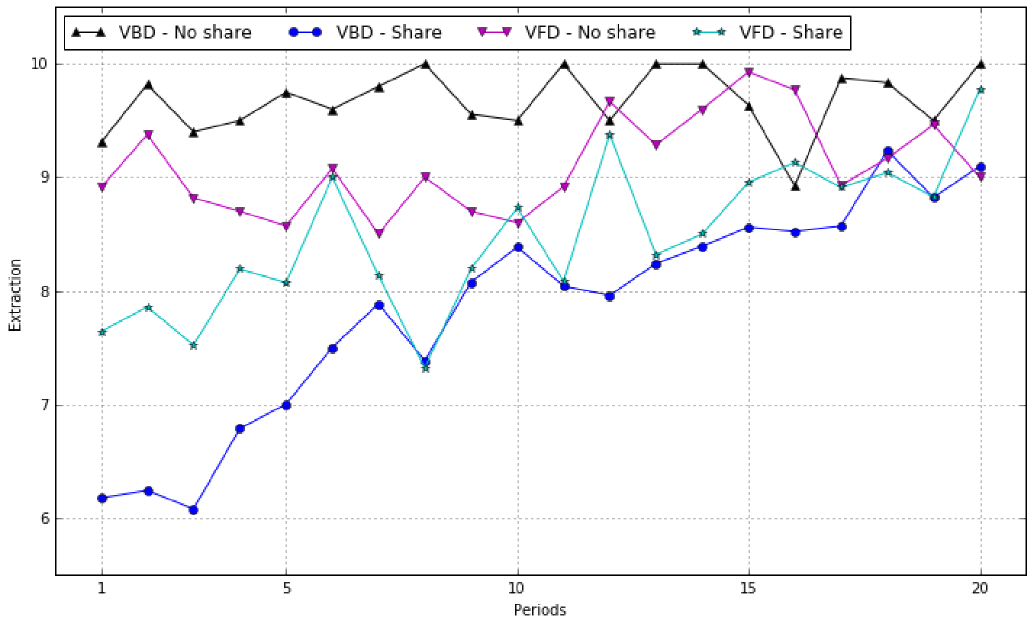


Figure 3: Average extraction depending on the sharing of information

test VBD $p$-value=0.109, VFD $p$-value=0.066). The second seeable fact is that those players who refuse to make public their decision extract a constant amount during the whole game, while the other players increase the amount extracted, as a response to observations, like conditional cooperators would do. Once again it seems to be more remarkable in VBD than in VFD. Our interpretation is that the VBD procedure is more discriminant: cooperators voluntarily make their decision public, while free riders don't. This is not so clear with the VFD procedure, as it will be discussed in the next paragraph.

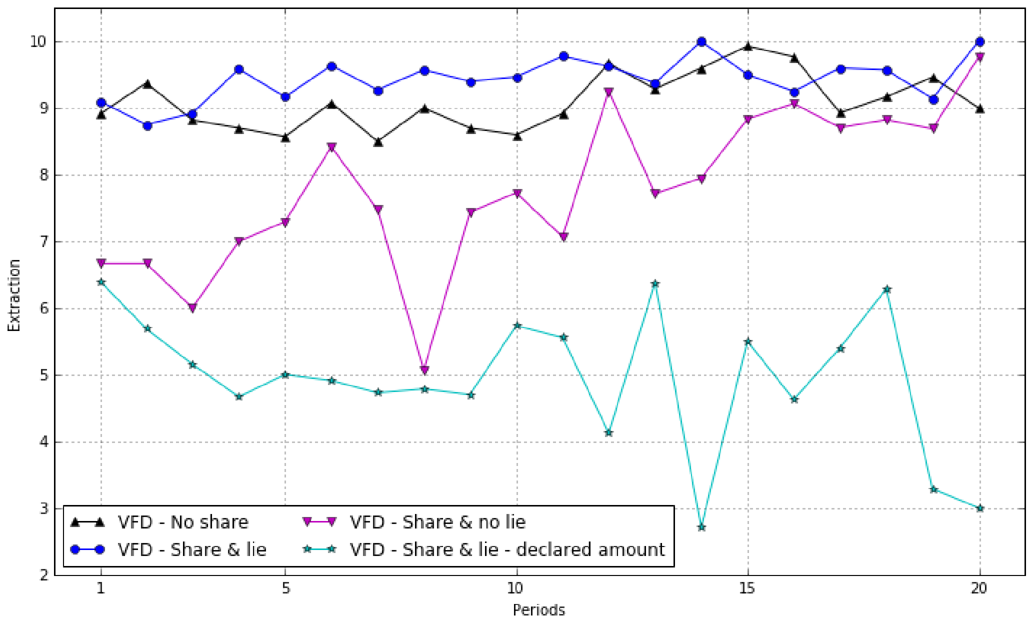


Figure 4: Average extraction in treatment VFD depending on the sharing of information and lying

Figure 4 reports the dynamic of the average amount extracted in the VFD treatment depending on whether the subject lies or not. More precisely, blue and magenta curves display the average extraction of players who voluntarily share their extraction decision, with the magenta line referring to those who then declare the true value of their extraction and the blue line to those who don't. Clearly liars extract significantly more than honest players (Wilcoxon $p$-value=0.008), and also more than those who refuse to make their decision public, even if not statistically provable (Wilcoxon $p$-value=0.260). Moreover, as shown by the cyan curve, liars declared on average a value of extraction corresponding to the social optimum (5, $p$-value=0.515). In other words, letting players choose the value of extraction that will be displayed on others' screen leads free riders to adopt a strategic behavior where they announce a level of extraction equal to the social optimum but besides extract almost the highest possible amount in order to maximize their individual payoffs. This explains why in Figure 3 the extraction curve of those who share their extraction decision is not so far from those who don't.

The last interesting trend shown in Figure 4 is the extraction behavior of players that declare and do not lie: they start the session with a sensible lower level of extraction but then act as conditional cooperators when observing the other members of their group extracting more (and perhaps declaring a much fewer amount if liars). Conversely, liars declare a progressively lower level of extraction (sending a false signal to the other members of the group maybe in an attempt to maintain their cooperative behavior) while keeping a constant and extremely high real extraction level.

In order to identify the effects of specific explanatory variables (in particular those related to information sharing), estimation is implemented treatment by treatment. Tables 4-6 report estimation results of the same model (dynamic Tobit with correlated random effects) for treatments MD, VBD, and VFD, respectively[4].

Table 4 provides results for the subsample corresponding to the MD treatment. By definition, the set of explanatory variables does not contain any information factors. It is shown that results are similar to the case of the whole sample as presented in Table 3. The models estimated with data under treatments VBD and VFD include some informational variables among the set of explanatory variables. More precisely, for treatment VBD, we add two dummy variables to indicate whether a player accepts to disclose her extracted amount in the current and in the previous period ("Information sharing, current period" and "Information sharing, previous period"). There is another additional variable, corresponding to the number of members in the group who choose to disclose their individual decision. Regarding the VFD treatment, as players can release a wrong information, there are three possible situations (each of them correspond to a dummy variable): (i) there is no release of information (the reference) (ii) information is wrongly released ("Information sharing & lying"), and (iii) information is truly released ("Information sharing & non-lying"). We add the present and the past value for the latter two dummies. Finally, the set of regressors for the VFD treat-

[4]As for the case of the whole sample, we perform a LR test to compare the models without and with correlated random effects (i.e. null hypothesis $\alpha_1 = \gamma = 0$) for each of the three treatments. The result is unambiguously in favor of the dynamic Tobit model with correlated random effects (test statistic is 61.051, 93.543, and 90.688 with a $p$-value close to zero for treatment MD, VBD, and VFD, respectively).

ment also includes, as in the VBD treatment, the number of members in the group who choose to disclose their individual decisions.

Table 4: Estimation results, treatment MD

| Variable | Coefficient | Standard errors |
|---|---|---|
| Initial individual decision | 0.059 | 0.253 |
| Individual decision in previous period | 0.260* | 0.140 |
| Group decision in previous period | 0.189** | 0.068 |
| Decision-making time | -0.049** | 0.018 |
| Time trend | 0.133** | 0.044 |
| Intercept | -10.860 | 14.438 |
| Log-likelihood | -470.060 | |
| Wald test $\chi^2(23)$, for the model's significance | 165.15 | $p$-value=0 |
| Number of observations | 608 | |
| Number of individuals | 32 | |
| Number of uncensored observations | 133 | |
| Number of left-censored observations | 2 | |
| Number of right-censored observations | 473 | |

Table 5: Estimation results, treatment VBD

| Variable | Coefficient | Standard errors |
|---|---|---|
| Initial individual decision | 0.476** | 0.141 |
| Individual decision in previous period | 0.217** | 0.106 |
| Group decision in previous period | 0.065* | 0.037 |
| Decision-making time | -0.059** | 0.014 |
| Time trend | 0.175** | 0.029 |
| Information sharing, current period | 4.629 | 3.384 |
| Information sharing, previous period | -3.382** | 1.549 |
| Information sharing, number of members in the group | 0.013 | 0.247 |
| Intercept | | |
| Log-likelihood | -783.552 | |
| Wald test $\chi^2(27)$, for the model's significance | 534.49 | $p$-value=0 |
| Number of observations | 684 | |
| Number of individuals | 36 | |
| Number of uncensored observations | 270 | |
| Number of left-censored observations | 20 | |
| Number of right-censored observations | 394 | |

It should be noted that including the decision to share information may create an estimation bias, especially when using data corresponding to treatments VBD and VFD. Indeed, an individual can simultaneously make several decisions about (i) the resource amount (s)he wants to attract, (ii) sharing

Table 6: Estimation results, treatment VFD

| Variable | Coefficient | Standard errors |
|---|---|---|
| Initial individual decision | -0.119 | 0.126 |
| Individual decision in previous period | -0.333** | 0.133 |
| Group decision in previous period | 0.178** | 0.061 |
| Decision-making time | -0.073** | 0.021 |
| Time trend | 0.139** | 0.056 |
| Information sharing & lying, current period | 4.530 | 3.855 |
| Information sharing & non-lying, current period | 8.347 | 5.276 |
| Information sharing & lying, previous period | -2.188 | 1.748 |
| Information sharing & non-lying, previous period | -4.731* | 2.694 |
| Information sharing, number of members in the group | -0.180 | 0.289 |
| Intercept | -14.047** | 4.576 |
| Log-likelihood | -823.005 | |
| Wald test $\chi^2(30)$, for the model's significance | 345.13 | $p$-value=0 |
| Number of observations | 684 | |
| Number of individuals | 36 | |
| Number of uncensored observations | 269 | |
| Number of left-censored observations | 4 | |
| Number of right-censored observations | 411 | |

or not sharing this information to her group (in the VBD treatment), (iii) not sharing this information, sharing this information, or sharing a wrong information (in the VFD treatment). This phenomenon urges us to consider the corresponding explanatory variables as endogenous regressors (i.e. variable "Information sharing, current period" for the VBD treatment, on the one hand, and variables "Information sharing & lying, current period" and "Information sharing & non-lying, current period" for the VFD treatment, on the other hand). For this purpose, we apply the control function approach proposed by Wooldridge (2014), which is particularly suitable for nonlinear models such as our Tobit model with correlated random effects[5]. Tables 5

[5]The control function approach of Wooldridge (2014), consisting in a two-step estimation, is relatively simple to implement. At the first step, a probit model for the endogenous regressor is estimated in order to obtain a generalized residuals. The second step corresponds to the estimation of the usual nonlinear model (i.e. Tobit model with correlated random effects) with the previously computed generalized residuals as an additional regressor. See Wooldridge (2014) for more computational details. Finally, we perform a $z$-test for the significance of these generalized residuals. For the VBD treatment, the $z$-statistic is -2.08, while for the VFD treatment, the $z$-statistic is -1.20 for the first generalized residuals (corresponding to "Information sharing & lying") and -1.97 for the second generalized residuals ("Information sharing & non-lying"). This result implies the significance of generalized residuals in the nonlinear regressions, therefore supporting the control for endogeneity of information sharing when using data under the VBD and VFD treatments.

and 6 provide estimation results which account for this endogeneity bias. It is shown that the results are very similar for all the variables that are not related to information (except individual decision in the previous period): variables "Group decision in previous period", "Decision-making time", and "Time trend" are statistically significant and of the same sign. Regarding individual decision in the previous period, the effect differs between treatments: it is positive in the MD and VBD treatments whereas the sign is negative in the VFD treatment. Tables 5 and 6 also confirm the visual observable trends shown in the figures. Table 5 shows that in treatment VBD subjects extract significantly less when they decide to release information in the previous round. Conversely, we do not find a significant correlation between the level of individual extraction and the number of members of the group who release information at the previous round. Table 6 shows that in treatment VFD, allowing players to lie when declaring the extracted amount, subjects extract significantly less (at the 10% level) when they release information and do not lie in the previous round (as previously observed from the plots). Conversely, no significant relation is found either between the individual extraction level and the decisions to disclose it at time $t$ (lying or not), or between the extraction level and the decision to disclose but lying it at time $t-1$.

# 5 Discussion

Information sharing and voluntary provision by CPR users is a controversial issue in real life situations, and the availability of relatively cheap information systems such as connected consumption gauges, cable or wifi networks to transfer data, computerized databases, etc. make it possible today to put in place a system where both management agencies and CPR users are informed in real time about the CPR situation and extractions.

Various devices and protocols allowing information sharing, including voluntary provision of information by CPR users, are possible and they have different investment and operation costs. Scholars have started to analyze experimentally the effects of information sharing (voluntary or not) on CPR use and different results have been shown, including the negative role of full information about other subjects extractions and performances on CPR use (Villena & Zecchetto 2011), and the positive role of voluntary disclosure of contributions in a public good context (Kreitmair 2015). We wanted here to explore the influence of voluntary provision of information about extraction by CPR users on their extraction behavior. In other words, we wanted to observe if and how the introduction of a second social dilemma (do I share an information or not) had an influence on the first one represented by the CPR context. Results show that the situation of full (compulsory) information is the one conducting to the higher extraction level (consistent with previous studies by Villena & Zecchetto (2011)).

The possibility given to users to choose whether to share information with the other group members resulted in very different consequences on the extraction behavior. If the choice is binary (no disclosure vs disclosure of the real extraction level), it conducts to the lower average extraction level. This is perfectly in line with the findings of Kreitmair (2015), who was dealing with Public Good rather than CPR. However, if users are free to disclose the level of their extraction when deciding to share information, then strategic behaviors appear: free-riders abuse the information system by disclosing a false extraction, much lower than their actual decisions. In fact, the voluntary free disclosure protocol revealed two types of free-riders: those who do not share information and those who share false information, the latter extracting even more than those who do not share.

Additionally, free riders in the VFD treatment send false signals to the other users, which seem to behave as conditional cooperators. These signals indicate that they "behave correctly", at a level of extraction close to the social optimum and without inequalities between group members. Conditional cooperators reciprocate their extraction level in the first periods of the game and then "give-up", loose their trust, and increase substantially their extraction until a level closer to the other treatments at the end of the game. One hypothesis could be made that by adding a degree of freedom, we also increased the boomerang effect: some individuals could lie without real negative intention, just as a try, and never do it again. However this action is perceived by others who, as conditional cooperators, could choose to punish others by free-riding themselves, and this could start an individualistic loop without anyone really wanting it.

These results have clear policy implications, as in the real life information sharing protocols of the type voluntary binary disclosure imply that the agency knows the extraction levels and this has a much higher cost, to be compared with the cost of providing full information to all subjects. The advantage of the binary choice is in the incentive to cooperate coming from the commitment into the process by the Common-Pool Resource users.

What is clear at this stage is that voluntary disclosure of information cannot attain the double goal of contributing to a database and inducing a better cooperation, at least not with the straightforward design we used. The design that could improve the CPR use is a system of voluntary binary disclosure where the agency would support the cost of the collect of information. It is thus necessary to evaluate the cost of this information sharing while comparing to other ways to preserve the resource at stake. Another way is to share the cost of information gathering among users (for instance asking them to pay, even partially, for the installation of the gauges when dealing with water issues). These questions are policy and strategic choices for the decision makers when an information sharing device must be implemented for the management of a common-pool resource.

If our hypothesis about the boomerang effect holds, one can say that the French state had a good idea when deciding for a pre-filled declaration of revenue, in the regular public good game of tax payment that we all play. In the document, most informations are already filled in, and provided beforehand by banks and employers. It is still possible to cheat, but in a way that is more cognitively costly, and which cannot be just a try or a mistake since real values have to be replaced by fake ones. And this relies indeed on a heavy information collection infrastructure, that is taken in charge by users.

# References

Apesteguia, J. (2006), 'Does information matter in the commons? experimental evidence', *Journal of Economic Behavior & Organization* **60**(1), 55–69.

Apesteguia, J. & Maier-Rigaud, F. P. (2006), 'The role of rivalry - public goods versus common-pool resources', *Journal of Conflict Resolution* **50**(5), 646–663.

Becker, H. S. (1960), 'Notes on the concept of commitment', *American Journal of Sociology* **66**, 32–40.

Cox, J. C., Ostrom, E., Sadiraj, V. & Walker, J. M. (2013), 'Provision versus appropriation in symmetric and asymmetric social dilemmas', *Southern Economic Journal* **79**(3), 496–512.

Dawes, R. M. (1980), 'Social dilemmas', *Annual Review of Psychology* **31**, 169–193.

Espinola-Arredondo, A. & Munoz-Garcia, F. (2011), 'Can incomplete information lead to under-exploitation in the commons?', *Journal of Environmental Economics and Management* **62**(3), 402–413.

Gardner, R. O. & Walker, J. (1990), 'The nature of common-pool resource problems', *Rationality and Society* **2**(3), 335–358.

Goldstein, N., Cialdini, R. & Griskevicius, V. (2008), 'A romm room with a viewpoint: using social norms to motivate environmental conservation in hotels', *Journal of Consumer Research* **35**(3), 472–482.

Greiner, B. (2015), 'Subject pool recruitment procedures: Organizing experiments with orsee', *Journal of the Economic Science Association* **1**(1), 114–125.

Gächter, S. (2006), 'Conditional cooperation: Behavioral regularities from the lab and the field and their policy implications', *CeDEx Discussion Paper, The University of Nottingham* **No. 2006-03**.

Hardin, G. (1968), 'The tragedy of the commons', *Science* **162**, 1243–1248.

Huck, S., Leutgeb, J. & Oprea, R. (2017), 'Payoff information hampers the evolution of cooperation', *Nature Communications* **8**.

Janssen, M. A. (2013), 'The role of information in governing the commons: Experimental results', *Ecology and Society* **18**(4).

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

Kreitmair, U. W. (2015), 'Voluntary disclosure of contributions: an experimental study on nonmandatory approaches for improving public good provision', *Ecology and Society* **20**(4).

Nikiforakis, N. (2010), 'Feedback, punishment and cooperation in public good experiments', *Games and Economic Behavior* **68**(2), 689–702.

Olson, M. (1965), *The logic of collective action: Public goods and the theory of groups*, Cambridge, MA: Harvard University Press.

Ostrom, E. (1990), *Governing the commons : the evolution of institutions for collective action*, Cambridge ; New York: Cambridge University Press.

Ostrom, E. (2010), 'Revising theory in light of experimental findings', *Journal of Economic Behavior & Organization* **73**(1), 68–72.

Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B. & Policansky, D. (1999), 'Revisiting the commons: Local lessons, global challenges', *Science* **284**(5412), 278–282.

Ostrom, E. & Walker, J. (2003), *Trust and reciprocity : interdisciplinary lessons from experimental research*, Russell Sage Foundation, New York.

Pfaff, A., Velez, M. A., Taddei, R. & Broad, K. (2013), 'Unequal Information, Unequal Allocation: Bargaining field experiments in NE Brazil', *Environmental Science & Policy* **26**, 90–101.

Poteete, A. R., Janssen., M. & Ostrom, E. (2010), *Working together: Collective action, the commons and multiple methods in practice*, Princeton University Press.

Villena, M. G. & Zecchetto, F. (2011), 'Subject-specific performance information can worsen the tragedy of the commons: Experimental evidence', *Journal of Economic Psychology* **32**(3), 330–347.

Walker, J. M., Gardner, R. & Ostrom, E. (1990), 'Rent dissipation in a limited-access common-pool resource - experimental-evidence', *Journal of Environmental Economics and Management* **19**(3), 203–211.

Willinger, M. & Ziegelmeyer, A. (1999), 'Framing and cooperation in public good games: an experiment with an interior solution', *Economics Letters* **65**(3), 323–328.

Wooldridge, J. (2014), 'Quasi-maximum likelihood estimation and testing for nonlinear models with endogenous explanatory variables', *Journal of Econometrics* **182**, 226–234.

Wooldridge, J. M. (2005), 'Simple solutions to the initial conditions problem in dynamic, nonlinear panel data models with unobserved heterogeneity', *Journal of Applied Econometrics* **20**, 39–54.

# CEE-M Working Papers[1] - 2018

WP 2018 - 01: Ilaria Brunetti., **Mabbel Tidball**, & Denis Couvet
« Relationship Between Biodiversity and Agricultural Production »

WP 2018 - 02: **Phillippe Le Coent**, **Raphaële Préget** & **Sophie Thoyer**
« Do farmers follow the herd? The influence of social norms in the participation to agri-environmental schemes.»

WP 2018 - 03: Ludivine Roussey & **Raphael Soubeyran**
« Overburdened judges »

WP 2018 - 04: **Nicolas Quérou**
« Interacting collective action problems in the Commons »

WP 2018 - 05: Karine Constant & **Marion Davin**
« Unequal vulnerability to climate change and the transmission of adverse effects through international trade »

WP 2018 - 06: Henrik Andersson & **Emmanuelle Lavaine**
« Nitrates and property values: evidence from a french market intervention »

WP 2018 - 07: **Mamadou Gueye**, **Nicolas Querou** & **Raphaël Soubeyran**
« Does equity induce inefficiency? An experiment on coordination »

WP 2018 - 08: **Douadia Bougherara** & Laurent Piet
« On the role of probability weighting on WTP for crop insurance with and without yield skewness »

WP 2018 - 09: **Douadia Bougherara, Carole Ropars-Collet** & Jude Saint-Gilles
« Impact of private labels and information campaigns on organic and fair trade food demand»

WP 2018 - 10: Sylvain Chabé-Ferret, **Philippe Le Coent**, Arnaud Reynaud, **Julie Subervie** & Daniel Lepercq
« Can we nudge farmers Into saving water? Evidence from a randomized experiment »

WP 2018 - 11: **Dimitri Dubois,** Stefano Farolfi, Phu Nguyen-Van & Juliette Rouchier
« Information sharing is not always the right option when it comes to CPR extraction management: experimental finding»

[1] CEE-M Working Papers
**Contact** : laurent.garnier@inra.fr/ 04 99 61 31 21