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**Laboratoire Montpellierain
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the social dilemma? »

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DR n°2007-09

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Do binding agreements solve the social dilemma?¹

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February 2007

Abstract:

We investigate whether "binding agreements" can provide a solution to the social dilemma that arises in the presence of pure public goods. Signing a binding agreement can prevent players to free ride on the contributions to the public good. However, a well known theoretical result is that the outcome of the endogenous formation of agreements is not necessarily efficient. In our setting, the individual level of contribution to the public good increases with the size of the coalition reaching an agreement and the global agreement is always the socially optimal structure. Agreements form sequentially. The equilibrium outcome is an asymmetric structure, which consists of two coalitions of different sizes, the small one free riding on the contributions of the bigger one. In our experiment, we propose two treatments which differ in the degree of strategic uncertainty with which the subjects are faced. The results lend force to the theoretical conclusion that outcomes may be inefficient. The average gains achieved are sub-optimal. They are even lower than predicted by the equilibrium agreement structure in the treatment in which the strategic uncertainty is high. They are larger than predicted in the treatment in which the strategic uncertainty is limited. However, it seems that subjects "learn to cooperate" over time and reach the global agreement more often towards the end of sessions.

Keywords: Agreement. Public good. Experiment. Externalities. Sequential game.

JEL Classification C72, C78, C91, C92

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1. Introduction

¹ We are grateful to the participants of the PLESS seminar in Princeton and of the Interactive workshop in Marseille. This research is in part supported by the funds of the ACI Complex Systems attributed by the CNRS.

² While this paper has been written, the author was a visitor at the Institute for Advanced Study in Princeton and at the Department of Economics at Princeton University. She wants to thank the Department for its hospitality and the Institute for its open minded atmosphere.

A standard result in economic theory is that public goods will generally be provided at a level which is lower than the socially optimum amount. In the absence of well-designed incentives, agents try to free ride on the contribution of others. If such behaviour is widespread in a community of agents, voluntary contributions will generally be insufficient to produce the optimal amount of public goods. However, experimental evidence on voluntary contributions to a public good, has shown that the average level of contributions of experimental subjects is larger than predicted by theory.

Experiments involving voluntary contributions to a public good have produced robust stylised facts about the average level of contribution and its evolution with repetition. On average subjects contribute a larger share of their endowment to the public good than predicted under the assumptions of rational and selfish behaviour. The stylised facts that emerge from the numerous experiments for the standard type of environment ³ is that the average contribution is about half the endowment in the first period, and declines with the repetition of the game towards the Nash equilibrium level of contribution, without, however, reaching this level (see Ledyard (1995) and Laury & Holt (1998) for a survey of this literature). While cooperation appears to be prevalent in the early stages of the game, many subjects seem to become less cooperative over time and even end up free riding completely on others' contributions.. Individual contribution behaviour appears therefore to be largely determined by the observation of past contributions by other group members as well as their own past contributions. Indeed, a large fraction of subjects appear to contribute conditionally (Keser & van Winden, 2000), and few subjects only act unconditionally without adapting their behaviour over time, remaining either cooperative the whole time or always acting as a free rider.

In recent years research has focused on ways to improve or sustain cooperation in public goods games. Fehr & Gächter (2000) made an important step by showing that, if free riding behaviour can be punished, there is a marked increase in the average level of contribution. Therefore the threat of individual sanctions, may create sufficient discipline to remove the temptation for agents to free ride. While this opens an important research avenue, in practice individual contributions are often unobservable. For example, many donators to charities

³ Yet, most of the available experimental evidence has been obtained for quite particular environments, for which the amount of public good is the output of a linear production technology, i.e. exhibiting constant marginal returns. In particular, public goods games with a unique dominant strategy equilibrium, assume that the amount of public good is a linear function of the total contribution of the group.

prefer to remain anonymous, a fact that is well accepted by the community. More important is the fact that complete observability of individual contributions may be too costly to be implemented. For example tax evasion cannot be eliminated completely since costly inspections are limited by the authorities' budget constraint. Even in situations where individual contributions are observable at a reasonable cost, punishment is not necessarily feasible. For these reasons it is worth exploring other tools that can improve the level of cooperation and contribution to the public good within a community of agents.

In this paper we investigate a new mechanism that can lead to higher contribution levels in an experimental game of contribution to a pure public good: binding agreements. In contrast to voluntary contributions, under a binding agreement players have to make a commitment to a fixed level of contribution. International environmental treaties constitute an obvious example. However, there is an ongoing debate, which is specially active in the case of the negotiation on global warming. On the one hand there are those countries which favour voluntary contributions and these include the United States and certain developing countries like China and, on the other hand there are those such as the European Union, in favour of a binding agreement which specifies targets and time table.

In the theoretical literature, the old debate about the necessity and the efficiency of binding agreements has been revived in the last 20 years. The problem of public goods and externalities has been analyzed by economists in the framework of Samuelson's public good theory (1954) or as developments of the Coase theorem (1961). The Coase Theorem explains how partners can reach an efficient outcome by bargaining, when externalities exist but they can sign a binding agreement at the end. The new theory of coalition formation explained that, even when the players have the possibility to sign a global agreement, they may fail to reach this efficient outcome and sign sub-global agreements. This is the problem of participation in agreements.

The numerous contributions to this literature converge towards the same result, but differ in the form of games used to model coalition or agreement formation. One part of this literature uses normal form games which are reduced form models, useful when the objective is not the analysis of the emergence of agreements but the analysis of their stability. The first ancestral exclusive membership game was proposed by Von Neumann and Morgenstern (1944) in their seminal book which marked the beginning of game theory. Later, Hart and Kurz (1983)

proposed a variation of the same model. At the same time, D'Aspremont et al. (1983) proposed a simpler game with an open-membership rule, which opened the way for numerous applications to industrial organization (the overabundant theory of stable cartels⁴) and environmental economics (Barrett (1994), Carraro and Siniscalco (1993), Hoel and Schneider (1997),...). A parallel literature uses extensive form games which allow one to describe, some aspects of the bargaining leading to the agreement. See for example Bloch (1996), or Ray and Vohra (1999), (2001). Finally, another part of the literature deals specifically with the complexity of farsightedness in a sequential framework. See for example Chew (1994) or Xue (1998).

In this paper, we adopt the extensive form game approach. We rely on the model of Ray and Vohra (2001) in which the players can reach agreement by making proposals and counter-proposals sequentially. At each period of time, one player can propose an agreement involving each of the players who would be required to sign. If the proposed agreement is accepted by all potential members the agreement is definitely created. If one of the potential members rejects the offer, he has to make a new proposal. The process continues until each agent belongs to an agreement. Then, the agents have to contribute to a pure public good and those who have reached an agreement contribute the amount which maximizes the sum of their partners' and their own payoffs, given what is decided by the other groups. When the game is symmetric, this leads to situations in which all agents who accept to sign an agreement have to contribute the same amount to the public good. This amount increases with the number of agents who sign an agreement. Individual contributions are therefore more costly in large agreements and the total amount of public good provided depends on the structure of agreements. For this reason the social dilemma is not completely eliminated since there is an incentive for small agreements to free ride on larger ones. Since the individual level of contribution is increasing with the size of the agreement, there is an incentive for players to stay alone, or to join few partners in order to free ride on existing bigger agreements. On the other hand, since the amount of public good depends on the size distribution of the agreements, there is an incentive to build up larger groups. There are two extreme structures which could emerge: the global agreement and the set of singletons. The global agreement corresponds to a social optimum in the sense that it leads always to the most efficient outcome. In contrast, the set of singletons leads to the worst social outcome.

⁴ See for example Donsimoni (1985), Donsimoni, Economides and Polemarchakis (1986), Thoron (1998).

However, Ray and Vohra show that, at the equilibrium of their game, several sub-global agreements can co-exist. Since the equilibrium structure of agreements differs from the set of singletons, binding agreements increase the level of cooperation in the population.

Our experiment is based on Ray and Vohra's (2001) game. We compare two protocols of agreement formation: the veto treatment and the dictator treatment. In the veto treatment, which corresponds to the agreement formation game described above, those individuals who are proposed as members of an agreement can reject the proposal. In contrast, in the dictator treatment, they are obliged to become members of the proposed agreement. From the theoretical point of view, the two treatments are equivalent at the equilibrium. With our choice of parameters there is a unique asymmetric equilibrium agreement for the two protocols in which a small coalition free rides on a large coalition. In contrast, the two treatments lead to very different experimental results.

Our experiment supports the theoretical result that the formation of binding agreements leads to inefficient outcomes. This seems to be the consequence of both cooperative and free riding behaviour. However, the degree of inefficiency is remarkably different in the two treatments. In the veto treatment, we obtain an even worse outcome than the one predicted by the equilibrium agreement structure and the equilibrium outcome is never observed. In contrast, in the dictatorial treatment inefficiency is still observable, but at a lower degree than at the theoretical equilibrium and the equilibrium outcome appears. In the veto treatment, the analysis of proposals in sub-games shows that most proposals correspond either to the willingness to reach an agreement with all the potential partners or to remain a singleton. Furthermore, it seems that subjects "learn to cooperate" over time and reach the global agreement more often towards the end of sessions.

The rest of the paper is structured as follows. Section 2 presents the extensive game of coalition formation under positive externalities. The game is solved assuming the rationality of players adopted in Ray and Vohra's paper. Section 3 introduces the experimental design. Section 4 presents our main findings about the realized agreements (4.1) and the proposed agreements for the veto treatment (4.2). Section 5 provides a discussion of our results with respect to possible interpretations, and section 6 concludes.

2. Theoretical background

2-1 The sequential game of agreement formation

We consider a two-stage model of sequential formation of binding agreements. In the first stage, n identical players have the possibility to sign binding agreements. The outcome is a partition of the set of players. In the second stage of the game, the players voluntarily contribute to a public good. The players who have signed the same agreement choose the contributions which maximize the sum of the partners' utilities, given the decision taken by the signatories of the other agreements.

The first stage of the agreement formation game is drawn from Bloch (1995), (1996) and Ray and Vohra (1999), (2001). They propose a sequential game of agreement formation based on a bargaining game *à la* Rubinstein (1986) and Ståhl (1972). Let N denote the set of players. A protocol designs the order in which the players in N enter into the game to make a proposal or to give an answer to somebody else's proposal. A proposal by player $i \in N$ is a coalition $S \subset N$ to which she belongs and which is characterized by the proposed members' names and a sharing rule. The agreement can only be signed if the different proposed members have sequentially accepted the proposal. If one potential member refuses, she has to make another proposal. If all proposed members accept, the agreement is signed and the game continues with new proposals made by players who have not reached an agreement yet. Once an agreement is signed its membership cannot be modified; in other words, there is no renegotiation. The outcome is an agreement structure $\pi = (S_1, \dots, S_m)$, a partition of the set of players, which means that each player signs one and only one agreement. Formally,

$$\forall k, l = 1, \dots, m, k \neq l, S_k \cap S_l = \emptyset \text{ and } \bigcup_{k=1}^m S_k = N.$$

This game is an extensive form game whose sub-games start each time a player has to make a proposal. Therefore, for each partition of each sub-set of players $T \subset N$, denoted by $B(T)$, and for each player $i \in N \setminus T$ designated by the protocol to make a proposal, we can define a sub-game denoted by $G_{B(T)}^i$. Players in $N \setminus T$, player i and his potential partners, have not reached an agreement yet and are the "active" players in this sub-game. If all the players in $N \setminus T$ reach an agreement, we will say that the *largest agreement* is reached in sub-game

$G_{B(T)}^i$. If the largest agreement is reached at the beginning of the game, that is in sub-game $G_{B(\emptyset)}^i$, we will say that the *global agreement* is reached.

When the game is symmetric and the players all identical, the net benefit generated by a given agreement $S_k \subset N$, in a given agreement structure $\pi = (S_1, \dots, S_m)$, only depends on the number of signatories of each agreement, element of the structure. Bloch (1996) proved that, in that case, the sequential game of agreement formation is equivalent to a simpler game in which each player designated by the protocol chooses a number of partners and the agreement is immediately signed. Indeed, the interests of the player who makes a proposal coincide with those of the partners she chooses and who are in the same position. The outcome of the game is then an ordered sequence of *agreement sizes* which sum to n , the total number of players. Ray and Vohra (1999) proved that the endogenous sharing rule in each agreement is then the equalitarian sharing of the net benefit generated among the signatories.

2.2 Positive externalities

Payoffs are generated in the second stage of the game. Ray and Vohra (2001) refer to a model of pollution control. Think for example that a set of partners have signed a binding agreement to improve the quality of air. In order to decrease pollution, they have to take a costly action to decrease their production or to adopt new technologies. Let z denote the public benefit of the control activity pursued by any particular partner, and let $c(z)$ be the private cost generated by this control activity. We assume that this cost function is quadratic: $c(z) = (1/2)z^2$. The payoff to partner i is then:

$$u_i(z_1, \dots, z_n) = \sum_{j=1}^n z_j - c(z_i)$$

For a given partition of the set of individual players N into m binding agreements $\pi = (S_1, \dots, S_m)$, the signatories of each agreement S_i of size s_i decide the amount of pollution control, z_i , each member has to produce given the effort of the other agreements' signatories:

$$\text{Max}_{z_i} s_i \left(s_i z_i - c(z_i) + \sum_{\substack{j=1 \\ j \neq i}}^m s_j z_j \right)$$

This is a non-cooperative game in which the new players are now the m binding agreements. At the Nash equilibrium of this game, each partner of an agreement of size s_i produces an amount s_i of pollution control and enjoys a payoff:

$$u_i(s_1, \dots, s_m) = \sum_{j=1}^m s_j^2 - \frac{1}{2} s_i^2$$

This payoff function generates positive externalities, which means two things. First, for a given structure of agreements, the signatories of small agreements get more than the signatories of large agreements. Secondly, for a given agreement, its signatories are better off if other agreements “merge”. As a consequence, for a given player, the best situation is the agreement structure in which she does not sign any agreement while all the other players sign a unique agreement of size $n - 1$. When the whole set of individual players in N sign the global agreement, all partners share equally the collective optimum, which is $n^2/2$. However, in this situation, each partner would prefer not to sign the agreement in order to free ride on the other signatories. Two opposite forces are therefore at stake : i) individual players have an incentive to sign agreements with many signatories in order to efficiently control pollution, and ii) each individual player has an incentive to free ride and would prefer the other players to sign the agreement without her participation.

2.3 Farsighted players

If the players are farsighted, as it is assumed in Ray and Vohra (2001), a unique Nash equilibrium of the sequential model of agreement formation is determined by backward induction. Let us again consider the symmetrical case. Ray and Vohra show that the global agreement is not necessarily reached. Furthermore, if several sub-global agreements emerge, they appear in size-increasing order. Consider for example, an original set of seven players. At the unique equilibrium, an agreement between two players is signed first, followed by the signature of another agreement by five other players. The smaller group "free rides" therefore on the contributions of the larger group.

Let us see how this happens. The simplicity of the following argument is a consequence of the linearity of the payoff function. Each decision about the size of the agreement to sign does not depend on the agreements already signed, but depends only on the number of players who did not take a decision yet.

Consider a sub-game $G_{B(T)}^i$ such that a structure of agreements B has already been reached.

Then, we denote by $g(B)$ the public good contributed by the sub-set of players T who have signed one of the B -agreements. If there is only one player remaining, $N \setminus T = \{i\}$, of course she forms a singleton and gets: $u_i(B,1) = g(B) + 1/2$. If there are two players left, $N \setminus T = \{i,j\}$, the first player required to take a decision compares two possibilities:

- 1) Staying alone, in which case her payoff will be $u_i(B, 1,1) = g(B) + 3/2$.
- 2) Signing an agreement with the other player to get $u_i(B, 2) = g(B) + 2$.

As a consequence, she signs an agreement with the other player who accepts because he gets more than the stand alone payoff.

If there are three players remaining, the first player who needs to take a decision compares three possibilities:

- 1) Staying alone and anticipating that the two other players will sign an agreement, in which case her payoff will be $u_i(B, 1,2) = f(B) + 4,5$.
- 2) Signing an agreement with another player, $u_i(B, 2, 1) = f(B) + 3$
- 3) Signing an agreement with the two other players, $u_i(B, 3) = f(B) + 4,5$

and she proposes an agreement to the two other players (assuming that the larger agreement will be chosen whenever there is payoff equality between several agreement structures). The same reasoning applies until we reach the first player who is perfectly farsighted and therefore anticipates the decisions of the subsequent players in the way just described. If $n = 7$, the equilibrium outcome is an agreement structure $B^* = (2, 5)$.

The above equilibrium depends on three assumptions about the players' behaviour : i) players' farsightedness allows them to anticipate all the subsequent actions of the other players. Because assumption i) is not sufficient to apply backward induction, we require that ii) all the players are selfish maximizers, i.e. individual payoff maximisers; and finally iii) players' rationality is common knowledge. We shall refer to assumptions i-iii as :

- i) Assumption A1: Selfishness
- ii) Assumption A2: Farsightedness
- iii) Assumption A3: Homogeneity

As a shortcut, if assumption A1, A2 and A3 are satisfied we shall talk about R&V's behaviour or simply R&V's players, where R&V refers to Ray and Vohra (1999).

3. Experimental design

Our experiment compares two theoretically equivalent protocols for agreement formation: the veto treatment and the dictator treatment. In the veto treatment subjects selected to become a partner of a proposed agreement can reject the offer, in which case a new proposal is made by one of the rejectors. In the dictator treatment subjects that are selected to become a partner of a proposed agreement cannot refuse. Therefore, in the dictator treatment the number of proposals in a round is always equal to the number of final coalitions, whereas in the veto treatment the number of observed proposals is generally larger than the number of final coalitions of the realized structure of agreements. We therefore need to analyse the veto treatment separately in order to study rejected offers. Each independent group of subjects played the agreement game for several rounds to allow for learning. The number of repetitions in each independent group was random. The subjects knew that an additional round would be played with some probability. As a result, the number of rounds differs across independent groups. In addition to our main treatment variable “veto versus dictator”, we compare for each treatment fixed groups with randomly matched groups. In fixed groups the group of subjects remains the same in all rounds. In randomly matched groups, subjects are assigned randomly to a new group of players after each round. We expected fixed groups to behave differently, because subjects could react to previously observed agreements in their group. For example, a subject who is disappointed by previous agreements could be inclined to act in a more selfish way in future rounds, when he is selected to make a proposal. This effect can even become stronger in the dictator treatment. We collected 8 independent groups of subjects for the veto treatment (6 fixed, 2 random) and 7 independent groups for the dictator treatment (5 fixed, 2 random). In each session, 14 participants played the agreement game, and were divided into groups of seven subjects. Table 1 summarizes the experimental design. Note that the number of rounds in sessions for random groups is larger because we counted this type of session as a single independent observation. The number of rounds of course is equal to the number of observed final agreements, except for random groups for which the number of rounds must be multiplied by 2. Table 1 indicates the number of observed proposals in each group. Of course the number of proposals is smaller for groups in the dictator treatment, since proposals cannot be rejected.

[INSERT TABLE 1]

The experiment was carried out using standard procedures. We developed a specific computer program for running the experiment. Our experimental procedure follows closely the protocol described in Ray and Vohra's model. In each period, one of the subjects who does not yet belong to an agreement is randomly selected to make a new proposal. A proposal consists simply in stating an agreement size. The members assigned to the agreement are chosen randomly among the players who do not yet belong to an agreement, and are privately informed that they have been selected.

In the veto treatment subjects must state privately if they agree or not to sign the agreement. If all of them accept the proposal, the agreement is signed. On the other hand, if one of the assigned players rejects the offer, he will have to submit a new proposal. If more than one player rejects the offer, one of them will be selected randomly to make a new proposal. Our procedure differs slightly from the theoretical procedure, where the proposed members are asked sequentially whether or not they accept to become a member of the proposed agreement. Under the sequential protocol the first player who rejects the offer is the one that makes a new proposal. To gather more data about subjects' reactions to proposed agreements, we chose instead to ask all the proposed members to answer simultaneously. In case of a rejection, subjects only knew that the proposed agreement was rejected without knowing by how many subjects⁵. Does the difference between the experimental design and the theory affect the subjects' incentives in the game? It may be the case that a subject's incentive to reject be affected by the fact that he cannot be sure that he will be the one who makes the next proposal. However, whether this uncertainty increases or decreases the incentive to reject is unclear.

For simplicity let us call "player 1" the subject who makes the first proposal, "player 2" the subject who makes the second proposal, and so on. Subjects were told at the beginning that they would be randomly assigned to a group of 7 subjects. They could rely on a table showing their payoff according to their group size and the final agreement structure (see table 2). Each period started by allocating randomly to each subject a "name" chosen from a list of seven names {A, B, C, D, E, F, G}. Then, one of the names was selected randomly to be "player 1", i.e. the subject who proposes the first group. The decision task was simply to choose an

⁵ Of course a subject who did reject but was not selected to make a new proposal could easily infer that there was at least one other subject who rejected. Note that this is also the case in the model.

integer number between 1 and 7. If the chosen number was equal to one, a singleton was formed. If the chosen number was larger than one, the potential partners of the agreement were randomly selected among the 6 remaining subjects. Once subjects were selected for agreement 1, in the veto treatment they were asked individually whether they accepted or rejected this proposal. If all the proposed subjects accepted, the first agreement came into force. However, if one or more subjects rejected the offer, the group was not created. Then one of the subjects who decided to reject was selected (randomly) to make a new proposal. This process was repeated until each subject was partner to an agreement or a singleton. Once all subjects were assigned to an agreement, the period ended and the gains were announced to the subjects on their computer screen. The gains were displayed according to agreement size.

[INSERT TABLE 2]

4. Results

4.1 Realized agreements

Figure 1 compares the cumulative frequency distributions of accepted agreements in all groups for the random and the fixed group conditions. The null hypothesis of equal frequency distributions under the random matching condition and the fixed group condition cannot be rejected (Kolmogorov-Smirnov, two-sided, 10%). We decide therefore to pool the data from the fixed and the random condition for each treatment.

[INSERT FIGURE 1]

Result 1 : The most frequently realized "agreement" is the singleton.

Figure 2 displays the frequency distribution of accepted agreements for all groups, for the veto (2a) and the dictator (2b) treatments. In the veto treatment more than 70% of the realized agreements are singletons, compared to 35% for the dictator treatment. However, we cannot reject the null hypothesis of equal size distributions (Kolmogorov-Smirnov, two-sided, 1%). Since there are many agreement structures that contain at least one singleton (11 out of 15

possibilities), singletons are more likely to emerge if subjects decide on a random basis. Furthermore, if subjects have a tendency to free ride, they are tempted to propose small agreements in which they contribute less. We need therefore to take a closer look at the frequencies of realized agreement structures.

[INSERT FIGURE 2]

Result 2 : We observe wide variations in the realized agreement structures. The equilibrium structure (2,5) is observed 11 times (9.6%) in the dictator treatment and never in the veto treatment. The modal structure is the global agreement in both treatments. In the veto treatment more than 50% of the agreement structures contain three or more singletons, compared to less than 8% in the dictator treatment.

[INSERT FIGURE 3]

Figure 3 shows the frequency distribution of agreement structures. Few structures (4.5% for the veto treatment, 25% for the dictator treatment) involve only two agreements, in contrast to the theoretical prediction. The total payoff of the structure has no significant effect on its frequency of appearance (see result 4). Furthermore, low payoff structures are quite frequent for the veto treatment.

Result 3 : The average gains achieved are higher than those predicted in the dictator treatment and lower than predicted in the veto treatment.

The average performance is equal to 108.19 and 145.17 for the veto and the dictator treatment, respectively, a significant difference (Mann-Whitney, one-sided, 1%). These numbers correspond to 79.49% and 105.96% respectively of the predicted performance (equal to 137, which corresponds to the performance at the equilibrium (2,5)). Only one of the veto groups reaches a better performance than the equilibrium level, and only one of the dictatorial groups has a lower performance than the equilibrium prediction. The performance is significantly lower than equilibrium performance for the veto treatment (Binomial test, one-sided, 3.5%) and significantly larger than equilibrium performance for the dictator treatment (Binomial test, one-sided, 6.2%). We conclude that binding agreements fail to solve the social dilemma in the veto treatment. In contrast, in the dictator treatment, the gap between the

social optimum performance and the equilibrium performance is reduced by binding agreements. This has to be related to Result 6 below, which says that the global agreement is the most frequent first proposal.

Result 4

Over the 3 last periods the frequency of the global agreement increases in both treatments.

In table 3, we aggregate all agreement structures that contain at least three singletons. We compare the frequencies of these agreement structures with the frequency of global agreements and the remaining agreement structures (others). The table compares all periods with respect to the three last periods. The frequency of the global agreement increases for both treatments in the last three periods (Wilcoxon signed rank test, $p = 0.0547$ for the veto treatment, $p = 0.1094$ for the dictator treatment). For the veto treatment we also observe that the frequency of agreement structures containing at least 3 singletons decreases.

[INSERT TABLE 3]

Result 5 : Agreement structures with low payoff disparity among members are more likely to emerge.

Table 4 shows the Gini index associated with each agreement structure and the corresponding observed frequencies for each treatment. For the veto treatment the frequencies are independent of the corresponding total payoff, in contrast to the dictator treatment. Note that for the veto treatment, extreme agreement structures for which the Gini index is close to zero, have a high frequency.

[INSERT TABLE 4]

We regress the frequency of observed agreement structures, on the corresponding Gini coefficient and total payoff of the structure. We include both the Gini index and the squared Gini index, to account for the fact that the relation is not necessarily linear. The results are summarized in table 5. For both treatments the Gini coefficient is negatively related to the frequency of realized agreements (ranked according to payoff disparity). Furthermore, the

Gini coefficient has a significant second order effect, which implies that the frequency of agreement structures increases when payoff disparity becomes very high. As can be seen from table 4, the two agreement structures with the highest Gini index ((1,1,5) and (1,1,1,4)) have a relatively high frequency. From table 5, we see that total payoff is highly significant for the dictator treatment, but not for the veto treatment.

[INSERT TABLE 5]

4.2 Proposed agreements

Our preliminary analysis of realized agreements does not take into account the fact that, in the veto treatment, many proposals were rejected. Actually, large agreements were frequently proposed and rejected, revealing the conflict between individual and group interests. While the realized agreements get clearly closer to the social optimum under the dictator treatment, the cooperative intentions are not necessarily weaker in the veto treatment. We analyse these intentions by looking at initial proposals at the beginning of each round. Then we analyse proposals in proper sub-games.

4.2.1 Initial proposals

Result 6: In both treatments, the global agreement is the most frequently proposed agreement at the beginning of rounds, followed by the singleton.

We assume that initial proposals in each round provide an indication of subjects' intentions to cooperate or to act strategically. Clearly the cooperative intention is the strongest. However since singletons are often formed, Result 6 illustrates the conflict between collective and individual interests. Figure 4 shows the frequency distribution of proposals ranked from the largest to the smallest agreement, at the beginning of each round. Clearly, the singleton (the smallest "agreement") and the global agreement are the most frequently proposed agreements. For the veto treatment, 57% of the initial proposals are global agreements, and 25% are singletons. The corresponding frequencies for the dictator treatment are 45% and 32% respectively. Other agreement sizes have a very low frequency, except agreements of size 2 which was proposed in 12% of the cases in the dictator treatment.

INSERT FIGURE 4

Although we decided to pool the data from the fixed and the randomly matched groups, it is worth mentioning that fixed groups behave more cooperatively than random groups, as can be seen from table 6. Global agreements are more frequent and singletons are less frequent in fixed groups than in random groups. We cannot test for significance however, since we have only two independent observations for the random treatments. Table 6 and figure 4 also show a difference in the cooperative intentions between the veto and the dictator treatments. Global agreements are more frequently proposed in the veto treatment, and singletons are less frequently proposed. We reject the null hypothesis of equal frequencies of global agreement proposals in initial rounds for the veto and the dictator treatments (Wilcoxon Mann-Whitney, two-sided, 5%), and of equal frequencies of singletons (Wilcoxon Mann-Whitney, two-sided, 10%).

INSERT TABLE 6

In the veto treatment 73.80% of the (non-singleton) initial proposals were rejected. Since agreement sizes between 2 and 6 were very rarely proposed at the beginning of rounds, rejection rates across agreement sizes cannot be compared. Furthermore larger agreements are more likely to be rejected. Note that global agreements as initial proposals are less frequently rejected by fixed groups (62% rejected) than by random groups (81% rejected).

Since the global agreement was the most frequently proposed and rejected agreement, of course a rejection was followed most of the time by a proposal of a smaller agreement. The rejection of the global agreement was frequently followed by the formation of a singleton⁶ (more than 50% of the cases overall).

4.2.2 Proposals in sub-games

Table 7 gives the proportion of proposals for various sub-games. Each sub-game is characterized by the number of subjects who are not yet partners of an agreement (row

⁶ In a few cases the rejection of the global agreement was followed by the same proposal.

numbers). For instance the row labelled 5 corresponds to situations in which the first two subjects have already signed a binding agreement, either an agreement of 2 subjects or two singletons. The possible agreement sizes in this example are 5, 4, 3 2 and 1. The last column of the table gives the percentage of “extreme” proposals, i.e. either the largest possible agreement in the sub-game or a singleton. Obviously for each sub-game, the most frequently observed proposal is either the largest agreement of the remaining players or the singleton. Together, these two possible proposals represent at least 70% of all proposals in each sub-game and in each treatment.

INSERT TABLE 7

Table 8 shows the aggregate frequency of extreme proposals (singleton + largest agreement) for each sub-game and each independent subjects’ group. Table 9 (appendix) provides detailed frequencies about singletons and largest agreements for each sub-game size and independent player group. Except for sub-game of size 3, the frequencies of extreme proposals are the same in both treatments (Wilcoxon Mann-Whitney, 5%). In sub-games of size 3 only extreme agreements were proposed in the dictator treatment, while intermediate coalitions of size 2 emerged sometimes in most groups in the veto treatment.

INSERT TABLE 8

Table 8 clearly shows that in all independent groups and for all sub-game sizes there is a strong tendency to propose extreme agreements. In order to test for significance of the observed tendency we use Selten’s (1991) measure of predictive success, $S = h - a$, where h is defined as the *hit rate* (frequency of compatible proposals) and a as the *area* (frequency of random compatible proposals). The *area* measures the possibility that extreme proposals could have been chosen randomly. For example, for sub-games of size 5, if we assume that a subject who chooses randomly proposes each possible size with equal probability, there is a probability of $2/5$ that he proposes an extreme agreement at random. Therefore we need to correct the hit rates associated with each sub-game size by the frequency of randomly chosen sizes. Of course a gets larger as sub-games get smaller, leading to $S = 0$ for sub-games of size 2. All measures of predictive success are significantly positive (Binomial test, one-sided, 5%)

for each sub-game size of each treatment. We conclude therefore that extreme agreements are not proposed at random, but are intentionally proposed by subjects.

5 Discussion

5.1 Cooperation and free riding

The results described in the previous section constitute strong evidence of the co-existence and combining of cooperative behaviour and an incentive to free ride. Indeed, we observe that the global agreement is the initial proposal in most cases and also the most frequently realized agreement. Furthermore, in each sub-game, the most frequently proposed agreement (or the second most frequently proposed agreement when the singleton was the most frequent), is the largest possible agreement. This observation suggests that cooperative intentions are pervasive in our data. However, singletons appear with the highest frequency in all agreement structures, indicating that free-riding behaviour seems also to be widespread in our data. The proposal of a global agreement is very often rejected and most of the time this rejection is followed by the formation of a singleton. In each sub-game the singleton is the most frequent or the second most frequent proposal (after the largest agreement).

We suggest that two forces are at work: the incentive to cooperate which drives the subjects to propose an agreement to all remaining potential partners and the incentive to free ride, which drives them to become singletons. The role of these two forces - an incentive to cooperate opposed to an incentive to free ride - was described in Ray and Vohra's paper and in several other papers demonstrating the inefficiency of binding agreements for solving the social dilemma. However in our experiment, the equilibrium predicted by Ray and Vohra, is never observed for the veto treatment and appears with a low frequency in the dictator treatment. The observed outcome for the veto treatment is even less efficient than predicted by the equilibrium. How can we interpret this difference from the theoretical result and this even greater inefficiency?

5.2 Other assumptions about subjects' rationality

In this section we try to determine which of the three assumptions (A1, A2 and A3) characterizing R&V's behaviour, is not compatible with our subjects' behaviour?

5.2.1 Cooperative players

First, we consider the case where the players are farsighted (A2) and believe in a common rationality (A3) but are not selfish. We assume that they want to maximize the sum of the payoffs and we define them as *cooperative players*.

Assumption A1': The objective of a *cooperative player* is to maximize the sum of all players' payoffs.

What would constitute an equilibrium under the assumptions A1', A2 and A3 ? Consider a group T of players. Whatever the organization of the rest of the population $N \setminus T$, the sum of payoffs is always larger if players in T sign a unique agreement than if they sign two distinct agreements, whatever the partition of T into two agreements. Indeed, consider that $T = S_i \cup S_j$, and calculate the sum of payoffs of players in T when S_i and S_j are disjoint:

$$s_i u_i(s_i, s_j, \dots) + s_j u_j(s_i, s_j, \dots) = (s_i + s_j)g(B(N/T)) + (s_i + s_j)(s_i^2 + s_j^2) - \frac{1}{2}(s_i^3 + s_j^3)$$

and when S_i and S_j are joint:

$$s_i u_i(s_i + s_j, \dots) + s_j u_j(s_i + s_j, \dots) = (s_i + s_j)g(B(N/T)) + (s_i + s_j)(s_i + s_j)^2 - \frac{1}{2}(s_i + s_j)^3.$$

Obviously the latter sum is greater than the first, whatever the sizes s_i and s_j . Using backward induction, this leads to the result that, in each sub-game $G_{B(N/T)}^i$, the first player to make a proposal proposes a unique agreement to the t remaining players. If a cooperative player has to respond to a proposal, for the same reason, she will accept to sign an agreement involving all the remaining players and will reject every other proposal in order to propose this agreement herself. Therefore, the following Proposition holds:

Proposition 1: If all players are cooperative, at equilibrium the largest agreement is proposed and signed in each sub-game and hence, the global agreement is proposed and signed immediately.

5.2.2 Myopic players

In this sub-section we keep assumptions A1 and A3 but instead of farsightedness (assumption A2), we assume that players are myopic. How would myopic players behave in this game? A player acting myopically is generally defined as a player who takes his decision by reacting to the existing situation without anticipating the other players' reactions to his own choice. Given that she anticipates no response, she plays her best response. In our framework, however, myopic behaviour has to be defined depending on the player's position at the outset. Does she have to make a proposal or to respond to a proposal?

Myopic behaviour is characterized by the following :

Assumption A2': myopic player

- A player who makes a proposal does not anticipate the possibility of subsequent counter-proposals by other players.
- A player who has to respond to a proposal does not anticipate any other counter-proposal, except her own counter-proposal if she decides to reject.

What would constitute an equilibrium under assumptions A1, A2' and A3? In each sub-game $G_{B(N/T)}^i$, the first player to make a proposal chooses the coalition size $s_i, t \geq s_i \geq 1$, which maximizes her payoff as a member. Therefore, her objective is to solve:

$$\text{Max}_{s_i} u_i = g(B) + s_i^2 + t - s_i - \frac{1}{2} s_i^2$$

The solution to this program is always to propose the coalition of the t remaining players in the sub-game. If a myopic player has to respond to a proposal, for the same reason she will accept a coalition of all the remaining players and will reject every other proposal in order to propose herself that coalition. Obviously, if all the players are myopic, the global agreement is proposed and signed immediately, like in the case where all players are cooperative,

Proposition 2: If all players are myopic, at the equilibrium the largest agreement is proposed and signed in each sub-game and the global agreement is proposed and signed immediately.

5.2.3 An alternative to homogeneity

Let us turn now to assumption A3. How is the equilibrium modified when players consider that the population is not homogeneous? For example, consider a selfish and farsighted

player. In a homogeneous population, it may be that his equilibrium strategy is to propose a sub-agreement in a given sub-game. In this case, the formation of a singleton is not the best strategy because the remaining players would be induced to sign several agreements. Now, assume that this farsighted player believes that all other players are either myopic or cooperative. Then, she believes that she has the opportunity to stand alone in a singleton while all remaining players will sign an agreement, which corresponds to the most beneficial situation for her. Call this player *a free rider*. The free rider thinks that he is “cleverer” than the other players.

Assumption A3’: A free rider is a selfish farsighted player who believes that all the other players are cooperative or myopic.

In each sub-game $G_{B(N/T)}^i$, the free rider believes that the remaining players will sign an agreement and she maximizes:

$$\text{Max}_{s_i} u_i = g(B) + s_i^2 + (t - s_i)^2 - \frac{1}{2} s_i^2$$

As a result, she refuses every proposal and always proposes the singleton. Then, if k players are free riders and $n - k$ myopic or cooperative, the following result holds:

Proposition 3: If k players are free riders and $n - k$ are myopic or cooperative, at the equilibrium the agreement structure is formed by k singletons, which form first, followed by the signature by $n - k$ players of the unique agreement.

This was the simplest case to consider. We could also have allowed the players’ conjectures to evolve. For example, myopic players could become free riders or free riders could learn that there are not isolated. While the characterization of such an equilibrium would be interesting, although much more complex because of incomplete information, it is beyond the scope of this paper to investigate such an issue. All we wanted to show is that if the players’ behaviours correspond to one or the other of the three types described previously, the only proposals would be, in each sub-game, the singleton or an agreement signed by all the remaining players. This prediction is close to what we observed in sub-section 4.2.2.

Proposition 4: If the players are either cooperative, myopic or free riders, in each sub-game each proposal is either the singleton or the largest agreement.

Table 11 summarizes, for each type of behaviour, the proposals at the equilibrium in the different sub-games in the case of a population of seven players. Note that, a player who adopts R&V's behaviour is only differentiated by her action in sub-games with 7 players left. Then, the R&V's player proposes an agreement of size 2, while the free rider becomes a singleton (1) and the cooperative or myopic player proposes the global agreement (GA). In sub-games of size 6, a R&V's player acts like a free rider and becomes a singleton. The cooperative or myopic players propose the largest agreement (LA). In sub-games with 5 or fewer players left, R&V's player acts like a myopic or cooperative player and she proposes the largest agreement of the remaining players. The formation of singletons in these sub-games is only consistent with the free rider rationality.

INSERT TABLE 11

Our data shows that subjects' initial proposals differ from the proposal predicted by R&V's behaviour. The global agreement and the singleton appear with a high frequency as first proposals. On the other hand, table 11 shows that, in all proper sub-games with less than seven subjects, we cannot distinguish between R&V's behaviour and other types of behaviour. However, even when the subjects' proposals coincide with R&V's equilibrium proposal, they might be generated by a mix of different kinds of behaviour. Furthermore, we observe proposals of the largest agreement in sub-games of size six and singletons formed in sub-games of size five and fewer. Such proposals are compatible with the three alternative types of behaviour that we described: cooperative, myopic and "basic" free riding.

Obviously other sorts of behaviour could coincide with observed proposals. However, the important point here is the difficulty generated by this multiplicity of types of behaviour. Earlier on, we discussed the complexity generated by the incomplete information. Here, subjects face up to an even more complex situation generated by the strategic uncertainty. In other words, not only do they know that their potential partners do not necessarily behave in the same way but they cannot be aware of all the possible kinds of behaviour. At this point,

we need to make a comment about what we call strategic uncertainty. Strategic uncertainty is uncertainty concerning the actions and beliefs of others⁷. Van Huyck, Battalio and Beil (1990) say that “strategic uncertainty arises even in situations where objectives, feasible strategies, institutions, and equilibrium conventions are completely specified and are common knowledge.” They refer to situations of multiple equilibria and claim that “the experimental method provides a tractable and constructive approach to the equilibrium selection problem”. The strategic uncertainty we are interested in exists even when there is a unique equilibrium. The reason is that, in an experiment, equilibrium conventions cannot be common knowledge. The subjects cannot have a representation of an experiment as a game of incomplete information. Generally, they do not have a precise representation of possible types of behaviour and if they do, they do not have precise beliefs about the distribution of these types.

Now, it is easy to understand that the dictatorial treatment decreases strategic uncertainty in comparison with the veto treatment. In the dictatorial treatment the subjects do not have to speculate about the possible counter proposals to their proposals. As a consequence, when the first proposal is made by a cooperative subject, she is guaranteed to reach the largest agreement she proposes. When it is made by a selfish subject, she is guaranteed to reach (2,5) if she proposes 2 since the five remaining players will reach the largest agreement whatever their type is. Therefore, the strategic uncertainty might be the reason why the theoretical equilibrium is never observed in the veto treatment and appears in the dictatorial treatment and the reason why the subjects are more efficient in this last treatment.

5.3 Non-maximizing behaviour

5.3.1 Inequity aversion

The analysis of proposals in sub-games provides strong evidence that subjects focus on two extreme proposals: the coalition of all remaining subjects and the singleton. While we provided several possible behavioural hypotheses that are consistent with the observed patterns, other hypotheses could be suggested. In particular, if subjects are concerned not only by their individual payoff, but also by other players' payoffs, they could act in a way that is

⁷ Adam Brandenburger (1996) draws a distinction between strategic and structural uncertainty. Structural uncertainty is an uncertainty about the fundamentals, the definition of the game to be played.

consistent with our data. If subjects dislike inequalities, as proposed in the seminal models by Fehr and Schmidt (1999) and Bolton and Ockenfels (2001), subjects have an incentive to reach “symmetric” agreement structures. Indeed, an interesting finding in our experiment is that the frequency of appearance of agreement structures is correlated with the Gini index which measures payoff disparities between coalitions of players. Agreement structures with low payoff disparity among members are more likely to emerge.

Another non-maximizing behaviour is often observed in these experiments on voluntary contributions. Subjects use contributions to send signals to their partners or to react to their partners’ contributions. Keser & van Winden (2000) say that subjects appear to contribute “conditionally”. We explain in what follows that this can play an important role in our experiment as well, but with a different outcome.

5.3.2 Another game

Another explanation for the fact that our subjects do not play the Nash equilibrium perfect in sub-games of the game proposed by Ray and Vohra could be that they are not playing the same game. It may be that the subjects “simplify” the game and think just in terms of two actions: “cooperation” or “defection”. Indeed, the proposal of an agreement could be interpreted as an intention to cooperate, rather than a tool in order to “free ride efficiently”. Subjects who want to free ride would therefore choose a singleton in order to “defect”. In this interpretation, each subject chooses between two actions:

- 1) the largest agreement of the available partners in each sub-game when she wants to “cooperate”
- 2) the singleton when she wants to “defect”.

In this simplified game, payoffs are given in the table 12:

INSERT Table 12

Note that, for the alternative rationalities Cooperative, Myopic and Free Rider the results of Section 5.2 are unchanged. However under assumptions A1, A2 and A3 characterizing Ray and Vohra’s rationality the equilibrium structure is now (1,1,5). In the experiment, (1,1,5) appears with a low frequency (see Figure 3) but we also observed in section 4 that almost all structures are composed of a unique non trivial agreement and singletons.

Let us highlight the peculiarities of this simplified game. Consider a subject A who has chosen to act cooperatively but whose proposal of the largest agreement has been rejected by a potential partner P. A cannot be forced to be in a less favourable position than subject P who decided to free ride by choosing to stay as a singleton. Subject A can always be, at the end of the round, in the same position as subject P who decided to free ride. She can simply decide to become a singleton as well. As a consequence, a cooperative subject could never lose in comparison to a selfish subject, by playing a Tit for Tat strategy. Defection is less frustrating for cooperators. This may explain why the global agreement is the most frequently observed first proposal (result 6). Furthermore, in an experiment, this “costlessness” of proposals to cooperate is true till the last round. This may explain why we do not observe any “end-effect”⁸. On the contrary, Result 4 states that the frequency of appearance of the global agreement increases over the rounds of the experiment and therefore the average performance. It is therefore likely that subjects “learn to play cooperative”. While many singletons are formed in the early rounds the frequency of the global agreement increases in the last rounds.

6. Conclusion

In this paper we have explored the capacity of binding agreements to mitigate the social dilemma arising in the provision of a pure public good. In our experiment, subjects have the possibility to sign binding agreements. We observe that the global agreement, which corresponds to the collective optimum for the whole group, is frequently proposed. Nevertheless, it is also very frequently rejected in the veto treatment. However, we observe that the frequency of realization of the global agreement increases over time. On the one hand our data provide an optimistic point of view on the capacity of binding agreements to mitigate the social dilemma, but on the other hand, we observe a tendency towards free riding, since the singleton is the second most frequently reached “agreement”.

A central result of the literature on endogenous formation of coalitions is that binding agreements do not necessarily lead to an efficient outcome. In the model proposed by Ray and Vohra (2001), players have the possibility to sign binding agreements to contribute to a public

⁸ We refer to the well known stylised fact obtained in experiments on voluntary contributions to a public good such that subjects “learn to play Nash”. They start contributing a lot but then, they adjust their contributions to the equilibrium level.

good. They show that the incentive to sign large agreements in order to “internalize” the positive externality does not eliminate the incentive to free ride. Their message is that the incentive to free ride is not solved by the signature of binding agreements because this incentive is shifted from the individual level to the group level. In our example, involving a population of seven players, the equilibrium agreement structure is formed by two agreements: a two-player agreement and a five-player agreement. The smaller of these is signed before the larger one and its partners free ride on the partners of the latter to obtain a larger benefit.

Our experiment lends partial support to this description, but the two driving forces of this process are somehow exacerbated in our data. Indeed, we observe that subjects have an incentive to cooperate by proposing a large agreement to all potential partners, and at the same time they try to free ride by staying as singletons. However, the theoretical equilibrium as described by Ray and Vohra is never observed in the veto treatment and appears only with low frequency in the dictator treatment. As a consequence, the outcome is even more inefficient in our veto treatment than predicted by the equilibrium.

We proposed two interpretations of this result. The first is that subjects are faced with strategic uncertainty. By strategic uncertainty we mean that, not only do subjects know that their potential partners do not necessarily behave in the same way as themselves but they are not aware of all the possible kinds of behaviour. The comparison of the veto and the dictatorial treatments shows that, when the subjects do not have to speculate about the answer to their proposals, they reach a more efficient outcome and the theoretical equilibrium can be observed. The alternative interpretation is that subjects “simplify” the game and reason in terms of two actions only: “cooperation” or “defection”, as in a multi-person prisoner dilemma game. Indeed, the analysis of proposals in sub-games provides strong evidence that the subjects focus on two extreme choices: the largest agreement of all the available partners or the singleton. The proposal of an agreement is associated with cooperation and it does not seem that the subjects free ride in groups. In fact, both interpretations may be linked to one another. By simplifying the game subjects might find a way to get around the problem of strategic uncertainty.

The last main result concerns the evolution of the outcome during each session. It seems that the frequency of appearance of the global agreement increases over rounds, leading to an

increase of the average performance with the repetition of the game. This is in contradiction with the well known stylized fact observed in experiments on voluntary contributions to a public good, which is usually interpreted as evidence of “learning to play Nash”. Subjects start contributing a large part of their endowment, but adjust over rounds their contributions towards the equilibrium level. In our experiment where the subjects have to sign binding agreements to contribute, it seems that the opposite occurs and that subjects “learn to play cooperative”. Many singletons are formed in the first rounds but the frequency of the global agreement increases in the last rounds. This effect seems to be particularly important in the veto treatment. One interpretation is related to the peculiarity of the game. Because the subjects have to make proposals, cooperation is contingent and can be used as a signal to other subjects with no cost till the end of the session. Furthermore, as a consequence of the strategic uncertainty, it is so difficult to “free ride efficiently” that it may be that defectors prefer to convert themselves to cooperators.

Therefore, in the light of this experiment, the answer to the question “do binding agreements solve the social dilemma” is ambiguous. On the one hand, strategic uncertainty seems to increase the inefficiency shown in the literature on endogenous formation of agreements. On the other hand, it might be that this strong inefficiency has the opposite effect in the long run and generates an incentive to cooperate.

References

- Barrett, S., 1992. Self Enforcing International Agreements. *Oxford Economic Papers*, 46, 878-94.
- Bloch F., 1996. Sequential Formation of Agreements with Externalities and Fixed Payoff Division. *Games and Economic Behavior*, 14, 90-123.
- Bloch F., 1997. Non-cooperative models of coalition formation in games with spillovers", 311-352 in *New directions in the economic theory of the environment*, Edited by C. Carraro and D. Siniscalco, Cambridge University Press.
- Bolton, G. E. and Ockenfels, A., 2001. ERC: A Theory of Equity, Reciprocity and Competition. *American Economic Review*, 90, 166-193.
- Carraro, C. and D. Siniscalco, 1993. Strategies for the International Protection of the Environment. *Journal of Public Economics*, 52, 309-28.
- Chwe M., 1994. Farsighted Coalitional Stability. *Journal of Economic Theory*, 63, 299-325.
- Coase, Ronald H., 1960. The Problem of Social Cost. *Journal of Law and Economics* 3, p. 1.
- D'Aspremont, C., Jean J. Gabszewicz, A. Jacquemin and J.W. Weymark, 1983. On the Stability of Collusive Price Leadership. *Canadian Journal of Economics*, 17-25.
- Donsimoni, M.-P., 1985. Stable Heterogeneous Cartels. *International Journal of Industrial Organization*, 3(4), 451-467.
- Donsimoni, M., N.S., Economides and H. M. Polemarchakis, 1986. Stable Cartels. *International Economic Review* 27, 317-27.
- Fehr E., Gächter S., 2000. Cooperation and Punishment in Public Goods Experiments. *American Economic Review*.

Fehr E., Schmidt, K. M., 1999. A Theory of Fairness, Competition, and Cooperation. *Quarterly Journal of Economics* 114, 817-868.

Hart and Kurz, 1983. Endogenous Formation of Coalitions. *Econometrica*, Vol. 51, No 4, 1047-1064.

Hoel, M. & K. Schneider, 1997. Incentives to Participate in an International Environmental Agreement. *Environmental and Resource Economics*, 9, 153-170.

Keser C., Van Winden F., 2000. Conditional Cooperation and Voluntary Contributions to Public Goods. *Scandinavian Journal of Economics*, 102, 23-39.

Laury Susan K. and Charles A. Holt, 1998. Voluntary Provision of Public Goods: Experimental Results with Interior Nash Equilibria. Forthcoming in C. Plott and V. Smith, (Eds.). *The Handbook of Experimental Economic Results*.

Ledyard J., 1995. Public Goods: A survey of Experimental Research. in Kagel, J. and Roth, A. (Eds.). *The Handbook of Experimental Economics*. Princeton University Press.

Ray D. and R. Vohra, 1997. Equilibrium Binding Agreements. *Journal of Economic Theory*, 73, 30-78.

Ray D. and R. Vohra, 1999. A Theory of Endogenous Agreement Structure. *Games and Economic Behavior*, 26, 286-336.

Ray D. and R. Vohra, 2001. Coalitional Power of Public Goods. *Journal of Political Economy*, 109, 6.

Rubinstein, A., 1982. Perfect Equilibrium in a Bargaining Model. *Econometrica*, 50, 97-109.

Selten, R., 1991. Properties of a measure of predictive success. *Mathematical Social Sciences* 21, 153-167.

Stähl I., 1972. *Bargaining Theory*. Stockholm School of Economics.

Thoron, S., 1998. Formation of a Coalition-Proof Stable Cartel. *Canadian Journal of Economics*, 31,1, 63-76.

Von Neumann, J. and O. Morgenstern, 1944. *Theory of Games and Economic Behaviour*. Princeton: Princeton University Press.

Xue L., 1998. Coalitional Stability under perfect foresight. *Economic Theory*, 11, 603-627.

Yi, 1997. Stable Coalition Structure with externalities. *Games and Economic Behavior*, 20, 201-237.

Session number	Group	Number of rounds	Number of proposals	Veto / Dictator	Random / Fixed
2	V1	13	140	veto	random
3	V2	8	49	veto	fixed
3	V3	8	67	veto	fixed
4	V4	11	76	veto	fixed
4	V5	11	65	veto	fixed
5	V6	14	173	veto	random
6	V7	10	48	veto	fixed
6	V8	10	84	veto	fixed
7	D9	15	25	dictator	fixed
7	D10	15	28	dictator	fixed
8	D11	10	48	dictator	random
9	D12	10	40	dictator	random
10	D13	15	33	dictator	fixed
11	D14	15	29	dictator	fixed
11	D15	15	27	dictator	fixed

Table 1 : Experimental design

#	Structure	s ₁	s ₂	s ₃	s ₄	s ₅	s ₆	s ₇	Total payoff
1	(7)	24,50							172,00
2	(1,6)	36,50	19,00						151,00
	(2,5)	27,00	16,50						137,00
	(3,4)	20,50	17,00						130,00
3	(1,1,5)	26,50	26,50	14,50					126,00
	(1,2,4)	20,50	19,00	13,00					110,50
	(1,3,3)	18,50	14,50	14,50					106,00
	(2,2,3)	15,00	15,00	12,50					97,50
4	(1,1,1,4)	18,50	18,50	18,50	11,00				99,50
	(1,1,2,3)	14,50	14,50	13,00	10,50				86,50
	(1,2,2,2)	12,50	11,00	11,00	11,00				78,50
5	(1,1,1,1,3)	12,50	12,50	12,50	12,50	8,50			75,50
	(1,1,1,2,2)	10,50	10,50	10,50	9,00	9,00			67,50
	(1,1,1,1,1,2)	8,50	8,50	8,50	8,50	8,50	7,00		56,50
7	(1,1,1,1,1,1,1)	6,50	6,50	6,50	6,50	6,50	6,50	6,50	45,50

Table 2 : Individual and total payoff according to the agreement structure

Agreement structure	Total payoff	Gini index	Veto	dictator
(7)	172.00	0.0000	0.2857	0.4609
(1,6)	151.00	0.0997	0.0446	0.1217
(2,5)	137.00	0.1099	0.0000	0.0957
(3,4)	130.00	0.0451	0.0000	0.0348
(1,1,5)	126.00	0.1366	0.0714	0.1043
(1,2,4)	110.50	0.1047	0.0179	0.0174
(1,3,3)	106.00	0.0325	0.0268	0.0000
(2,2,3)	97.50	0.0440	0.0000	0.0087
(1,1,1,4)	99.50	0.1292	0.0982	0.0696
(1,1,2,3)	86.50	0.0743	0.0357	0.0522
(1,2,2,2)	78.50	0.0164	0.0089	0.0261
(1,1,1,1,3)	75.50	0.0908	0.0804	0.0000
(1,1,1,2,2)	67.50	0.0381	0.1071	0.0000
(1,1,1,1,1,2)	56.50	0.0379	0.1339	0.0087
(1,1,1,1,1,1,1)	45.50	0.0000	0.0893	0.0000

Table 4 : frequency of agreement structure according to the Gini coefficient

Source	SS	df	MS	Number of obs = 15	
-----+-----				F(3, 11) = 2.09	
Model	.028273687	3	.009424562	Prob > F = 0.1600	
Residual	.049658446	11	.004514404	R-squared = 0.3628	
-----+-----				Adj R-squared = 0.1890	
Total	.077932134	14	.005566581	Root MSE = .06719	

freqveto	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
-----+-----						
totalpay	.0003446	.0005302	0.650	0.529	-.0008224	.0015117
gini	-3.338544	1.50256	-2.222	0.048	-6.645656	-.0314319
gini2	20.45931	10.92963	1.872	0.088	-3.596641	44.51526
_cons	.1216331	.0665864	1.827	0.095	-.0249226	.2681887

Regression veto

Source	SS	df	MS	Number of obs = 15	
-----+-----				F(3, 11) = 12.05	
Model	.146053323	3	.048684441	Prob > F = 0.0008	
Residual	.044458753	11	.004041705	R-squared = 0.7666	
-----+-----				Adj R-squared = 0.7030	
Total	.190512076	14	.013608005	Root MSE = .06357	

freqdic	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
-----+-----						
totalpay	.0024618	.0005017	4.907	0.000	.0013576	.003566
gini	-4.181379	1.421719	-2.941	0.013	-7.310562	-1.052195
gini2	24.76188	10.34159	2.394	0.036	2.000188	47.52358
_cons	-.0676457	.0630039	-1.074	0.306	-.2063164	.0710249

Regression dict

Table 5 : analysis of total payoff and payoff disparity

	All periods	3 final periods
Global agreement	0,2857	0,4333
at least 3 singletons	0,5089	0,4000
others	0,2054	0,1667

(a) Veto

	All periods	3 final periods
Global agreement	0,4609	0,5556
at least 3 singletons	0,0783	0,0741
others	0,4609	0,3704

(b) Dictator

Table 3 : Aggregated frequencies of types of agreement structures

	Type	Global	singleton
Veto	Fixed	63.79	17.24
	Random	50.00	33.33
dictator	Fixed	50.67	30.67
	Random	35.00	35.00

Table 6 : Comparison of initial proposals of extreme agreements for fixed and random groups

	Subgame Size								
Remaining players	7	6	5	4	3	2	1	Total	Extreme Proposals
7	0.422	0.055	0.042	0.025	0.055	0.101	0.300	237	171 (0.722)
6	-	0.366	0.030	0.015	0.075	0.097	0.418	134	105 (0.784)
5	-	-	0.375	0.042	0.021	0.083	0.479	96	82 (0.854)
4	-	-	-	0.372	0.053	0.181	0.394	94	72 (0.766)
3	-	-	-	-	0.382	0.147	0.471	68	58 (0.853)
							Total	629	488 (0.776)

(a) veto treatment

	Subgame Size								
Remaining players	7	6	5	4	3	2	1	Total	Extreme proposals
7	0.461	0.026	0.043	0.026	0.009	0.122	0.313	115	89 (0.774)
6	-	0.306	0.111	0.000	0.056	0.000	0.528	36	30 (0.833)
5	-	-	0.424	0.061	0.030	0.152	0.333	33	25 (0.757)
4	-	-	-	0.750	0.083	0.167	0.000	12	9 (0.750)
3	-	-	-	-	0.600	0.000	0.400	10	10 (1.000)
							Total	206	163 (0.791)

(b) dictator treatment

Table 7: Proposals and extreme proposals in sub-games (in % of all proposals)

(N.B. subgames of sizes 1 and 2 are omitted because they are necessarily compatible)

Group	7	6	5	4	3
V1	0.9024	0.8438	0.7917	1.0000	1.0000
V2	0.7778	0.8889	0.8889	0.8333	1.0000
V3	0.4400	0.6364	0.6667	0.7778	0.6667
V4	0.8333	0.6923	0.9167	0.7857	0.8000
V5	0.7500	1.0000	0.7778	0.5385	0.8000
V6	0.6964	0.7381	0.8636	0.6957	0.9286
V7	0.6818	0.6364	0.8333	1.0000	0.7500
V8	0.6757	1.0000	1.0000	0.7692	0.8182
Mean	0.7197	0.8045	0.8423	0.8000	0.8454

(a) veto treatment

Group	7	6	5	4	3
D9	0.9333	1.0000	1.0000	1.0000	1.0000
D10	0.8667	1.0000	1.0000	0.6667	
D11	0.8000	0.7000	0.5714		1.0000
D12	0.6000	0.7500	0.6667	1.0000	1.0000
D13	0.6667	0.6667	0.7500	0.5000	1.0000
D14	0.6000	1.0000	0.8333	0.5000	1.0000
D15	1.0000	1.0000	0.6667	1.0000	1.0000
Mean	0.7810	0.8738	0.7840	0.7778	1.0000

(a) dictator treatment

Table 8 : Proposals of extreme agreements (in %) for each subgame size and each independent group

Group	7		6		5		4		3	
	<i>Global</i>	<i>Single</i>	<i>Largest</i>	<i>Single</i>	<i>Largest</i>	<i>Single</i>	<i>Largest</i>	<i>Single</i>	<i>Largest</i>	<i>Single</i>
V1	0.4634	0.4390	0.3750	0.4688	0.3333	0.4583	0.3077	0.6923	0.3000	0.7000
V2	0.5556	0.2222	0.4444	0.4444	0.4444	0.4444	0.5000	0.3333	0.0000	1.0000
V3	0.2400	0.2000	0.4545	0.1818	0.3333	0.3333	0.2222	0.5556	0.2222	0.4444
V4	0.3889	0.4444	0.1538	0.5385	0.3333	0.5833	0.3571	0.4286	0.5000	0.3000
V5	0.4500	0.3000	0.1429	0.8571	0.2222	0.5556	0.3846	0.1538	0.4000	0.4000
V6	0.3393	0.3571	0.4048	0.3333	0.3636	0.5000	0.3478	0.3478	0.3571	0.5714
V7	0.5000	0.1818	0.4545	0.1818	0.6667	0.1667	0.6667	0.3333	0.5000	0.2500
V8	0.5135	0.1622	0.3333	0.6667	0.4545	0.5455	0.3077	0.4615	0.5455	0.2727

(a) veto treatment

Group	7		6		5		4		3	
	<i>Global</i>	<i>Single</i>	<i>Largest</i>	<i>Single</i>	<i>Largest</i>	<i>Single</i>	<i>Largest</i>	<i>Single</i>	<i>Largest</i>	<i>Single</i>
D9	0.7333	0.2000	0.0000	1.0000	0.0000	1.0000	1.0000	0.0000	1.0000	0.0000
D10	0.6000	0.2667	0.2500	0.7500	0.2500	0.7500	0.6667	0.0000	-	-
D11	0.3000	0.5000	0.2000	0.5000	0.5714	0.0000	-	-	0.5000	0.5000
D12	0.4000	0.2000	0.2500	0.5000	0.5000	0.1667	1.0000	0.0000	0.3333	0.6667
D13	0.2667	0.4000	0.5000	0.1667	0.5000	0.2500	0.5000	0.0000	0.0000	1.0000
D14	0.4667	0.1333	0.0000	1.0000	0.5000	0.3333	0.5000	0.0000	1.0000	0.0000
D15	0.5333	0.4667	0.5714	0.4286	0.3333	0.3333	1.0000	0.0000	1.0000	0.0000

(b) dictator treatment

Table 9 : Hit rates per independent group of singletons and largest agreement proposals

Group	7	6	5	4	3
v1	0.6167	0.5104	0.3917	0.5000	0.3333
v2	0.4921	0.5556	0.4889	0.3333	0.3333
v3	0.1543	0.3030	0.2667	0.2778	-0.0238
v4	0.5476	0.3590	0.5167	0.2857	0.1333
v5	0.4643	0.6667	0.3778	0.0385	0.1333
v6	0.4107	0.4048	0.4636	0.1957	0.2619
v7	0.3961	0.3030	0.4333	0.5000	0.0833
v8	0.3900	0.6667	0.6000	0.2692	0.1515
Mean	0.4340	0.4711	0.4423	0.3000	0.1758

(a) veto treatment

Group	7	6	5	4	3
D9	0.6476	0.6667	0.6000	0.5000	0.3333
D10	0.5810	0.6667	0.6000	0.1667	
D11	0.5143	0.3667	0.1714		0.3333
D12	0.3143	0.4167	0.2667	0.5000	0.3333
D13	0.3810	0.3333	0.3500	0.0000	0.3333
D14	0.3143	0.6667	0.4333	0.0000	0.3333
D15	0.7143	0.6667	0.2667	0.5000	0.3333
Mean	0.4952	0.5405	0.3840	0.2381	0.2857

(b) dictator treatment

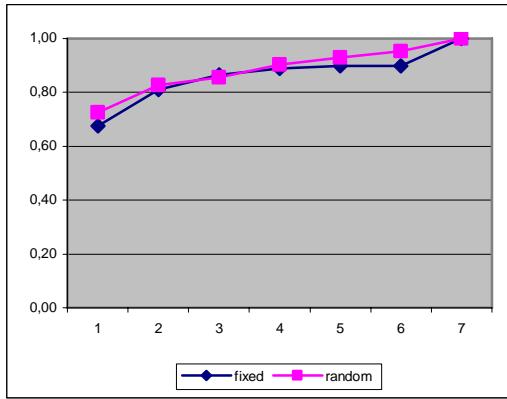
Table 10 : Measures of predictive success for extreme agreements

	R&V's behaviour	Myopic or Cooperative behaviour	Free rider
7	2	LA (GA)	1
6	1	LA	1
5 and fewer	LA	LA	1

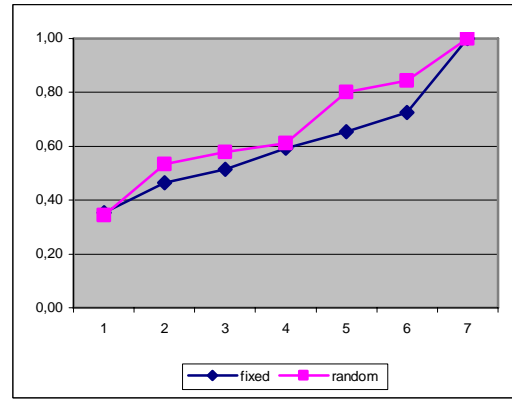
Table 11 : Proposals depending on behaviour type and sub-game

Structure	s ₁	s ₂	s ₃	s ₄	s ₅	s ₆	s ₇	Total payoff
(7)	24,50							172,00
(1,6)	36,50	19,00						151,00
(1,1,5)	26,50	26,50	14,50					126,00
(1,1,1,4)	18,50	18,50	18,50	11,00				99,50
(1,1,1,1,3)	12,50	12,50	12,50	12,50	8,50			75,50
(1,1,1,1,1,2)	8,50	8,50	8,50	8,50	8,50	7,00		56,50
(1,1,1,1,1,1,1)	6,50	6,50	6,50	6,50	6,50	6,50	6,50	45,50

Table 12 : Payoffs in the simplified game



(2a)



(2b)

Figure 1 : Cumulative frequencies of agreement sizes : veto (2a), dictator (2b)

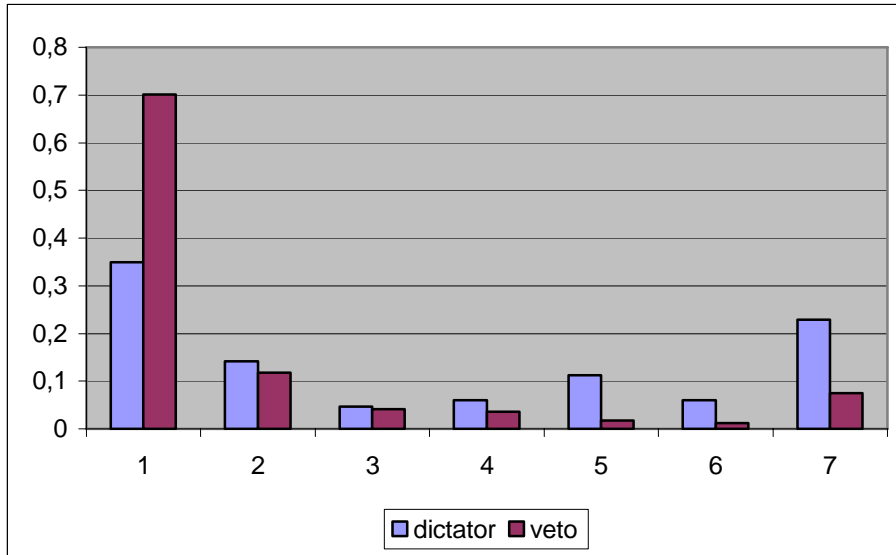


Figure 2 : Size distribution : comparison veto and dictator treatments

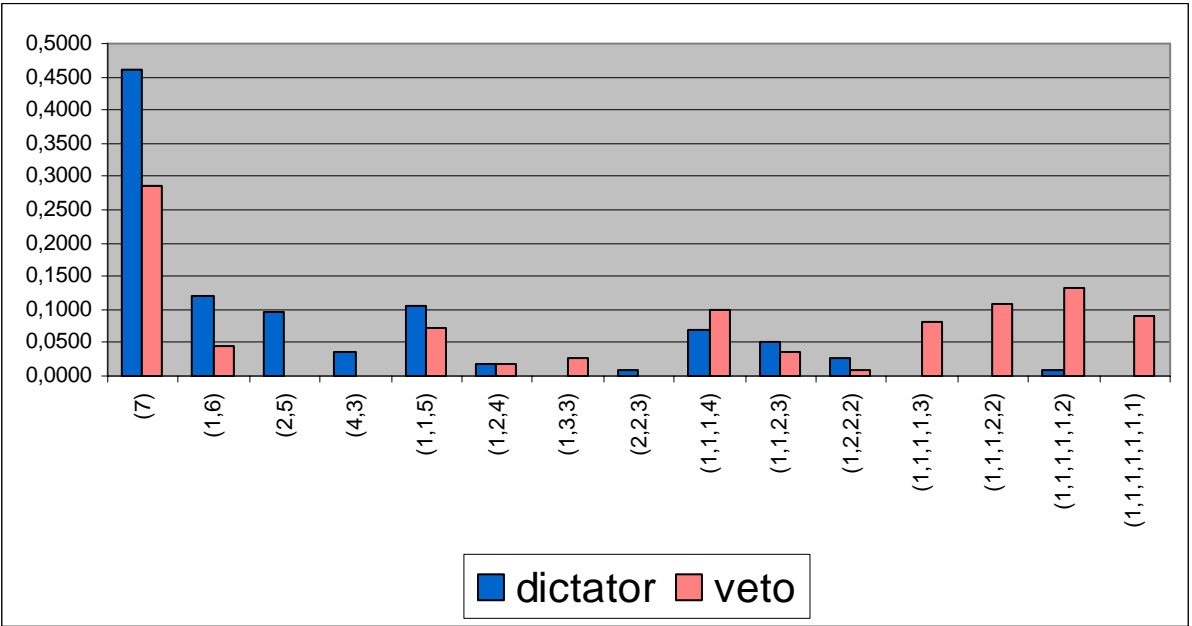


Figure 3 : Frequency of agreement structures

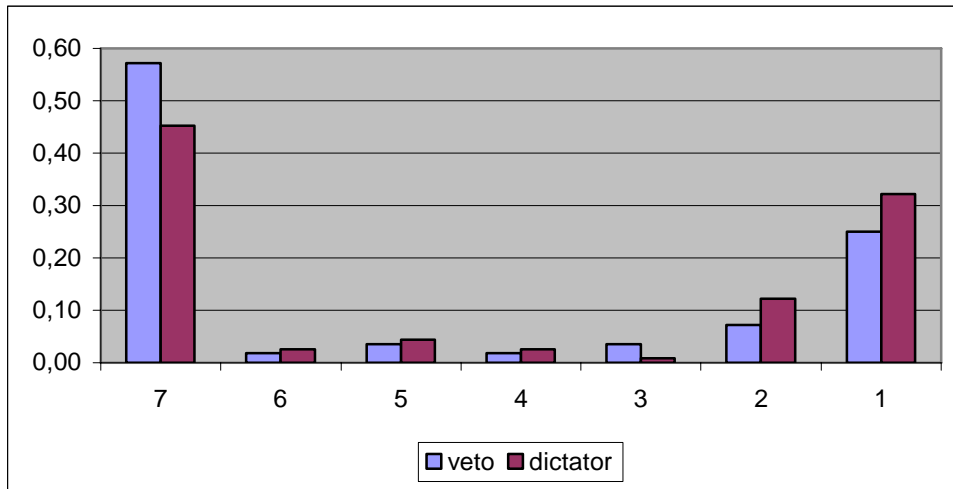


Figure 4 : Frequency distribution of initial proposals (all rounds)

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