

DEMOCRATIC PUNISHMENT IN PUBLIC GOOD GAMES
WITH PERFECT AND IMPERFECT OBSERVABILITY*

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ABSTRACT

In the context of repeated public good contribution games, we experimentally investigate the impact of democratic punishment, when members of a group decide by majority voting whether to inflict punishment on another member, relative to individual peer-to-peer punishment. Democratic punishment leads to more cooperation and higher average payoffs, both under perfect and imperfect monitoring of contributions. A control treatment with random dictator punishment verifies that this effect primarily works by curbing anti-social punishment and thereby establishing a closer connection between a member's contribution decision and whether subsequently being punished by others. We also find that participating in a democratic punishment procedure makes even non-contributors' punishment intentions more pro-social.

Keywords: public good contribution experiments, punishment, voting

JEL Classification: C72, C92, H41

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I INTRODUCTION

Several papers in the experimental literature, starting from Fehr and Gächter (2000), demonstrated that the availability of a costly punishment option for individuals can increase cooperation in public good contribution games. Gächter, Renner and Sefton (2008) showed that this increases overall net payoffs in the population, provided that the time horizon for interaction is long enough. However, Grechenig, Nicklisch and Thöni (2010) and Ambrus and Greiner (2012) found that the above results hinge on the assumption that individuals can perfectly monitor each others' actions. If there is a small amount of noise in monitoring, then the availability of costly individual punishment does not help the participants' welfare, and it can even decrease it. The reason is that with imperfect monitoring from time to time a contributor gets punished by fellow team members who received an incorrect negative signal regarding the contribution. This discourages future contributions and can trigger antisocial punishment by the contributor who was "unfairly" punished.¹ Hence even in the long run, contribution levels stay away from the socially efficient levels, and individuals keep on punishing each other, further decreasing each others' payoffs. Moreover, in a recent paper Fischer, Grechenig and Meier (2013) find that if monitoring is imperfect, centralizing punishment, in the form of delegating punishment rights to a particular individual, does not remedy the issues above, and cooperation levels remain low.²

¹In experiments on social dilemma games with imperfect observability and no direct punishment option available, Aoyagi and Fréchette (2009) and Fudenberg, Rand and Dreber (2012) find that players under noise are more forgiving than without noise. On the prevalence of anti-social punishment in public good contribution games with individual punishment, see Cinyabuguma, Page and Putterman (2006), Herrmann, Thöni and Gächter (2008), and Ertan, Page and Putterman (2009). The latter use the term "perverse punishment", that refers to punishment of above-average contributors regardless of the punisher. Hauser, Nowak and Rand (2014) provide a theoretical analysis in the context of a dynamic learning model, explaining why punishment might not promote cooperation when anti-social punishment is possible. Nikiforakis (2008) shows that the possibility of subsequent (anti-social) counter-punishment neutralizes the positive effects of the existence of the peer-punishment institution. Kamei and Putterman (2015), however, provide evidence that this negative effect is mitigated when there is very detailed information available about individual contribution and punishment choices.

²In a recent paper Rand, Fudenberg and Dreber (2015) find evidence that it is the inability to directly observe each other's contribution intentions which leads to deterioration of cooperation in environments with imperfect monitoring.

In this paper we find that democratic punishment, in the form of group members after each round of the contribution game deciding which members to punish using simple majority rule, outperforms individual punishment, both in terms of cooperation levels and average payoffs, and in both perfect and imperfect monitoring environments. A key reason is that democratic punishment mitigates anti-social punishment, and makes the relationship between one's contribution decision and whether she gets subsequently punished clearer: Specifically, it makes it more likely that contributing members do not get punished, and that non-contributing members get punished. In particular it greatly reduces the opportunities of those who get punished by others for non-contributing to punish back, either preemptively or subsequently. This is partly because such retaliatory punishments are usually not supported by a majority of members, and for this reason majority voting tends to suppress such attempts.

However, we find evidence that individual punishing intentions also differ between the two types of punishment environments. A group member is more likely to vote to punish a non-contributor in a democratic procedure than deciding to punish in the individual punishment environment. Interestingly, this holds not only for contributing members, but also for non-contributing ones (when deciding whether to punish fellow non-contributors). We also find evidence that individuals react differently, with respect to subsequent contributions to the public good, when they are punished democratically by group members versus when they get punished individually by fellow members. In both cases getting punished after not contributing increases expected contribution in the next round. The difference is that when an individual gets punished even though he contributed (but others observed an incorrect negative signal about the contribution), this punishment discourages her to contribute in the next round in the individual punishment treatment, but not in the democratic punishment treatment. These findings suggest that participation in a democratic procedure facilitates pro-social behavior, and they are in line with Dal Bó, Foster and Putterman (2010), who show that endogenous democratic adoption of a policy that automatically fines unilateral non-contributors increases cooper-

ation relative to when the same policy is imposed on the group exogenously, and also with several papers (Frey, 1994; Frey, Benz and Stutzer, 2004; Pommerhne and Weck-Hannemann, 1996) showing that there is a positive relationship between direct-democratic participation rights and pro-social behavior.

Our experimental design involves groups of five subjects, playing twenty times repeated public good contribution games. In the individual punishment treatment, after each round each group member decides independently which other members to punish. In the democratic punishment treatment, after each round members simultaneously cast votes which members should be punished, and punishment is inflicted on those members who received at least three votes. In order to put the two punishment schemes on an equal footing, we set payoffs in the democratic punishment treatment such that if the group votes to punish a member, the punishment inflicted is the same as when all four other members punish the member in the individual punishment treatment. Similarly, the cost of a group punishment on each of the other members is the same as the cost of punishing in the individual punishment treatment.

We also implemented a control treatment, dictator punishment. In this treatment after each round of contributions, for each possible punishment recipient a random group member gets selected, and her punishment choice applies to every other member of the group. We designed this treatment to investigate whether the improved welfare with democratic punishment is simply due to the fact that a pivotal group member can effectively impose a higher punishment with the same cost for herself than an individual in the individual punishment treatment. The individual cost, the cost imposed on others, and the amount of punishment are exactly the same for a group member in the dictator punishment treatment (conditional on being selected) as in the democratic punishment treatment (conditional on being the pivotal group member). We find that at the aggregate, dictator punishment does not lead to different contribution, punishment, or profit levels than individual punishment. Compared to democratic punishment, punishment levels with dictator punishment are significantly higher, and net profits are signif-

icantly lower. As opposed to democratic punishment, dictator punishment does not curb anti-social punishment, and relatedly reduces the effectiveness of punishment on non-contributors.³

In our setting, members of a group cannot commit ex-ante to a particular punishment rule, instead in each round a majority decides on whether to punish someone or not. There are several papers in the literature taking a different approach, in which there is a democratic group decision at the beginning of the game, deciding on whether to adopt a punishment scheme (either the option of individual punishment or an automated punishment rule) and in some cases on features of the punishment scheme (how severe punishment is allowed to be, or who can be punished): see Andreoni and Gee (2012); Dal Bó et al. (2010); Ertan et al. (2009); Kamei, Putterman and Tyran (2015); Markussen, Putterman and Tyran (2014); Sutter, Haigner and Kocher (2010); Tyran and Feld (2006). Other studies allow the punishment to be delegated to a specific subject, who carries them out without commitment: see for example Baldassarri and Grossman (2011); Fehr and Fischbacher (2004); Kamei et al. (2015); Leibbrandt and López-Pérez (2011, 2012).⁴ More related to our investigation are Cinyabuguma et al. (2006), Casari and Luini (2009) and Van Miltenburg, Buskens, Barrera and Raub (2014). Cinyabuguma et al. (2006) study a setting in which after each round group members can vote whether to expel certain members of the group, and show that the threat of expulsion can facilitate more cooperation. Casari and Luini (2009) show that in a repeated public good contribution game with punishment, it increases average payoffs if only coalitions of at least two members can inflict punishment (with the whole cost of punishment being borne by members of the coalition). In contrast to these results, Van Miltenburg et al. (2014), not in a repeated games context but in a setting in which partners are randomly rematched after each round, find that group

³The results from the control treatment also indicate that increased punishment of noncontributors in the democratic punishment treatment relative to individual punishment is not because of dispersion of responsibility, as would be posited by the identifiability theory of group shifts (Wallach, Kogan and Bem, 1962, 1964). With dictator punishment the punishing player is clearly identified, still punishment levels remain high.

⁴For a related theoretical analysis, see Aldeshev and Zanarone (2014).

voting on whether to punish certain group members underperforms individual punishment, in terms of the level of cooperation achieved. All of the above papers only consider settings with perfect monitoring, as opposed to our study, in which the main emphasis is on the imperfect monitoring environment.

II EXPERIMENTAL DESIGN

We implemented six treatments in a 3×2 factorial design. Our main comparison is between a repeated 5-person public good game that allows for *individual punishment* and a public good game in which a majority of group member votes is required in order to punish another group member (*democratic punishment*). We employ both games in two different environments, one with perfect observation of other group members' contributions, and one in which the signal about other group member's contribution is noisy, such that there is a small chance of 10 percent that a contribution is displayed to others as a defection.⁵

In addition to the two punishment stage designs, we tested a further design (with and without noise) with *dictator punishment*. In this condition, each member states whether she would like to punish other members, and for each punishment receiver one of the other group members is randomly selected and the punishment of this group member is implemented on behalf of this and the three remaining members. Thus, punishment is still individual (and not filtered through a democratic majority requirement), but the punishment incentives of each individual are exactly the same as for the marginal voter in the democratic punishment condition. The *dictator punishment* condition allows us to distinguish whether differences between *individual punishment* and *democratic punishment* are due to the effect of majority rule or due the effect of increased punishment effectivity from the perspective of the decisive member.

⁵The same design of imperfect monitoring was used in Ambrus and Greiner, 2012. Markussen, Putterman and Tyran (2016) find that such Type I errors have a similar effect in undermining cooperation as Type II errors (where a non-contribution may be shown as a contribution), but that when given a choice, experimental subjects dislike Type I errors more than Type II errors.

At the beginning of the experiment, participants were matched to groups of five, that stayed constant for all 20 rounds. Within each group, participants were assigned IDs from 1 to 5, which also stayed constant for the course of the experiment. Each round consisted of 2 stages, a public good contribution stage and a punishment stage. In the public good contribution stage, each group member was endowed with 50 points, and decided whether she wanted to contribute these 50 points to a “project” or not. If the endowment was kept, it increased the participant’s payoff by 50 points. If the endowment was contributed, it benefitted each of the five group members by 0.3 times $50 = 15$ points. Thus, if no group member contributed, each would earn 50 points, while the symmetric efficient outcome of 75 points for each could be reached if all contributed their endowment.

Our treatments differ only in the second stage of each round. First, after their simultaneous decisions in Stage 1, participants were informed about the contribution of each group member in their group. In our *No noise* treatments, the actual contribution of the respective participant was displayed. In the *Noise* treatments, the display showed a “public record” of each group member’s contribution. Participants were informed that if a group member did not contribute his endowment, then the public record would always indicate “no contribution”. If the group member contributed, however, then there was a 10 percent chance that the public record showed “no contribution” rather than “contribution”. The same public record of a member was displayed to all other group members.

Second, participants were asked to indicate their willingness to monetarily punish (“reduce the earnings of”) each other group member. In our *Individual Punishment* treatments, each group member could directly reduce the earnings of another group member by 15 points, at a cost of 5 points. In the *Democratic punishment* condition, group members simultaneously cast votes for each group member whether to punish that group member or not. Thus, for each group member, votes from all four other group members were collected. If three or more group members voted to punish a participant, then the earnings of that group member were reduced by 60 points, and each of the other four group members (independent of how

they voted) incurred a cost of 5 points for this punishment. If no majority was reached (because two or less group members voted for punishment), then no points are reduced and no costs incurred. Thus, the equivalent of a punishment by a group (when majority is reached) in the *Democratic Punishment* treatments is being punished by each other group member in the *Individual Punishment* treatments, and the equivalent of no group punishment (because there was no majority to punish) is not being punished at all in the *Individual Punishment* treatments. In the *Dictator Punishment* treatments, each group member was asked to make a punishment decision as under *Individual Punishment*. After all group members made their choices, for each punishment recipient the computer randomly selected one of the other group members, and that group member's punishment decision was implemented for all remaining group members as well. Thus, the monetary incentives of an individual are the same in the *Democratic Punishment* and the *Dictator Punishment* treatments (conditional on being selected / being the marginal voter, a choice of punishment implies a reduction of 60 points at a cost of 5 points), but (in expectation) the relation between individual punishment decisions and implemented punishment are the same across *Individual Punishment* and *Dictator Punishment*.

After all participants simultaneously made their punishment decisions, they were informed about the punishments and votes in their group, and the consequences for their round payoffs. In the *Noise* treatments, any payoff information was provisional based on public records; participants were informed about their true earnings in each round at the end of the experiment.

Twelve experimental sessions, on *Individual Punishment* and *Democratic Punishment*, took place in March and April 2014 at the Business School Experimental Research Laboratory at the University of New South Wales. Six further sessions, on *Dictator Punishment*, were conducted in the same laboratory in June 2016. Experimental subjects were recruited from the university student population using the online recruitment system ORSEE (Greiner, 2015). Overall, 480 subjects participated in 18 sessions, with either 20, 25, or 30 subjects per session. Upon arrival participants were seated in

front of a computer at desks which were separated by dividers. Participants received written instructions and could ask questions which were answered privately. The experiment was programmed in zTree (Fischbacher, 2007). Sessions lasted about one hour. At the end of the experiment, participants filled out a short demographic survey. They were then privately paid their cumulated experimental earnings in cash (with a conversion rate of AU\$ 0.02 per point) plus a AU\$ 5 show-up fee. Participants could incur losses in a particular round, but session losses were capped at the show-up fee. No participant incurred losses over the whole session. The average earning was AU\$ 26.59 (including showup-fee), with a standard deviation of AU\$ 4.81, a minimum payoff of AU\$ 7.70 and a maximum payoff of AU\$ 35.30.

TABLE 1: AVERAGE CONTRIBUTIONS, PUNISHMENT AND NET PROFITS IN TREATMENTS

	N part.	N groups	Avg. contr.	Avg. punishm.	Avg. net profits
No noise					
Individual punishment	75	15	23.33	5.96	53.72
Democratic punishment	80	16	36.75	2.40	65.18
Dictator punishment	70	14	27.57	10.63	49.61
Noise					
Individual punishment	80	16	18.78	6.36	50.92
Democratic punishment	90	18	27.58	4.37	57.97
Dictator punishment	85	17	21.03	10.94	45.93

III RESULTS

III.A Aggregate results

In our analysis, we will first focus on our main comparison between individual and democratic punishment. Then, in order to highlight the channels through which the described effects work, we will discuss how the results from the dictator punishment treatment relate to the individual and democratic punishment treatments. Tables and figures refer to data from all treatments.

TABLE 2: P-VALUES FROM NON-PARAMETRIC WILCOXON RANKSUM TESTS ACROSS TREATMENT DIMENSIONS

	Contributions	Received Punishment	Net profits
<i>Individual Punishment vs. Democratic punishment</i>			
with No noise	0.012**	0.005***	0.000***
with Noise	0.055*	0.137	0.003***
<i>Individual Punishment vs. Dictator punishment</i>			
with No noise	0.631	0.028**	0.359
with Noise	0.627	0.121	0.177
<i>Dictator Punishment vs. Democratic punishment</i>			
with No noise	0.050*	0.000***	0.001***
with Noise	0.137	0.009***	0.000***
<i>No noise vs. Noise</i>			
with Individual punishment	0.489	0.874	0.385
with Democratic punishment	0.023**	0.030**	0.005***
with Dictator punishment	0.275	0.937	0.634

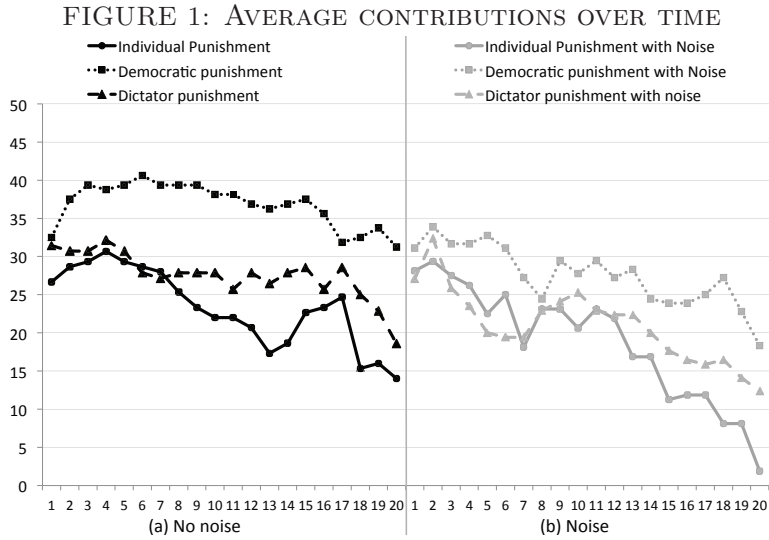
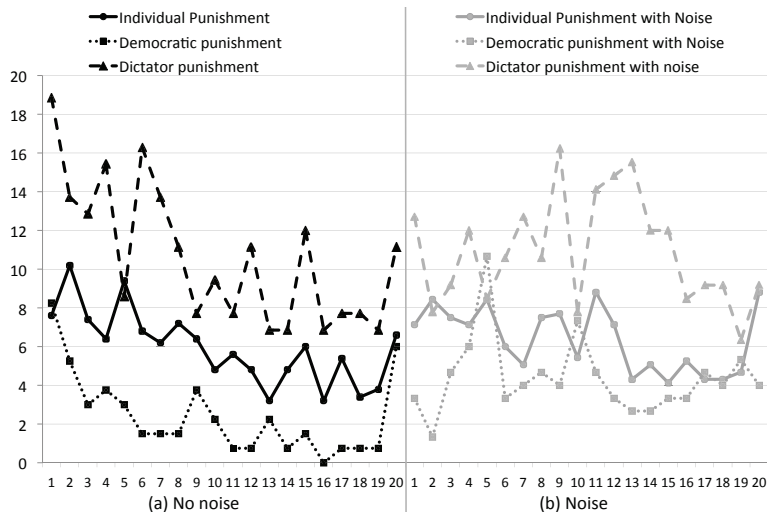


Table 1 lists the average contributions, punishments, and net profits observed in our six treatments. Figures 1, 2 and 3 display the evolution of public good contributions, punishment, and net profits over time. As groups stay constant over all 20 rounds, each group in our experiment constitutes one statistically independent observation. To test for treatment differences

non-parametrically, we apply 2-sided Wilcoxon rank-sum tests, using group averages as independent observations. Table 2 reports the results.

In both the perfect monitoring and the noisy environment, we observe higher contributions, less punishment (only significant for the *No Noise* condition), and consequently higher net profits when groups vote over punishment compared to when group members can punish individually. Introducing *Noise* in the observation of other group members' contribution behavior lowers contributions and net profits, and increases observed punishment for both when punishment is individual as well as when punishment is a group decision, but statistically significantly so only for the latter environment.^{6,7}

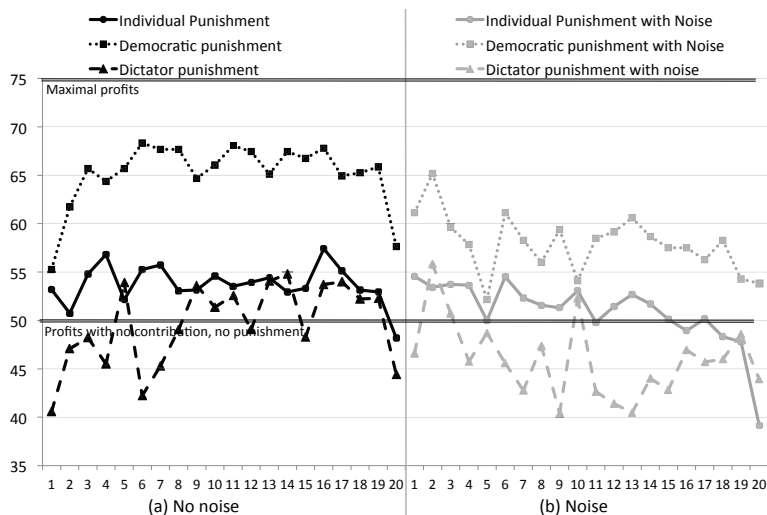
FIGURE 2: AVERAGE RECEIVED PUNISHMENT OVER TIME



⁶Ambrus and Greiner (2012) only study an individual punishment environment and find a significant effect of noise on all three observables. However, in Ambrus and Greiner (2012) the game was repeated 50 times (while only 20 times here) and featured smaller (3-person) groups.

⁷Figure 1 suggests different time trends in contributions across our treatments, at least until just before the end. When running Probit models of contribution decision on the only explanatory variable *Round* (excluding Round 20), we reject the Null hypothesis of no time trend for the *Individual Punishment* treatments at the 5% significance level (p-values of average marginal effect of *Round* 0.032 and $p < 0.001$, respectively), while we cannot reject a zero time trend for *Democratic Punishment* at this level ($p = 0.352$ and $p = 0.100$, respectively). Under *Dictator Punishment* we observe a negative time-trend with noise ($p = 0.003$) but not without noise ($p = 0.242$).

FIGURE 3: AVERAGE NET PROFITS OVER TIME



The regressions reported in Table 3 confirm and further detail these results. We estimate the likelihood of contribution (Model 1), the amount of punishment points received in a round (Models 2-5), as well as the net profits in a round (Model 6) using treatment dummies and a *Round* control. The dummy *Noise* equals 1 in the Noise treatments and 0 otherwise; the dummy *Democratic Punishment* is 1 for the treatments with voting over punishment and 0 in the individual punishment treatments; and the interaction effect $Noise \times Democratic\ punishment$ equals 1 only in the respective treatment with democratic punishment under noise. Similarly, the dummy *Dictator Punishment* equals 1 in dictator punishment treatments and 0 otherwise, and the interaction effect $Noise \times Dictator\ punishment$ captures the additional effect of noise in these conditions. For each estimation we ran additional post-estimation F-tests in order to determine the total effect of *Noise* under democratic and dictator punishment ($Noise + N \times DemP$, $Noise + N \times DicP$) and the total effect of *Democratic/Dictator punishment* under noise ($DemP + N \times DemP$, $DicP + N \times DicP$).

TABLE 3: PROBIT/TOBIT/OLS ESTIMATIONS OF CONTRIBUTIONS, PUNISHMENTS AND NET EARNINGS BASED ON TREATMENT DUMMIES

Dependent Model	Public Good Contribution	Received Punishment				Net Profits
		All	PR Defect	PR Coop.	True Coop.	
	Probit	Tobit	Tobit	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept		-78.10*** [24.00]	-19.56 [16.38]	2.61*** [0.83]	2.43*** [0.85]	54.77*** [2.01]
Round	-0.013*** [0.002]	-1.80*** [0.58]	-3.17*** [0.74]	-0.06* [0.03]	-0.04 [0.04]	-0.10 [0.08]
Noise	-0.090 [0.085]	10.28 [15.24]	-0.33 [16.43]	-0.02 [1.03]	1.25 [0.99]	-2.80 [2.47]
Democratic punishment	0.270** [0.106]	-103.87*** [23.01]	-38.20 [33.35]	-2.03*** [0.69]	-2.05*** [0.69]	11.46*** [2.71]
Noise \times Democratic punishment	-0.098 [0.132]	28.03 [23.88]	-2.92 [38.60]	0.20 [1.04]	0.73 [1.03]	-4.40 [3.33]
Dictator punishment	0.081 [0.105]	3.09 [18.54]	14.44 [24.93]	3.63** [1.77]	3.61** [1.78]	-4.11 [3.72]
Noise \times Dictator punishment	-0.035 [0.128]	-7.39 [26.32]	-11.66 [32.37]	-0.84 [2.38]	-0.31 [2.26]	-0.88 [4.84]
<i>P-values from post-estimation F-tests</i>						
Noise + N \times DemP = 0	0.066	0.046	0.926	0.110	0.000	0.002
DemP + N \times DemP = 0	0.021	0.000	0.040	0.018	0.082	0.000
Noise + N \times DicP = 0	0.193	0.894	0.668	0.690	0.647	0.377
DicP + N \times DicP = 0	0.532	0.810	0.894	0.080	0.020	0.110
N	9600	9600	4875	4725	4957	9600
Pseudo R-squared	0.058	0.026	0.013			
N left-censored		7952	3510			
N right-censored		777	649			
Adjusted R-squared				0.047	0.038	0.073

Note: For the Probit estimation on contributions, we report marginal effects dy/dx rather than coefficients. Received punishment points are censored at 0 and 60, but Models 4 and 5 do not converge as Tobit models, so we report results from OLS regressions in these cases. For all estimations, robust standard errors are clustered at group level and given in brackets. *, **, and *** indicate significance at the 10%, 5%, and 1%-level, respectively.

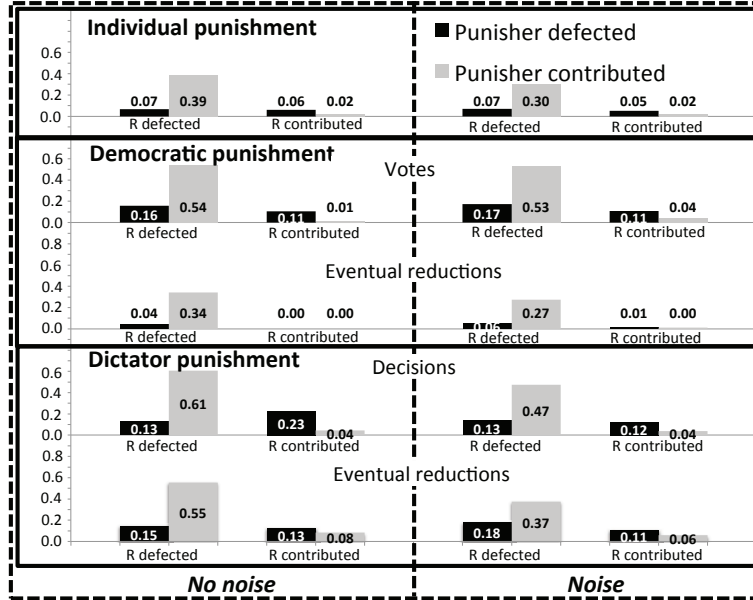
The results of Model 1 and 6 in Table 3 replicate the non-parametric tests, in that we observe a significant increase in contributions and net profits when the group votes to punish compared to individual punishment (both when there is perfect and imperfect monitoring), and that noise has a statistically significant detrimental effect on contributions and net profits only in the democratic punishment condition.

The Models 2 to 5 in Table 3 explore effects of treatment conditions on punishment behavior. Model 2 predicts all punishments (independent of towards whom they were directed), and shows that introducing democratic punishment significantly reduces overall punishment in both non-noisy and noisy environments. *Noise* increases punishments when groups punish but not when individuals punish, which is related to the observation that democratic voting seems to be less effective in reducing punishments under noise than when there is no noise. Models 3 and 4 regress punishment of defectors (as identified by their public record) and cooperators, respectively. The results show that democratic punishment leads to a significant decrease of punishment of cooperators in both environments, but to a decrease of punishment of defectors only in the noise environment and there only weakly significantly. Model 5 serves the purpose of showing that due to the relatively low likelihood of "noise" in public records, the punishment patterns towards "true cooperators" (some of which might have a wrong public record of no cooperation) are very similar to those towards the subset of cooperators who are clearly identified as such by their public record.

Dictator punishment has very different effects compared to *Democratic punishment*. Allowing one individual to punish on behalf of all group members does not significantly affect overall contribution and punishment levels or net profits, with and without noise (see Models 1, 2, and 6 in Table 3). However, when considering only punishment towards contributors in Models 4 and 5 in Table 3, we observe an actual *increase* in punishment under *Dictator punishment* compared to *Individual punishment*, both with and without noise. We will explore these effects more deeply in the next subsection. On the aggregate level, as Tables 1, 2, and 3 indicate, *Dictator*

punishment leads to very similar contribution, punishment and net profits levels as *Individual punishment*, and significantly higher punishment levels and significantly lower net profits as *Democratic punishment*.

FIGURE 4: FREQUENCY OF (VOTE FOR AND EVENTUAL) PUNISHMENT, CONDITIONAL ON PUNISHER'S OWN CONTRIBUTION AND RECEIVERS' PUBLIC RECORD



III.B Punishment pattern

Figure 4 shows the punishment pattern in our six treatments. It displays the frequency of punishment conditional on whether the punisher contributed or not and whether the punishment receiver contributed or not. For the democratic punishment treatments, the figure distinguishes between votes for punishment and eventual punishment (when votes for punishment reached the required majority). For the dictator punishment treatments, we distinguish between the punishment decisions of all (potential dictator) members and the decisions of the eventually selected dictators (which should be the same in expectation and differ only due to the random selection process).

TABLE 4: P-VALUES FROM NON-PARAMETRIC TESTS COMPARING RESULTS REPORTED IN FIGURE 4

Individual punishment vs. Democratic punishment (votes)			
<i>No noise</i>		<i>Noise</i>	
P defect, R defect	0.029	P defect, R defect	0.000***
P defect, R contr	0.791	P defect, R contr	0.171
P contr, R defect	0.093	P contr, R defect	0.000***
P contr, R contr	0.511	P contr, R contr	0.049
Democratic punishment (votes) vs. Democratic punishment (eventual)			
<i>No noise</i>		<i>Noise</i>	
P defect, R defect	0.728	P defect, R defect	0.001***
P defect, R contr	0.003***	P defect, R contr	0.000***
P contr, R defect	0.030	P contr, R defect	0.000***
P contr, R contr	0.005**	P contr, R contr	0.000***
Individual punishment vs. Democratic punishment (eventual)			
<i>No noise</i>		<i>Noise</i>	
P defect, R defect	0.187	P defect, R defect	0.730
P defect, R contr	0.000***	P defect, R contr	0.010**
P contr, R defect	0.373	P contr, R defect	0.796
P contr, R contr	0.001***	P contr, R contr	0.051
No noise vs. Noise			
<i>Individual punishment</i>		<i>Democratic punishment (votes)</i>	<i>Democratic punishment (eventual)</i>
P defect, R defect	0.874	P defect, R defect	0.894
P defect, R contr	0.791	P defect, R contr	0.648
P contr, R defect	0.206	P contr, R defect	0.091
P contr, R contr	0.343	P contr, R contr	0.046
			P defect, R defect
			0.401
			P defect, R contr
			0.092*
			P contr, R defect
			0.051*
			P contr, R contr
			0.176
Punisher defected vs. Punisher contributed			
<i>Individual punishment</i>		<i>Democratic punishment (votes)</i>	<i>Democratic punishment (eventual)</i>
No noise, R defect	0.001***	No noise, R defect	0.001***
No noise, R contr	0.728	No noise, R contr	0.023*
Noise, R defect	0.001***	Noise, R defect	0.000***
Noise, R contr	0.074	Noise, R contr	0.045
			No noise, R defect
			0.071
			No noise, R contr
			no diff
			Noise, R defect
			0.004**
			Noise, R contr
			0.084
Receiver defected vs. Receiver contributed			
<i>Individual punishment</i>		<i>Democratic punishment (votes)</i>	<i>Democratic punishment (eventual)</i>
No noise, P defect	0.019*	No noise, P defect	0.012**
No noise, P contr	0.001***	No noise, P contr	0.000***
Noise, P defect	0.063	Noise, P defect	0.002***
Noise, P contr	0.001***	Noise, P contr	0.000***
			No noise, P defect
			0.002***
			No noise, P contr
			0.001***
			Noise, P defect
			0.000***
			Noise, P contr
			0.000***

Note: All tests rely on averages at independent group level. For comparisons across treatments (within a treatment) we employ Wilcoxon Ranksum tests (Wilcoxon Matched Pairs Signed Ranks tests), respectively. *, **, and *** indicate significance at the 10%, 5%, and 1%-level, respectively, after applying an ex-post Bonferroni correction for repeated hypothesis tests, assuming each set of n=4 tests to be a test family (that is, dividing the required p-value for a level by 4).

Table 4 displays results from non-parametric tests comparing the results from *Individual Punishment* and *Democratic punishment* reported in Figure 4 along treatment dimensions and punishment source and target characteristics.^{8,9}

In general, contributors are much more likely than non-contributors to punish defectors (highly significant except for eventual democratic punishment under *No Noise*), but are less likely than non-contributors to punish contributors (but not significantly so). As one would expect, defectors attract more punishment than contributors, significantly so from contributors and under democratic punishment also from defectors.

Interestingly, under democratic punishment defectors are more likely to punish other defectors than other contributors, both when looking at votes as well as when looking at eventual outcomes. While the latter observation could be caused by majorities of cooperators dragging defectors along to punish another defector, the former result suggests that this is not the case: defectors also intend to punish other defectors more than cooperators).

Across treatments, we observe a higher likelihood to vote for punishment in democratic decisions compared to the willingness to individually punish in the same situation (except for punishment of contributors towards contributors). These differences, however, are statistically only significant for the nominally largest differences, towards defectors under *Noise*, and are not significant at a reasonable level in the other conditions. With *Democratic Punishment*, we observe a drop in punishment frequency from votes to eventual punishments, indicating that often some group members wanted to punish but did not reach the required majority. This drop is significant

⁸Since we are employing a full battery of tests here, we decided to adjust the p-values required for a particular significance level with a Bonferroni correction. We assume each set of four tests in Table 4 to belong to the same ‘family’ of hypotheses, and correspondingly divide the required p-value for a particular significance level by 4. As a result, a Null hypothesis is rejected at the 10% level when the p-value is 0.025 or below, and it is rejected at the 5% level (1% level) when the p-value is 0.0125 (0.0025) or below, respectively. Table 4 reports original p-values obtained from the tests, but stars represent the corrected significance level. Group-level averages serve as independent observations.

⁹For expositional reasons, we report results from comparisons with our control treatments on *Dictator punishment* only selectively in the discussion below.

across all types of punishment interactions for the *Noise* treatment, but only for punishment towards contributors (where it literally dropped down to zero) in the *No Noise* condition. As a result, as inspection of Figure 4 reveals, the *eventual* punishments in the different cases do not differ that much anymore between *Individual* and *Democratic Punishment* treatments.¹⁰

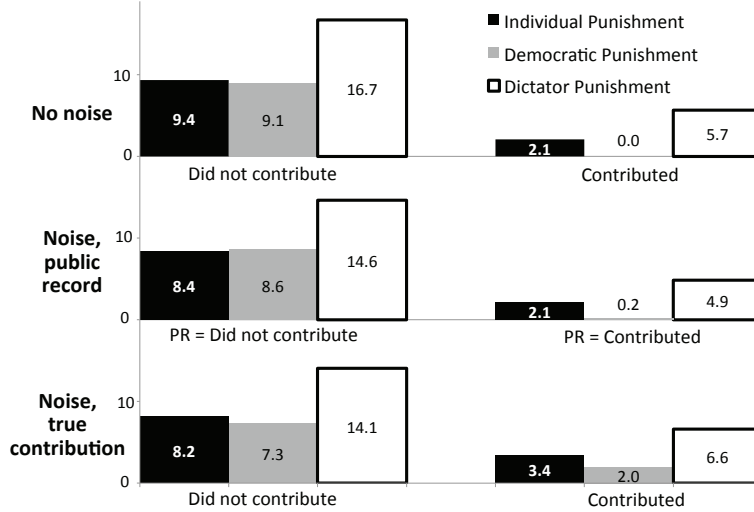
In our control treatment *Dictator punishment*, we observe punishment *decision* patterns which are similar to the *voting* pattern in *Democratic punishment*. Comparing the conditional frequencies statistically (i.e. comparing the size of bars in row 2 and row 4 in Figure 4) does not yield significance at the 10%-level for any of the comparisons. However, under *Dictator punishment* there is no filtering democratic process at work, and thus a random draw of the punishment choices is implemented directly. This implies higher (expected) punishment levels compared to *Individual punishment*, across all conditions.¹¹

The main effect of introducing *Democratic Punishment* on punishment patterns is that cooperators are effectively not punished anymore (difference highly significant under *No noise*, and significant for punishment from defectors under *Noise*). Figure 5 visualizes these consequences. It displays the resulting average number of received punishment points conditional on whether (the public record indicated that) the participant had contributed or not. Participants who did not contribute were deducted an average of 9.4 points (8.4 points) when there was *No Noise* (*Noise*), and this changed only slightly to 9.1 points (8.6 points) when employing *Democratic Punishment*. But for punishment towards contributors, introducing the voting procedure resulted in a drop from an average of 2.1 points (2.1 points) to literally 0 points (0.2 points) when there was *No Noise* (*Noise*). In the *Noise*

¹⁰To create another counterfactual, we treat the punishments in the *Individual Punishment* treatments as votes and simulate the respective group vote outcomes. The resulting hypothetical group punishment levels are lower than the ones observed in *Democratic Punishment*. This provides additional evidence that pure punishment preference aggregation is not sufficient to explain differences between individual and democratic punishment, and that there also exists an associated behavioral change.

¹¹In Wilcoxon ranksum tests, these comparisons yield p-values smaller than 0.05, except for the case of punishment from contributors towards contributors without noise ($p = 0.510$), and the contributions from defectors towards defectors with noise ($p = 0.056$).

FIGURE 5: AVERAGE PUNISHMENT POINTS DEDUCTED, CONDITIONAL ON PUNISHED SUBJECT’S (TRUE) CONTRIBUTION AND PUBLIC RECORD



treatment, this drop did not benefit all contributors, since some of them were burdened with a "no contribution" public record, such that the real expected punishment of a contributor decreased from 3.4 points on average with noisy *Individual punishment* to 2.0 points with noisy *Democratic punishment*. With *Dictator punishment*, on the other hand, we observe almost a doubling of received punishment points, on average, both for contributors and non-contributors, and both with and without noise in the observation of contribution decisions.

III.C Reactions to received punishment

In Table 5 we report results from Probit regressions that explore how participants' contribution behavior responds to punishment received in the previous round. In Model 1 of Table 5, we regress the current contribution of a participant on the number of punishment points that were deducted from his income in the previous round ($RecPnmt_{PR}$). We control for whether the participant contributed in the previous round or not ($Contr_{PR}$), and interact previous punishment and previous contribution with each other as

TABLE 5: PROBIT ESTIMATIONS OF CURRENT CONTRIBUTION BASED ON PREVIOUS ROUND BEHAVIOR

	Model 1	Model 2
$RecPnmt_{PR}$	0.009*** [0.002]	0.006*** [0.002]
$RecPnmt_{PR} \times Noise$	-0.001 [0.002]	
$RecPnmt_{PR} \times DemPun$	0.002 [0.002]	0.001 [0.002]
$RecPnmt_{PR} \times Noise \times DemPun$	-0.002 [0.003]	
$RecPnmt_{PR} \times DicPun$	-0.003* [0.002]	-0.002 [0.002]
$RecPnmt_{PR} \times Noise \times DicPun$	0.000 [0.003]	
$Contr_{PR}$	0.576*** [0.028]	0.450*** [0.034]
$Contr_{PR} \times RecPnmt_{PR}$	-0.023*** [0.006]	-0.015*** [0.005]
$Contr_{PR} \times RecPnmt_{PR} \times Noise$	0.008 [0.007]	
$Contr_{PR} \times RecPnmt_{PR} \times DemPun$	0.012*** [0.004]	0.006 [0.008]
$Contr_{PR} \times RecPnmt_{PR} \times Noise \times DemPun$	<i>Omitted due to collinearity</i>	
$Contr_{PR} \times RecPnmt_{PR} \times DicPun$	0.015** [0.006]	0.008 [0.005]
$Contr_{PR} \times RecPnmt_{PR} \times Noise \times DicPun$	-0.007 [0.007]	
$Contr_{PR} \times PRwrong_{PR}$		0.090 [0.057]
$Contr_{PR} \times PRwrong_{PR} \times RecPnmt_{PR}$		0.011** [0.005]
$Contr_{PR} \times PRwrong_{PR} \times RecPnmt_{PR} \times DemPun$		-0.002 [0.008]
$Contr_{PR} \times PRwrong_{PR} \times RecPnmt_{PR} \times DicPun$		-0.006 [0.006]
N	9120	4845
Pseudo R-squared	0.218	0.144

Note: We report average marginal effects. Clustered robust standard errors in brackets. *, **, and *** indicate significance at the 10%, 5%, and 1%-level, respectively. $Contr_{PR}$ and $RecPnmt_{PR}$ refer to contribution and punishment received in the previous round, respectively, while $PRwrong_{PR}$ indicates whether a contributor's previous round public record was wrong. $Noise$, $DemPun$, and $DicPun$ are dummies indicating the presence of noise and whether democratic/dictator punishment was employed, respectively.

well as with treatment dummies that indicate whether noise was present (*Noise*), whether punishment was determined individual, democratically, or by a dictator (*DemPun*, *DicPun*), or combinations of these (*Noise* \times *DemPun*, *Noise* \times *DicPun*).¹² The second model in Table 5 only looks at choices in the three *Noise* treatments and analyzes whether having received a wrong public record in the previous round (dummy *PRwrong_{PR}*, indicating that the public record displayed that participant hasn't contributed even though he did) changes next-round reactions to received punishment.

Table 5 shows that participants who did not cooperate increase their next-round contribution for each punishment point they received, but (weakly significantly) less so under *Dictator Punishment* than in the other two punishment conditions. This effect is reversed when the participant cooperated and got punished (Model 1 post-estimation F-test of $RecPnmt_{PR} + Contr_{PR} \times RecPnmt_{PR} = 0$ rejected at $p = 0.009$), but this aversive reaction of cooperators is not existent when punishment was the consequence a democratic vote or a dictator decision, or when the punishment was received due to a wrong public record in the *Noise* treatments.¹³

IV CONCLUSION

In this paper we observed that democratic punishment, when punishment decisions in a group are decided by majority voting, facilitates more cooperation and higher payoffs than individual punishment. It achieves so by establishing a stronger connection between a member's contribution decision and whether the member gets punished, in particular by decreasing anti-social punishment while keeping the same level of pro-social punishment. We also see some evidence that participation in democratic punishment makes pun-

¹²Since under *Democratic Punishment*, the only punishment of contributors happens when there is *Noise* (and never when there is *No Noise*), we have a problem of perfect collinearity in that condition, and therefore do not include the variable "*Contr_{PR} \times RecPnmt_{PR} \times Noise \times VotePun*" in our estimations.

¹³Post-estimation F-tests in Model 1 cannot reject the hypotheses $RecPnmt_{PR} + Contr_{PR} \times RecPnmt_{PR} + Contr_{PR} \times RecPnmt_{PR} \times DemPun = 0$ ($p = 0.708$) and $RecPnmt_{PR} + Contr_{PR} \times RecPnmt_{PR} + Contr_{PR} \times RecPnmt_{PR} \times DicPun = 0$ ($p = 0.792$). In Model 2, we cannot reject $Contr_{PR} \times RecPnmt_{PR} + Contr_{PR} \times PRwrong_{PR} \times RecPnmt_{PR} = 0$ ($p = 0.278$).

ishment intentions themselves more pro-social. The findings suggest that social norms or institutions that help members of a group to coordinate punishment decisions, and make it contingent on majority approval, can be welfare enhancing, even without the ability to make future commitments for punishment. A direction for future research is investigating what voting rule for punishments is optimal for society's welfare, for different levels of noise in observations, although addressing this question would ideally require larger groups than in our study. Presumably the expected welfare in the group is non-monotonic in the strictness of the voting rule, since if the threshold for punishing is very low, outcomes might be similar to individual punishment, while if they are too high then it might become impossible for the group to agree upon punishing someone, resulting in a lot of free riding.

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Supplementary Material for
**Ambrus & Greiner: “Democratic punishment in public good
games with perfect and imperfect observability”**

Experimental Instructions

Treatment parameters:

Stage 2-rule: IND, VOTE, DIC

Noise: BIN-NONOISE vs. BIN-NOISE

INSTRUCTIONS

Welcome. This is an experiment on decision-making. If you read the following instructions carefully, you can, depending on your and other participants' decisions, earn a considerable amount of money. It is therefore very important that you read these instructions carefully.

It is prohibited to communicate with the other participants during the experiment. If you have a question at any time please raise your hand and the experimenter will come to your desk to answer it. Please switch off your mobile phone or any other devices which may disturb the experiment. Please use the computer only for entering your decisions.

In the experiment you will be making decisions that will earn you points. At the end of the experiment, the points you earned will be converted into Australian Dollars at an exchange rate of 50 points = AUD\$1, and paid out in cash. This amount will be added to your show-up fee of \$5.

The experiment will run over 20 rounds. At the beginning of the experiment, you will be randomly matched with 4 other participants to form a group of 5, and you will be randomly assigned a group member number between 1 and 5. You will stay in the same group and keep your group member number for all rounds.

In each round, you will receive an endowment of 50 points. Each round consist of two stages:

STAGE 1: In the first stage, you decide whether or not you want to contribute your endowment of 50 points to a project.

Your **earnings from stage 1** consist of two parts:

(1) The points which you have kept for yourself.

(2) The “income from the project”. Each group member will benefit equally from the amount you contribute to the project. On the other hand, you will also get a payoff from the other group members' contributions. In particular, your income from the project equals *0.3 times* the sum of all contributions to the project in your group (including yours).

Therefore, your **earnings** from stage 1 are:

Your endowment of 50

– **your contribution to the project**
+ 0.3 × (total contributions to the project in your group)

So, for example,

- if **no group member contributes**, each group member's earnings will be $50 - 0 + 0.3 \times 0 = 50$ points;
- if **one group member contributes 50 points, but the other four contribute 0 points**, then the earnings of the contributing member will be $50 - 50 + 0.3 \times 50 = 15$ points, and the earnings of each of the four other group members will be $50 - 0 + 0.3 \times 50 = 65$ points;
- if **two group members contribute 50 points, but the other three contribute 0 points**, then the earnings of each of the two contributing members will be $50 - 50 + 0.3 \times 100 = 30$ points, and the earnings of each of the three other group members will be $50 - 0 + 0.3 \times 100 = 80$ points;
- if **three group members contribute 50 points, but the other two contribute 0 points**, then the earnings of each of the three contributing members will be $50 - 50 + 0.3 \times 150 = 45$ points, and the earnings of each of the two other group members will be $50 - 0 + 0.3 \times 150 = 95$ points;
- if **four group members contribute 50 points, but the fifth contributes 0 points**, then the earnings of each of the four contributing members will be $50 - 50 + 0.3 \times 200 = 60$ points, and the earnings of the non-contributing group member will be $50 - 0 + 0.3 \times 200 = 110$ points;
- if **all five group members contribute 50 points**, then each group member's earnings will be $50 - 50 + 0.3 \times 250 = 75$ points.

At the end of stage 1, after all group members made their decisions, all group members' decisions are revealed publicly **[NOISE]**, but with the possibility of an error in your public record (which will be shown to all other group members):

- If you did not contribute, then your public record will be that you did not contribute, without error.
- If you contributed the 50 points, then with 90% probability your public record will indicate that you contributed. With 10% probability an error occurs, and your public record will be that you did not contribute.

The same potential error may apply to other group members' public records. However, errors in the public record do not influence payoffs from Stage 1 (those payoffs only depend on the actual contributions)].

STAGE 2: In the second stage, you can decide whether you want to reduce the earnings of some group members.

[IND: For each of the other four group members, each group member can decide whether or not he/she wants to reduce that group member's earnings by 15 points. Reducing another group member's income by 15 points will impose a cost of 5 points on you.]

[VOTE: For each of the other four group members, each group member is asked to cast a vote whether or not he/she wants to reduce that group member's earnings by 60 points. If 3 or more group members (i.e. a simple majority) vote for reducing a group member's earnings, then that group member's earnings will be reduced by 60 points, and a cost of 5 points is imposed on each of the other four group members, no matter how they voted.]

[DIC: For each of the other four group members, each group member is asked to cast a decision whether or not he/she wants to reduce that group member's earnings by 60 points, in case he/she is the "decider", at a cost of 5 points to each of all other group members including him-/herself. After all group members casted their choices for everyone else, for each individual group member it is randomly determined which other group member is the "decider", and the decider's decision (regarding whether to reduce the earnings of that individual) gets implemented.]

At the end of stage 2, you will be informed about how many points your own earnings were reduced, and how much the reduction of other's earnings costs you.

After stage 2 the rounds end.

Thus, your round earnings will be:

Your endowment of 50

– your contribution to the project

+ $0.3 \times$ (total contributions to the project in your group)

[IND: - 5 points \times number of group members whose earnings you reduced by 15 points

- 15 points \times number of group members who reduced your earnings]

[VOTE: - 5 points \times number of group members for which majority voted for earnings reduction

- 60 points if majority voted to reduce your earnings]

[DIC: - 5 points \times number of group members for which the selected "decider" decided for earnings reduction

- 60 points if the decider selected for you decided to reduce your earnings]

At the end of the experiment, you will be informed about **[NOISE:** the public records and actual contributions of all group members in each round, as well as] your earnings in each round and your total earnings.