Groups in economics

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Chapter 2

The Tragedy of the Commons Revisited: The Importance of Group Decision-Making

2.1 Introduction[1]

Are groups more likely to fall prey to the tragedy of the commons (Hardin, 1968) than individuals? Though there is a large and abundant literature on this tragedy and other social dilemma's (for references, see Ostrom 1998; Ostrom *et al*. 2002), this question has never been raised. In fact, its analysis has to a very large extent been restricted to choices made by individual decision-makers. In particular, the behavior of individuals facing the commons is by now well understood (e.g., Herr *et al*. 1997). When involved in a common pool dilemma people often find ways to govern behavior in a more efficient way than predicted by rational choice theory (Ostrom *et al*. 1992; Ostrom 1998). Yet there is widespread evidence that groups behave differently than individuals in many (other) circumstances (*e.g.,* Cooper and Kagel 2005, Cox and Hayne 2006; Kocher and Sutter 2005, 2007, Sutter 2007, Sutter *et al.* 2009; see Kerr *et al*. 1996 and Kerr and Tindale 2004 for reviews of the psychological literature). This may be important, because in many real world examples of the tragedy of the commons decision makers are more likely to be groups than individuals. For example, fishing on common waters is usually characterized by multiple-member crews per boat as opposed to single fishermen and farms using common water wells are often run by families. As noted by, *i.a.,* Kocher and Sutter (2005) decisions in organizations and companies are generally not made by individuals but by teams. We use laboratory experiments to study the difference in behavior between groups and individuals in this type of dilemma.

More specifically, the environment we are interested in is an inter-temporal common pool dilemma. To picture the situation, consider a lake with fish and one or more fishing boats. We distinguish between a non-strategic and a strategic setting. In the *non-strategic* case, there is one boat on the lake deciding how many fish to catch, and how many to leave in order to ensure future populations of fish. The situation where there is only one fisherman on the boat represents an individual decision-making environment. A crew of three

[1] This chapter is based on Gillet, Schram and Sonnemans (2009)

fishermen on the boat represents the group decision-making case. In the *strategic* setting, various boats affect each other's earnings via the price of fish on the market (determined by the number of fish caught) and by the consequences of their current catch for future periods. Once again, each boat may have one fisherman or a crew of three.

A significant body of research about the differences between individual and group decision-making is primarily based on economic or social psychological laboratory experiments. Two general conclusions are directly relevant for decisions in an inter-temporal common pool dilemma: (i) groups make 'qualitatively better' decisions than individuals do; (ii) groups are more 'competitive' than individuals. We discuss each of these in turn.[2]

At first sight, the evidence about the quality of decisions by groups and individuals is mixed. Often, choices are compared to optimal choices as determined by some (usually rational choice) theory. A deviation from the theory is labeled a 'bias'. A question that has been addressed is whether groups are as prone to such biases as individual decision makers are. For example, Bone *et al.* (1999) and Rockenbach *et al.* (2007) find no evidence that groups act more in line with expected utility theory than individuals. Cox and Hayne (2006) even find that groups more easily fall prey to the winner's curse in common value auctions than individuals do. Moreover, Argote *et al.* (1990) find that group discussions amplify the base rate fallacy and Kerr *et al.* (1999) show that in many cases individual biases are amplified in groups. Sutter et al (2009) show that teams are more prone to the winners' curse. On the other hand, Bornstein *et al.* (2004) report that group decisions are closer to the rational equilibrium prediction in a centipede game, Cooper and Kagel (2005) show that groups act more strategically in signaling games and Sutter (2007) shows that groups exhibit less myopic loss aversion than individuals. Using a theory to define the 'correct' choice obviously implies that the theory itself is 'correct', however. For many of the theories used in these examples this is under dispute. On the other hand, there are tasks with a demonstrably correct answer ("What is the cubic root of 29791?"). In this type of problems, groups perform better than individuals (Laughlin and Ellis 1986; Blinder and Morgan 2005; for a recent overview see Laughlin *et al.* 2003). In the non-strategic version of our inter-temporal common pool dilemma, there is such a demonstrably correct solution. Hence, we predict that groups will make qualitatively better decisions in this dilemma than individuals.

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[2] The literature reports other differences between individuals and groups that are less directly relevant for our purpose: (i) groups are less trusting than individuals (Cox 2002; Kugler *et al.* 2007; Song 2005); (ii) groups are more polarized when measuring risk or other attitudes (see Baron and Kerr 2002 for a review); (iii) groups are (incorrectly) more optimistic than individuals in time prediction (Buehler *et al.* 2005); (iv) groups learn faster than individuals do (Kocher and Sutter 2005); (v) individuals and groups may differ in their preferences; for example, some find that groups' preferences are more other-regarding (Cason and Mui 1997)) whereas others report the reverse (Bornstein and Yaniv 1998, Luhan *et al.* 2009).

The finding that groups are more competitive than individuals is often referred to. This conclusion is mainly based on a series of results obtained by Chester Insko and John Schopler (and various colleagues) on prisoners' dilemma games (*e.g.,* Schopler and Inkso 1992). For an overview, see Insko *et al*. 1998. These authors have repeatedly found that groups choose the competitive option (*i.e*., 'defection') more often than individuals do.[3] Note, however, that defection is a dominant strategy in the prisoners' dilemma. Hence, more defection by groups could also be interpreted as more rational behavior. It is therefore not clear whether the alleged higher competitiveness of groups can be deduced from their choices in the prisoners' dilemma (or similar games). Isolating differences in competitiveness requires controlling for differences in the quality of decision making. This control is a key element of our experimental design.

We believe to be the first to deliberately study the competitiveness of groups versus individuals while correcting for differences in the quality of their decisions (which in our setting reflects the rationality of the decision maker). Our experimental design distinguishes between a strategic and non-strategic setting. The non-strategic inter-temporal problem allows us to determine differences in the quality of decisions. In the strategic interaction part of the experiment, differences between groups and individuals in the quality of decisions may affect differences in competitiveness. Our design allows us to use the result on quality obtained in the non-strategic problem to 'filter out' the effect of competitiveness in the inter-temporal common pool dilemma. If groups choose differently than individuals, we know from the first part the extent to which this is attributable to differences in decision-making quality. Any remaining differences can be attributed to distinct levels of competitiveness.

On the other hand, the extent of competitiveness of groups may depend on the mechanism used to reach a group decision (Bornstein *et al*. 2004). In particular, it may matter whether a group decision is reached when a majority of group members agrees on a particular choice or that all members have effective veto power (Blinder and Morgan 2005). For this reason our experimental design includes both majoritarian and unanimous group decision making.

The remainder of this chapter is organized as follows. The following section presents the experimental design. Our theoretical predictions follow in section 2.3. Section 2.4 presents our results and our concluding discussion is in section 2.5.

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[3] The conclusion that groups are more competitive seems at odds with the finding by Mannix & Loewenstein (1994) that groups playing the role of firms withdraw less from a joint fund than individuals do. The role-playing methodology used in this paper is very different than the other designs discussed here, however. Moreover, other explanations for the result (such as distinct time horizons) may also explain the result. Mannix and Loewenstein prefer the latter explanation.

2.2 Experimental Design

2.2.1 General Design and Procedures

For presentational purposes, we will sometimes refer to 'boats' and 'crews' when describing our design, even though these terms were never used in the instructions (*cf.* appendix 2A). The experiments revolve around a 'pool' filled with 'tokens'. In every period either one or three boats decide how many tokens to harvest from the pool. In the one-boat case, the problem to be solved is basically an inter-temporal choice problem. With three boats, subjects are dealing with an inter-temporal common pool dilemma. We distinguish between three treatments in a between-subject design: one where decisions are made by individuals and the other where they are made by groups of three individuals. For the latter we distinguish between groups that decide by majority vote and groups that decide unanimously. When a boat has a crew of three, earnings are shared equally.

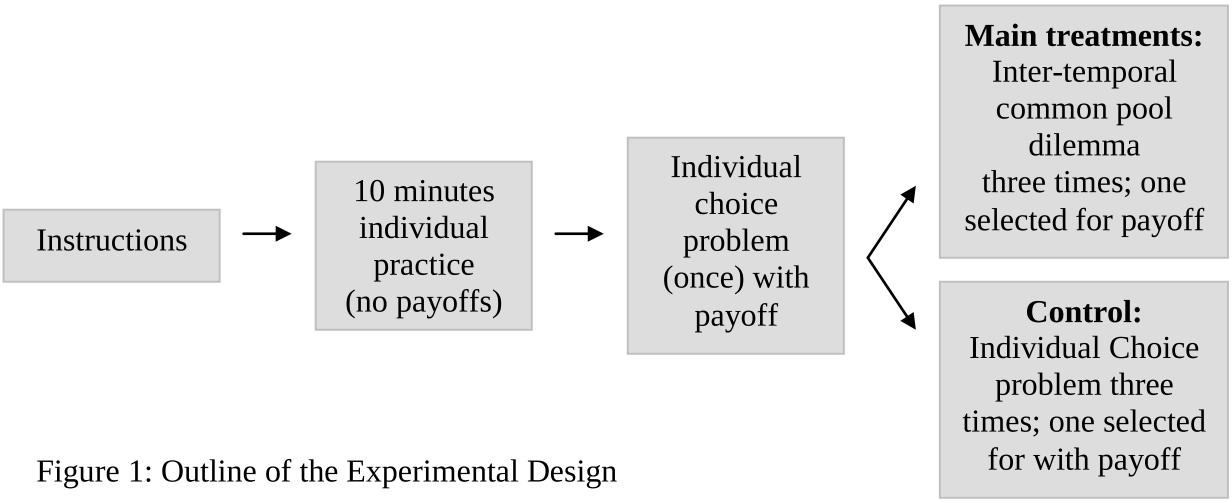

Figure 1: Outline of the Experimental Design

Both treatments start with a practice period. Participants can individually try to solve the non-strategic inter-temporal problem (without payment). The practice period intends to allow participants to acquaint themselves with the workings of the model and to get a feeling for how to maximize their pay-offs. In this period, subjects can try the non-strategic intertemporal problem as often as they like. In every attempt they receive full feedback of the (at this stage hypothetical) payoff consequences of their choices. After the 10 minutes of practice the first part starts in which participants play the non-strategic problem once. The outcome is paid. In part 2, subjects in the experimental treatments participate in the inter-temporal common pool dilemma three times. One of these is randomly selected for payment.

Finally we added two control treatments where we test whether observed behavior in the inter-temporal dilemma is caused by experience. We replaced the second part by three additional runs of the non-strategic individual choice problem (one session for individuals and one for teams), one of which was selected for payoff. Figure 2.1 summarizes the time-line of the experiment.

Table 2.1 summarizes our sessions.

	#sessions	**#subjects**	**#groups**	**decision-making**	**Part 1**	**Part 2**
Main treat-ments	3	48	n.a.	individual	non-strategic	dilemma
	5	90	30	majority rule	non-strategic	dilemma
	4	72	24	unanimity	non-strategic	dilemma
Con-trol	1	25	n.a.	individual	non-strategic	non-strategic
	1	18	6	majority rule	non-strategic	non-strategic

Table 2.1: Overview of sessions and treatments

The experimental currency used is denoted by 'francs'. At the end of a session francs are exchanged for euros. The exchange rate depended on the part of the experiment and on whether players were individuals or groups. For the non-strategic individual choice problem, the exchange rate was € 4 for each 10,000 francs for individuals and € 12 per 10,000 francs for crews of three (to be split equally). For the inter-temporal common pool dilemma, the rate was € 12 per 10,000 francs for individuals and € 36 per 10,000 francs for crews.[4] On average, subjects earned € 17.06 euro in approximately 75 minutes (on top of a €7 show-up fee).[5]

2.2.2 The Model

Earnings are equal to revenue minus costs. Each token harvested in period t yields an average revenue r_t for the boat determined by the inverse demand for tokens:

$$r_t = 250 - \frac{h_t}{4}, \tag{2.1}$$

[4] We preferred to vary the exchange rate in the two parts of the experiment to varying the parameters of the model used in order to keep the problem itself constant throughout the experiment.
[5] The sessions with unanimous decision making took much longer (up to three hours) than all other sessions. In order to minimize differences across treatments we did not want to introduce a time limit. Note that the majority rule sessions that we organized first did not have a time limit either.

where h_t is the (aggregate) number of tokens harvested in period t. Average cost per token harvested in t are inversely related to the number of tokens in the pool:

(2.2) $$c_t = \frac{120{,}000}{x_t},$$

where x_t denotes the number of tokens in the pool at the beginning of period t. Net revenue per token, n_t, is equal to average revenue minus average costs:

(2.3) $$n_t = r_t - c_t = 250 - \frac{h_t}{4} - \frac{120{,}000}{x_t},$$

Each game starts with a pool of 600 tokens (x_1 = 600) and lasts for ten periods. After each period the number of tokens remaining in the pool grows at a rate of 10%:

(2.4) $$x_{t+1} = 1.1 \bullet (x_t - h_t),$$

As a consequence, in any given period (except in the final period) taking out the number of tokens that maximizes the revenue for that period (denoted by h_t^*), *i.e.*:

(2.5) $$h_t^* = 2 \bullet \left(250 - \frac{120{,}000}{x_t}\right),$$

will decrease future revenues. Maximizing the cumulative 10-period revenue requires a level of *forward lookingness* where a boat foregoes immediate pay-off in favor of higher, long-term revenue.

2.2.3 The Group Decision-Making Process

An important issue when comparing group and individual behavior is the way in which a group reaches its decision. There is surprisingly little attention for this issue in the existing literature (for exceptions, see Blinder and Morgan 2005; Bornstein *et al.* 2004, Bosman *et al.* 2006; Kocher and Sutter 2007; chapter 3 in this thesis). In the literature referred to above on group versus individual decision-making, the most common practice is to use face-to-face discussion between group-members without formal requirements for the way group decisions are reached.[6]

In contrast, we apply a formal process of decision-making. There is no face-to-face discussion. Group members act anonymously. A very limited form of communication is

[6] Bosman *et al.* (2006) show that in such “unitary groups” majority rule is the procedure most commonly used to make decisions, albeit often implicitly. Blinder and Morgan (2005) explicitly distinguish between majority rule and unanimity. They find no differences between the two. This may be attributable to the fact that all decisions are made in face-to-face group decisions, however. In fact even majority groups usually make unanimous decisions in their environment. Our environment provides more control for the comparison between majority rule and unanimity.

possible: group members can propose a number of tokens to be harvested. In each period, each member first must propose a number. When all three members have made a first proposal, these are simultaneously made known to the members of the group. After this, any and each member can adapt her or his proposal and the revision is instantaneously made known to others. Our design distinguishes between two ways to reach a group decision. In our majority rule treatment (denoted by MAJ), a group decision is reached when any two members of the group propose the same number. In the unanimity treatment (UNA) all three members need to propose the same number for a decision to be reached. There is no time limit for groups to reach a decision. In all MAJ sessions, groups reached decisions within a few rounds of proposals, however (43.6% of the decisions were reached in the first, simultaneous, round of proposals). In the UNA sessions 12.7% reached a unanimous decision immediately. It typically took much longer for groups to make a decision in UNA than in MAJ.[7]

We prefer this structured method of group decision-making because of the control it gives over the interaction between group members. Once we know the effect of groups for this minimal type of communication, we can explore the additional effects of extended forms such as chat boxes (for an example, see chapter 3). Moreover, this controlled method allows us to analyze the group decision-making process in detail (cf. section 2.4.4).

2.3 Theoretical Predictions

In this section we present the optimal path for the non-strategic inter-temporal choice problem (section 2.3.1) and the subgame perfect Nash equilibrium for the inter-temporal strategic game (2.3.2). In addition, we present predictions for both cases assuming limited forward lookingness, *i.e.*, decision-makers consider only a limited number of future periods. Unless indicated otherwise, solutions were obtained numerically.

2.3.1 Part 1: Non-strategic Problem

With only one boat per pool maximizing the cumulative pay-off is an individual choice problem. In the optimum, the marginal benefit of current harvest is balanced with that of allowing the pool to grow for future harvest. The optimal strategy in the non strategic game is

$$\bar{h} = \arg\max_{h} \left(\sum_{t=1}^{10} h_t \quad r_t - c_t \right) = \arg\max_{h} \left(\sum_{t=1}^{10} h_t \left(250 - \frac{h_t}{4} - \frac{120000}{x_t} \right) \right) \tag{2.6}$$

[7] Though in 50.4% of the cases two out of three members agreed already in the first round of proposals, single members often proved to be very reluctant to yield, giving a deadlock in proposals.

with h= (h_1,h_2,...h_{10}) a vector of harvests, x_1=600 and x_t=1.1*(x_t-1-h_{t-1}) for t>1. The second equality uses eq. (2.3).

On the other hand, decision makers may be more myopic and not take all future consequences of a current decision into account. A forward lookingness of only k periods will in period j use the strategy

$$(2.7) \quad \overline{h_s^k} = \arg\max_h \left(\sum_{t=s}^{\max(s+k,10)} h_t \; r_t - c_t \right) = \arg\max_h \left(\sum_{t=s}^{\max(s+k,10)} h_t \left(250 - \frac{h_t}{4} - \frac{120000}{x_t} \right) \right)$$

with h=(h_s,h_{s+1},...$h_{\max(10,s+k)}$) and x_t defined as above.

Table 2.2 shows the optimal (top half) and purely myopic (k=0; bottom half) strategies.

period	1	2	3	4	5	6	7	8	9	10	Total
optimally forward looking											
pool	600	660	726	799	878	966	1028	1035	990	890	
harvest	0	0	0	0	0	32	87	135	181	230	
earnings	0	0	0	0	0	3769	9702	13542	15120	13264	55396
myopic											
pool	600	550	535	532	531	531	531	531	531	531	
harvest	100	64	51	49	48	49	48	48	48	49	
earnings	2500	1012	652	596	582	588	573	579	585	593	8260

Table 2.2: Strategies in the non-strategic problem

Following the optimal strategy leads to a total cumulative pay-off of 55396 francs. Note that it requires postponing the first harvest until period 6. At the other extreme of this ‘complete’ forward lookingness, we find the completely myopic decision maker who maximizes current period earnings in each and every period, without taking future consequences into account at all (k=0). The results for this case are derived using eqs. 2.3-2.5. This leads to total cumulative earnings of 8260 francs. Intermediate levels of forward lookingness yield harvest paths between these two extremes. Appendix 2B shows how pool sizes develop for various levels of forward lookingness.

A global measure of forward lookingness is the total cumulative pay-off. The less myopic a decision maker is, the higher her revenue after 10 periods will be. Figure 2.2 describes the nature of this relationship. The convex shape of the earnings curve shows a decreasing marginal benefit of looking further ahead. For decision makers with limited cognitive resources, it may not be worthwhile to look more than 2 or 3 periods ahead. Because earnings are monotonically increasing in the number of periods a decision maker looks ahead, we will sometimes use total cumulative earnings as a measure of forward lookingness.

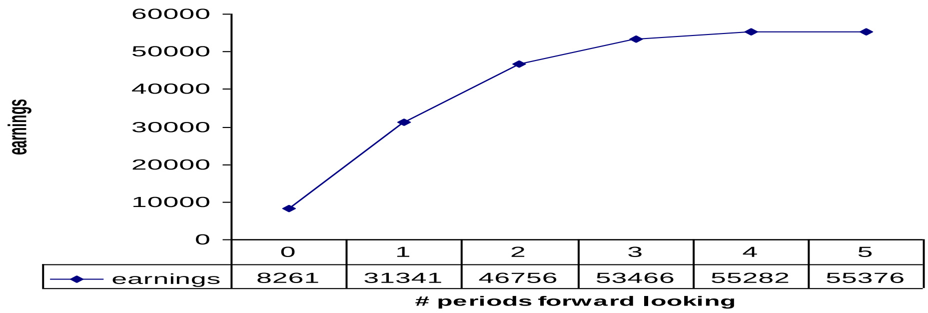

Figure 2.2: Cumulative revenue and forward lookingness; non-strategic problem

2.3.2 Part 2: Strategic Game

In the second part of the experiment there are three boats per pool. The number of tokens harvested (h_t in eq. 2.1) now refers to the aggregate harvest by the three boats. This situation is an 'inter-temporal common pool dilemma' (*cf*. Herr *et al*., 1997). The socially optimal strategy for this game is for the aggregate harvest to be equal to the optimal strategy in the one-boat case. The dilemma arises because each player in the strategic game has the incentive to take out more. This will decrease the price per token but is to a certain point compensated by the increase in the number of tokens harvested. An additional consequence of harvesting more than is socially optimal is that this will decrease future pool size (eq. 2.4), raising future costs (eq. 2.2) and decreasing future revenue (eq. 2.1). This is an externality affecting all boats sharing the pool.

Table 2.3 shows the subgame perfect Nash-equilibrium derived assuming that every player is forward looking and expects all other players to be the same. This yields an aggregate payoff of 11716 francs per boat. A comparison to table 2.2 shows that competition makes boats start to harvest 2 periods earlier and that the harvest is also higher. In fact, the equilibrium aggregate earnings of 35148 are only 63% of the earnings in the social optimum (55396).

period	1	2	3	4	5	6	7	8	9	10	Total
Subgame perfect Nash (optimal forward looking)											
harvest per player	0	0	0	15	35	43	46	41	33	25	
aggregate harvest	0	0	0	45	105	129	138	123	99	75	
pool size	600	600	726	799	829	796	734	656	586	536	
earnings per player	0	0	0	1328	2765	2881	2393	1489	676	184	11716
aggregate earnings	0	0	0	3984	8295	8643	7179	4467	2028	552	35148
Myopic equilibrium											
harvest per player	50	8	18	15	16	15	16	15	16	15	
aggregate harvest	150	24	54	45	48	45	48	45	48	45	
pool size	600	495	518	510	512	510	512	510	512	510	
earnings per player	625	13	87	52	58	52	58	52	58	52	1107
aggregate earnings	1875	38	261	156	174	156	174	156	174	156	3321

Table 2.3: Strategic game: subgame perfect Nash equilibrium and a myopic equilibrium

At the other extreme, if every player is myopic *and thinks that all others are myopic*, a Nash-like (myopic) best response criterion yields a series of 10 Cournot equilibria. The myopic Cournot harvest depends on the pool size. It can be straightforwardly derived from eq. 2.3 that this yields $h_{it} = 250 - {}^{120{,}000}\!/_{x_t}, t = 1,..,10.$ This prediction is displayed in the lower part of table 2.3.

Similarly, we can derive Nash-like mutual best response equilibria for any given level of forward lookingness. We shall call such solutions *n-myopic equilibria*. For example, a 3-myopic equilibrium is a situation where each player looks three periods forward, assumes that all others look three periods ahead and best responds to this belief. There is some rationale for this ‘false consensus’ of common myopia to exist. First, it does not make sense for an individual to assume that another player looks further into the future than she herself does. In that case, she would realize that one should look ahead and would do so. Second, assume that an individual thinks others are more myopic than she herself is. Because these others are depleting the pool too soon, she herself will have to harvest sooner than planned, *i.e.*, act more myopically.[8]

[8] Dropping the assumption that players assume that others are equally forward looking makes the game impossible to solve. Alternatively, one could consider determining the empirical distribution of choices and the optimal response to this distribution. Actual choice could then be compared to this optimum. This is infeasible

Figure 2.3 shows cumulative earnings per boat for several *n*-myopic equilibria. In this case, the gains from looking an additional period ahead increase almost linearly up to 5 periods. Looking beyond that gives only small marginal benefits.

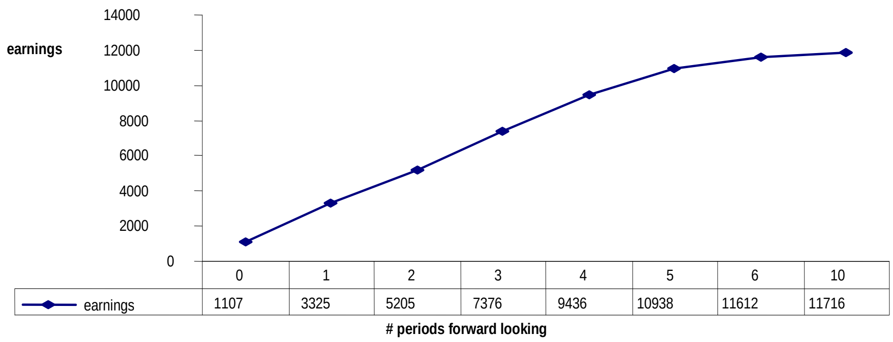

Figure 2.3: Cumulative Earnings per player in *n*-myopic equilibria, strategic game

The two parts of the experiment allow us to compare choices by any particular participant in the two situations. As mentioned above, we will use the non-strategic inter-temporal problem to determine a level of forward lookingness for each decision maker and use this when analyzing behavior in the strategic case. We can do so for both groups and individuals.

Figure 2.4 describes the relationship between predicted earnings (as a fraction of optimal earnings) in the non-strategic problem and the earnings (as a fraction of earnings in the subgame perfect Nash equilibrium) in the inter-temporal common pool dilemma.

For instance, a decision maker looking two periods into the future will earn 84% of the optimum in the non-strategic problem and a pool with three decision-makers looking two periods ahead will, in the 2-myopic equilibrium, earn 44% of the earnings of the subgame perfect Nash equilibrium. The strong convexity at the upper end of the curve in figure 2.4 reflects the earlier observations that the marginal benefits from looking one period further ahead are more or less constant for the strategic game but are decreasing in the non-strategic problem (*cf*. figures 2.2 and 2.3).

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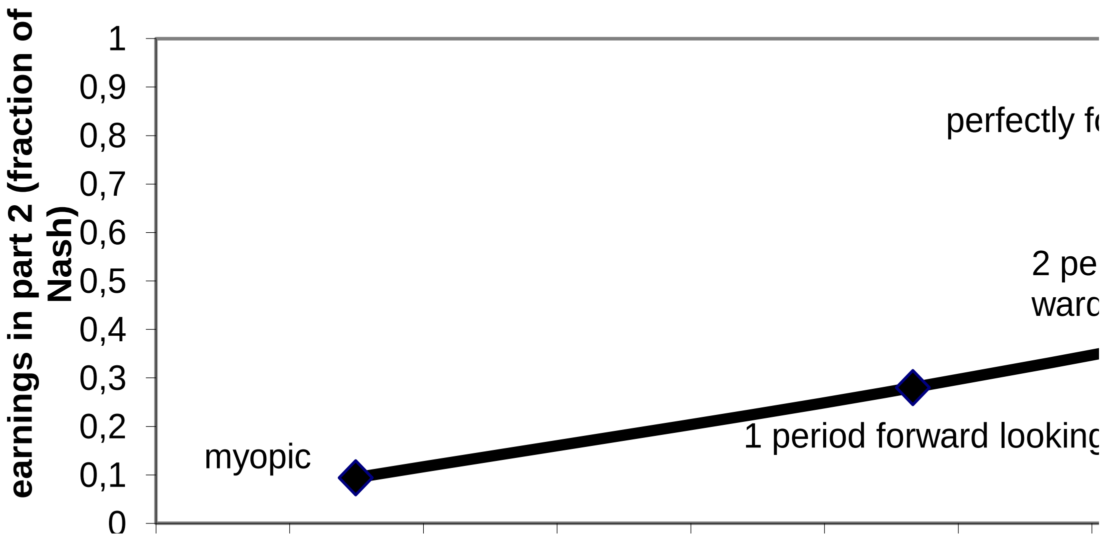
in the present context, however because both the empirical distribution and the optimal response depend on the pool size a decision maker is facing (as well as on the number of remaining rounds).



Note: The horizontal axis gives the fraction of optimal earnings realized in the non-strategic problem. The vertical axis gives the fraction of subgame perfect earnings realized in the strategic game. Points in the graph represent discrete levels of forward lookingness.

Figure 2.4: Relationship between earnings in Parts 1 (non-strategic problem) and 2 (strategic game)

If we assume that decision makers are equally forward looking in both parts of the experiment and that they believe that others are equally forward looking, figure 2.4 predicts earnings in the strategic game (vertical axis) based on the earnings in the non-strategic problem (horizontal axis). Experimental observation southeast of the curve imply that the players concerned are not earning as much in the strategic game as we would predict given the forward lookingness observed in part 1. The reverse holds for observation northwest of the curve. In particular, we are interested in comparing individuals and groups in this respect.

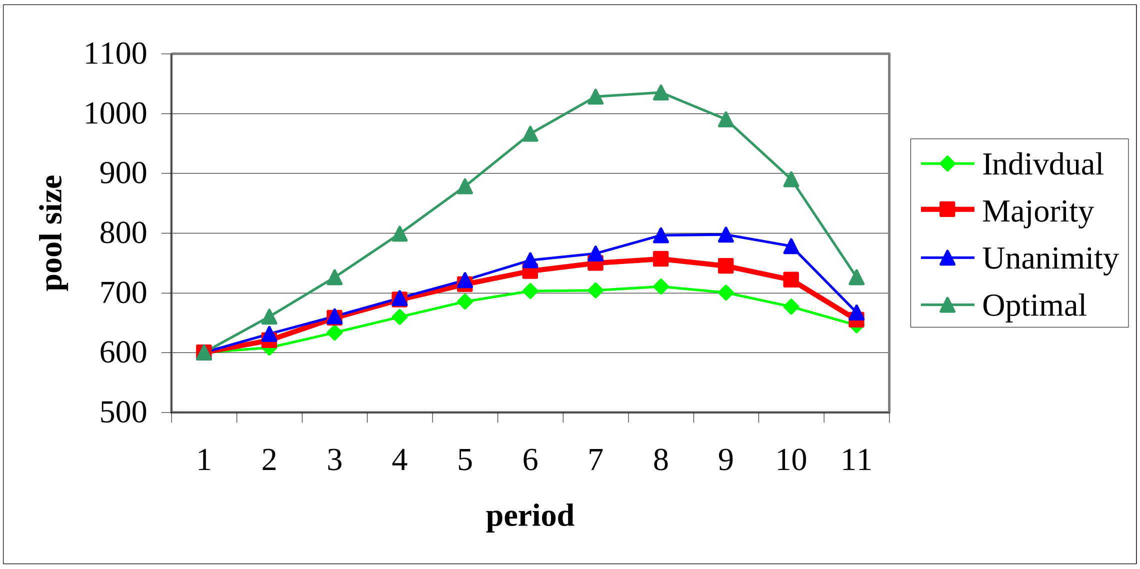
2.4 Results

We will first present the results for the two parts of the experiment separately, and then discuss the relationship between the two. Unless otherwise indicated, all statistical tests are 2-sided Mann-Whitney or Kruskal-Wallis tests, using either individual (or group) choices or the common pool as (independent) unit of observation.

2.4.1 Part 1: Non-strategic Problem

Figure 2.5 depicts the development of the average pool size for the three treatments.[9] It also shows the optimal path, reproduced from table 2.2. A first thing to notice is that in all treatments the average pool size is much smaller than optimal. The difference in pool size across treatments is statistically significant at the 5%-level in periods 9 and 10 and at 10%-level in periods 2 and 8.

We estimate the extent of forward lookingness for each decision-maker (be it an individual or a group) by comparing the development of the pool size to the development for distinct levels of forward lookingness (cf. appendix 2B). We do so by determining the quadratic distance (summed across periods) between the observed pool sizes and the pool size for a given level of forward lookingness. The smallest quadratic distance determines the decision maker's level.



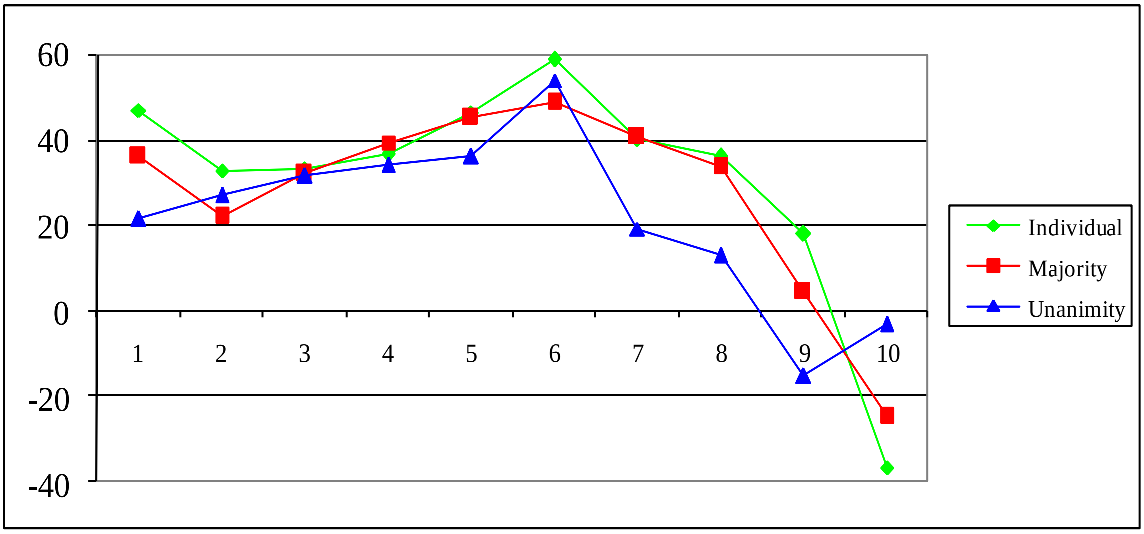
Note. Pool size is measured at the beginning of the period. Period 11 refers to the size after round 10 decisions.

Figure 2.5: Average pool size in the non-strategic problem

On average individuals look 1.26 periods forward, majority groups 1.56 periods, and unanimity groups 1.71 periods. Though the differences appear to be substantial, they are not statistically significant. Note, however, that a decision maker may make a mistake in an

[9]For the analyses of the non-strategic problem, we also use the first round data from the two control sessions where the non-strategic game was repeated four times. No player in any session knew what was to follow.

early period, but act optimally thereafter. In that case, this categorization may be misleading.[10] Therefore we calculated for each observation the optimal decision given the current pool size and period and compared this to the actual decision. The results are shown in figure 2.6.



Note: for each period, the graph shows the difference between observed harvest and the optimal decision, given the current pool size.

Figure 2.6: Non-strategic problem: Observed harvest minus optimal harvest.

Note that there is a tendency to harvest too much in all treatments. Only in the last period do decision makers tend to harvest too little. This last period shows that myopic behavior cannot be the only cause of non-optimality because myopia is optimal in the final period. The average absolute error is 47.6 for individuals (IND), 41.3 for groups with majority rule (MAJ), and 39.0 for groups were decisions must be unanimous (UNA). This difference is significant across all three groups (p=.037). Testing pair wise, the differences IND-MAJ and IND-UNA are significantly different at the 5% level (p=0.014, p<0.001, respectively) whereas the difference MAJ-UNA just misses significance (p=0.059). As a consequence of their better forward lookingness, the cumulative earnings of unamimous groups (33874; which is 61% of the maximum amount) is significantly (p=.024) higher than for individuals (25982; 47%). The cumulative earnings of majority groups (32311; 58%) is also

[10] For this reason we prefer to use a different measure of forward lookingness −based on realized earnings− below.

significantly higher than for individuals (p=0.030) but the earnings difference MAJ-UNA is not significant (p=0.740).

We conclude that groups make qualitatively better decisions in the non-strategic problem than individuals do, irrespective of the decision making procedure. Unanimous groups make slightly better decisions than groups deciding by majority, but this difference is not large enough to cause significant differences in earnings.

2.4.2 Part 2: Strategic Game

Interpreting the results of the strategic part of the experiment is more difficult than for the non-strategic problem. The earnings of any particular boat are very much dependent on the actions of the other boats harvesting from the pool. We therefore start by considering the aggregate earnings at the pool-level. On average individuals earned an aggregate of 9798 experimental francs. Groups in MAJ earned on average 8223 francs per pool while groups in UNA earned on average 11733 francs. The difference across three treatments is statistically significant (p=0.017). Pair wise comparisons show that this is mainly caused by the higher earnings in UNA: IND-MAJ is not significant (p=0.484), whereas IND-UNA (p=0.008) and MAJ-UNA (p=0.021) are.

Recall from figure 2.1 that the strategic game is played three times. Figure 2.7 shows the development of the average pool size for groups (distinguishing between MAJ and UNA) and individuals for these three games. In the first game the most noticeable feature is that groups deciding by unanimity allow the pool to grow much more than individuals or majority groups; the latter two behave similarly. In game 2, groups in UNA do not let the pool grow as much as in game 1, but they are still postpone harvesting longer than in IND and MAJ. Majority groups appear to harvest more early on than individuals, leading to smaller pool sizes. In game 3, differences are small but majority groups still appear to have the smaller pool sizes.

These averages may cover up underlying differences, however. For each period, appendix 2C provides the cumulative distribution of pool sizes per treatment (averaged across the three games). These show that there are two countervailing forces in the strategic game: (i) a large majority of both individuals and groups harvest too much, too soon; groups deciding by majority see their pool size declining most in early periods;[11] (ii) there is always

[11] In 14.6% (16.7%; 16.7%) of the games with individual (majority group; unanimity group) players the pool size decreased below the critical value of 450 where revenue per token becomes negative. In that case players can only wait for the pool to grow again to a profitable size.

a minority that allows the pool to grow, but growth leads to larger pool sizes for groups than

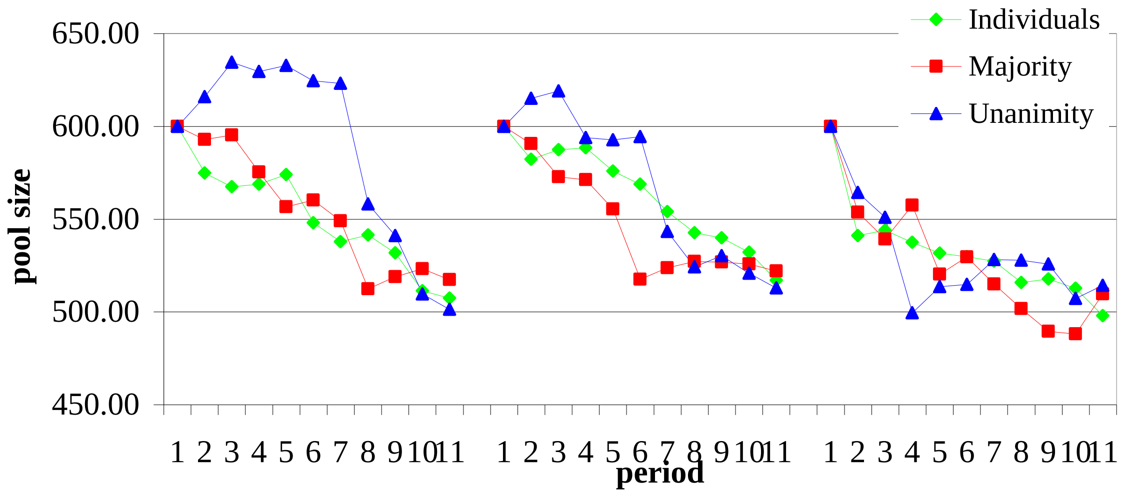


Figure 2.7: Average pool size in the three strategic games[12]

for individuals. The strongest growth is observed for groups deciding unanimously.[13] The means shown in figure 2.7 imply that effects (i) and (ii) compensate each other for MAJ and IND the first time the strategic game is played whereas (ii) dominates for UNA. In the second and third games (i) is dominant in the MAJ-IND comparison, leading to a lower mean pool size for majority groups than for individuals. Unanimity groups are somewhere in between.

In the interaction between ships on a lake, we attribute larger and earlier harvesting to higher levels of competitiveness. As in previous studies comparing groups to individuals (*e.g.*, Insko *et al*. 1998), competitive behavior refers to choices that move the outcome away from the joint optimum. Note that in many games, rational behavior will be competitive in this sense (*e.g.*, the subgame perfect Nash equilibrium of our strategic game is not socially optimal). The question we ask, however, is whether groups move the outcome further away from the optimum than individuals do (or *vice versa*). Using this terminology, the two most striking features in the comparisons between individuals and groups for our strategic game are that (i) groups in UNA are less competitive the first time they play the game, but by the

[12] The ‘11th round’ in this graph refers to the size of the pool after the 10th round (including replenishment).
[13] The UNA groups allowing the pool to grow strongly are mainly observed in the first two games, however; in the last repetition, UNA groups are more or less the same as MAJ.

third time they are as competitive as individuals are; (ii) groups deciding by majority rule are more competitive than individuals, specifically the second and third time they play the game.[14]

2.4.3 Relating part 1 to part 2: Comparing Groups and Individuals

In part 1 we observed that groups make qualitatively better decisions than individuals do, i.e., groups look further into the future. Groups earned 61% (UNA) and 58% (MAJ) of the total possible earnings and individuals earned only 47%. Based on this, one would predict that groups do better (i.e., let the pool grow initially and earn more) in the strategic game as well. The results of part 2 show that only unanimous groups perform significantly better than individuals in the strategic game. Moreover, this result for UNA disappears with repetition of the game. Groups deciding by majority vote do not fare better in the strategic game, in spite of their better forward lookingness; in fact, they fare worse.

Before analyzing these differences in more detail, an issue to consider is that the timing of our experimental design may have affected these results; perhaps individuals are initially less forward looking than groups but quickly catch up. To investigate this, we ran two control sessions where the second part consisted of three repetitions of the non-strategic game and no inter-temporal dilemma was played (cf. figure 2.1). In one session participants made individual decisions, in the other they were in groups of three using majority rule to make a decision. Table 2.4 shows average earnings in francs per round.

	Individuals (N=25)	Majority Groups (N=6)
Round 1	24840	31109
Repetition 1	28298	34294
Repetition 2	30029	36522
Repetition 3	33636	39939

Note. Numbers show average earnings in francs. Round 1 and one of the three repetitions (randomly chosen) were paid.

Table 2.4: Control with repeated non-strategic problem

[14] Note that we do not discuss the cause of distinct levels of competitiveness. At least two possibilities come to mind. First, groups may be more inclined to reciprocate actions by other ships on the lake, *i.e.*, they may simply harvest more because others are doing so. Second, there may be differences between individuals and groups with respect to the way in which they adapt their beliefs to observed harvests while their response to any given belief is the same. We leave possible explanations as an interesting avenue for future research.

These numbers clearly show that both individuals and groups become more forward looking with repetition but that groups are more forward looking in any particular repetition. Hence the observed differences cannot be attributed to an artifact of our design. We therefore focus on explaining the differences between individuals and groups in the inter-temporal dilemma. Using the benchmark of figure 2.4, figure 2.8 makes this difference more explicit. Recall that decisions southeast (northwest) of the benchmark reflect sub-(above-)par performance in the strategic game (*i.e.* part 2), given decision-makers' extent of forward lookingness derived from the non-strategic problem.

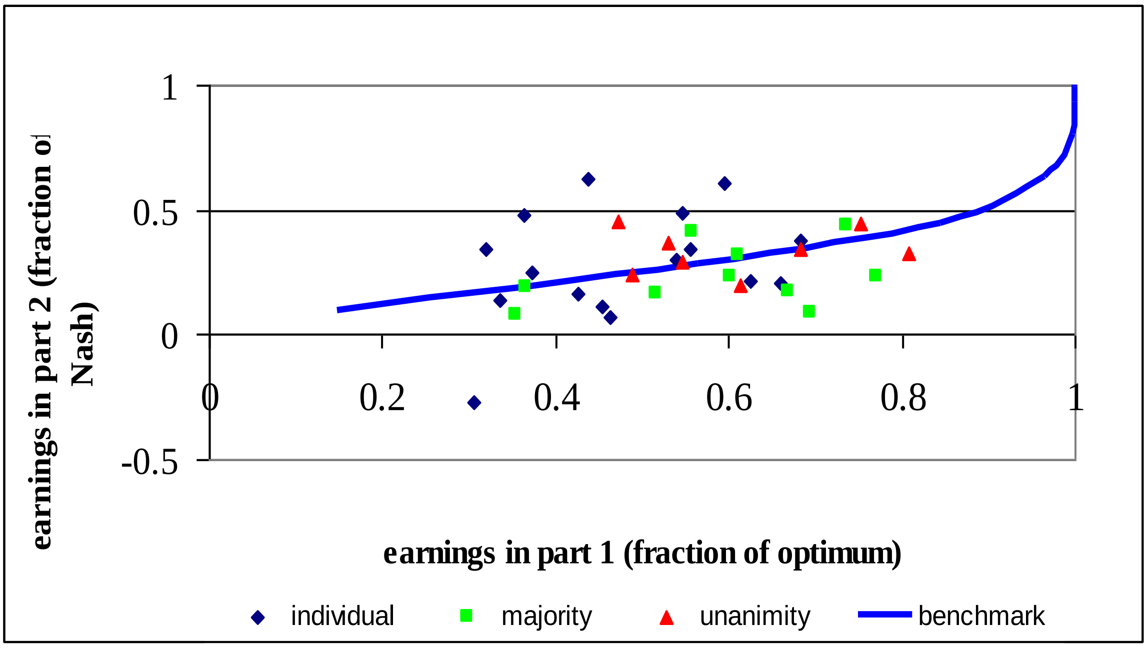


Figure 2.8: Earnings of groups and individuals in Parts 1 and 2

Figure 2.8 shows small, but interesting differences across treatments. When decisions about the number of tokens to harvest are made in crews of three by majority vote, most (6 out of 10) of the observations are found southeast of the benchmark, whereas the majority of the individual decision makers (9 out of 16) are northwest of the benchmark. Observations in groups deciding by unanimity are equally split. These differences across treatments become larger when we consider the extent to which the observed choices in the strategic game deviate from the choices predicted by the harvest decisions in the non-strategic game. More specifically, we determined for each player in the strategic game (be it an individual or a group) the n-myopic equilibrium level of earnings given the forward-lookingness, n, observed in the non-strategic problem. We then calculated the difference with observed earnings. On average, aggregated across the three strategic games, individuals earned slightly more (369 points) in the strategic game than expected from the non-strategic problem. Majority groups earned on average 799 points less than expected and unanimity groups earned 236 more across all three games (due to their high earnings in the first game). The difference across three groups is significant across all three games (p=0.07) and significant for the joint observations from games 2 and 3 (p=0.04).

Because distinct levels of forward lookingness are not reflected in behavior in the strategic game (with the exception of unanimity groups in the first plays of the game) we attribute treatment effects in the strategic game to the second difference described in the introduction: groups are more competitive. This increased competition means that groups choose more myopically for their own direct, short-term earnings and take less account of the consequences of current harvest for future earning possibilities for their own and the other teams. As a consequence, earnings in the third game are only 52% (MAJ) and 54% (UNA) of what they would be had groups curtailed their tendency to compete and maintained the level of forward lookingness they showed in the non-strategic problem. In contrast, in the third game individuals are making 82% of the earnings they would make in the equilibrium that corresponds to their forward lookingness.

The increased competitiveness of groups is most easily noticed in early periods. Recall from section 2.3 that in the social optimum nothing should be harvested in the first 5 periods and in the subgame perfect Nash equilibrium the first three periods should be harvest-free. Increased competitiveness means harvesting earlier. To further investigate the difference between individuals and groups we therefore focus on behavior in these early periods.[15] We distinguish between the first period (where there is no prior history for the pool) and periods 2-5 (where players can condition on the pool size and prior behavior by other players in the pool). More precisely, we use the following (random effects) regression equations:

$$\text{(2.8)} \quad h_{tg}^{ij} = \beta_0 + \beta_1 fw + \beta_2 g + \beta_3 t + \beta_4 x_{tg}^{j} + \beta_5 \left(x_{tg}^{j}\right)^2 /1000 + \beta_6 \Delta x_{tg}^{j} + \beta_7 \left(\Delta x_{tg}^{j}\right)^2 /1000 + \varepsilon_{tg}^{ij} + \mu^{j}$$
$$, i = 1,2,3;\ j = 1,..,J;\ g = 1,2,3;\ t = 1,..,5,$$

[15] In contrast, it is hard to attribute differences in harvests in later periods to competition. As the game progresses, the optimal harvest depends more and more on the history and the number of remaining periods.

where i denotes the individual participating in pool j, fw denotes the extent of forward lookingness in the non-strategic game[16], g denotes the game and t the period. As before, h refers to the harvest and x to the pool size. Furthermore, $\Delta x_{tg}^{j} \equiv x_{tg}^{j} - x_{t-1g}^{j}$ and ε and μ are white noise error terms. Finally, the β's are parameters to be estimated. We estimate these parameters separately for period 1 (where $\beta_3=\beta_4=\beta_5=\beta_6=\beta_7=0$) and periods 2-5. Table 2.5 gives the results.

		Constant	**Forward-look**	**Game**	**Period**	**Pool-size**	**(Pool size)^2/1000**	**Δpool size**	**(Δpool size)^2/1000**
Period 1	Individuals	32.77 (3.72)***	-30.28 (3.06)***	5.125 (1.77)*	--	--	--	--	--
	MAJ: harvest	42.12 (4.18)***	-50.05 (4.23)***	5.933 (1.80)*	--	--	--	--	--
	UNA: harvest	11.34 (1.17)	-13.53 (1.22)	7.81 (2.68)***	--	--	--	--	--
	MAJ: proposals	43.84 (6.63)***	-43.10 (5.55)***	4.227 (2.06)**	--	--	--	--	--
	MAJ: median	36.432 (0.94)	-50.98 (5.28)***	8.033 (3.01)***	--	--	--	--	--
Periods 2-5	Individuals	-4.369 (0.31)	-6.326 (2.11)**	-0.132 (0.14)	1.622 (2.30)**	-0.010 (0.19)	0.079 (1.65)*	-0.090 (3.44)***	-0.244 (2.41)**
	MAJ: harvest	57.16 (0.66)	-13.27 (2.20)**	1.832 (1.04)	0.815 (0.58)	-0.237 (0.86)	0.306 (1.38)	-0.130 (3.21)***	-1.045 (2.32)**
	UNA: harvest	-219.7 (2.71)	-6.213 (1.09)	6.352 (3.33)***	1.544 (1.14)	0.611 (2.41)**	-0.381 (1.85)*	-0.166 (3.70)***	-0.555 (1.73)*
	MAJ: proposals	-95.10 (1.57)	-7.704 (1.82)*	2.115 (1.72)*	1.562 (1.59)	0.287 (1.50)	-0.161 (1.04)	-0.071 (2.50)**	-0.186 (0.59)
	MAJ: median	-82.52 (1.58)	-11.31 (3.10)***	0.781 (1.06)	0.743 (0.88)	0.263 (1.59)	-0.144 (1.07)	-0.084 (3.47)***	-0.226 (0.83)

Note: The table gives the random effects regression results for the parameters in eq. 8. Absolute z-values are given in parentheses. *=significance at 10%-level; **=significance at 5%-level; ***=significance at 1%-level. The rows 'Groups proposals and 'Groups median' are discussed in the following subsection.

Table 2.5: Harvest decisions and pool size

[16] This is measured by the earnings realized in the non-strategic game as a fraction of the maximum.

For the time being, we compare the results for individuals to the harvest decisions for groups (rows 2/3/4 and 7/8/9). We start with period 1, which is an interesting period because players can not yet react to others' choices. The extent of forward lookingness ‒as estimated by choices in the non-strategic game‒ negatively affects the harvest (though not significantly so in UNA). Given the average values for this variable forward lookingness (0.47, 0.59, 0.61, for IND, MAJ, UNA, respectively), the predicted initial harvest in IND rises from 23.7 in game 1 to 33.9 in game 3. In MAJ it rises from 18.5 to 30.4 and in UNA from 10.9 to 26.5. Hence, individuals tend to harvest more than groups (in line with the larger forward lookingness of the latter) though the difference diminishes slightly across games.

For periods 2-5 first note that more forward lookingness again leads to lower harvests (once again, not significantly so for UNA). The increased harvests across games that we observed for UNA is reflected in the high (and statistically significant) coefficient for the variable *game*. As for pool size (and its square), the relatively high parameter estimates for UNA are noteworthy. This can be mainly attributed to the large pools developed in the first two games. With larger pools, much larger harvests are possible.

Note that changes in the size of the pool appear to be statistically far more important than the size itself. Both individuals and groups respond to shrinking pools by increasing harvest and *vice versa* (recall that most players are facing shrinking pools). We consider the response to (limited) changes in pool size to be an indication of competiveness in this setting, because it expresses the competition with other players in the pool, *i.e.*, the response to others' previous choices. The reason why only limited changes are relevant is that large changes often yield pool sizes that are too small to profitably harvest. Competitiveness does not lead to higher harvest in these cases. This may affect the comparison across treatments. For rounds 2-5, majority groups face very small pools much more often than individuals or unanimity group.[17] The relatively high negative coefficient for the term (Δ pool size)^2/1000 in the regression for MAJ reflects the impossibility to harvest large amounts for these pool sizes. Therefore, the most direct method of measuring competitiveness in these regressions is through the direct linear effect of changes in pool size. The results in table 2.5 show that this coefficient is much larger for groups than for individuals. The strongest linear response to shrinking pool size is by unanimity groups and the weakest by individuals. We conclude that the higher competitiveness of groups manifests itself in how they respond to shrinking pools in early periods.

[17] By round 5, 53% of the groups in MAJ are confronted with a pool that is smaller than 525 as opposed to only 27% of the individuals and 29% of the groups in UNA.

2.4.4 Group Decision-making

In order to explain why groups are more competitive than individuals in the strategic game, we consider the decision-making process within groups in periods 2-5 in more detail. We restrict this analysis to groups that decide by majority. Whereas decision making by majority can be carefully analyzed using the median voter theorem, we have no such framework to guide the analysis of the unanimity rule where every group member essentially has veto power but (unmeasured) differences in time preferences may cause some members to yield to others' wishes sooner than others.[18]

We investigate three reasons why groups may be more competitive than individuals when group decisions are made by majority vote. First, individuals may be more competitive when they are in groups than when they are not. Second, the distribution of preferences in a group may be skewed, causing the median preference to be different than the average preference in a group.[19] Third, the median voter may be willing to deviate from her initial preference when the group has to make a decision. We will investigate these three possibilities in turn, using the group decision-making data from our experiment. Recall that the group negotiations start with a round where each of the three individuals proposes a number to harvest. As a starting point, we assume that these first round proposals represent the individuals' preferences[20].

We investigate the first possibility (that individuals are more competitive when in groups) by considering the average initial preference of each group in each round. The rows in table 2.5 denoted by 'MAJ: proposals' show the way in which the average group proposals respond to the development of the pool (*i.e.* in eq. 6 the dependent variable is replaced by the average initial proposal in the group). A first thing to note here is that the results correspond closely to the results for individuals. In other words, even though groups respond more competitively to changes in the pool size than individuals do, individuals react to these changes in similar ways, irrespective of whether they are in groups.[21] The fact that these comparative statics are the same (*i.e.*, the coefficients in table 2.5 are similar) does not

[18] The lack of a framework to analyze UNA is a direct consequence of the fact that we had to adopt the design for unanimity groups to that used in MAJ (cf. footnote 5).

[19] For example, in one of our groups in round 2 (facing a pool size of 550) the proposals were 10, 40 and 50, yielding an average of 33 and a median of 40).

[20] It is easy to see that proposing one's own preference in the first round is an equilibrium strategy if the conditions of the median voter model are fulfilled. Voters know that if it turns out that they have the median preference, this is what they should propose. If not, their preference doesn't matter (given the strategies of the other players).

[21] We cannot directly compare across rounds average individual proposals in the group treatment to choices in the individual treatment because these decisions are affected by pool size and changes therein.

necessarily mean that the average harvest preferred by individuals in groups is the same as the average harvest of individuals acting as single member crews. In fact, the estimates in table 2.5 imply that the average individual proposes a higher harvest when participating in a group than she chooses when deciding alone; for pool sizes between 500 and 700 and changes between –75 and +75[22] individuals always prefer a higher harvest when in the group. Across the three games and 4 periods (2-5) the mean predicted difference is 3.7 units. The difference is highest in the third game, where the regression results predict a difference of 7 units. We conclude that individuals prefer to harvest more when they are in groups than when they act alone.

The second and third explanations for the higher competitiveness in MAJ are related to the majority rule used to reach decisions. In this case, the median preference is the expected outcome. For a first comparison, we estimated the relationship between the median proposal and (changes in) pool size in the same way we did above (cf. the rows in table 2.5 denoted by 'MAJ: median'). Once again, the response of the median proposal to the pool size and its changes is very similar to the decisions by individuals. In this case, the levels are also similar: median proposals are very close to individual harvest and (generally less than one unit apart for various pool sizes). Hence, whereas in all relevant circumstances the average individual would prefer to harvest more when in a group, this does not hold for the median individual in the group. This can also be tested directly. Averaged across all groups, the median group proposal is lower than the average group proposal in every period, indicating that the median proposal is typically closer to the lower proposed harvest than to the higher. Wilcoxon signed rank tests show that this difference is significant at the 1%-level in four out of the first five periods. Apparently, the median outcome diverges from the average outcome. Note that this is in the opposite direction than hypothesized above. Whereas we conjectured that the higher harvest by groups might be due to the median preference being higher than the average, what we observe is the reverse. This compensates for the higher average proposed harvest in groups and brings the predicted group harvest back to the observed harvest by individuals.

Because we know that groups tend to harvest more, the median voter must deviate from her initial preference. This is the third possible explanation for the higher competitiveness of groups. Recall that our subjects do not directly vote on the three initial proposals. After all group members have entered such a proposal, these are simultaneously revealed to

[22] Across all rounds and treatments 81.2% of our observations are within these boundaries.

the three members. Subsequently, individuals can propose new numbers, which are immediately conveyed to the others. When two individuals propose the same number, this determines the group's harvest. In our experiment this process leads the median voter to depart from her initial preference. On average in periods 2-5, the median voter is willing to add 3.1 units to her initial preference in these group negotiations.

All in all, the process that is causing groups to harvest more early on is as follows. Initially, the average individual wants to harvest more than when not in a group. This is typically caused by one of the three individuals wanting to harvest (much) more, irrespective of the pool size and its changes. Even though the median voter does not initially intend to act differently than when alone, she lets herself be convinced in the negotiations phase to harvest more. This process reinforces itself. The increased harvest in one period makes groups want to harvest even more in the next (*cf.* the MAJ: harvest results in table 2.5).

One reason why the median voter may be willing to change her position lies in the role of social norms. If taking out too much from a common pool is frowned upon, this might restrict the harvest individuals intend to take. In a group, this social norm may affect the median voter to a lesser extent for two reasons. First, she may feel that she is helping co-members by accepting a higher harvest. Second, she sees one co-member preferring to take out more than she suggested. Both effects serve to diminish the effect of the social norm, making it easier for the median voter to depart from her original proposal and accept a higher harvest. [23,24]

2.5 Conclusions

The two results from our experiments that stand out are that (i) groups make qualitatively better decisions than individuals when there is no competition with other players in an inter-temporal common pool environment; and (ii) in an environment with other players groups deciding by majority rule act more competitively than individuals while unanimous groups

[23] We can compare these conclusions to the group decision process in the non-strategic problem. There, individuals harvest on average 36.5 units in periods 2-5. When in groups, the average initial proposal is slightly higher at 38.6. The median proposal is much lower: 32.4. Contrary to the strategic case, the median is not convinced to deviate much, however: average harvest is 33.4. Note that social norms will be much less important in this case, because there is a 'correct' solution and no common pool where extraction harms other players.

[24] Alternatively, one might consider the possibility that group polarization is causing the median voter to shift. This is said to occur when an initial tendency of individual group members in a given direction is enhanced following group interaction (Isenberg 1986). Two explanations for this phenomenon have been successful: persuasive argumentation and social comparison theory. The former is not applicable to our setup because in our design no arguments are exchanged. According to social comparison theory interaction will enhance a group norm. If the group norm is to 'take care of the in-group' this may explain the shift.

become more competitive with repetition. The aggregate result of groups making better decisions and being more competitive is that competition between groups yields lower levels of efficiency than competition between individuals in an inter-temporal common pool dilemma, though for unanimous groups this decrease in efficiency is only observed after repetition. To the best of our knowledge our design is the first that allows one to unambiguously filter out the effect of differences in decision quality between individuals and groups when studying the higher competitiveness of the latter.

For decisions by majority rule, we concluded that the median voter model applied to initial preferences does not explain group choices. The negotiation process affects the median position even in the (intentionally) highly structured environment of our experiments. Note that the control offered by the laboratory setting allowed us to carefully disentangle the group decision-making process. This would not have been possible had we used face-to-face negotiations as typically applied in group decision-making experiments. These have the disadvantage of a complete loss of control over both the negotiation and the decision-making procedures. In contrast, we are able to attribute the higher competitiveness of majority groups to their response to decreasing pools in the early rounds (where theory prescribes increasing pools and no harvests). In a typical group, there is one individual suggesting a large harvest and the median voter –initially not predisposed to harvest too much– allows herself to be (partly) convinced by this extreme position.

The differences between unanimity groups and majority groups are also of interest. Though the quality of their decisions hardly differs (both make better decisions than individuals do), the competitiveness of majority groups is not directly observed for groups that decide by unanimity. Only with repetition of the game do the latter lose the advantage that the higher quality (compared to individuals) of their decisions gives them in the inter-temporal social dilemma.

Combined, our results open interesting avenues for further experiments. First, they show the importance of studying alternative negotiation processes when applying majority rule. Second, they imply that other group decision-making procedures may resolve the difference in competitiveness between individuals and groups. In the next chapter, we will show that groups where a dictator makes the decision are *less* competitive than individuals facing the same situation. Combined with the results presented here this means that the often-cited conclusion by Insko and Schopler (e.g., Insko *et al*., 1998) that groups are more competitive needs to be considered with a *caveat*. There is no reason to believe that it will hold for other decision-making procedures than majority rule. As observed, even for unanimity rule repetition is needed before one can conclude that groups are more competitive.

All in all, when decisions are made by majority rule groups most easily fall prey to the tragedy of the commons. Given that decisions in this environment are often made by groups and that majority voting is a rule that is often used, this result has consequences for the way we think about common pool dilemmas. The literature has always focused on the interaction between individuals in these dilemmas. Though excessive depletion of the pool has been observed in laboratory experiments, it has also been recognized that harvests are typically less than self-centered rational choice theory predicts. Moreover, individuals often find ‘spontaneous’ ways to regulate the common. Given our results, it is questionable whether the conclusions of the previous literature can be generalized to the world outside of the laboratory. When doing so, one needs to take the higher competitiveness of groups into account.

Appendix 2A: Instructions

At the start of the experiment

You are about to participate in an experiment on decision-making. You will be able to earn money in this experiment. How much you earn depends on your decisions and on the decisions of the other participants in the experiment.

It is important that you understand these instructions thoroughly. We ask you to read them carefully. The instructions use numerical examples. These are for illustrative purposes only; they have no particular relevance regarding the experiment. During the experiment you are not allowed to communicate with the other participants in any way.

Introduction

The experiment revolves around a pool filled with tokens. The experiment consists of a number of rounds, which in turn consist of 10 periods each. You will be part of a team of three people who will be able to earn an amount each period by taken tokens out of the pool. We will explain the way in which a team reaches a decision later. First we cover the decision-making process that the team is involved in. The team earns an amount per token taken out of the pool. Taking a token out of the pool also costs something. After each period the amount of tokens in the pool grows with a fixed factor.

In the experiment all amounts are expressed in francs. To keep things simple all amounts will be expressed in whole francs. At the end of the experiment the number of francs you have earned will be exchange for euro's. You will learn the exact exchange rate later.

Costs

How much it costs to take a token out of the pool depends on how many tokens are in the pool. The fewer tokens there are in the pool, the higher the costs. When there are many tokens in the pool the costs per token are lower. Within a particular period the costs per token are the same. The cost per token will be calculated according to the following formula:

cost per token = 120.000/(number of tokens in the pool)

Some examples: if there are 550 tokens in the pool taking out a token costs 120.000/550 = 218fr.. When there are 750 tokens in the pool it costs 160fr (120.000/750) per token to take them out.

Earnings

Your earnings per token depend on how many tokens are taken out of the pool in a period. The more tokens are taken out in a particular period, the lower the earnings. The fewer tokens you take out of the pool in a particular period, the higher the earnings. Your earnings are the same for each token you take out of the pool. These earnings will be made public after you have taken the tokens out of the pool. The earnings will be calculated according to the following formula:

earnings per token = 250 – 0.25 x (number of tokens taken out of the pool)

Some examples: if you decide to take out 25 tokens in a particular period, the earnings per token are 250 – 0.25 x 25 = 244fr.. If you take out 400 tokens, the earnings are 150fr. (= 250 – 0.25 x 400) per token.

Profit

Your profit for each token taken out of the pool is equal to the earnings minus the cost. So, your total profit in a particular period is:

the number of tokens you take out of the pool

times

[the earnings per token minus the cost per token]

Some examples:

Assume there are 700 tokens in the pool and you take out 150. Per token you earn
250 – 0,25*150 = 213fr., while they cost you 120.000/700 = 171fr. each. Your profit per token is 213 – 171 = 42fr.. Your total profit is 150*42 = fr.6300.

If there are 700 tokens in the pool and you take out 200 you earn, per token, 250 – 0,25*200 = 200fr., while they cost you 120.000/700 = 171fr. each. Per token your profit here is 200 – 171 = 29fr. and your total profit is 200*29 = fr.5800.

Assume now there are 500 tokens in the pool and you take out 50. You earn 250 – 0,25*50 = 238fr., while they cost you 120.000/500 = 240fr. each. Per token you lose 240 – 238 = 2 fr.. Your total loss in this case is 50*2 = 100 fr..

Growth

Each round starts with a pool with 600 tokens and lasts for 10 periods. After each period the number of tokens still in the pool will be replenished with factor 1.1. For example, if there are 500 tokens in the pool in a particular period and you take out 100, there will be (500 – 100) x 1.1 = 440 tokens in the pool in the next period.

You don't have to take out tokens in each period. You can choose to take 0 tokens out of the pool. You cannot take out more tokens then there are in the pool. If you take out exactly the number of tokens there are in the pool, the round ends.

You will get enough time to practice and the formulas will be shown on the screen the whole time.

Phases

The experiment consists of three phase:

1. PRACTICE PHASE – where you will get the chance to practice, on your own, for 10 minutes in order to get familiar with the rules and to get an idea of how you can maximize your earnings in 10 periods. After each round of 10 periods your earnings will be reset to 0 and the number of tokens in the pool to 600. You won't be paid in this phase.
2. FIRST PHASE – where you will play one round, as part of your team, and your earnings will be paid. Who the other people in your team are and how the team decisions come about will be explained after the practice phase.
3. SECOND PHASE – where will change the rules slightly. This will be explained later.

After the practice phase

This concludes the practice phase. We will now play one round whereby you will be paid.

(*Team condition only*)

From now on you will not decide alone any more, but you are part of a team of three people. Each period you will have to decide collectively how many tokens you want to take out of the pool. The profit you earn as a team will be divided equally among the three team members after the experiment. Each franc your group will earns in the round you are about the play will be exchanged for 12 euro's at the end of the experiment. You will share these earnings equally with the other members of your team.

The teams are randomly made up out of the participants of the current experiment. For the remainder of the experiment you will be in a team with the same people. You are player 1. We call the other members of your team player 2 and player 3.

The team **decision-making process** goes as follows:

Instead of directly deciding how much tokens to take out of the pool (as in the practice phase) you are now asked to make proposals. After every member has made a proposal and clicker 'okay', all see the three proposals made. After this first round of proposals, your fellow team members will see how much you think should be taken out of the pool immediately after you click 'okay' and vice versa you will be able to see what the other members of your team propose as soon as they make a proposal. When two members of the team propose the same number of tokens to take out of the pool this will be accepted as the team decision.

Again, you will start with a pool with 600 tokens and a round consists of 10 periods.

After phase 1

In this second phase of the experiment we change the rules slightly. From now on you share the pool with two other teams, also consisting of three players each. The way in which costs and earnings are calculated and how the size of the pool develops will stay the same, but these are now the result of the decisions of all three teams that are active in the pool together. You are still a member of the same team as in the previous phase and the way in which the team decision comes about will not change either. You are team A. The other teams with whom you share the pool we call team B and team C. For the remainder of the experiment you will share the experiment with the same teams. Each franc your group will earns in the round you are about the play will be exchanged for 36 euro's at the end of the experiment. You will share these earnings equally with the other members of your team.

It is still the case that the more tokens are taken out of the pool the lower the earnings you will receive per token. But this now depends on the total number of tokens taken out of the pool by all three teams.

For example, if you take 50 tokens out of the pool in a particular period, the second team 60 and the third 70, the earnings, per token, in this period are: 250 – 0,25*(50 + 60 + 70) = 205fr..

Another example: if you take out 120, the second team 100 and the third 200, the earnings are 250 – 0,25*(430) = 145fr. per token.

The costs of taking a token out of the pool still depend on how many tokens there are in the pool at the start of the period. To remind you, the corresponding formula is:

cost per token = 120.000/(number of tokens in the pool)

Again, the number of tokens in the pool is replenishes after each period with a factor 1.1 and a round consists of 10 periods. In this phase you will play 3 rounds of 10 periods in a row. Afterwards we will randomly select one of the rounds to be paid out. What you have earned in the previous PHASE still stands.

The decisions will be made simultaneously in each period. So you will not know how many tokens the other two teams will take out of the pool when you are making your decision in a particular period. Only when all three teams have made their decision will the costs and earnings be calculated and will you learn how much you've earned but also how many tokens the other teams have taken out of the pool and how much they have earned by doing so.

If the three teams combined try to take out more tokens then there are in the pool the round ends. The pay-out procedure in this period will then be as follows: the cost and earnings per token will be based on the maximum number of tokens that could be able to be taken out at that instance, which means on how many tokens there are in the pool. If there are X tokens in the pool, the cost per token are 120.000/X and the earnings per token are 250 – 0.25 x X. Randomly one team will be appointed to be allowed to take its planned number of tokens out of the pool. If there are still tokens left one of the other two teams will be appointed to take out its token. If there are still tokens in the pool after this, these will be for the third team. All three teams will earn 250 – 0,25 x X – 120.000/X per token. This will be the end of the round.

Appendix 2B: Forward Lookingness and Pool Size

One way to distinguish between levels of forward lookingness is by considering the development of the pool size, assuming optimal choices given the number of periods the decision maker looks ahead. In this appendix we present the development of pool size for distinct levels of forward lookingness. We do so separately for the strategic and non-strategic cases.

B.1. Non-Strategic Problem

Figure 2B.1 shows how the pool size develops for various levels of forward lookingness, when there is only one player harvesting form the pool.

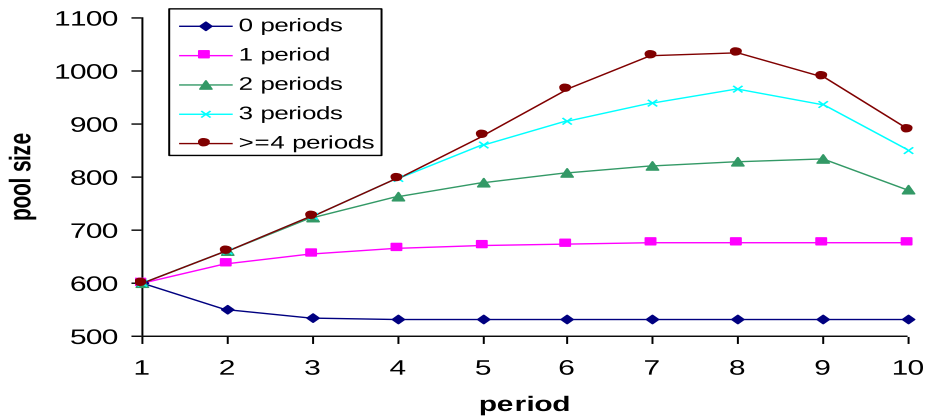


Figure 2B.1: Dynamics of pool size and forward lookingness; non-strategic problem

The development of the pool size is the same whenever the decision maker looks 5 or more periods ahead.[25] In these cases, optimal play involves harvesting nothing in periods 1-5 (*cf.* table 2.1). Of course, for any level of forward lookingness, the optimal harvest depends on the pool size, *i.e.* on the history of the game. As soon as a decision maker departs from one of the graphs above, it will be hard to attribute her behavior to any particular level of forwardlookingness. For this reason, we use aggregate earnings as an indicator of this level in the main text.

[25] The difference between 4 or 5 periods ahead is too small to show in the figure.

B.2. Strategic

Figure 2B.2 depicts the development of the pool size in the Nash equilibrium, and for a variety of *n*-myopic equilibria. An *n*-myopic equilibrium is a situation of mutual best responses where that each player looks n periods ahead and assumes that others do the same.

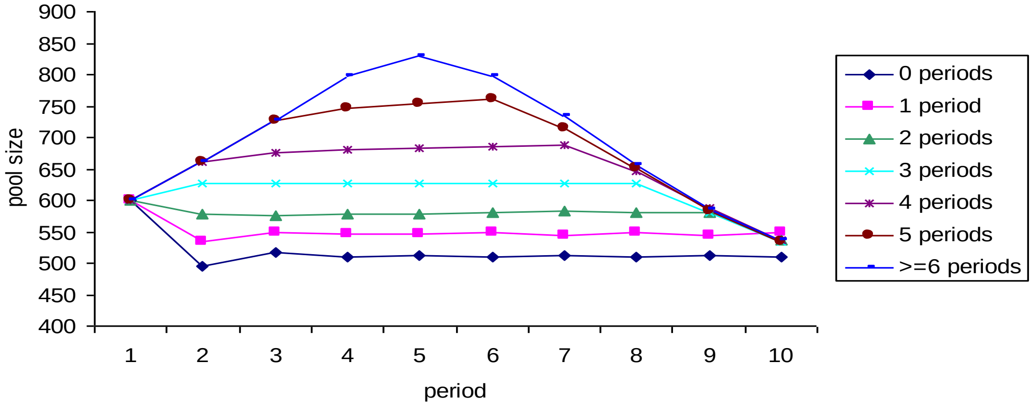


Figure 2B.2: Dynamics of pool size and forward lookingness; strategic game

Note the differences with figure 2B.1. First of all, for any given extent of forward lookingness, pool sizes remain much lower when there is competition. Moreover, figure 2B.2 shows an end effect occurring whenever the decision makers manage to let the pool increase in size: players foresee that others will withdraw and try to 'beat them to it'. In equilibrium, this leads to an earlier depletion of the pool than we observed in figure 2B.1. Finally, note that players have to look at least 3 periods ahead for the pool to increase above its original size.

Appendix 2C: Groups and Individuals: Pool Size Differences

In this appendix we consider how the distribution of pool sizes develops across periods for individuals and groups. Table 2C.1 shows the cumulative distributions across 7 categories of pool size for the aggregated data from the three games.

The table shows that most majority groups start to harvest more than individuals from period 3 onward. By the time they have reached period 5, 53% of these groups have seen their pool size drop below 525. For individuals, this is only 27%. Unanimity groups are have a similar number as individuals (29%) but almost half of these (13%) have extremely depleted pools smaller than 475 (as opposed to 2% if the individuals and 3% of the majority groups). On the other hand, there are also many more unanimity groups that have allowed the pool to increase above 725 (12%, as opposed to 7% of the majority groups and only 4% of the individuals). In short, the distribution for UNA is flattest. And MAJ is the treatment where pool sizes most often shrink in the first five rounds. We conclude that in early periods more majority groups end up with low pool sizes. However, the minority of groups that allow the pool size to grow across periods let it grow further than individuals do. Unanimous groups are most extreme in differences in pool size.

		Pool Size						
Period	**Treatment**	**≤474**	**475-524**	**525-574**	**575-624**	**625-674**	**675-725**	**≥725**
1	**Individual**	0	0	0	100	100	100	100
	Majority	0	0	0	100	100	100	100
	Unanimity	0	0	0	100	100	100	100
2	**Individual**	10	17	48	86	100	100	100
	Majority	3	20	43	80	100	100	100
	Unanimity	4	8	29	75	100	100	100
3	**Individual**	2	31	56	77	94	98	100
	Majority	10	27	54	83	90	93	100
	Unanimity	0	13	42	58	88	100	100
4	**Individual**	4	25	65	77	92	94	100
	Majority	7	27	73	83	90	90	100
	Unanimity	13	21	58	75	83	88	100
5	**Individual**	2	27	69	81	96	96	100
	Majority	3	53	77	90	90	93	100
	Unanimity	13	29	67	75	83	88	100
6	**Individual**	6	40	71	86	98	98	100
	Majority	10	37	80	93	93	97	100
	Unanimity	4	25	63	79	88	92	100
7	**Individual**	8	44	73	90	98	98	100
	Majority	7	43	87	97	100	100	100
	Unanimity	8	21	75	88	92	96	100
8	**Individual**	8	50	79	92	100	100	100
	Majority	10	63	93	100	100	100	100
	Unanimity	0	32	91	94	100	100	100
9	**Individual**	6	50	86	92	100	100	100
	Majority	10	60	100	100	100	100	100
	Unanimity	4	35	100	100	100	100	100
10	**Individual**	8	65	92	98	100	100	100
	Majority	13	57	100	100	100	100	100
	Unanimity	13	54	100	100	100	100	100

Note: Numbers give the cumulative percentage per category, for each period and treatment.

Table 2C.1: Cumulative distribution of pool sizes