From a blind truncheon to a one-eyed stick: testing in the lab an optional target-based mechanism adapted to groundwater withdrawals

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Abstract:

This paper proposes an optional target-based mechanism to improve the management of groundwater withdrawals when farmers' behavior is imperfectly monitored. It combines a classical ambient tax (a blind truncheon), paid by the group of farmers when the water table level falls below a pre-defined target, with an optional individual contract that enables signatory farmers to signal their withdrawals and to avoid the collective sanction if they comply with an individual quota (a one-eyed stick). This mechanism is expected to be more acceptable than the ambient tax and to help reduce information asymmetries between the regulator and farmers. It is tested experimentally in the lab with a contextualized protocol. First results show that such mechanism reduces withdrawals but that subjects are able to coordinate in a repeated setting to extract an informational rent.

Keywords:

Groundwater management; Imperfect information; Target-based mechanism; Coordination game; Experimental economics.

1. Introduction

Being a common-pool resource, groundwater is often subject to the well-known *Tragedy of the Commons* (Hardin 1968), namely overexploitation. Several economic instruments are mobilized to limit over-exploitation such as pumping taxes, water quotas or marketable pumping permits. However, they focus on individual behavior and impose that water managers be perfectly informed on each water user's consumption. This is rarely the case in the real world. When legal and administrative settings are insufficient to monitor individual withdrawals, for example when wells are neither officially declared to the authorities, nor properly metered, then the groundwater may present open-access resource features (Howe 2002). Groundwater is withdrawn in an imperfect informational context and the above instruments become inoperative.

Only little attention has been paid by scholars to the specific issue of groundwater withdrawals management under imperfect information[1]. Studying non-point source pollution (Segerson 1988) or moral hazard in team (Holmstrom 1982), several authors have nonetheless

[1] Dinar and Xepapadeas (2002) studied partially observed groundwater withdrawals as an input of partially observed pollution emissions (Dinar and Xepapadeas 2002).

designed incentive instruments adapted to imperfect information settings. Segerson (1988) proposes a *target based mechanism* (TBM) where an authority able to estimate the aggregate pollution emissions of a well-defined group imposes to each group member a tax (or a subsidy) proportional to the difference between observed group emission level and the group target. . She shows that for a sufficiently high level of the ambient tax, the Nash equilibrium yields an aggregate pollution level equal to the group target. Giordana and Montginoul (2006) point out that such a TBM is well suited to manage unobserved groundwater withdrawals since withdrawals of a well-defined group can be approximated by the groundwater table level monitored at some observation points (Giordana and Montginoul 2006). By analogy with non-point source pollution, we name unobserved groundwater withdrawals *non-point withdrawals*. The ambient tax (subsidy) would be charged (paid) if the groundwater table falls below (above) the target level set by a regulator.

Although theoretically appealing, TBM are rarely implemented in real world situations for numerous technical, practical and political reasons (Shortle and Horan 2001)[2]. In our opinion, the two decisive reasons for the lack of success of TBM are:

(i) The lack of acceptability: even agents who supply a costly effort to reduce their individual emissions may be liable for the collective tax if the group pollution exceeds the target. This can be challenged socially as a very unfair sanction and can even be considered unlawful by many legal systems. Reichhuber et al. (2009) mentioned the use of a TBM for forest protection in Costa Rica that has been abolished due to unfairness (Reichhuber et al. 2009).

(ii) The imprecise link existing between group behaviour and the observation of this behaviour by the regulator.

The distinction between point source and non-point source problems depends on the cost of observing individual behaviour (Millock et al. 2002). In the groundwater case, increasing observability is feasible by inventorying wells and metering withdrawals. Several authors support the introduction of an individual dimension to TBM by increasing observability to

[2] For some examples see Ribaudo and Caswell (1999) and Segerson (1999) and for an overview of the practical conditions under which TBM are the most suited, see Weersink et al. (1998) (Weersink et al. 1998; Ribaudo and Caswell 1999; Segerson 1999).

overcome the issue of acceptability (Xepapadeas 1995; Dinar and Xepapadeas 2002). We define *combined TBM* as mechanisms combining group-based and individual-based mechanisms, and *optional TBM* giving the choice between individual or group mechanisms.

Xepapadeas (1995) studies an optimal combined TBM under uncertainty. A mix of individual and group taxes leads agents to reveal all or part of their individual behaviour. Kritikos (2004) develops an optimal combined *TBM* with individual and group taxes along with random inspection. The individual tax is paid if the inspection reveals that the agent used more his declared withdrawals (Kritikos 2004). Studying the impact of groups' cooperation on TBM, Millock and Salanié (2005) propose an optional TBM: agents must choose between a monitoring system with an individual tax and a TBM where group taxes depend on the cooperation level of groups (Millock and Salanié 2005). Karp (2005) extends Millock and Salanié's mechanism to a dynamic setting, addressing groups' cooperation as the formation of *clubs* purchasing monitoring equipments (Karp 2005).

None of these papers do combine a TBM with an individual quota system. The latter may however be preferred by water users. Molle and Berkoff (2007) recall that a quota system "*appears a far more satisfactory and practical solution to water savings in almost all real-life circumstances*" due to transparency, administrative simplicity and because it ensures equity among users without imposing additional income losses (Molle and Berkoff 2007).

We focus in this paper on practical aspects of the implementation of an OTMB adapted to manage non-point withdrawals in an agricultural context: acceptability, information asymmetry and contract duration. We test in a contextualised lab experiment an optional TBM proposing a choice between *(i)* a *no contract situation* where farmers are liable for a TBM (e.g. a blind truncheon) and *(ii)* a *contract situation* where an individual quota is allocated to the signatory farmer, provided he changes his irrigation technology, reveals information on his withdrawals and accepts to be controlled by a regulating authority if the group's withdrawals exceeds the target. We assume that the control can only ascertain whether a farmer exceeds his quota or not, but not by how much. A contractor is thus liable for a group tax if a control proves he exceeded his quota (e.g. a one-eyed stick). This mechanism enables any complying agent to escape the group tax. The remainder of this paper is organised as follows. Section 2 formally develops the optional TBM. The experimental procedure and hypothesis are described in section 3 while section 4 presents lab results.

Section 5 links these results to practical aspects of a real world implementation of the optional TBM. Section 6 concludes.

2. The Optional Target Based Mechanism

In this section we present an optional TBM which improves the acceptability issue.

2.1. Baseline

Consider a group of n identical agents withdrawing w_j individually and $W = \sum_{j=1}^{n} w_j$ collectively from an aquifer. Each agent has the profit function $R^0(w_j)$, increasing, concave and twice differentiable in w_j. Due to technical or agronomic constraints, let be $w_j \leq \overline{w^0}$ the maximum water volume each agent can withdraw. Profit maximization imposes agents to withdraw $\overline{w}$ each to earn $\overline{R^0} = R(\overline{w^0})$. The collective withdrawals equals $n\overline{w^0} = \overline{W^0}$.

2.2. *No contract situation*: a blind truncheon based on a simple TMB

Consider now a regulating authority *(i)* able to estimate perfectly the aggregate behavior of the n agents *(ii)* willing to impose each agent to withdraw $w^* < \overline{w^0}$. Unable to observe w_j, he imposes to the n agents a group target $W^* = nw^*$. If the group withdraws $W > W^*$, each of the group member must pay the group tax $\theta_j^0 = \tau_j^0.(W - W^*)$. If $W \leq W^*$, nothing appends.

2.3. *Contract situation*: a one-eyed stick combining a TMB with quotas and random controls

Knowing that the blind truncheon mechanism might be massively rejected, the manager proposes to each agent a contract which *(i)* allocates the quota w^*, *(ii)* imposes to declare each borehole possessed, *(iii)* and to measure individual withdrawals *(iv)* subsidises a change of irrigation technique *(v)* imposes that the farmer cooperates fully in case of inspection.

An agent signing the contract has a new profit function $R^1(w_j)$, with $w_j < \overline{w^1} < \overline{w^0}$ and $\frac{\partial R^1(\overline{w^1})}{\partial w_j} = 0$. Contracting enables a more efficient use of water so $R^1(w_j) > R^0(w_j)$, $\forall w_j < \overline{w^1}$. Maximizing profit, contractors however loose compare to the *no contract* situation: $\overline{R^1} < \overline{R^0}$.

Since $w^* < \overline{w^1}$, there is no guarantee that a contracting agent respects his quota. If the manager observes the group overtakes groundwater (i.e. $W > W^*$), he imposes to contracting agents a random inspection occurring with a probability $\varphi \in [0,1]$. If the inspection reveals that the agent respected his contract (i.e. $w_j < w^*$) or if the agent is not controlled, then he pays no tax. Else he is liable for the group tax $\theta_j^1 = \tau_j^1.(W - W^*)$. We assume here that controlling authorities are unable to measure precisely the excess quantity withdrawn by a contracting agent. In practice, farmers can cheat with a skewed meter or an undeclared borehole.

Figure 1: Description of the mechanism.

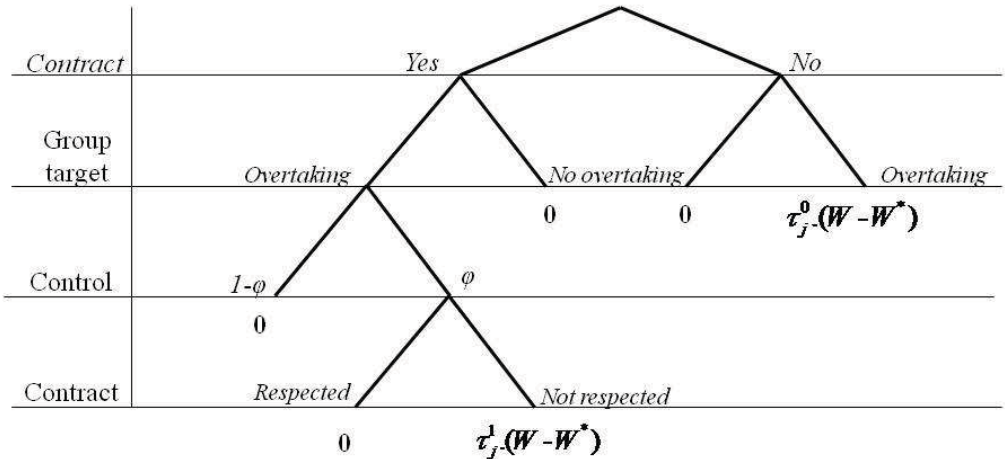

Figure 1 resumes the optional TBM. The right side of the tree represents the blind truncheon where a group tax is applied in case of group overtaking. The left side schematizes the one-eyed stick with random inspections occurring in case of group overtaking and the payment of a group tax if a control reveals an agent has cheated his contract. To avoid certainly being liable for a group tax, one can see that a complying agent has to sign the proposed contract and to withdraw $w_j \leq w^*$. Doing so he will pay no group tax whether controlled or not.

2.4. Incentive tax rates

The aim of the authority is to induce the *n* agents *(i)* to sign up the contract during the so-called *contract stage* and *(ii)* to respect the contract by withdrawing $w_j \leq w^*$ through minimal tax rates during the so-called *volume stage*.

Looking at the *volume stage*, it is straightforward that equation 1 defines the minimal tax rate ensuring that a contracting agent will withdraw $w_j = w^*$, provided he is not risk-lover. Under such a tax rate, the expected profit of a contracting agent equals $R^* = R^1(w^*)$ [3].

$$\tau^{1*}{}_{(\varphi)} = \frac{1}{\varphi}\frac{\partial R^1(w^*)}{\partial w} \qquad [1]$$

Looking at the *contract stage*, one can address the blind truncheon as a threat obliging agents to sign up. Under [1], τ^{0*} must be set so the expected profit with *no contract* is lower or equal to R^*. Let be $\widehat{w^0}$ the water volume maximising the expected profit in the *no contract situation*. It can be shown that τ^{0*}, the minimal tax rate insuring that any non risk-lover agent will sign up the contract, is defined by equations 2:

$$\tau^{0*} = \frac{\partial R^0(\widehat{w})}{\partial w} \qquad [2a] \qquad\qquad \tau^{0*} = \frac{R^0(\widehat{w}) - R^1(w^*)}{\widehat{w} - w^*} \qquad [2b]$$

The minimal incentive tax rate equals then the water marginal value with *no contract* at the point where this marginal value equals the per water unit gain from not contracting and overtaking water.

Figure 2: Graphic presentation of the impact of the mechanism on agent's profit.

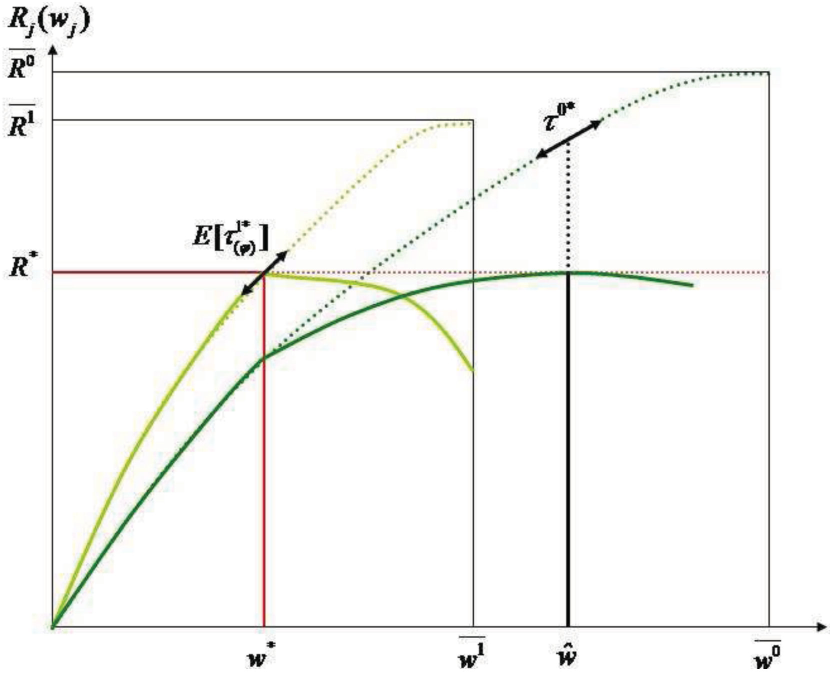

Figure 2 graphically illustrates the incentive tax rates calculation in a case of symmetric players, with in light green the *contract situation*, and in dark green the *no contract situation*.

[3] Risk-adverse agents will withdraw $w_j = w^*$ too since this behavior guaranties the secured pay-off R^*.

2.5. Impact of an over-stated group target

In the case of groundwater, authority estimates the group withdrawal W by observing groundwater table level Ω. This estimate is imprecise due to the complexity of the relationship between withdrawals and the water table level. To be sure of triggering the optional TBM if and only if $W > W^*$, authority may voluntarily decide to increase the threshold above which the group is submitted to the collective sanction. Assume that the water table signaling a total withdrawal of W^* is Ω^*. Assume however that there is positive probability that there is a mistake in measuring the link between the two: for example $\Omega \equiv N(W,\sigma)$. To avoid punishing the group when the target withdrawal is not exceeded, the threshold is set at $\Omega^{IR} \equiv N(W^* + IR, \sigma)$ with $IR \geq 0$ being proportional to the estimate quality of the group behavior (i.e. the hydrogeological knowledge of authority).

In practice, authority sets up Ω^{IR} at the beginning of the irrigation period. Farmers can however daily know Ω by observing the water table level into boreholes. We assume that farmers do have better information than authority and that IR can be interpreted as an *informational rent*[4].

Under such a rent, the incentive tax rates defined by equations 1 and 2 still incite agents to sign up, provided the informational rent is not too important[5]. They however miss in inciting agents to withdraw $w_j = w^*$. Each situation where $W = W^* + IR$ and $\forall j$, $w_j \geq w^*$ constitutes a Pareto-efficient equilibrium. All those equilibrium are asymmetric but for the one where each agent withdraws $w_j = w^* + IR/n$. The informational rent is thus a source of inequity among agents and may thus impact acceptability of the optional TBM. We wonder thus about the ability of agents *(i)* to enjoy the informational rent and (ii) the way they would enjoy it in a real world situation. To address this issue we set up the following experimental design.

3. Experimental design

In this section, we first describe the practical procedure of the experiment and then present the specific parameters we used. We finally derive and discuss the corresponding predictions.

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[4] Authority may in practice define two reference levels: a first one warning users that there are suspicions of group overtaking and a second one below which sanctions and controls are triggered.

[5] Let be w' the water volume giving $R^0(w') = \overline{R^1}$. This proposition holds for $IR \leq n(w' - w^*)$.

3.1 Practical procedure

The experiment was run at the Montpellier's Laboratory of Experimental Economics (LEEM) in June 2010. A total of 51 subjects were recruited randomly with economic or scientific background. Five 2-hour sessions were carried out, each session gathering between 4 or 6 groups of three subjects. Each subject earned an average payoff of 20 € plus a 10 € fixed payoff (5 € if subjects study on the LEEM site). Subjects were split into 3-subject groups of "irrigating farmers" with no possibility to communicate and were unable to identify the 2 other group members. They do physically interact only with experimenters for instructions and payment, and a computer for playing[6]. Each session lasted 35 periods, three treatments were successively played.

3.2. The treatments

Three treatments were played in each session (within subject treatments): treatment 0 serves as a baseline while treatments T and D are the core of the experiment. In each treatment, subjects play a 2 stage game with, at each period, first a *contract stage* – each subject decides whether he contracts or not and is warned about the number of contracting subjects in its group – and second a *volume stage* – each subject decides how much water he withdraws.

Treatment 0 lasts for 5 periods only. Subjects are given the group target and individual quotas, but they know that there is no control or sanctions.

Treatments T and D last for 15 periods each. Groups are rematched after periods 5 and 10. Each group of 5 periods can be considered a "supergame" in which repetition with the same players can help coordination[7]. The optional TBM is introduced with an informational rent as explained in section 2.5. Treatment D differs from treatment T in that once signed up, a contract lasts until the end of a supergame. Here "T" reminds a *temporary* contract (i.e. lasting a single period) and "D" a *definitive* one (i.e. lasting until the end of the supergame).

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[6] The computer interface was run with the Z-Tree software (Fischbacher 2007). Instructions are available in French upon request.

[7] We thus used a *partner design* with a rematching procedure which is close to the one set up by Selten and Stoecker (1986) to address end-behaviour in repeated Prisoner's Dilemma (Selten and Stoecker 1986). This design has been carried out *(i)* because *partner design* is likely to be more realistic than *strangers design* when policies are implemented in non-point situations (Cochard et al. 2005) *(ii)* to disentangle learning from coordination effects.

A long-term contract implies that farmers are bound by their commitment and are unable to use a trial and error strategy. It is important to notice that if different in the *contract stage*, treatments T and D are equivalent in the *volume stage* (provided the same number of subjects have signed up).

Adopting a *within* procedure, we do not randomly assign group. Groups in the first supergame in treatment T were the same as in treatment D (ditto in second and third supergames). Comparing treatment 0 and T isolates the *TBM effect*, while comparing treatment T and D controls for the *contract duration effect*. We further test for an *order effect* between treatment T and D with 33 subjects playing treatment 0, T and then D and 18 subjects playing O, D and then T. We finally observe 51 subjects playing within 17 independent groups in treatment 0 and 51 quasi independent groups in treatment T and D.

3.3. Parameters

Sessions were run with groups of M = 3 subjects having the same two-part linear profit function $R^k(w_j)$ depending on whether they sign (k = 1) or not (k = 0) the proposed contract. The profit function, expressed in tokens, can be summarized as follows:

$$R^k(w_j) = (13+k).\min(w_j, w^*) + 6.\max(w_j - w^*, 0)$$

Water marginal value equals 13+k tokens before the quota limit is reached and 6 tokens beyond. The following table provide the value of the main parameters.

Table 1: Parameters used in the lab.

Parameters	k=0	k=1
$\overline{w^k}$	95 units	80 units
w^*	-	50 units
$\overline{R^k}$	970 tokens	930 tokens
R^*	-	750 tokens

Since the quota value is $w^* = 50$ units, the group target equals $W^* = 150$ units. In treatments T and D, we assume that the informational rent $IR = 30$ units so that controls and sanctions are undertaken only if the group withdraws collectively $W > 180$ units. We set up the probability control of contracting subjects in case of excess total withdrawals at $\varphi = 0.25$ so that equations [1] and [2] give the following minimal incentive tax rates:

$$\tau^{1*}_{(0.25)} = 24 \text{ and } \tau^{0*} = 6 \qquad [3]$$

3.4. Theoretical and conjectural hypothesis

TREATMENT 0

1) Subjects do not sign the contract and withdraw 95 units each. In the absence of any sanction, a subject maximizing his gain will refuse to sign the contract and will withdraw the maximum amount. We thus predict any subject not to sign and to withdraw $\overline{w^0} = 95$ units while a group will withdraw $W = 285$ units.

TREATMENT T AND TREATMENT D

Contract stage

2) All subjects sign the contract in both treatments.

With the tax rates given by equation [3] it is a dominant strategy to sign the proposed contract in both treatments. Contract duration has thus no theoretical impact on the *contract stage*.

3) Due to learning, an order effect may exist in treatment D.

Subjects may be reluctant to commit definitively because there are unable to experiment the contract before backtracking: the definitive contract may restrict learning. When treatment T is introduced to subjects before treatment D, the *contract situation* has already been experienced by subjects and the definitive nature of the contract should have no impact. Conversely, when treatment D is played before, subjects may fear to sign up the contract because they cannot come back to the *no-contract situation* until the end of the supergame. If true, this may lead to the observation of an *order effect*, that is, a significant difference between contracting occurrences according to the order subjects face both treatments. Attention is paid to the first period of each supergame and to the first supergame as a whole.

Volume stage: at group level

We remind that treatments T and D are equivalent during the *volume stage* provided groups have the same number of contractors. Assuming that groups are composed by 3 contractors:

4) Some subjects will exceed their quota; it is Pareto-optimal to seek collectively the informational rent.

Since contracting subjects may withdraw $50 \leq w_j \leq 80$, the game constitutes a 3-player 31-choice (subjects can only choose integer values for withdrawals) coordination game with

$31^3 = 29\ 791$ outcomes[8]. Each of the 496 outcomes where $W = 180$ is Pareto-optimal. Subjects have thus an interest in coordinating their withdrawals on one of these equilibria[9].

5) Coordination will increase with repetition.

Repetition in a *partner design* is a coordination device since it gives information on the behavior of the other members of the group. Reducing the strategic uncertainty, repetition is likely to increase coordination so that W converges to the trigger point with periods. To ascertain the increase in coordination is due to the reduction of strategic uncertainty we design our experiment in a *quasi-partner* way, i.e. by rematching groups after a 5-period supergame. If the magnitude of the convergence within groups (if convergence) is still important during the last supergames, coordination increase can be seen as a reduction of strategic uncertainty.

Volume stage: at individual level

6) We test the hypotheses that a focal point is to coordinate on an equal sharing of the informational rent.

The game is akin to a discrete Chicken game with a cooperative outcome. The Chicken game (also known as a Hawk-Dove game) simulates a situation "*where [agents] differ strongly over which equilibrium is preferred, where a Pareto-optimal but non-equilibrium compromise outcome is available to cooperative [agents] and disaster occurs in the form of the mutually worst outcome if neither cooperates*" (Snidal 1991). Here, the "disaster" is the trigger of the one-eyed stick and each subject "prefers" the asymmetric outcome where he withdraws $w_j = 80$ units and the 2 others $w_i = 50$ units. The preferred outcome constitutes a Nash equilibrium in pure strategy, but this equilibrium is threefold and no dominant strategy exists. One can thus hardly expect coordination to occur in a Chicken game due to strategic uncertainty, i.e. the fact of not knowing the strategy adopted by the others. Disasters ($W > 180$) or inefficient outcomes ($W < 180$) are likely to occur.

Our game indeed differs from a classical one-shot Chicken game because we introduce two coordination devices – reciprocation and repetition (Bornstein et al. 1997) – that are pregnant

[8] Withdrawing $w_j < 50$ would be irrational. We exclude this possibility from the analysis.

[9] A Pareto-optimal outcome means there is no other equilibrium with greater or equal payoffs to all subjects and a strictly higher payoff to at least one subject.

in an agricultural context[10]. The discrete choice feature of our game mimics the ability play in mixed-strategy in a 2-choice Chicken game. The equilibrium where each subject withdraws $w_j = w^* + IR/n = 60$ is Pareto-optimal. Being a symmetric equilibrium, it constitutes the cooperative outcome of the game and a focal-point (Schelling 1960). Subjects are thus more likely to coordinate than in a pure Chicken game.

Repetition impacts cooperation with 2 counteracting forces. On one hand, repetition may help in establishing confidence helping subject to settle on the cooperative equilibrium. Some experiments reveal that players are able to cooperate in repeated Chicken game without symmetric equilibrium – by adopting mixed-strategy, i.e. through turn-taking (Deutsch and Lewicki 1970; Bornstein et al. 1997). One can thus expect the cooperative equilibrium to be often reached in our game. On the other hand, repetition gives information on group members' behavior. Due to subjects' anticipations, believes and motivations, the cooperative equilibrium is likely to be unstable. The following story illustrates this instability:

> *"After a first period of equal sharing, subjects A withdraws in period 2 more than the cooperative strategy betting he will not be controlled in case group overtaking. Subjects B and C observe the above behavior and escape the group mechanism by withdrawing* $w^* = 50$ *in period 3. Observing B and C's behavior, subject A takes the "shares" left by B and C and withdraw* $\overline{w^1} = 80$ *in period 4."*

This story recalls the first mover advantage in repeated Chicken game. Preemption is there another coordination device (Bornstein et al. 1997) and arm wrestling between subjects to capture the rent may result in reaching stable asymmetric Pareto-optimal equilibrium. We identify 3 strategies likely to be often chosen by contracting subjects:

- The *Dove* strategy where a subject withdraws $w_j = 50$ and escape the group sanction. It may reflect the will of escaping an arm wrestling or be related with risk aversion.
- The *Cooperative* strategy where a subject withdraws $w_j = 60$ to share equally the informational rent.

[10] A third important coordination device is communication which could mimic irrigators unions already existing worldwide in many irrigated areas.

- The *Pure hawk* strategy where a subject withdraws $w_j = 80$ to capture the rent share of other subjects. It may reflect the will of engage in arm wrestling or risk behavior. It can be interpreted as free-riding too[11].

We wonder whether subjects will converge to or diverge from the cooperative equilibrium.

The equity issue

7) Will subjects judge the optional TBM as equitable?

Asking 76 irrigating farmers about group taxes, Montginoul and Rinaudo (2009) found an acceptance rate of 0% (Montginoul and Rinaudo 2009). Enabling complying subjects to escape surely the one-eyed stick, we expect our mechanism would perform better. We do not however ask subjects about acceptability but rather about equity since it would be incongruous to ask students whether they would "accept" such an instrument or not. The acceptability issue seems however to the authors closely linked to the inequity one. The informational rent being a source of inequity among subjects, we fear the optional TBM will be judged as inequitable by our subject pool. The following section presents the main experimental results.

4. RESULTS

We first present the experimental results of the first supergame carried out in treatment 0 and then jointly the results from the 6 supergames conducted under treatments T and D.

4.1. Treatment 0

1) A large minority of contracts are signed and efforts are made to reduce water withdrawals.

Although there are no financial reasons for signing and/or withdrawing less than allowed, some subjects frequently do so. A majority of subjects refuse the contract, but 36.4% of proposed contracts are signed, so that groups do contain 1.1 contractor in average. Groups are thus able to withdraw up to $1.1 \times \overline{w^1} + (3 - 1.1) \times \overline{w^0} = 268.6$ units, but they "only" withdraw 244.3 units in average with a high dispersion (Figure 3). The environmental target is even reached in nearly 5.5% of cases.

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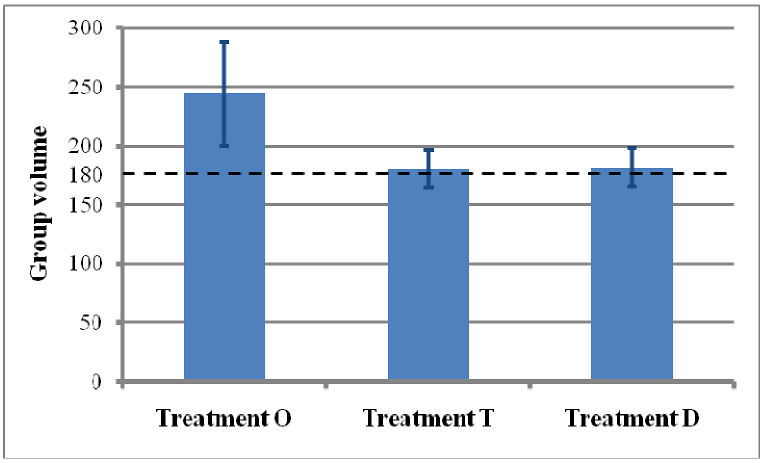
[11] The game can be seen as a threshold public bad game: each subject has to choose the amount he invests in a collective account (or avoided withdrawal) and below a given amount of collective investment, a public bad is produced (the one-eyed stick).

Figure 3: Average and standard deviation of the volume withdrawn by groups according to treatment.



4.2. Treatment T and D

Contract stage

2) A minority of contracts are not signed.

85.5% (respectively 86.7%) of the proposed contracts are signed by subjects in treatment T (treatment D). This percentage increases during supergames and from a supergame to another. All the three members of a group are under contract in 63.1% (65.1%) of cases.

2') There is no contract duration effect.

Looking at the number of contracting subjects per group, there is no significant difference between treatments T and D ($p = 0.517$, paired WMW test). If the average percentage of *contract situation* in the first period of each supergame is lower in treatment D (78.4%) than in treatment T (84.3%), the number of signed contracts per group is not significantly lower ($p = 0.1406$, one-sided Wilcoxon-Mann-Whitney (WMW) test). In treatment D, the first period average percentage of *contract situation* is much lower than later on (from 85.6% to 92.2%). if the existence of an effect cannot be totally rejected, it is at least partially due to the cumulative nature of sign occurrence in treatment D.

3) There is an overall order effect on signing in treatment D.

The average commitment rate in treatment D is 89.5% if treatment T is played before treatment D, and 81.5% else. This difference is significant ($p < 0.001$, WMW one-sided test): an overall *order effect* exists in treatment D. Focusing on first played supergame and first played periods, this effect surprisingly vanish ($p > 0.11$ in both cases) The *order effect* is inexistent during the first period and the first supergame but appears later on: learning is not a reasonable explanation for the *order effect*.

Volume stage: at group level

4) The collective target is exceeded.

Figure 3 displays group withdrawals in each treatment. The comparison between treatment 0 and treatments T and D shows a clear *TBM effect*: the average group volume drops from 244.3 units in treatment 0 to 180.6 and 181.5 units in treatments T and D. This effect falls short of the target $W^* = 150$ units which is less respected than in treatment 0 (3.53% of cases).

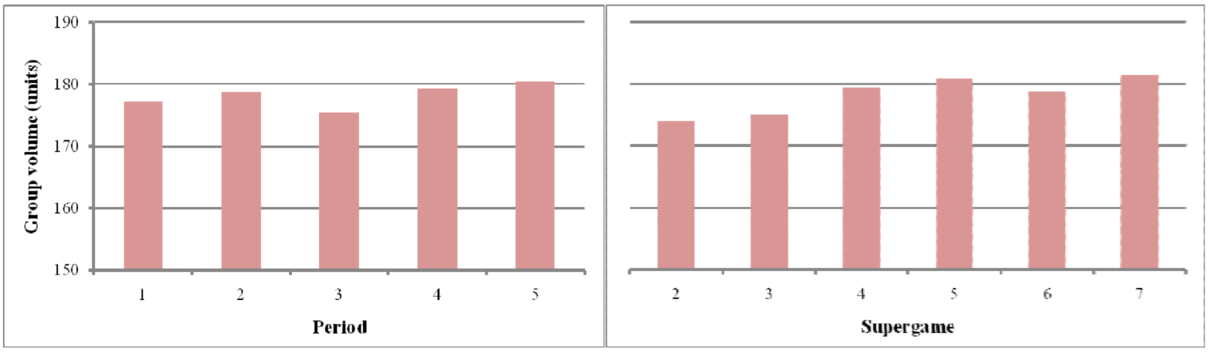
4') Subjects coordinate on the trigger point, but inefficient equilibria are often reached.

Looking at Figure 3, one can see that group volumes do not statistically differ from the trigger point ($p > 0.35$ in both treatments, WMW test). Group volume however equals 180 units in only 20.0% (27.8%) in treatment T (treatment D) while the one-eyed stick is triggered in nearly one third of cases (24.8% and 37.3%).

5) Repetition within a group improves coordination within a group.

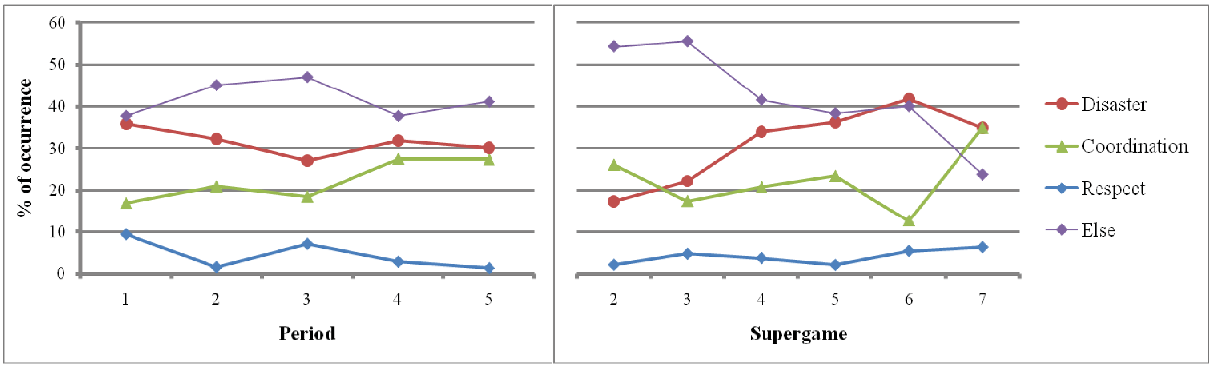
From this point, some choices have been made in analyzing the data. First, to ease the analysis, we focus on the 64.1% of groups with 3 contracting members. Second, as coordination evolves during the experiment, we analyze our data keeping periods and supergames as explanatory variables. This means we pool data of treatments T and D carried out in different orders since 31 subjects played treatment T (D) during supergames 2 to 4 (5 to 7), and 18 subjects played treatment T (D) during supergames 5 to 7 (2 to 4). This is expected to have no impact on data since treatments T and D are equivalent during the *volume stage*. We finally found that coordination increases with periods but not with supergames.

Figure 4: Group volume according to period and supergame. Data from 3-contractor groups.



Looking at average group withdrawals (Figure 4), equilibrium types occurences (Figure 5) and group volume dispersion (Figure 6), three observations can be made. First, the volume withdrawn by groups tends to increase with both periods and supergames to get closer to (and sometimes exceed) the trigger point in average. Group withdrawals increase for example from 177.7 to 180.4 units from period 1 to period 5, while from 174.0 to 181.4 units from supergame 2 to supergame 7. Groups tend to shift upward their withdrawals risking "disaster" rather than under-exploiting the informational rent.

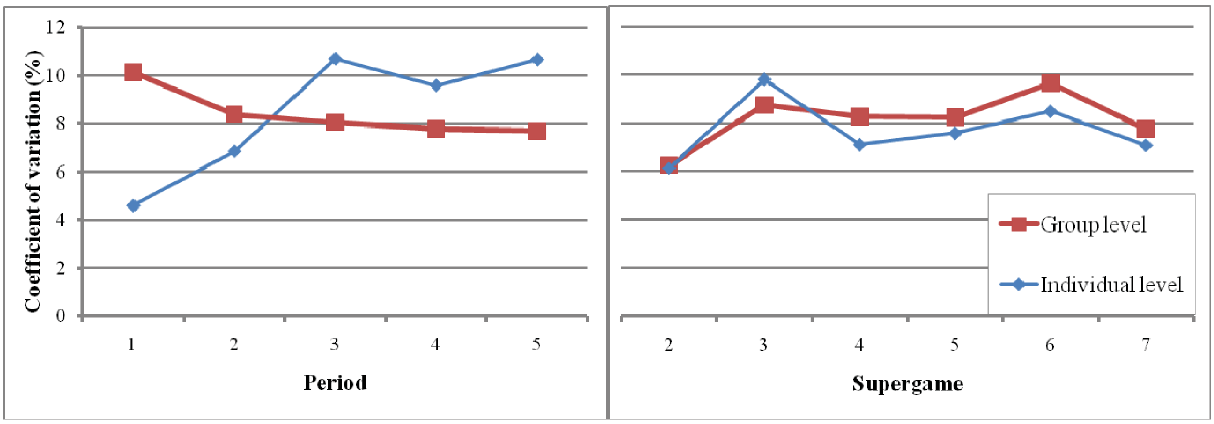
Figure 5: Evolution of the occurrence of "disaster" (W>180), coordination (W=180) and respected target (W≤150) according to period and supergame. Data from 3-contractor groups.



Second, coordination seems to decay from a supergame to another. Figure 5 presents the frequency of different equilibrium types according to period and supergame. As group volume increases toward the trigger, one can expect that the one-eyed stick will be implemented more frequently by authority with periods and supergames. This is clearly the case with supergames since the occurrence of disaster almost doubles from nearly 20% up to roughly 40%: seeking the rent, subjects fail in coordinating sufficiently to avoid the sanction. Coordination decays but for the last supergame.

Third, coordination equilibria are more frequently reached with repetition within groups. Its occurrence rises from 17.0% to 27.4%. Despite groups increase withdrawals, repetition improves coordination to avoid disaster: sanction occurrence falls from 35.9% to 30.1%.

Figure 6: Coefficient of variation of volume withdrawn by groups and subjects according to period and supergame. Data from 3-contractor groups.



One can synthesize the above information looking at the coefficient of variation of group volumes in Figure 6 (red bold curve). The lower the dispersion of group volumes, the more likely the Pareto-optimal outcome, and the more successful the cooperation. One can see a decrease of the coefficient of variation with periods from 10.1% to 7.7%. This confirms coordination improvement within groups: group volumes tend to converge with periods. Notice that no convergence appears with supergames.

To conclude, groups tend to increase withdrawals with periods and supergames. On the one hand, repeating the game within the same group allows subjects to compensate this increase through a better coordination to avoid the one-eyed stick. On the other hand, the experiment going on, groups apparently fail in improving coordination changing from a group to another. The general rise in group volume leads to a more frequent use of the one-eyed stick.

Volume stage: at individual level

6) The cooperative strategy is not a focal point; the dove strategy is more frequently chosen.

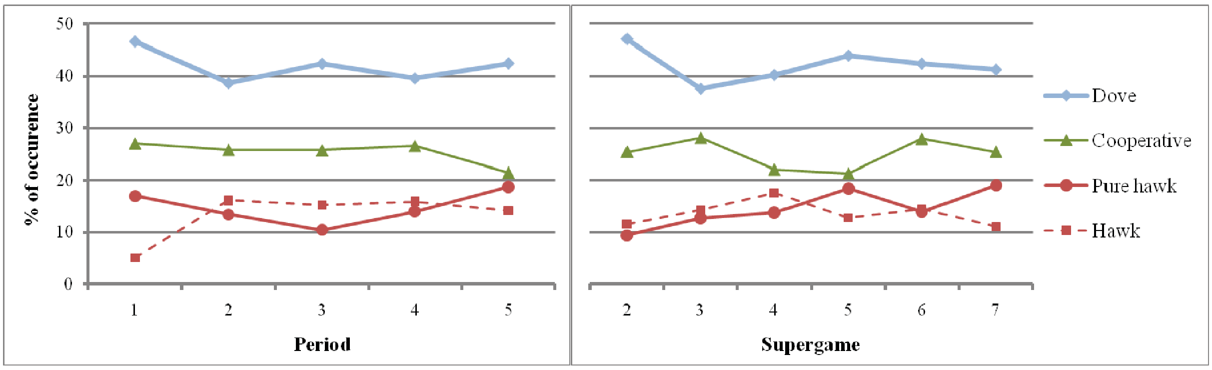
We focus now on data at the individual level. If a high heterogeneity of withdrawing strategies exists, around 80% of this heterogeneity is resumed by our 3 expected strategies. The *dove* one is most used with 41.8% of occurrence. Subjects do comply much more than one could expect. The *cooperative* strategy has been played only in 25.2% of cases and seems at first glance far from being a focal point. The *pure hawk* strategy has been chosen in 14.7% of cases that is roughly as much as intermediate strategies with $60 < w_j < 80$ units (13.7%) that we latter call the *hawk* strategy.

6') If strategies are globally stable, some subjects individually adopt first a predefined strategy before adapting to the behavior of the group.

We look at the stability of individual behaviour by analysing the coefficient of variation of the volume withdrawn by each subject and its evolution with periods and supergames (blue thin curve in Figure 6). While volume dispersion decreases at group level, the dispersion of individual choices interestingly increases within groups between period 1 and 3 from 4.6% to roughly 10%. This reflects that subjects routinely adopt a given strategy during period 1 before diverging from this strategy. This divergence points that subjects gradually adapt their strategy according to the behaviour of the different groups they play with.

Figure 7 presents the evolution of the three identified strategies occurrence with periods and supergames plus the hawk strategy. The dove strategy is more chosen during the first period (46.5%) and the first supergame (47.1%) than latter (stable close around 40%). Some subjects use thus this strategy as a safe haven before apprehending clearly both the rules of the game and the behavior of other group members. Notice further that subjects rarely chose other strategies than the 3 identified in period 1 (9.4%): subjects prefer to follow routinely one of the identified strategies before adapting.

Figure 7: Individual strategy occurrence in treatment T and D according to period and supergame. Data from 3-contractor groups.



We wonder about the stability of the *cooperative* strategy within groups. Its occurrence is constant with periods (between 25.7% and 27.0%): it does not "attract" subjects as should a focal point. A slight *end game effect* even appears in period 5 (21.5%).

If no clear pattern emerges by period, the *pure hawk* strategy is more frequently used as the session progresses: chosen in 9.4% of cases during supergame 2, its occurrence roughly double to reach 19.1% in supergame 7. Other strategies being roughly constant, the increase of disaster occurrence with supergames is provoked by an uncompensated increase of *pure hawk* occurrence. Since this strategy can be interpreted in term of free-riding, this evolution echoes the increase of free-riding in repeated public good games[12].

To conclude on subjects coordination, let first underline that the *cooperative* strategy does not exhibit the property of a focal point since too few subjects chose it. A potential explanation is that the difference between gains before sanction of *cooperative* and *dove* strategies are to close. The expected gain from risking cooperation is insufficiently incentive compare to

[12] For concrete data, see for example papers from Cadsby and Maynes studying threshold public good games (Cadsby and Maynes 1998, 1999). In our experiment, the trigger point assumes the role of the threshold.

securing gains by escaping the one-eyed stick. Potential cooperators may thus behave as *dove.* This explanation is consistent with the high number of subjects respecting the quota. Second, the first supergame and first periods act as observation rounds between members of a same group. The *dove* strategy enables subjects to wait and see, mainly during first periods where the strategic uncertainty is the highest. Third, the increasing number of *pure hawk* we observe with supergames is responsible for the increase in group volumes and sanction occurrence. The experiment progressing, free-riders endanger coordination.

The equity issue

7) The subject pool is divided on the equity issue.

We asked the following question to subjects: "*Does the system of control and differentiated sanctions in treatments T and D seem equitable to you?*". 49% do answer negatively and 47% positively. If our mechanim do not achieve unanimity, equity is apparently not an insuperable hurdle to the implementation of the optinal TBM , even with a mispecified target.

5. SUMMARY AND DISCUSSION OF THE EXPERIMENTAL RESULTS

Our results show a clear effect of the control and sanction mechanism on both contracting and withdrawals. The existence of an informational rent however impedes the respect of the environmental group target. The mechanism only shifts average withdrawals down to the trigger point. If our mechanism is not robust to the informational rent, the later is likely to decrease as the hydrogeological knowledge of the authority improves. The smaller the rent, the less the *cooperative* strategy pays off compare to the *dove* one. Quotas are thus likely to be increasingly respected with time.

The number of contracting subjects does impact the group volume. Increasing the amount of the blind truncheon – keeping the one-eyed stick equal – would increase the percentage of contractors and thus decrease group volume.

Groups increase withdrawals with periods and supergames, willing to seek the informational rent. Willing to avoid disaster, they do improve coordination within group but not from a group to another. Individual strategies seem to be relatively stable with time at the global level, but subjects individually change their strategies to adapt the group behavior. An uncompensated increase of rent seeking strategy occurrence from group to group endanger the effectiveness of coordination. Furthermore, the observed rise of withdrawals within group poses the following questions: *what if more than 5 periods? Would groups exceed the trigger? By much?*

In real world, farmers are unlikely to be frequently rematched. We should pay more attention to the evolution with periods than with supergames. The rise of coordination within groups presents 2 major advantages for a regulating authority. First, the decrease of "disaster" occurrence limits the implementation cost of the mechanism (control cost) and the financial transfers between farmers and the authority. Second, the decrease of group volume dispersion by implementing the optional TBM (Figure 3) is accentuated with periods (Figure 6). The authority will thus better anticipate the collective impact of withdrawals on the water resource. The increasing dispersion of the volumes withdrawn by subjects however induces that individual behaviors are less and less predictable.

6. Conclusion

Imperfect information impedes the use of classical instruments – tax, quotas or water markets – to manage groundwater withdrawals in numerous real-world cases, mainly in an agricultural context. Target based mechanisms that have been developed in a context of moral hazard in team management or of non-point source pollution can be suited to address the issue of non-point groundwater withdrawals. The implementation of those mechanisms seems to be hindered for practical and political reasons among which a blatant lack of acceptability by water users.

In this paper, we develop and test in the lab an optional target based mechanism combining *(i)* group taxes based on a collective target and differentiated depending on whether private information is revealed or not with *(ii)* a system of individual quotas and random inspections. Agents are incited to reveal information and to comply with the individual quota. Conversely to previously developed target based mechanism, we enable complying agents to escape surely group sanctions so that they do not bear any excess burden but the cost of reducing groundwater withdrawals.

The mechanism is however not robust to a mispecified collective target and people repetingly interacting achieve to coordinate to exhauste the informational rent without suffering much the group sanction. Despite this rent is a source of inequity, equity is apparently not an insuperable hurdle to the practical implementation of the optinal TBM.

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