Voting, Punishment, and Public Goods

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Abstract:
Researchers have found that voting can help increase voluntary contributions to a public good—provided enforcement through a third party. Not all collective agreements, however, have guaranteed third-party enforcement. We design an experiment to explore whether a voting rule with and without a punishment mechanism increases contributions to a public good. Our results suggest that voting by itself does not increase cooperation, but if voters can punish violators, contributions increase significantly. The effect of opportunities to punish those that do not contribute enough, an effect found in individual public good experiments, holds even under the constraint of a voting institution. While costly punishment increases contributions at the price of lower efficiency, overall efficiency for a voting-with-punishment rule still exceeds the level observed for a voting-without-punishment rule. Results indicate that it also exceeds efficiency levels in comparable experiments with individual contributions and punishment.

Keywords: public goods, voting, punishment

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I. Introduction

In many real-world situations, people work as a collective to set policy rules to manage common property and to assign individual contributions to public goods; for example, in OPEC summits, environmental quality councils, or school board meetings. Rather than choosing between cooperation versus non-cooperation or selecting an individual level of contribution, people in large groups frequently use a voting procedure to coordinate their efforts. Most experimental research on public or common goods, however, has focused on individual decisions rather than voting rules.[1] Walker, Gardner, Herr and Ostrom (2000) (WGHO henceforth) is an exception. They are the first to consider the efficiency implications of a combined common-property-with-voting allocation scheme in the laboratory. Group members voted on a proposal over how much everybody should contribute to the common good. All votes were binding and a third-party authority existed to guarantee that all voters abided by the majority proposal.[2] Their evidence suggests people cooperate more with perfectly enforced voting rules relative to a no-vote scheme.[3]

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[1] For excellent overviews see, for example, the books by Ostrom (1990) and Ostrom, Walker and Gardner (1994), and the survey articles by Ostrom (1998, 2000), Ledyard (1995) and Fehr and Gächter (2000a).

[2] Footnote 4 in WGHO: "Note that the setting we investigate assumes the existence of an authority with the power to implement an adopted rule." This assumption is not important for the focus of their investigation, which is rather what kind of rule will be adopted than whether a rule will be adopted and obeyed or not.

[3] Margreiter et al. (forthcoming) find that homogenous groups as in WGHO are more likely to reach an efficient outcome than heterogeneous groups in an equivalent situation.

But not all common-property or public goods have such an external authority to guarantee enforcement of a proposal agreed on by majority rule. For instance, international environmental treaties between sovereign nations suffer from frail enforcement mechanisms (see Barrett, 2003). The Kyoto Protocol over climate change is the prime example. Within the protocol, no third-party mechanism exits to enforce the attainment of the carbon reduction targets and timetables for the sovereign signatory nations (e.g., members of the European Union, Japan).

Other, smaller-scale common-property goods like fisheries and irrigation communities do have supra-authorities *de jure*, but *de facto* these external authorities are frequently either disinterested or do not have the resources to monitor, enforce and sanction any policy rule (Dolsak and Ostrom, 2003). In those cases, evidence from the field suggests that a regime is better built and enforced endogenously within the collective (see the overview in Ostrom et al., 1994, chapter 12). Ostrom (1990, p. 94) notes that "[i]n these robust institutions, monitoring and sanctions are undertaken not by an external authority but rather by the participants themselves." A large number of participants, however, can generate the need for a formal institutional mechanism such as voting, as opposed to a pure face-to-face communication system (WGHO). This voting might be non-binding per se, but informal social sanctions defined by the collective can help enforce the voting outcomes (e.g., a small financial penalty coupled with reputation loss). Ostrom (1990, see Table 5.2, p. 180) reviewed fifteen self-organized collectives around the globe, and her results suggest that these sanctions seem to be a necessary condition for robust institutional performance.

In this paper, we relax the assumption of perfect enforcement by a third party and examine how a non-binding voting rule affects economic efficiency. Without third party authority and enforcement, one of two things could happen: voting could degenerate into non-binding cheap talk that does not guarantee the efficient allocation of public goods, or voting could become a coordination instrument that generates a social norm. While some researchers have observed no or very limited effect of (particularly non-oral) cheap talk in several experimental studies consistent with mainstream theories (e.g., Kroll et al., 1998; Cason and Gangadharan, 2002), others found that cheap talk can increase cooperation even when the equilibria of the game are suboptimal (e.g., Ostrom, 2000; Duffy and Feltovich, 2002; Croson et al., 2003).[4] Bochet et al. (forthcoming) found face-to-face and "chat-room" communication increased cooperation compared to a baseline without communication, but communication limited to sending numerical messages did not, a finding consistent with observations in Frohlich and Oppenheimer (1998). The question then arises whether the effects of non-binding voting is closer to the effect of verbal communication or numerical communication.

Experimental research on the effects of non-binding voting and voting with little consequence has generated ambiguous results. Some evidence suggests that majority voting "brings everybody on the same page" or generates a social norm. Feld and Tyran (2002) observed in their tax experiments that a fine on tax evasion endogenously agreed on by majority vote resulted in higher tax compliance than an exogenously determined fine (or no fine at all). Tyran (2004) found voters tend to agree of a costly proposal if

[4] The effect of communication in coordination games with several equilibria, one of which Pareto-optimal, is less disputed. See Parkhurst et al. (2004) for a recent example.

they expect others will approve as well. Voting on policies that do not change the Nash equilibrium in public goods games also influences overall contribution levels (Sutter and Weck-Hannemann, 2004; Tyran and Feld, forthcoming). Messer et al. (2005), however, found that voting by itself had little effect on contributions in their public good experiments.

In addition, we consider whether adding explicit opportunities to punish those who do not abide by the majority vote can reduce the inefficiencies that arise from imperfect enforcement. Following Fehr and Gächter (2000b), we introduce a punishment mechanism into a public-good-with-voting experiment. By adding a punishment mechanism to the voting rule, we bring into play Ostrom's (2000) observation that three types of subjects inhabit public-good and common-property experiments—"conditional cooperators" and "willing punishers" in addition to the standard "rational egoists." Conditional cooperators initiate cooperation when they expect others to reciprocate; otherwise they do not.[5] Willing punishers are willing to bear some cost to sanction others. In our voting-with-punishment environment cooperation could increase since *conditional cooperators* should go along with a non-binding majority vote because they expect *rational egoists* to contribute now to avoid being punished by the *willing punishers*. In a related no-vote public good game, Fehr and Gächter (2000b) observed that cooperation rates increased substantially when the willing punishers had the opportunity to punish. They also found that just the threat to punish can be enough to

[5] In a one-shot public game experiment with a clever design, Fischbacher, Gächter and Fehr (2001) found that around 50% of their subjects were conditional cooperators.

coerce others to cooperate (especially in later rounds), without even exercising the threat.[6,7]

Bochet et al. (forthcoming) observed the two influential forms of communication—face-to-face and chat room communication—had a bigger impact on cooperation than giving the subjects punishment opportunities without communication. Punishment, however, had also some effect: Cooperation was still significantly higher in a treatment with punishment opportunities (and without any communication) compared to the baseline treatment without punishment or communication.[8]

Masclet et al. (2003) compare monetary punishment in a set-up similar to Fehr and Gächter's with non-monetary punishment, i.e., cheap talk. They find that both regimes increase cooperation rates compared to a regular individual contribution game, but that cooperation in the non-monetary punishment treatment declines faster. Cheap talk was not enough to maintain contribution levels as the players learned their was no bite with bark. In addition, the simultaneous availability of both monetary and non-

[6] This observation contrasts Ostrom, Walker and Gardner's (1992) observation that sanctions alone were not enough to increase cooperation, but sanctions combined with face-to-face communication were sufficient.

[7] Note, however, that Nikiforadis (2004) found that "counterpunishment," the opportunity of punishing the punishers, has a strong negative effect on contribution and efficiency levels in a public good set-up similar to the one in Fehr and Gächter (2000b).

[8] Different punishment rules used in Decker et al. (2003) also yielded higher contribution levels but not all of them resulted in higher efficiency.

monetary sanctions increases contributions and welfare than when only either one is available (Noussair and Tucker, 2005).[9]

After setting the lower and upper benchmarks in a treatment without voting and another treatment with binding votes, we combine the key elements of the WGHO and Fehr and Gächter experimental designs to examine whether cooperation occurs without third-party enforcement. Using a classic linear public good game,[10] we observe cooperation does occur under voting, but the opportunity to punish is important. Without this punishment condition, voting degenerates quickly into cheap talk, and the rates of cooperation are not substantially higher compared to a standard public good game with individual contributions and without voting. Providing the opportunity to punish those voters that do not adhere to the majority proposal increases cooperation and efficiency

[9] There is a growing literature on the use of rewards in addition to punishment (Dickinson, 2001; Offerman, 2002; Andreoni et al., 2003; Sefton et al., 2005). The main findings in this literature indicate that punishment mechanisms are used more frequently and are more successful than rewards in several different settings, but there is a synergistic effect from having both mechanisms available. In addition, Walker and Halloran (2004) report no difference in contribution and efficiency levels across treatments with and without reward and sanction mechanisms in one-shot public good games.

[10] There are two differences between our experiment and WGHO's: We are using a public good game, which is strategically similar to a common pool resource game with closed access (as in WGHO), and in our experimental set-up there is merely one element in the core—no coalition smaller than the entire group can agree on a proposal that would make them better off compared to the non-cooperative case and could win a vote. In WGHO, a minimum winning coalition other than the entire group can form, and WGHO examine whether this coalition would settle for an outcome that maximizes the payoffs for the members of the majority but put the members of the minority at a disadvantage.

rates substantially. Our results suggest that punishment works even under the constraints of an exogenous institution, the voting mechanism.

II. Theory and Experimental Design

Theoretical Framework. Following Fehr and Gächter (2000b), we examine a linear public goods environment. In the basic framework without punishment opportunities, each individual i divides her endowment E into contributions to a public good, x_i ($0 \leq x_i \leq E$), and a private good, $E - x_i$. The n members of a group make their contribution decisions independently and simultaneously, and the monetary payoff π_i^o for each member i is

$$\pi_i^o = E - x_i + a * X, \tag{1}$$

in which $0 < a < 1 < na$, where a is the marginal per capita return from a contribution to the public good, and $X = \sum_{k=1}^{n} x_k$. The constraint on a ensures that the individually optimal contribution to the public good is zero, although the socially optimal outcome is achieved when all group members contribute their entire endowments to the public good.

When a punishment mechanism is added to the voting scheme, a group member can be punished by one or more peers if she deviates from an agreed-upon contribution scheme. Using Fehr and Gächter's (2000b) specific punishment mechanism, we define $c_{i,j}$ as the punishment that member i imposes on non-abiding member j, with $0 \leq c_{i,j} \leq 10$ and $c_{i,j}$ integer, and we define $f(c_{i,j})$ as the fee function that indicates how much member i pays to be able to punish non-abiding member j, whereby $f(c_{i,j})$ is positive and strictly increasing in $c_{i,j}$. With $f_i = \sum_{j=1, i \neq j}^{n} f(c_{i,j})$, a member abiding by the scheme receives the payoff:

$$\pi_i = \pi_i^o - f_i. \tag{2}$$

A non-abiding group member—a cheater—can be punished by other group members reducing her payoff. We cap punishment $p_i = (1 - c_i / 10)$ at 100% of the income, whereby $c_i = \sum_{j=1, i \neq j}^{n} c_{j,i}$ indicates the total amount others have contributed to punish member i. The payoff of i can then be written as:

$$\pi_i = p_i * \pi_i^o - f_i \text{, if } c_i \leq 10$$

$$\text{or} \tag{3}$$

$$\pi_i = -f_i \text{ if } c_i > 10 \text{,}$$

An aggregate punishment of c_i decreases i's earnings by c_i*10 percent provided that c_i does not exceed 10. If c_i exceeds 10, group member i loses all of his or her earnings (but not more if she he or she does not punish somebody else).

Because of the fee function f_i, a punisher i can end up with a negative payoff in a given period, which occurs when a proposal wins a majority vote, at least one other member j decides to ignore the majority proposal, and member i chooses to punish j high enough. Since the focus of this paper is on the voting institution and the norms it might generate, not on punishment *per se*, we chose a design that allows punishment only in periods in which there was a majority vote and for those members that do not adhere to this majority vote. Therefore we exclude the motives of "blind revenge" (Ostrom, Walker and Gardner, 1992) or raising one's own *relative* payoff by "punishing" others independent from their contributions (Saijo and Nakamura, 1995).

Experimental Design. One hundred and forty students from St. Lawrence University participated in a computerized public goods experiment with four treatments in fourteen sessions.[11] The parameters chosen for each period are E = 10 tokens, marginal return a = 0.4 and number of group members n = 5.

Table 1 shows the fee function $f_i = f(c_{i,j})$ for the punishment mechanism, which is the same as in Fehr and Gächter (2000b) and Masclet et al. (2003). Each punishment point decreases the earnings of the subject for that period by 10%. For example, if one subject punishes another subject with five points, the punished subject lost 50% of her earnings in that period (plus whatever she lost due to punishment from other group members), while the punisher lost nine tokens in this period.

Other features of the experimental design include: Only if a subject decides to punish a cheater can he or she lose tokens in that period; a subject can always avoid being punished by adhering to the majority proposal; a subject can always avoid getting a negative payoff in a period by not punishing any cheaters; and if no proposal gets a majority vote, no one can be punished in that period. Also, a group stays the same throughout the experiment (the "partner" design).

The experiment has four treatments: Individual-Contribution, Binding-Vote, Non-Binding-Vote, and Non-Binding-Vote-With-Punishment. Each treatment consists of two

[11] A session of the experiment lasted on average 95 minutes, including reading the instructions. The exchange rate is 10 tokens = $ 0.60 and subjects earned on average $19.50. Vivek Bachhawat wrote all programs for this experiment. Fehr and Gächter (2000b) and other public goods experiments have been conducted on "z-tree," developed by Urs Fischbacher (1999).

10-period stages. In the first stage, subjects play an operational game—a standard public goods contribution game—that is identical across treatments. The second stage varies across the four treatments to examine the impact of voting with punishment on behavior in the public good game. As in Fehr and Gächter (2000b), subjects are unaware at the beginning of each treatment that there will be an additional 10 periods after period 10 ended.

Individual-Contributions treatment: Group members continue to play the operational game in the second stage of the treatment. There are no changes in institutional rules across stages; only a brief pause between stages to mimic the other treatments (the subjects do not know during periods 1-10 that they would play an identical game in periods 11-20). The structure of this treatment can be summarized like this (O represents the operational game):

	Periods 1-10	Periods 11-20
Individual-Contributions	O, O, …, O	O, O, …, O

Binding-Vote treatment: In each period in stage two, group members can make proposals on how much members should contribute to the public good. Group members then vote for one of the proposals. If a proposal receives a majority vote (3 or more votes), it is automatically imposed on the group members. If no proposal is made or no proposal receives an absolute majority, then (and only then) the operational game is played. The structure of this treatment can be summarized like this (V represents the voting stage, and letters in parentheses indicate that the stage might not be played in that period):

	Periods 1-10	Periods 11-20
Binding-Vote	O, O, …, O	V (O), V (O), …, V (O)

Non-Binding-Vote treatment: Subjects confront the same framework as in the Binding-Vote treatment except that the vote is non-binding—a proposal that receives a majority vote is not imposed on group members; rather members only observe the voting results prior to playing the operational game. The structure of this treatment can be summarized like this:

	Periods 1-10	Periods 11-20
Non-Binding-Vote	O, O, …, O	V O, V O, …, V O

Non-Binding-Vote-With-Punishment treatment: As in the Non-Binding-Vote treatment, stage two has group members making proposals, voting and playing the operational game. But while the vote is still not binding, this treatment introduces a punishment opportunity—group members can now punish others in the group that do not adhere to a majority voting outcome. If no proposal gets a majority vote, no one can be punished in that period. The structure of this treatment can be summarized like this (P represents the Punishment stage):

	Periods 1-10	Periods 11-20
Non-Binding-Vote-With-Punishment	O, O, …, O	V O (P), V O (P), …, V O (P)

Six groups participated in the Individual-Contributions treatment, six groups in the Binding-Vote treatment, eight groups in the Non-Binding-Vote treatment, and eight groups in the Non-Binding-Vote-With-Punishment treatment. Each group consisted of five subjects.

With four treatments, six pair-wise comparisons of cooperation and efficiency are possible. The Individual-Contributions and Binding-Vote treatments are the baseline treatments. Since previous work has shown limited and declining cooperation in the basic public good game (e.g., Ostrom 2000) and significantly greater cooperation in the presence of a binding voting mechanism (WGHO), we expect that these two treatments set the lower and upper contribution benchmarks against which we compare the impact of the voting/punishment rules.

There is also a theoretical difference between the second stage of the Binding-Vote treatment and the other three treatments: the Binding-Vote treatment is the only treatment with multiple subgame-perfect equilibria, one of which consists of efficient contributions in each period. In the subgame-perfect equilibria of the other three treatments, nobody contributes in any period since the dominant strategy in the last period is not to contribute and, in the Non-Binding-Vote-With-Punishment treatment, not to punish.

III. Results: Contributions

The experimental design allows for both a between- and within-treatment analysis. Tests of proportions provide unconditional between-treatment comparisons of individual contribution levels across the four treatments for each stage. Table 2 reports the between-treatment results. We complement the between-treatment analysis with a conditional within-treatment analysis that estimates data from each treatment separately using the following panel model:

$$C_{it} = \psi_t + \omega_i + \varepsilon_{it}, \qquad i = 1,2,\ldots N;\ t = 1,2,\ldots T \qquad (4)$$

where the dependent variable, C_{it}, denotes the i^{th} subject's contribution to the public good in period t, ψ_t captures any systematic changes in contributions over time, ω_i captures individual subject effects; and ε_{it} is the contemporaneous additive error term. There are two items of note with equation (4). First, Hausman tests fail to reject othogonality between the regressors and individual effects, which therefore indicates a preference for a random (not fixed) effects specification. Second, the vector of period dummies is of particular interest because it will reveal any significant treatment effects on contribution levels and the persistence of any treatment effect over time.[12] Table 3 reports the panel estimates.

Figure 1 provides an overview of the aggregate group contributions by stage and treatment. We first review stage one (periods 1-10), in which subjects participated in the operational game across all four treatments. Observed behavior in stage one replicate the general findings reported in the literature (Ostrom, 2000): contribution levels are greater than the theoretically predicted zero, and although levels decline over time they remain above zero. Group members initially contributed about 46 percent of their endowments to the public good, and decreased contributions to about 27 percent in period 10. Results in table 2 indicate individual contributions in stage one were statistically equivalent across the four treatments.

In stage two, subjects were introduced to one of four treatment variables: individual contributions, binding vote, non-binding vote, and non-binding vote with punishment. Figure 1 provides a general illustration of the impact of each treatment variable on contribution levels. The individual-contributions treatment provides a baseline by simply continuing the operational game in stage two. As figure 1 illustrates, the restart of the baseline setting temporary increases contribution levels similar to those

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[12] By omitting period 10 from the vector of period dummies, estimates show how the introduction of the treatment variable in stage two impacts contributions (period 11 vs. period 10), and tests whether any initial treatment effect persists (period 11-20 vs. period 10).

observed at the beginning of stage one (45 percent), but contributions return to levels observed at the end of stage one within 4 periods and continue to decline to 13 percent at the end of stage two.[13] Estimates reported in table 3 confirm these results. Contribution levels significantly increased immediately after the restart of stage two, but quickly returned to levels statistically equivalent to those observed at the end of stage one.

The binding-vote treatment introduced a voting mechanism that automatically implements the outcome established by a majority vote. Figure 1 shows the voting mechanism led to subjects initially contributing 90 percent of their endowments to the public good, and the level of contributions remained high throughout stage two, reaching 100 percent in the final three periods. The stage two between-treatment comparison, reported in table 2, finds that contribution levels in the binding-vote treatment were significantly greater than those in the individual-contributions treatment ($t=16.7$; $p<0.0001$). This is confirmed by the within-treatment conditional estimates reported in table 3, which find that individual contributions in the binding-vote setting (stage 2) are significantly greater than those in the stage one baseline setting (p<0001). Further, the highly significant difference persisted over all ten periods of stage two—implying the treatment effect is significant and permanent. Results indicate that groups generally identified the socially optimal outcome and the binding vote mechanism led to the realization of that outcome. This finding is consistent with the results from WGHO.

[13] The observation that restarting a public good experiment, even with the same groups, briefly increases cooperation is not a new result. See Figure 1 in Isaac and Walker (1988). More recently, Cookson (2000) observed that contribution levels returned on average to about 50% after each of three restarts in a repeated linear public good game similar to ours.

Binding Vote result: *Binding voting significantly and permanently increased contributions to the public good.*

Voting outcomes, however, may not be enforceable. Non-binding voting might act as a coordination mechanism that directs group members to voluntarily follow the majority's preferences. But then again, such voting may be cheap-talk that has no impact on actual behavior. The non-binding-vote treatment explores this by introducing a voting mechanism identical to the binding-vote treatment except that the majority determined outcome is not automatically implemented; rather it is simply announced.

As figure 1 illustrates, contribution levels correspond closely to those observed in the individual-contributions treatment—after an initial increase, contribution levels fall to 17 percent within three periods, and to 12 percent by the end of stage two. Test results reported in table 2 find contribution levels in stage two of the non-binding-vote treatment are not significantly different than those observed in the individual-contributions treatment (t=1.7; p=0.12). Estimates in table 3 elaborate on this result by showing contributions do significantly increase with the introduction of the non-binding vote mechanism and this effect persists for 7 periods, but contributions eventually return to levels statistically equivalent to those observed in the final round of the stage one baseline. While the non-binding vote mechanism allowed groups to identify the socially optimal outcome and may have provided temporary support for greater contributions, it failed to provide sufficient incentives for any lasting impact on contribution levels.

Non-Binding Vote result: *A non-binding voting mechanism increased contributions to the public good marginally and temporarily, and the contributions were significantly lower than with the binding-vote mechanism.*

The weak performance of non-binding voting seems to be due to a lack of commitment, and not a lack of sophistication. In the initial period, members of six groups proposed and voted for the socially optimal contribution plan, and the other two groups did so within four periods. Of the 80 opportunities, 54 cases resulted in a proposal receiving a majority vote, in which 44 of the 54 were the socially optimal plan. This is further illustrated by comparing actual contributions to proposed contributions receiving a majority vote. Proposals receiving majority votes entailed an average group contribution of 45.8—close to the optimal 50—while the actual average contribution was 18.6 (table 3). Right from the start in period 11, a majority of group members cheated on the proposed contribution plan. While the voting allowed groups to express and learn what was best for them, it failed to deter individual members from deviating from the optimal plan. This finding contrasts the sizable effect reported with verbal communication, another form of cheap talk (e.g., see general finding 5 in Ostrom 2000 or the findings in Bochet et al., forthcoming), and is also inconsistent with the results in voting-on-tax experiments, but it is in line with the small effect voting had on public good contributions in Messer et al. (2005).

While it may be impossible to compel groups to adhere to a voting outcome, it may be doable for group members to punish other members. The final treatment therefore introduces a non-binding vote with punishment mechanism to examine whether punishment can provide the incentives necessary to enable a non-binding vote to match a binding vote setting. Figure 1 illustrates the impact of a non-binding vote with punishment setting, with contributions initially approaching 80 percent and remaining at or above this level throughout stage two. Table 2 reports contributions in the non-binding vote with punishment treatment were significantly greater than the individual-contributions treatment ($t=8.0$; $p<0.0001$) and the non-binding-vote (without punishment) treatment ($t=5.4$; $p<0.0001$). Test results also find that contribution levels in the non-binding-vote-with-punishment treatment was not statistically different than those observed in the binding-vote treatment ($t=1.7$; $p=0.14$). The within-treatment results in table 3 confirm the impact of the non-binding vote with punishment mechanism with estimates indicating contributions were significantly greater in the non-binding vote with punishment setting than in the final round of the stage one baseline setting. Estimates further show the highly significant positive effect on contributions effect persists until the final period of stage two. Results indicate the threat of punishment may provide a sufficient incentive to match the benefits of a binding vote mechanism, which implies punishment may suffice when an enforceable vote is not feasible.

> **Punishment result**: *Non-binding voting with the opportunity to punish cheaters significantly and permanently increased contribution levels to the public good, with a magnitude similar to the effect from the binding vote mechanism.*

Similar to observations in Fehr and Gächter (2000b), voting with the fear of punishment seems to outweigh the motives that drive cheating. With punishment, group members not only propose and vote for socially optimal contribution plans, they also follow through on the plan. As Table 4 reports, proposals with and without punishment did not differ much (48.6 vs. 45.8), but actual contributions differed dramatically (41.2 vs. 18.6). Correspondingly, the number of cheaters differed substantially (0.54 vs. 3.34).

The impact on voting with potential punishment arises even though punishing itself is not an individually optimal strategy since subjects should free-ride on others' willingness to punish cheaters. We observe voters do consistently contribute to the punishment public good. When cheating occurred, 2.8 of 5 subjects on average were willing to incur between 1.5 and 3.4 tokens in punishment fees. Even in the last period, when there are no apparent reputation advantages from punishment, 3 of 5 group members were still willing to bear punishment costs.

IV. Results: Efficiency

Achieving cooperation under voting with punishment is a success, but it comes at a cost because punishment reduces the net returns to both the punisher and the punished. The open question is whether the gains of adding the punishment mechanism to the voting scheme exceed the costs such that overall efficiency is improved. For example, Fehr and Gächter (2000b) found in their “Stranger” experimental treatment with randomly changing group members, the increased contribution to the public good does not compensate for the costs of the punishment tool until the next-to-last period. In their “Partner” treatment with fixed groups, which is more comparable to our experimental set-up, efficiency loss occurred in the first three periods of the punishment condition. Decker et al. (2003) found also that some punishment rules had positive and some had negative effects on efficiency.

For purpose of comparison between the treatments, we define efficiency as the percentage of potential payoff realized by the group. It corresponds to payoffs in the non-punishment treatments and may differ with the introduction of costly punishment.

Figure 2 shows the average group payoffs including punishment costs in stage two for each treatment; Figure 3 shows the same for periods in which a proposal was accepted by a majority of voters (since the individual-contributions treatment did not have voting the payoffs from the treatment are omitted in Figure 3). As expected, binding voting achieves the greatest efficiency. The question is whether voting without or with punishment leads to greater efficiency gains. Examination of the individual data reveals that efficiency is significantly greater when non-binding voting is supplemented with punishment ($p<0.0001$).[14] The cost of punishment is more than recovered with gains provided by adding punishment to voting.

> **Punishment Efficiency result**: *Given our parameters, the gains realized from adding the threat of punishment exceed the costs of the punishment and therefore non-binding voting with punishment achieves significantly greater efficiency than without punishment and approaches similar efficiency levels observed with binding voting.*

Voting with punishment generates substantial gains as players gain experience. While the efficiency gains in the first period of stage two are about 80 percent regardless of the treatment, things quickly diverge. With punishment, the non-binding voting maintains efficiency above 80 percent; without punishment efficiency drops to about 65 percent.

Our results suggest a stronger efficiency effect from punishment than that observed in Fehr and Gächter (2000b). Consider Figure 4, in which efficiency gain and loss of the treatment with punishment opportunities is presented as the difference between average payoffs in the non-binding-vote-with-punishment and non-binding-vote treatments, normalized by the average payoffs in the non-binding-vote treatment. For comparison, the corresponding graph for the "partner treatment" from Fehr and Gächter

[14] Wilcoxon tests comparing treatment 3 (non-binding) and treatment 4 (non-binding with punishment) revealed efficiency was statistically equivalent in stage 1 ($z=-0.113$; $p=0.91$) while being significantly different in stage 2 ($z=-11.316$; $p<0.0001$).

(1999) is replicated.[15] While a statistically rigorous comparison between the two efficiency curves is inappropriate due to the differences between the two experiments, Figure 4 still paints a clear picture: the punishment mechanism has an even stronger effect on efficiency in public good experiments when the contribution levels are determined by a (even non-binding) majority vote than when they are determined individually, as in Fehr and Gächter's experiment.[16] This could be due to a stronger social norm imposed through a vote—it is not only implicitly expected that everybody contributes to the public good as in a individual contribution game, but now this expectation has been stated explicitly and is out in the open for everybody to see.

V. Conclusion

Groups commonly use a voting mechanism to provide public goods—group members offer alternative options and then they vote on which option to implement, if any (e.g., global climate change, OPEC and the oil output level, villagers and fishing quota). In many situations, however, no external enforcement mechanism exists to guarantee that each member adheres to the majority proposal. The group must find an internal enforcement mechanism to discipline or punish those who ignore the majority proposal. The problem is that punishment itself is a public good—each member wants to

[15] Fehr and Gächter (1999) is the working paper on which Fehr and Gächter (2000b) is based. The graph, which is part of Figure 6 in the working paper, was not shown in the journal version of the paper; we thank Simon Gächter for sharing the average efficiency data from that Figure with us. We also thank a referee for making us aware of this graph.

[16] Small or non-existent efficiency gains from punishment have been observed in other experiments similar to Fehr and Gächter (2000b) as well. See, for example, Figure 7 in Nikiforakis (2004) or Figure 2 in Noussair and Tucker (2005).

see the non-cooperator(s) punished but their rational strategy is to free-ride on another's punishment efforts. According to this theory, in the subgame-perfect equilibrium of the game nobody punishes deviators and therefore it is rational to deviate from the majority vote. Thus, adding an explicit punishment mechanism to a non-binding voting mechanism should not help improve cooperation.

This paper provides evidence that voting alone as a tool of cooperation and communication is not enough; many subjects quickly realize that non-binding votes are cheap talk so they deviate from what the group majority decides. This result is consistent with Messer, Kaiser and Schulze (2005) who also find that voting alone does not make a difference in a VCM game But when group members—i.e., voters—are able to punish cheaters, our results suggest that cooperation can be sustained on a higher level than without punishment opportunities. This result supports Fehr and Gächter's (2000a, 2000b) findings that punishment opportunities discipline group members and help establish group norms that extend into the last period of a repeated game even though it is individually rational to forego punishment and to free-ride on other members' punishment efforts. Greater cooperation, however, does not necessarily translate into greater efficiency. More cooperation comes at a cost since adding the punishment tool to voting reduces the returns to both the cheater and the punisher. But while efficiency decreased in the treatment with punishment relative to the binding-vote treatment, we find it was significantly greater relative to the non-binding-vote treatment. The efficiency gain from punishment in the voting institution is large compared to results in Fehr and Gächter (1999, 2000b) and other experiments in which punishment opportunities are added to a individual contribution scheme without vote.

Two important questions remains for future work: do these results hold for non-linear public goods and for minimum winning coalitions smaller than the grand coalition? In many real-world situations, the relevant choice is not only between whether to join the entire group vs. free-riding but what coalition within the group to form and join. The negotiations following Kyoto again serve as an example.[17] But when agreements are non-binding, an additional trade-off appears: Members of the minority in a 3-2 vote might be required to contribute more to the public good according to the majority proposal, which makes them less inclined to follow the proposal even if punishment opportunities exist. This behavior could give rise to unanimous decisions even if the members of a minimum winning coalition are better off compared to the members of a grand coalition.

In addition, recent experimental papers have found significant differences in behavior and efficiency between homogeneous and heterogeneous groups (Margreiter et al., forthcoming; Cherry et al., 2005; Kroll et al., 2005). Margreiter et al. observe that heterogeneous groups in their common-pool-resource experiment with binding votes have a more difficult time to agree on and vote for a single proposal, which results in a loss of efficiency for such groups (even though whenever a proposal is adopted by a heterogeneous group, efficiency is much higher than if group members decide individually). It is unclear what to expect when punishment opportunities are added to a non-binding voting scheme with heterogeneous groups.

[17] WGHO's experiment allows for smaller coalitions than the grand coalition. Ray and Vohra (2001) provide a theoretical examination of coalition formation in non-linear public good games. Both papers assume all agreements are binding and do not allow for punishment.

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Table 1: Punishment Level and Associated Costs

Punishment $c_{i,j}$ for group member j	0	1	2	3	4	5	6	7	8	9	10
Costs $f(c_{i,j})$ for group member i	0	1	2	4	6	9	12	16	20	25	30

Table 2: Between-Treatment Individual Contribution Results[a]

	Individual Contributions	Binding Vote	Non-Binding Vote
Stage 1			
Binding Vote	0.733		
	(0.4821)		
Non-Binding Vote	0.397	0.470	
	(0.7006)	(0.6487)	
Non-Binding Vote w/ Punishment	0.588	0.282	0.247
	(0.5729)	(0.7841)	(0.8083)
Stage 2			
Binding Vote	16.662		
	(0.0000)		
Non-Binding Vote	1.696	9.327	
	(0.1179)	(0.0000)	
Non-Binding Vote w/ Punishment	8.044	1.661	5.441
	(0.0000)	(0.1352)	(0.0000)

[a] t-test statistics allowing for unequal variances are reported along with p-values in parentheses.

Table 3: Within-Treatment Individual Contribution Analysis

	Individual Contributions		Binding Vote		Non-Binding Vote		Non-Binding Vote w/ Punishment	
	Coefficient	(z)	Coefficient	(z)	Coefficient	(z)	Coefficient	(z)
Constant	2.300***	4.604	3.033**	6.323	2.425***	5.713	2.775***	5.668
Period 1	2.033***	3.799	1.367***	2.208	2.425***	4.040	1.725***	2.864
Period 2	2.467***	4.609	2.000*	3.231	1.475**	2.457	1.400**	2.325
Period 3	1.767***	2.678	1.033	1.669	2.050***	3.415	1.475***	2.449
Period 4	1.433***	2.678	0.900	1.454	1.100*	1.832	0.700	1.162
Period 5	0.767	1.433	0.633	1.023	2.050***	3.415	1.250**	2.076
Period 6	1.567***	2.927	0.767	1.239	0.625	1.041	0.900	1.494
Period 7	0.833	0.852	0.967	1.562	1.250**	2.082	0.975	1.619
Period 8	0.100	0.187	-0.100	-0.162	1.050*	1.749	0.050	0.083
Period 9	0.200	0.375	0.167	0.269	0.100	0.167	0.700	1.162
Period 10	--	--	--	--	--	--	--	--
Period 11	2.100***	3.924	5.967***	9.639	3.375***	5.622	4.975***	8.261
Period 12	1.500***	2.803	5.900***	9.531	2.000***	3.332	4.600***	7.638
Period 13	0.767	1.433	6.967***	11.254	1.050*	1.749	6.200***	10.295
Period 14	-0.067	-0.125	6.200***	10.016	1.700***	2.832	4.700***	7.804
Period 15	0.133	0.249	6.967***	11.254	1.200**	1.999	6.225***	10.336
Period 16	0.200	0.374	5.633***	9.100	1.100*	1.832	5.125***	8.510
Period 17	0.267	0.498	3.967***	6.408	1.350**	2.249	5.425***	9.008
Period 18	-0.733	-1.370	6.967***	11.254	0.850	1.416	6.400***	10.627
Period 19	-0.333	-0.623	6.967***	11.254	0.450	0.750	5.925***	9.838
Period 20	-1.000*	-1.869	6.967***	11.254	-0.125	-0.208	5.100***	8.468
$\chi^2(\mu_i = 0)$	1034.94 (p<0.0001)		160.13 (p<0.0001)		1133.64 (p<0.0001)		450.65 (p<0.0001)	
N	600		600		800		800	

Notes:
1) Dependent variable is individual contributions; panel estimates with random individual effects.
2) Stage 1 consists of periods 1-10 and represents the within treatment baseline, while stage 2 consists of periods 11-20 and introduces the treatment variable.
3) Period 10 is omitted and therefore represents the baseline period, which illustrates the change in contributions within and across stages.

Table 4: Cheating and Punishment in Non-Binding-Vote and Non-Binding-Vote-With-Punishment

	Non-Binding-Vote		Non-Binding-Vote-With-Punishment	
	Stage 2	Final Period	Stage 2	Final Period
Average Aggregate Contribution Level of Majority Proposal	45.8	42.5	48.6	50
Average Actual Contribution Level (When There Was a Majority Proposal)	21.2	12.7	44.4	41.7
Average Actual Contribution Level (all periods)	18.6	11.5	41.2	39.5
Average Number of Cheaters	3.34	4.33	0.54	0.86
Average Number of Punishers	n. a.	n. a.	2.84	3.00
Average Punishment per Cheater	n. a.	n. a.	4.32	4.00
Average Punishment Costs per Punisher	n. a.	n. a.	2.34	1.60

Figure 1: Aggregate Group Contributions

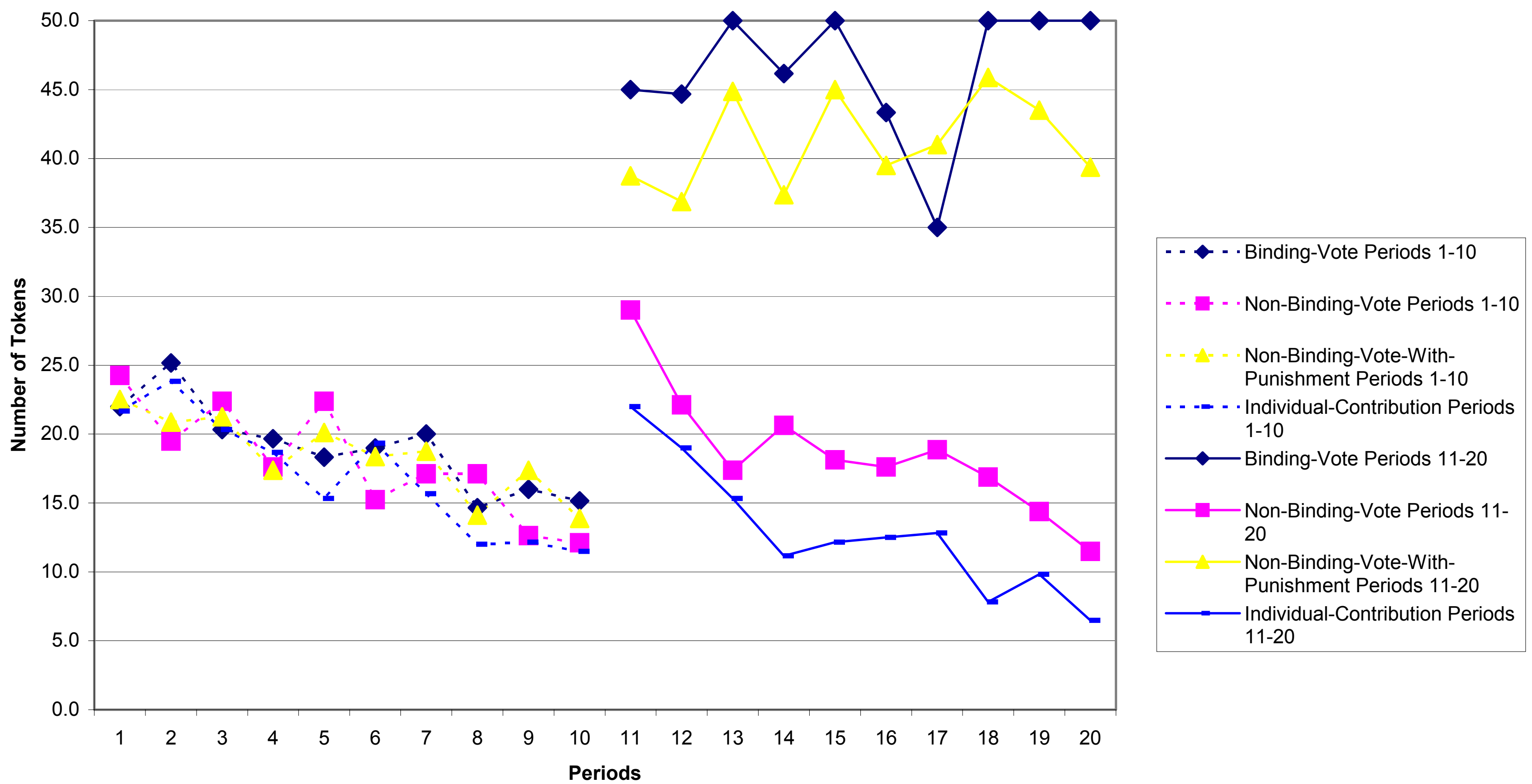


Figure 2: Average group payoffs as indication of efficiency

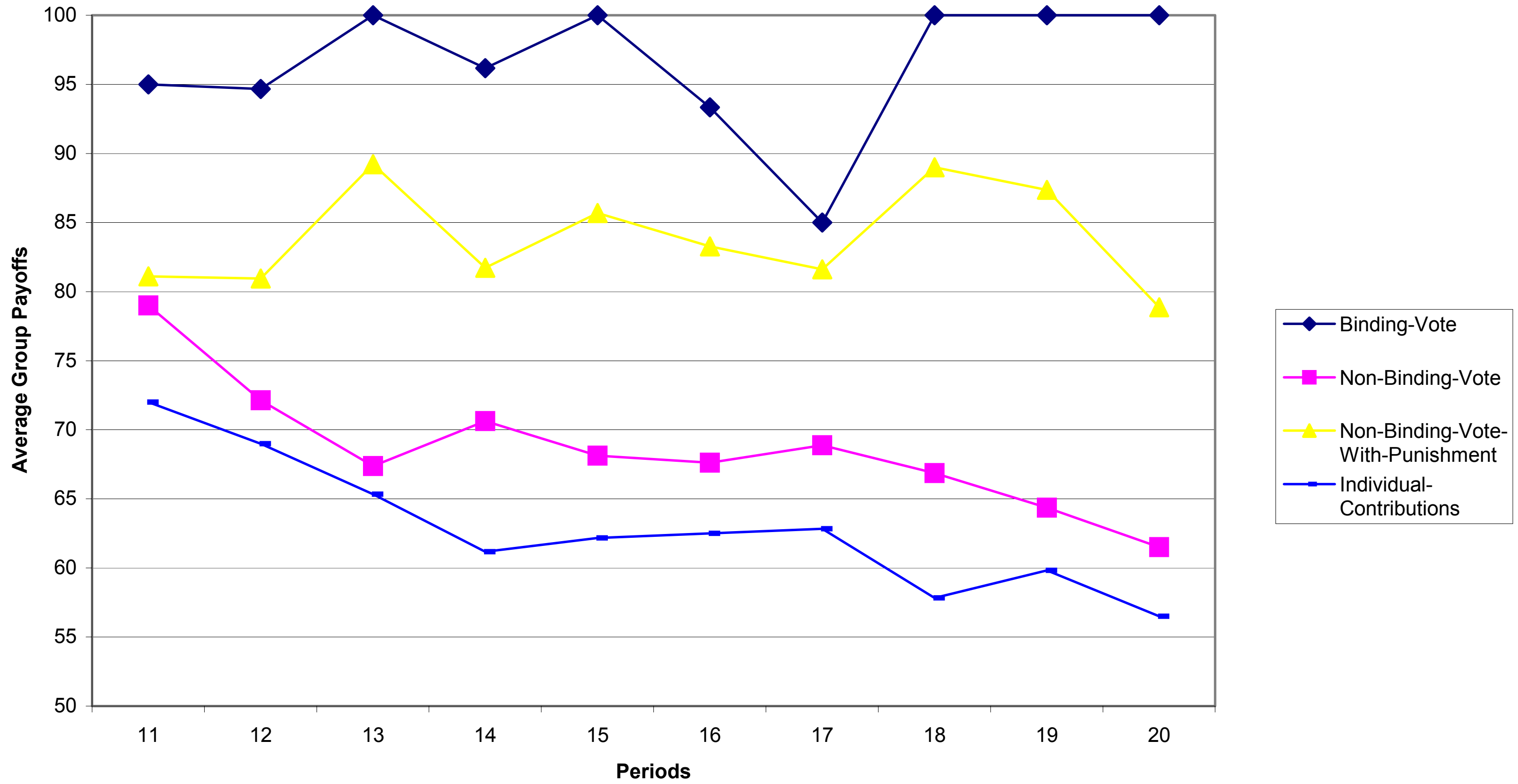


Figure 3: Average group payoffs as indication of efficiency (for periods with majority proposals only)

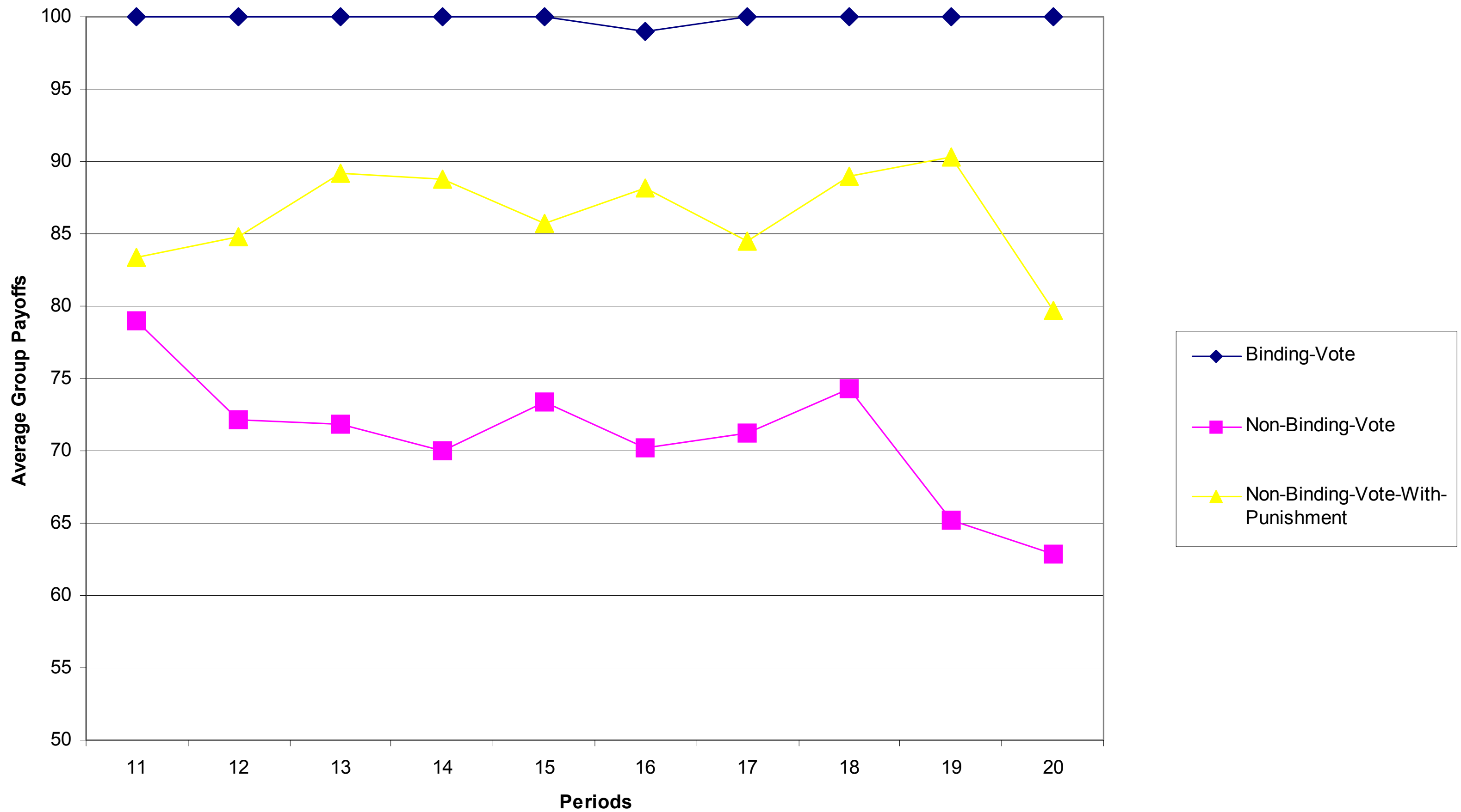
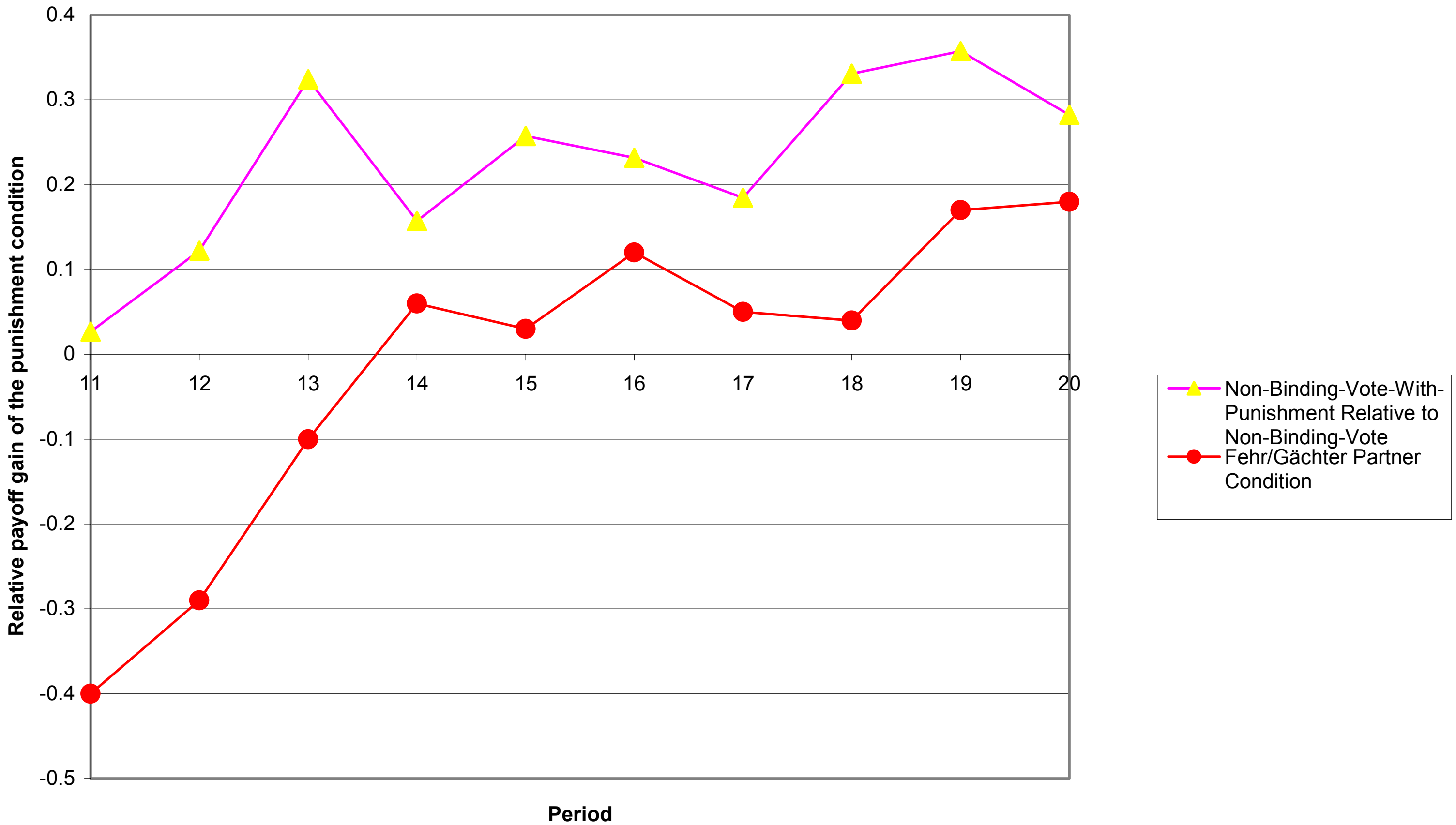


Figure 4: Average payoff gain of the punishment treatment relative to the non-punishment treatment



Appendix A: Individual Group Data from Periods 11-20 in Treatments with Voting

Group	**Binding-Vote Treatment**	11	12	13	14	15	16	17	18	19	20	*Average in p. 1-10*
1	Majority Vote	50	50	50	50	50		50	50	50	50	*15.7*
	Individual Contributions						15					
2	Majority Vote	50	50	50	50	50	45	50	50	50	50	*21.1*
	Individual Contributions											
3	Majority Vote		50	50	50	50	50	50	50	50	50	*24.1*
	Individual Contributions	20										
4	Majority Vote	50	50	50	50	50	50		50	50	50	*12.7*
	Individual Contributions							7				
5	Majority Vote	50		50	50	50	50	50	50	50	50	*20.1*
	Individual Contributions		18									
6	Majority Vote	50	50	50		50	50		50	50	50	*20.5*
	Individual Contributions				27			3				

Group	**Non-Binding-Vote Treatment**	11	12	13	14	15	16	17	18	19	20	*Average in p. 1-10*
	Majority Vote	50	40		50		50			50	50	*19.9*
1	Individual Contrib. in case of majority vote	20	13		25		10			10	4	
	Individual Contrib. in case of no maj. vote			4		9		20	19			
	Number of Deviators from majority proposal	3	3		3		5			4	5	
	Majority Vote	50	50	50	50	50	50	50	50	50	50	*19.6*
2	Individual Contrib. in case of majority vote	35	38	37	34	41	30	35	30	19	17	
	Individual Contrib. in case of no maj. Vote											
	Number of Deviators from majority proposal	2	2	3	4	2	4	3	2	4	5	
	Majority Vote	50	50	50	50	50	50	50	30	50	50	*12.5*
3	Individual Contrib. in case of majority vote	40	27	26	36	37	26	29	27	15	13	
	Individual Contrib. in case of no maj. Vote											
	Number of Deviators from majority proposal	1	3	3	2	2	2	3	2	4	4	
	Majority Vote	50	50	50	50	50	40	35		50		*16.4*
4	Individual Contrib. in case of majority vote	14	23	12	16	1	6	5		10		

	Individual Contrib. in case of no maj. Vote								9		5	
	Number of Deviators from majority proposal	4	3	5	4	5	4	5		5		
	Majority Vote	50	50	50		50	50	50	50	50	50	*24.5*
5	Individual Contrib. in case of majority vote	31	18	27		24	31	30	16	22	18	
	Individual Contrib. in case of no maj. Vote				25							
	Number of Deviators from majority proposal	2	4	3		4	3	2	4	3	4	
	Majority Vote	50	50		25	50		30			25	*16.5*
6	Individual Contrib. in case of majority vote	40	20		7	14		7			9	
	Individual Contrib. in case of no maj. Vote			8			9		0	12		
	Number of Deviators from majority proposal	1	3		4	4		4			4	
	Majority Vote	40	46		50		40				30	*19.7*
7	Individual Contrib. in case of majority vote	32	24		20		18				15	
	Individual Contrib. in case of no maj. Vote			18		11		8	14	11		
	Number of Deviators from majority proposal	1	4		4		3				4	
	Majority Vote	25	31	50	18							*15.2*
8	Individual Contrib. in case of majority vote	20	14	7	2							
	Individual Contrib. in case of no maj. Vote					8	11	17	20	16	11	
	Number of Deviators from majority proposal	1	4	5	4							

Group	**Non-Binding-Vote-With-Punishment**	11	12	13	14	15	16	17	18	19	20	*Average in p. 1-10*
	Majority Vote	50	50	50	50	50			50	**50**	50	*22.3*
1	Individual Contrib. in case of majority vote	40	34	38	40	31			40	**50**	32	
	Individual Contrib. in case of no maj. vote						15	11				
	Number of Deviators from majority proposal	1	2	2	1	2			1	0	2	
	Number of Punishers	4	3	4	3	4			2		3	
	Majority Vote	**50**	**50**	**50**	**50**	50	**50**	**50**	**50**	**50**	50	*19.5*
2	Individual Contrib. in case of majority vote	**50**	**50**	**50**	**50**	45	**50**	**50**	**50**	**50**	40	
	Individual Contrib. in case of no maj. Vote											
	Number of Deviators from majority proposal	0	0	0	0	1	0	0	0	0	1	
	Number of Punishers					3					3	
	Majority Vote	50	**50**	**50**	50	**50**	50	50	**50**	50	50	*12.2*
3	Individual Contrib. in case of majority vote	40	**50**	**50**	47	**50**	40	40	**50**	45	40	

	Individual Contrib. in case of no maj. Vote											
	Number of Deviators from majority proposal	1	0	0	1	0	1	1	0	1	1	
	Number of Punishers	4			3		3	4		3	4	
	Majority Vote	50		50		**50**	50	**50**	**50**	**50**	50	*18*
4	Individual Contrib. in case of majority vote	40		40		**50**	49	**50**	**50**	**50**	40	
	Individual Contrib. in case of no maj. vote		18		11							
	Number of Deviators from majority proposal	1		1		0	1	0	0	0	1	
	Number of Punishers	3		1			2				3	
	Majority Vote			**31**		36		50	38			*16.5*
5	Individual Contrib. in case of majority vote			**31**		34		39	37			
	Individual Contrib. in case of no maj. vote	15	21		10		22			17	23	
	Number of Deviators from majority proposal			0		1		2	1			
	Number of Punishers					2		4	1			
	Majority Vote	**50**	**50**	**50**	**50**	**50**	50	50	**50**	50	50	*21.5*
6	Individual Contrib. in case of majority vote	**50**	**50**	**50**	**50**	**50**	40	48	**50**	40	40	
	Individual Contrib. in case of no maj. vote											
	Number of Deviators from majority proposal	0	0	0	0	0	1	1	0	1	1	
	Number of Punishers						3	3		3	3	
	Majority Vote	**25**	**24**	**50**	50	**50**	**50**	50	50	50	**50**	*20*
7	Individual Contrib. in case of majority vote	**25**	**24**	**50**	41	**50**	**50**	40	40	46	**50**	
	Individual Contrib. in case of no maj. vote											
	Number of Deviators from majority proposal	0	0	0	1	0	0	1	2	2	0	
	Number of Punishers				3			1	2	1		
	Majority Vote	**50**	50	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	*17.7*
8	Individual Contrib. in case of majority vote	**50**	48	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	
	Individual Contrib. in case of no maj. vote											
	Number of Deviators from majority proposal	0	1	0	0	0	0	0	0	0	0	
	Number of Punishers		3									