Asymmetric Enforcement of Cooperation in a Social Dilemma

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Abstract

We use a public-good experiment to analyze behavior in a decentralized asymmetric punishment institution. The institution is asymmetric in the sense that players differ in the effectiveness of their punishment. At the aggregate level, we observe remarkable similarities between outcomes in asymmetric and symmetric punishment institutions. Controlling for the average punishment effectiveness of the institutions, we find that asymmetric punishment institutions are as effective in fostering cooperation and as efficient as symmetric institutions. At the individual level, we find that players with higher punishment effectiveness contribute similar amounts to the public account, but have higher earnings and punish more than their weak counterparts.

> *[I]f only a few very powerful actors want to promote a certain pattern of behavior, their punishments alone can often be sufficient to establish it, even if the others are not vengeful against defections. (Axelrod 1997; p.63)*

1 Introduction

A number of daily decisions involve making a choice between the private and the public interest. In these cases, following the private interest reduces efficiency and imposes a negative externality on others. A common way of dealing with negative externalities is the imposition of sanctions on parties that deviate from a widely accepted norm of behavior (Ostrom 1990). Given that the purpose of such sanctions is to lower the return from acting against the social interest, the efficacy of sanctions in enforcing cooperation will depend critically on the punishment power of the sanctioning party. The greater the power of the party abiding to a given norm, the less appealing a deviation from that norm will be for other parties.

This paper presents the results from a laboratory experiment investigating the efficacy of decentralized sanctions in fostering cooperation when negative externalities exist and players are asymmetric in their punishment effectiveness. The use of a laboratory experiment permits us to control a number of factors in a way that is difficult to do in the field (e.g. endowments, returns to cooperation, information), and focus on variables of interest such as the players' punishment power and the extent of the asymmetry in their power.

To the best of our knowledge, this is the first study to investigate behavior in *asymmetric* punishment institutions. However, there have been numerous social dilemma experiments in which players have the same punishment power (see below). Our goal is to examine how the asymmetry in the players' punishment power affects cooperation rates and efficiency, as well as how behavioral regularities observed in symmetric institutions, such as the determinants of punishment, carry over to asymmetric institutions.

For our study, we use the two-stage public-good game that was introduced by Fehr and Gächter (2002). The game is as follows. In the first stage, each individual is given an endowment in experimental currency units (ECU). Individuals have to decide how much of their endowment they wish to contribute to a public account. The higher the contributions to the public account, the higher the group earnings. However, every individual has also an incentive to free-ride and not contribute. In the second stage, individuals are informed of each group member's contribution to the public account and can reduce their earnings by assigning costly punishment points. Each punishment point costs the punisher one ECU and reduces the earnings of the punishment recipient by a factor larger than one. We refer to this factor as *punishment effectiveness* and use the term interchangeably with punishment- and sanctioning power.

To evaluate the impact of asymmetries in the players' punishment effectiveness we compare behavior in symmetric and asymmetric punishment institutions. In the symmetric case, as studied in previous papers, group members are given the same punishment effectiveness. That is, they are all equally effective in punishing each other. By contrast, in asymmetric punishment institutions, players differ in their punishment effectiveness: one player has higher punishment effectiveness than the other three players who all have the same power. To ensure the robustness of our findings, we examine behavior in two symmetric institutions that differ in the players' *average* punishment effectiveness and four asymmetric punishment institutions. The asymmetric institutions differ in the extent of the asymmetry between strong and weak players.

Experimental economists have repeatedly used the two-stage public-good game to analyze the resolution of the tension between social good and self interest in symmetric punishment institutions (Anderson and Putterman 2006; Bochet, Page, and Putterman 2006; Carpenter 2007a, 2007b, 2008; Egas and Riedl 2008; Fehr and Gächter 2000, 2002; Masclet, Noussair, Tucker, and Villeval 2003; Nikiforakis and Normann 2008; Noussair and Tucker 2005; Page, Putterman, and Unel 2005; Sefton, Shupp, and Walker 2007). The two main goals of this literature have been to understand what triggers punishment and whether the threat of punishment can promote cooperation.

With respect to the motivation behind punishment, the experimental results show that individuals tend to punish those who free ride by contributing less than the group average even in one-shot interactions (e.g. Fehr and Gächter, 2002). This suggests that punishment does not serve the exclusive purpose of increasing one's earnings by raising future contributions to the public account (Falk, Fehr, and Fischbacher 2005). However, despite the non-strategic use of sanctions, punishment is sensitive to economic incentives. Anderson and Putterman (2006), Carpenter (2007a), Egas and Riedl (2008) and Nikiforakis and Normann (2008) find that, the higher the cost of punishment is (which is the inverse of punishment effectiveness), the less is the punishment inflicted on free riders and the disciplinary power of decentralized punishment.[1]

With respect to the efficacy of punishment in fostering cooperation, the evidence shows that when individuals interact repeatedly with the same people throughout the experiment (fixed matching), decentralized punishment leads to high cooperation rates as free riders react to punishment by raising their contribution in subsequent periods. When individuals interact with different people in every period (random matching), cooperation rates are higher than they are in the absence of a punishment institution, but lower than under fixed matching. However, the efficacy of punishment depends critically on its effectiveness. Nikiforakis and Normann (2008) find a monotonic relation between punishment effectiveness, cooperation rates and efficiency. Unless punishment is sufficiently effective, cooperation unravels.[2]

The main reason for studying behavior in asymmetric punishment institutions is the empirical relevance of such institutions. In most naturally occurring situations, asymmetric players are the norm rather than the exception.[3] Individuals differ in their physical ability to enforce cooperation just as countries differ in their military budgets and technology. Given the documented willingness to punish free riders even in one-shot interactions and the efficacy of symmetric punishment institutions in promoting cooperation, we believe it is interesting to investigate whether asymmetric institutions are as effective in mitigating free riding.

Another reason for studying the performance of asymmetric punishment institutions is that it seems challenging to predict the impact these asymmetries will have on cooperation. This is because, for our setting, arguments can be made in either direction. On the one hand, an asymmetric institution might have a positive effect on cooperation. Firstly, experimental evidence suggests that higher punishment effectiveness increases the demand for punishment (Anderson and Putterman 2006; Carpenter 2007a; Egas and Riedl 2008; Nikiforakis and Normann 2008). The high punishment effectiveness of strong players suggests that they might be able to unilaterally enforce cooperation. In contrast, in a symmetric punishment institution, more than one individual might be required to discipline free riders (controlling for average punishment effectiveness). This is essentially the reason Axelrod (1997) argues that a "dominant power" will have a positive effect on cooperation. Secondly, punishment of free riders is (partly) a public good: all group members benefit from the increase in cooperation due to punishment, but all have an incentive to let others carry the cost of punishment.[4] By giving more power to one player, the free-rider problem at the punishment stage may be alleviated. Similarly, endowing a single player with more punishment power provides a natural focal point and may help alleviate any coordination problems in punishment.

On the other hand, the asymmetric nature of the institution might impact negatively on cooperation. This can happen through two different channels. First, strong players face a reduced threat relative to players in symmetric institutions since we control for average punishment effectiveness in our experiments. Therefore, they will be more likely to free ride, ceteris paribus, if they are self-regarding. In turn, this jeopardizes the cooperative performance of the whole group since their behavior is likely to be imitated by reciprocal group members (Fischbacher, Gächter, and Fehr 2001). Second, the reliance on fewer individuals to enforce cooperation (or, in our case, the reliance on a single strong player) might make cooperation more fragile compared to a symmetric situation as the outcome depends on the preferences of the strong player who might not wish to enforce cooperation.

The impact of asymmetries in public-good games has been previously studied almost exclusively in the absence of punishment opportunities. In general, there seems to be no consensus about the effect of asymmetries on cooperation (see Varughese and Ostrom 2001; Anderson, Mellor, and Milyo 2008). Isaac, McCue and Plott (1985) were the first to study behavior in a public-good game when agents have asymmetric endowments from which to contribute. The authors argue that the asymmetric environment gives the game-theoretic prediction of zero contributions to the public account its best chance. Cherry, Kroll, and Shogren (2005) provide evidence supporting this conjecture by comparing treatments with symmetric and asymmetric endowments. Another study finding evidence that asymmetries have a negative impact on cooperation is Anderson et al. (2008) who examine a public-good game in which participants receive different show-up fees. When this is made salient through a public announcement, cooperation levels are negatively affected. In contrast, Fisher, Isaac, Schatzberg, and Walker (1995) investigate the effect of asymmetric returns to cooperation (that is, unequal marginal per capita returns) and find that they do not affect cooperation rates. Similarly, Visser and Burns (2008) study a linear public-good experiment with South African fishermen and find that heterogeneous endowments do not affect the effectiveness of a symmetric punishment institution in promoting cooperation.

The main results from our experiment are as follows. At the aggregate level, asymmetric institutions are not only equally successful in fostering cooperation as symmetric institutions, but they are also equally efficient. At the individual level, we find that all of the behavioral regularities observed in symmetric institutions carry over to asymmetric institutions. Interestingly, we find that strong players do not take advantage of their privileged position; they contribute similar amounts to the public account to those of their weak counterparts. However, strong players punish more than others and enjoy higher earnings than weak players.

The rest of the paper is organized as follows. Section 2 presents the experimental design and the procedures. Section 3 presents the experimental results and section 4 concludes.

2 The Experiment

The experiment is based on the design of Fehr and Gächter (2002) who use the public-good game with n players. In each period, all participants are given an endowment y. Players then decide simultaneously and without communication how much of the endowment to contribute to a public account, c_i, where $0 \leq c_i \leq y$. The rest $(y - c_i)$ remains in the player's own account. In addition to the money player i keeps, i receives a fixed proportion of the group's total contribution to the public account, α, where $1/n < \alpha < 1$. The earnings of player i in the first stage of a period are

$$\pi_i^1 = y - c_i + \alpha \sum_{i=1}^{n} c_i. \quad (1)$$

In the second stage of a period, participants are informed about how much the other individuals in their group contributed. They can then, if they wish, purchase punishment points to reduce the earnings of one or more other participants. Punishment is costly for the punisher. The price for each punishment point is 1 ECU (experimental currency unit). Let p_{ij} denote the number of punishment points that player i assigns to j (where i, j=1, ..., n; $j \neq i$), and e_i denote i's *punishment effectiveness*, that is, the reduction in earnings that one punishment point from player i causes to its recipient. Punishment effectiveness is the inverse of the cost of punishment (that is, the cost of reducing the earnings of player j by 1 ECU). Player i's earnings at the end of a period are accordingly

$$\pi_i^2 = y - c_i + \alpha \sum_{i=1}^{n} c_i - \sum_{j \neq i} p_{ij} - \sum_{j \neq i} e_j p_{ji}. \qquad (2)$$

The maximum number of points a participant can distribute to others is equal to his earnings from the first stage, that is, $\sum_{j \neq i} p_{ij} \leq y - c_i + \alpha \sum_{i=1}^{n} c_i$. As in stage one, punishment decisions are made simultaneously and without communication.

Table 1 describes the treatments in the experiment. The treatments can be divided into two categories: symmetric treatments where e_j is the same for all players, and asymmetric treatments with one "strong" and three "weak" players. In the asymmetric treatments, the punishment effectiveness of the strong player, e_s, is larger than the effectiveness of the weak players, e_w. In all treatments, it is common knowledge that y=20, n=4 and α=0.4. The treatment labels read "$e_s\_e_w$", such that the number on the left indicates the effectiveness of the strong player and the number on the right the effectiveness of the weak players. So, for example, in treatment "5_1", one punishment point from the strong player reduces the earnings of its recipient by 5 ECU, while one punishment point from the weak players reduces the earnings of its recipient by 1 ECU. In the instructions, strong players were referred to as "type A" and weak players as "type B".[5]

The treatments differ in two dimensions: First, *average effectiveness,* $\bar{e}$, is the average punishment effectiveness of the group members, $\bar{e} \equiv (e_s + 3e_w)/4$. We ran treatments with $\bar{e} = 2$ and $\bar{e} = 3$. This permits us to test the robustness of our findings with respect to the impact of asymmetric punishment institutions. Based on the findings of Nikiforakis and Normann (2008), we anticipated that the higher the level of average punishment effectiveness the higher the level of cooperation. Second, the *asymmetry level* indicates the relative strength of the strong player's punishment and is denoted by $l \equiv e_s/e_w$. For both $\bar{e} = 2$ and $\bar{e} = 3$, we conducted sessions with $l = 3$ in addition to the symmetric control sessions with $l = 1$. We also ran a treatment with $\bar{e} = 2$ and $l = 5$ ("5_1"). However, we were concerned that a treatment where $\bar{e} = 3$ and $l = 5$ (e.g., "7.5_1.5") would be risking losses for the weak players due to the magnitude of the strong players' punishment effectiveness in this case. This could have caused frustration and have led to erratic behavior. Instead, we decided to conduct treatment "4_2.6" with $\bar{e} = 3$ and $l = 1.5$.[6]

insert Table 1 *about here*

Information feedback is as follows. At the beginning of each experimental session, subjects are informed whether they are assigned the role of a strong (type A) or a weak player (type B). These roles remained fixed for the duration of the experiment. At the beginning of each period every player is randomly given a number between 1 and 4 to distinguish their actions from those of the others in that period. To prevent the formation of individual reputation, the numbers are randomly reallocated in the beginning of every period. Participants are aware of this. Such a mechanism ensures that, even though the group members remain the same, the participants cannot link the actions of the other subjects across the periods.

Once participants have completed stage one, they are informed about their group's total contribution to the public account, individual contributions and their earnings from the period as given by equation (1). At the end of each period, participants are informed about the total number of punishment points they received from their peers, the associated earnings reduction and their earnings from the period as given by equation (2). Subjects are not informed about the individual punishment decisions of the other players. That is, subjects know neither which of their peers punished them nor whether other group members were punished. Participants only know how many points they assigned to the other group members, and, thus, targeted counter-punishment as in Denant-Boemont et al. (2007) and Nikiforakis (2008a) is not possible.[7]

All treatments last for 10 periods. For the experiment we use fixed (or "partners") matching. This implies that each group can be regarded as an independent observation. For treatments "2_2", "3_3" and "5_1"we have six independent observations. For treatments "4_1.3", "4_2.6" and "6_2" we have five independent observations. In two cases, we missed the target of six groups due to individuals not showing up. In the third case ("4_1.3"), we had to discard one group from the analysis due to a bankruptcy problem.[8] The duration of each experiment and the matching protocol were common knowledge. From equations (1) and (2), and backward induction, the finite duration of the experiment implies that in the subgame perfect equilibrium self-regarding players do not punish and do not contribute to the public account in all periods and in all treatments.

The experiments were conducted at Royal Holloway (University of London) and University College London. The total number of participants was 132 (not counting the discarded group).[9] The subjects were recruited using an e-mail list of voluntary potential (student) candidates. Participants were from a variety of backgrounds. None of the participants had participated previously in a public-good experiment. Sessions lasted approximately fifty minutes. The rate of exchange between the experimental currency unit and the British pound was 1 ECU = £0.04. The average earnings in the experiment were £10.61 or roughly $20 at the time of the experiment. The experiments were conducted using z-Tree (Fischbacher 2007).

3 Results

We begin the analysis by taking an overview of the data and reporting non-parametric tests of our key variables. We then proceed with a more detailed analysis of the impact of the asymmetric punishment institution on contributions to the public account, punishment behavior, and on earnings. All

p-values reported are based on two-tailed tests.

Overview

Table 2 presents summary statistics from the experiment. Columns (2) to (4) include average contributions, columns (5) to (7) average punishment inflicted, and columns (8) to (10) average earnings. The information is also presented separately for strong and weak players. Looking at column (2) one can see that, in all treatments, the punishment institution can sustain cooperation at higher levels than the ones predicted by the subgame perfect Nash equilibrium.

The results from non-parametric tests (counting one group as one observation and using data from all periods) are as follows. At the aggregate level, when we pool the data into two groups according to the presence or not of asymmetries, we find that asymmetric institutions appear to be as effective as symmetric institutions, in the sense that contribution levels are not significantly different (Mann-Whitney rank-sum test, p-value= .99), and as efficient, in the sense that earnings are not significantly different (Mann-Whitney rank-sum test, p-value= .63). Comparing the entries in columns (3) and (4) we see that the average contribution of strong players tends to be lower than that of weak players. However, this difference is not significant (Wilcoxon signed-rank test, p-value = .30). Comparing columns (6) and (7), it appears that strong players take the role of the enforcer of cooperation as they punish more than weak players (Wilcoxon signed-rank test, p-value $< .01$). In addition, columns (9) and (10) reveal that strong players have higher earnings on average than their weak counterparts (Wilcoxon signed-rank test, p-value = .02). Finally, contributions in treatments with $\bar{e} = 3$ are higher than in treatments with $\bar{e} = 2$ (Mann-Whitney rank-sum test, p-value= .07; column 2), while earnings are not (Mann-Whitney rank-sum test, p-value= .45; column 8).

insert Table 2 *about here*

Contributions to the public account

The impact of average effectiveness ($\bar{e}$) and asymmetry level (l) on contribution rates can be identified clearly in Figure 1. Contributions in treatments with $\bar{e} = 3$ are at a high level and, overall, appear to be increasing over time. On the other hand, contributions in treatments with $\bar{e} = 2$ are at a lower level and remain more or less constant. The striking fact is that the evolution of contributions is very similar amongst the three treatments with $\bar{e} = 2$ (the lower three lines) and also amongst the three treatments with $\bar{e} = 3$ (the upper three lines). The level of asymmetry appears to have no impact on cooperation at the aggregate level.

insert Figure 1 *about here*

Table 3 shows the results of a series of regressions investigating the effect of different sets of explanatory variables on contributions. To model the effect of asymmetric institutions we use *Asymmetric,* a dummy variable which takes the value of one for all asymmetric treatments (that is, whenever $l \equiv e_s/e_w > 1$) and zero otherwise, or separate dummy variables for each realized level of asymmetry. The other independent variables are *Three*, a dummy variable which takes the value of one for all treatments with $\bar{e} = 3$ and zero otherwise; *Strong,* a dummy variable which takes the value of one when individual i is a strong player in an asymmetric treatment and zero otherwise;[10] *Period* to account for the different time paths in Figure 1, and the interaction *Period*Three.*[11] All regressions include individual random effects to account for the fact that we have repeated observations from the same individuals, and group random effects to control for the interaction within groups.[12]

The results in Table 3 are fully consistent with the non-parametric tests and the observations made regarding Figure 1. Contributions in asymmetric institutions are not significantly different from those in symmetric institutions. Similarly, the level of asymmetry does not have a significant impact on contributions. As average effectiveness increases from $\bar{e} = 2$ to $\bar{e} = 3$, so do average contributions. The difference increases over time as indicated by the positive sign of *Period*Three.* Strong players contribute less than weak players on average. However, this difference fails to be significant. This implies that strong players do not exploit their relative power to free ride. We summarize:

Result 1: *Asymmetric punishment institutions are as successful in fostering cooperation as symmetric institutions.*

Result 2: *A higher average effectiveness of punishment significantly increases contributions.*

Result 3: *Strong and weak players contribute similar amounts to the public account.*

insert Table 3 *about here*

Punishment behavior

We now turn our attention to punishment behavior. The literature has already identified some regularities with regards to punishment behavior (see e.g. Carpenter 2008). The first is that punishment is mostly aimed towards individuals who contribute less than their peers on average and that the severity of punishment increases as the difference between the free-rider's contribution and that of his group members becomes larger. Second, individuals often punish group members who contribute less than they do, irrespective of the target's relative position in the group. We will look for these regularities in our dataset. In addition, we are interested to provide answers to two questions that have previously not been investigated: (i) Do strong players punish more than weak players? And if they do, what accounts for the difference in the behavior of strong and weak players? (ii) Does punishment differ in asymmetric institutions? That is, is there more or less punishment in asymmetric institutions?

To address the first question, Figure 2 compares the punishment of strong, symmetric and weak players as a function of the deviation of individual j's contribution from that of his peers. Figure 2 provides clear evidence that, as in previous studies, the greater the extent of free riding the greater punishment is. With respect to the punishment activity of strong and weak players, Figure 2 reveals that, for all levels of deviation, strong players are found to punish more than symmetric and weak players. However, Figure 2 cannot explain the cause of this difference. This could be due to the low punishment cost for strong players (Anderson and Putterman 2006; Carpenter 2007a; Egas and Riedl 2008; Nikiforakis and Normann 2008) but it could also be due to the very role of the strong player. For example, it is plausible that some weak players abstain from punishing knowing that the strong player will punish free riders. As a result, strong players might adopt (or might be pushed to adopt) the role of the cooperation enforcer and punish more than they otherwise would.

insert Figure 2 *about here*

Table 4 presents a series of regressions analyzing the determinants of punishment inflicted. Formally, the dependent variable in these regressions, is $p_{ij}e_i$. As before, we build our model in steps starting with our variables of interest and controlling for other factors that might be effecting behavior. The first regression shows that there is no difference in the punishment activity in symmetric and asymmetric institutions. The result is robust when we control for the average punishment effectiveness in regression (2) which also shows that punishment is higher when average effectiveness increases.

In regression (3), the negative coefficient of *Asymmetric* shows that weak players punish less than players in symmetric treatments. The positive coefficient of *Strong* shows that strong players punish more than players in symmetric treatments.

To test for the robustness of these findings and to account for the regularities in punishment behavior discussed at the beginning of the section, regressions (4) to (7) include the following independent variables: $Own\_Neg\_Diff_{j,t} \equiv \max\{0, c_{i,t} - c_{j,t}\}$, $Group\_Neg\_\ Diff_{j,t} \equiv \max\{0, (\sum_{h \neq j} c_{h,t})/(n-1) - c_{j,t}\}$, as well as $Own\_Pos\_Diff_{j,t} \equiv \max\{0, c_{j,t} - c_{i,t}\}$, and $Group\_Pos\_Diff_{j,t} \equiv \max\{0, c_{j,t} - (\sum_{h \neq j} c_{h,t})/(n-1)\}$ where $c_{j,t}$ is the contribution of individual j (that is, the target of the punishment) in period t and $c_{i,t}$ is the contribution of the punisher, individual i, in period t. Given the diminishing returns to punishment as the experiment approaches its end, the variable *Period* is also included in these regressions. The results show that deviating from the group average increases the extent of punishment ($Group\_Neg\_Diff_{j,t}$). Similarly, individuals on average punish more heavily group members who contribute less than they do ($Own\_Neg\_Diff_{j,t}$). The variable *Period* is found to be highly significant. Given that we control for the variance in contributions in regressions (4) to (7), the negative sign of *Period* suggests that punishment is to some extent used strategically to promote cooperation; as the experiment approaches the end, the future benefits of punishment decrease. As a result, so does punishment. Therefore, we conclude that we find in our dataset the punishment patterns observed in previous experiments.

In order to to understand the reason behind the higher punishment activity of strong players we need to disentangle the effect of being a strong player from that of having a low punishment cost and to evaluate their relative impact on punishment behavior. To this end, regressions (6) and (7) add *Punishment Effectiveness* (e_i) as an explanatory variable. *Of course,* e_i *has* *to be significant by construction. However, if the variable Strong remains significant in these regressions, it will imply that the mere role of a strong player induces individuals to purchase more points in order to punish others.*

The results of the regressions indicate that the higher punishment activity of strong players (and the lower activity of weak players) can be attributed to their higher punishment effectiveness (or alternatively their lower punishment cost). Comparing the estimates in regressions (4) and (5) and regressions (6) and (7) we see that the way we model asymmetric treatments has little effect on our results. Moreover, we see that there does not appear to be a systematic relation between punishment and the level of asymmetry.

Results 4 and 5 summarize the main findings from this section and provide answers to questions (i) and (ii) stated above.

Result 4: *Strong players punish more than weak players. The difference is due to the higher punishment effectiveness of strong players.*

Result 5: *The punishment inflicted does not differ between asymmetric and symmetric punishment institutions.*

insert Table 4 about here

Figure 2 and Table 4 overlook the fact that of the 3960 possible punishment cases (132 participants times 3 targets per period times 10 periods), punishment was carried out in only 613 cases. That is, the modal behavior in the second stage is not to punish. It seems possible, that the asymmetric institutions have an effect on punishment which is masked by studying the extent of punishment. For example, individuals who would normally abstain from punishing might be more willing to engage in punishment if they are assigned the role of the strong player. In other words, the asymmetric nature of the institutions might affect the decision whether to punish or not.

Figure 3 gives a first answer about whether this is the case in the experiment. As before, we plot the deviation of individuals j's contribution from that of his peers on the horizontal axis. On the vertical axis we plot the *likelihood* of j being punished by strong, symmetric and weak players. For all levels of deviation, strong players are found to be more likely to punish than weak players.[13] The difference exceeds 20 percent in some cases.

insert Figure 3 *about here*

To evaluate the significance of the difference in Figure 3, Table 5 presents a series of probit regressions. The dependent variable is a dummy taking the value of one if subject i punished subject j and zero otherwise. The logic behind the different regressions is the same as that in Table 4. The results from the regressions show that once we control for individual and group random effects the difference between strong and other players in the propensity to punish is not significant.[14] Therefore, we conclude that the role of a player does not influence significantly the decision to punish or not in our experiment. The decision to punish appears to be a negative function of the time that has elapsed and the extent of free riding.

insert Table 5 *about here*

Evolution of contributions

In order to understand better punishment behavior, we need to take a look at how individuals adjust their contributions across periods. As before, we will be looking for regularities observed in previous public-good experiments, while focusing our attention on two questions that have been previously not been investigated: (i) How do strong players adjust their behavior across periods? And (ii), is the way in which individuals adjust their contributions across periods different in symmetric and asymmetric institutions?

In order to provide answers for these questions, Table 6 presents regressions of the changes in individual contributions from period t to period $t+1$ (that is, $c_i^{t+1} - c_i^t$), on whether a subject was assigned the role of a strong player, the average effectiveness in the punishment institution ($Three$), the punishment inflicted to player i in period t, the average contribution of the other group members in period t, and a variable that controls for the number of periods left ($Period$). As we did before, we present regressions where we pool the data across asymmetric institutions, and regressions where we include dummies for each level of asymmetry.

Previous studies have shown that the way in which individuals respond to punishment depends on their relative position in the group, and, in particular, whether a subject was contributing more or less than his peers on average (e.g. Masclet et al., 2003). For this purpose, we run separate regressions for the individuals who contributed more than the average of the group in period t (henceforth, *high contributors*) and those who contributed less than the average of the group in period t (henceforth, *low contributors*).

insert Table 6 *about here*

Let us begin by addressing question (i). Table 6 shows that strong players do not adjust their contributions between periods differently to weak players. This is interesting given the reduced threat that they face. Regarding question (ii), we find that the way in which individuals adjust their contributions from one period to the other is not different in asymmetric and summetric institutions. However, regression (4) provides some evidence that there is a positive relationship between the level of asymmetry and the reduction in contribution in period $t + 1$ for high contributors. A possible explanation for this is that if a high contributor reduces her contribution she risks becoming a low contributor. In treatments with high levels of asymmetry, low contributors might be subject to (heavy) punishment from strong players.

The significant constant in regressions (1) and (3) in Table 6 shows that low contributors increase their contributions to the public account in the following period on average. In contrast, the significant constant in regressions (2) and (4) show that, as in previous studies, high contributors lower their contributions in the following period. These results explain why punishment reduces the variance in contributions within groups; if we compare the standard deviation of contributions in the first and the second half of the experiment (excluding the final period) we find that standard deviation is smaller in the second half of the experiment in 31 out of 33 groups. The reason behind the observed convergence in contribution levels is presumably due to the fact that contributing less than the group average triggers punishment, while contributing more than the average is individually costly.

Regressions (1) and (3) in Table 6 show that low contributors respond to punishment by increasing their contribution in period $t+1$, while they are not influenced by the contribution of the other group members in period t. For high contributors, there is a positive relation between the contribution of other group members in period t and the contribution of high contributors in period $t+1$, but punishment does not have an effect. The latter might be due to the few cases in which high contributors were punished. These results are comparable to those in previous studies (e.g. Carpenter, 2007a). High and low contributors become less responsive to punishment as the experiment approaches the end. We summarize:

Result 6: *The change in contributions across periods is similar in symmetric and asymmetric institutions. However, the higher the level of asymmetry, the lower the reduction in the contribution of high contributors in the following period.*

Result 7: *Strong and weak players adjust their contributions over time in a similar manner.*

Result 8: *High (low) contributors in period t tend to lower (increase) their contribution in period $t+1$. The increase in the contribution of low contributors becomes greater as punishment increases.*

Earnings

Earnings are a measure of the efficiency of a punishment institution. From equation (2), the earnings per period are 20 ECU per person in the subgame perfect Nash equilibrium (no punishments and no contributions). If each member contributes the whole endowment to the public account and abstains from punishments, each individual will earn 32 ECU. These are the benchmarks against which we measure the performance of asymmetric and symmetric punishment institutions.

The average earnings in each of the six treatments can be found in Table 2 (column 8). As indicated by equation (1), higher contributions (column 2) imply higher group earnings. However, earnings are reduced by the punishment inflicted to individuals (column 5), and also the cost of punishment paid by the punisher. Figure 4 complements Table 2 by illustrating the evolution of average earnings for each of the treatments separately.

insert Figure 4 *about here*

The following facts become apparent. First, earnings are somewhere between the Pareto-optimal earnings of 32 ECU and the earnings predicted by the subgame perfect Nash equilibrium of 20 ECU. Second, there appear to be no pronounced differences in earnings between asymmetric and symmetric institutions. This is not surprising given Results 1 and 5.

Columns 9 and 10 in Table 2 present the earnings of strong and weak players. Strong players have higher earnings in all treatments except "4_1.3": Given the similar amounts contributed by strong and weak players to the public account, the difference in earnings can be attributed to the greater punishment inflicted by strong players (see columns 6 and 7) and the lower cost of punishment for strong players.

Table 7 presents the results of a random-effects regression where the dependent variable is the earnings of individual i at the end of a period, π_i^2. Earnings are not significantly different in symmetric and asymmetric institutions. There also appears to be no systematic relation between earnings and the level of asymmetry as it can be seen in regression (5). Strong players have higher earnings than weak players and also players in symmetric treatments. Regressions (2) and (3) show that, on average, the level of average effectiveness does not have a significant effect on earnings. However, earnings increase over time in treatments with $\bar{e} = 3$ relative to earnings in treatments with $\bar{e} = 2$ as regressions (4) and (5) show. This can be attributed to the increasing contributions in treatments with $\bar{e} = 3$ and the falling expenditure on punishment. By contrast, while punishment also declines in treatments with $\bar{e} = 2$, contributions remain stable over time. We summarize:

Result 9: *Earnings are not significantly different in asymmetric and symmetric institutions.*

Result 10: *The average effectiveness of punishment does not have a significant impact on average earnings.*

Result 11: *Strong players have significantly higher earnings than weak players.*

insert Table 7 about here

4 Conclusion

Most naturally occuring interactions involve players that are asymmetric in their ability to enforce cooperation when free riding incentives exist. In this paper we have presented the results from a laboratory experiment to investigate the efficacy of an asymmetric punishment institution in fostering cooperation. As such, our study contributes to two strands of the literature on social dilemmas. The first of them examines whether groups can sustain cooperation when free riding incentives exist and there is no central authority to enforce cooperation. To this end, we find that the asymmetric punishment institution is as effective at sustaining cooperation and as efficient as the symmetric institution. In other words, asymmetries in punishment effectiveness neither promote cooperation nor do they constitute an obstacle to it. The second strand of the literature deals with the impact of asymmetries on cooperation (see Isaac et al. 1985; Cherry et al. 2005; Anderson et al. 2008; Fisher et al. 1995; Visser and Burns 2008). The effect of different types of asymmetries on cooperation has only mixed support for the conjecture that asymmetries hinder cooperation (Varughese and Ostrom 2001). Our paper provides further evidence against this conjecture by showing that heterogeneity in punishment effectiveness does not harm cooperation.

At the individual level we find that the behavioral regularities observed in symmetric punishment institutions are also found in asymmetric punishment institutions. Punishment is mostly aimed towards free riders. It increases with the extent of free riding and decreases with the cost of punishment. Interestingly, we also find that the percentage of punishments aimed towards cooperators is equally high in symmetric and asymmetric institutions even though there are strong players in the latter. Another interesting finding is that strong players do not exploit their privileged position and contribute similar amounts as weak players to the public account. This might be taken as further evidence for the importance of reciprocity in social dilemmas: strong players either do not wish to exploit their peers or understand that by exploiting them they will harm cooperation. Strong players, however, punish more than weak players. The increased punishment activity can be attributed to the reduced cost of punishing for strong players rather than strong players adopting the role of the enforcer. The upshot is that strong players benefit from the asymmetry and enjoy higher earnings than the weak players.

Our study should be seen as only a first step towards understanding how players that differ in their punishment effectiveness can cooperate in the presence of externalities without an external intervention. It would be interesting to examine the effect of asymmetric punishment institutions when punishment can lead to a cycle of punishment and counter-punishment (e.g. Nikiforakis and Engelmann 2008). One possibility is that the presence of strong players will reduce the cases of counter-punishment in fear of further reprisals. This could potentially lead to higher rates of cooperation and efficiency. It will be also interesting to see how players in public-good games would behave if they were given the opportunity to invest in improving their punishment effectiveness. The difference in earnings between strong and weak players could indicate that, given the option, weak players will have an incentive to invest a part of their endowment in enhancing their punishment effectiveness, and such incentives may give rise to an “arms race” for punishment effectiveness.

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Notes

[1]Similarly, Denant-Boemont, Masclet, and Noussair (2007), Nikiforakis (2008a) and Nikiforakis and Engelmann (2008) observe that, if counter-punishment is possible, individuals are less willing to punish free riders. This behavior reflects an increase in the expected cost of enforcing cooperation.

[2]Nikiforakis (2008b) finds that the efficacy of decentralized punishment also depends critically on the information available to subjects. If subjects receive information about individual earnings (rather than individual contributions), the threat of punishment cannot prevent the breakdown of cooperation.

[3]Of course, in field settings, players may well differ not only in their punishment effectiveness but also in their endowments, the returns from cooperation, and so on. In this paper, we focus on the impact of asymmetric punishment effectiveness on behavior while maintaining symmetry elsewhere.

[4]The fact that individuals punish even in one-shot interactions suggests that punishment has private returns. However, it is unclear whether these returns come from punishing—a type of cold prickle (Andreoni 1995)—or from knowing that the free rider has been punished, in which case punishment is a pure public good. On the notion of

punishment as a second-order public good, see Yamagishi (1986) and Heckathorn (1989).

[5]Neutral language was used throughout the instructions. Punishment points were termed as "points that reduce another player's income". The instructions can be downloaded at *www.economics. unimelb.edu.au/nnikiforakis/research.htm.*

[6]We decided not to use treatments with $\bar{e} = 1$ as this would require $e_w < 1$ in the asymmetric treatments. If $e_w < 1$, a punishment carried out by the weak players increases payoff inequality between the victim and the punisher. This would prevent a ceteris paribus comparison with treatments where $\bar{e} = 2$ and $\bar{e} = 3$ as in these cases punishment reduces inequality. Similarly, we chose not to study treatments with $e_w = 0$, (e.g., "8_0" or "12_0" such that $l = \infty$), as these treatments would not only risk losses for weak players but also differ along two dimensions relative to the other treatments: the level of asymmetry and the fact that weak players cannot punish at all.

[7]As one of our referees points out, while targeted counter-punishment is not possible in our experiment, it is possible that a free rider anticipating being be punished (for example, because he has contributed substantially less than his peers) uses pre-emptive "counter-punishment." Indeed, there is evidence that cooperators often get punished (e.g., Anderson and Putterman 2006; Cinyabuguma, Page, and Putterman 2006; Hermann, Thoeni, and Gächter 2008). Nikiforakis (2008a, p.102-103) reports evidence suggesting that punishment of cooperators might be more due to a dislike of cooperators and less due to pre-emptive "counter-punishment".

[8]The group had one subject contributing nothing for several periods and the other three subjects, who contributed the maximum amount, punished her harshly, causing the bankruptcy of the subject in period 5. In order for the experiment to continue we credited her account with £5. Whereas we did continue collecting data beyond that period, we decided not to include the group in the data analysis. In the first five periods, punishment in this group was six times higher than the treatment average which would cause a severe bias if we included this group in our statistical analysis. Moreover, a post-experimental questionnaire indicated that the behavior of the punished person was due to a misunderstanding.

[9]The observations for the symmetric treatments "2_2" and "3_3" are taken from Niki-

forakis and Normann (2008) who recruited individuals from the same subject pool and used the same experimental procedures.

[10]We ran alternative regressions in which the *strong* dummy is equal to one for strong players in the asymmetric treatments and for all players in the symmetric treatments. Results from these regressions did not differ qualitatively from the ones reported here.

[11]We also ran regressions (not reported in the paper) interacting *Strong* with *Period* to see whether strong players behave differently over time relative to the other players. The interaction term was always far from being significant.

[12]The estimation was made using Generalized Linear Latent and Mixed Models (Rabe-Hesketh and Skrondal 2005). The downside of using GLLAMM is that we cannot use a Tobit specification to account for the considerable concentration of observations with contributions of 20 ECU. If we use Tobit with random effects at either the individual or group level and compare the results with the respective linear regressions results are qualitatively similar and, most importantly, none of our main results is affected.

[13]An oddity in the literature on punishment in social dilemmas is the tendency to punish cooperators. Despite the presence of strong players in asymmetric institutions, the percentage of punishments aimed towards cooperators is equally high in symmetric and asymmetric institutions (18.1% and 17.6%, respectively).

[14]We also ran a regression where the omitted category was *Weak* (rather than Symmetric). The coefficient of *Strong* remained insignificant at all conventional levels showing that the difference in the propensity to punish between strong and weak players is not significant once we control for individual and group random effects.

Treatment	Average Effectiveness[a] ($\bar{e}$)	Effectiveness[b] of Strong (e_s)	Effectiveness[b] of Weak (e_w)	Asymmetry Level [c] (l)	No. of participants
"2_2"	2	2	2	1	24
"4_1.3"	2	4	1.3	3	20
"5_1"	2	5	1	5	24
"3_3"	3	3	3	1	24
"4_2.6"	3	4	2.6	1.5	20
"6_2"	3	6	2	3	20

[a] "Average Effectiveness" is the average punishment effectiveness of the group members, i.e. $(e_s + 3e_w)/4$.

[b] "Effectiveness" refers to the income reduction in ECU caused to the recipient by a single punishment point.

[c] "Asymmetry Level" is defined as e_s / e_w.

Table 1 - Experimental Design

Treatment	Contribution by All Players	Contribution by Strong Players	Contribution by Weak Players	Punishment[b] by All Players	Punishment[b] by Strong Players	Punishment[b] by Weak Players	Earnings of All Players	Earnings of Strong Players	Earnings of Weak Players
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
"2_2"	11.83	-	-	0.71	-	-	23.90	-	-
"4_1.3"	12.36	13.42	12.00	0.69	1.49	0.42	24.34	23.24	24.69
"5_1"	12.49	10.30	13.22	0.34	0.92	0.15	26.00	28.40	25.20
Asymmetric[a] ($\bar{e}$ =2)	12.43	11.72	12.67	0.50	1.18	0.27	25.24	26.05	24.97
"3_3"	15.87	-	-	0.84	-	-	26.15	-	-
"4_2.6"	15.92	15.64	16.01	0.65	0.80	0.61	26.91	27.85	26.56
"6_2"	15.17	14.86	15.27	1.07	2.80	0.49	24.99	26.17	24.59
Asymmetric[a] ($\bar{e}$ =3)	15.55	15.25	15.65	0.86	1.80	0.55	25.93	27.01	25.57

[a] "Asymmetric" pools data from the asymmetric treatments ignoring the level of asymmetry.

[b] "Punishment" refers to the earnings reduction caused by assigning points.

Table 2 - Summary Statistics (all entries are average ECU)

Dependent variable: Contribution of player $i,(c_i)$					
	(1)	(2)	(3)	(4)	(5)
Asymmetric	0.06	0.15	0.32	0.32	
	(1.69)	(1.57)	(1.58)	(1.58)	
Three		3.45**	3.45**	0.96	0.99
		(1.51)	(1.51)	(1.57)	(1.89)
Strong			-0.68	-0.68	-0.68
			(0.61)	(0.61)	(0.61)
Period				0.03	0.03
				(0.05)	(0.05)
Period*Three				0.45***	0.45***
				(0.08)	(0.08)
Asymmetry Level: 1.5					0.50
					(2.49)
Asymmetry Level: 3					0.09
					(1.86)
Asymmetry Level: 5					0.55
					(2.36)
Constant	13.85***	12.13***	12.13***	11.97***	11.96***
	(1.35)	(1.46)	(1.46)	(1.49)	(1.58)
Observations	1320	1320	1320	1320	1320
Subject Variance	4.31	4.31	4.24	4.34	4.34
	[0.86]	[0.86]	[0.85]	[0.85]	[0.85]
Group Variance	20.22	17.25	17.27	17.27	17.24
	[5.35]	[4.62]	[4.62]	[4.62]	[4.61]
Log Likelihood	-3870.96	-3868.53	-3867.91	-3830.77	-3830.75

Linear regression, Estimation was done in STATA 10.1 using GLLAMM with random effects at the individual and group level, and adaptive quadrature, Standard errors are in parentheses, Squared brackets include the covariance of the random effects, *** Indicates significance at 1% level, ** Indicates significance at 5% level.

Table 3 – Determinants of contributions

Dependent variable: Punishment inflicted on player j	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Asymmetric	-0.10	-0.10	-0.37**	-0.38**		0.06	
	(0.17)	(0.16)	(0.17)	(0.16)		(0.20)	
Three		0.28*	0.28*	0.44***	0.45***	-0.14	-0.12
		(0.15)	(0.15)	(0.14)	(0.16)	(0.22)	(0.23)
Strong			1.07***	1.15***	1.19***	-0.61	-0.63
			(0.19)	(0.19)	(0.18)	(0.55)	(0.54)
Period			-0.08***	-0.05***	-0.05***	-0.05***	-0.05***
			(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Group_Neg_Diff$_{j,t}$				0.20***	0.20***	0.20***	0.20***
				(0.02)	(0.02)	(0.02)	(0.02)
Group_Pos_Diff$_{j,t}$				0.02	0.02	0.02	0.02
				(0.02)	(0.02)	(0.02)	(0.02)
Own_Pos_Diff$_{j,t}$				-0.00	-0.00	-0.01	-0.00
				(0.01)	(0.01)	(0.01)	(0.01)
Own_Neg_Diff$_{j,t}$				0.14***	0.14***	0.14***	0.14***
				(0.02)	(0.02)	(0.02)	(0.02)
Asymmetry Level: 1.5					-0.66***		-0.15
					(0.22)		(0.27)
Asymmetry Level: 3					-0.17		0.29
					(0.17)		(0.22)
Asymmetry Level: 5					-0.54**		-0.07
					(0.21)		(0.24)
Effectiveness						0.58***	0.58***
						(0.17)	(0.17)
Constant	0.78***	0.64***	1.09***	0.20	0.19	-0.94**	-0.97**
	(0.13)	(0.15)	(0.16)	(0.16)	(0.16)	(0.37)	(0.38)
Observations	3960	3960	3960	3960	3960	3960	3960
Subject Variance	0.55	0.55	0.37	0.42	0.43	0.39	0.37
	[0.10]	[0.10]	[0.08]	[0.07]	[0.07]	[0.07]	[0.06]
Group Variance	0.03	0.02	0.06	0.02	0.00	0.03	0.01
	[0.06]	[0.05]	[0.05]	[0.04]	[0.00]	[0.04]	[0.03]
Log Likelihood	-8931.54	-8929.98	-8893.30	-8406.73	-8403.57	-8400.97	-8398.33

Linear regression, Estimation was done in STATA 10.1 using GLLAMM with random effects at the individual and group level, and adaptive quadrature, Standard errors are in parentheses, Squared brackets include the covariance of the random effects, *** Indicates significance at 1% level, ** Indicates significance at 5% level, * Indicates significance at 10% level.

Table 4 – Determinants of punishment

Dependent variable: Likelihood of punishing player j	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Asymmetric	-0.01	-0.01	-0.02	-0.02		0.01	
	(0.04)	(0.04)	(0.04)	(0.03)		(0.04)	
Three		0.02	0.02	0.03	0.03	-0.01	-0.02
		(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)
Strong			0.03	0.04	0.04	-0.09	-0.09
			(0.03)	(0.03)	(0.03)	(0.09)	(0.09)
Period			-0.02***	-0.01***	-0.01***	-0.01***	-0.01***
			(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$Group\_Neg\_Diff_{j,t}$				0.03***	0.03***	0.03***	0.03***
				(0.00)	(0.00)	(0.00)	(0.00)
$Group\_Pos\_Diff_{j,t}$				-0.01***	-0.01***	-0.01***	-0.01***
				(0.00)	(0.00)	(0.00)	(0.00)
$Own\_Pos\_Diff_{j,t}$				0.00	0.00	0.00	0.00
				(0.00)	(0.00)	(0.00)	(0.00)
$Own\_Neg\_Diff_{j,t}$				0.01***	0.01***	0.01***	0.01***
				(0.00)	(0.00)	(0.00)	(0.00)
Asymmetry Level: 1.5					-0.04		-0.01
					(0.04)		(0.05)
Asymmetry Level: 3					0.02		0.05
					(0.03)		(0.04)
Asymmetry Level: 5					-0.06		-0.03
					(0.04)		(0.04)
Effectiveness						0.04	0.04
						(0.03)	(0.03)
Constant	0.16***	0.15***	0.24***	0.14***	0.14***	0.05	0.05
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.06)	(0.06)
Observations	3960	3960	3960	3960	3960	3960	3960
Subject Variance	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Group Variance	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Log Likelihood	-1404.77	-1404.67	-1365.01	-886.60	-884.30	-885.36	-883.07

Probit regression, Estimation was done in STATA 10.1 using GLLAMM with random effects at the individual and group level, and adaptive quadrature, Standard errors are in parentheses, Squared brackets include the covariance of the random effects, *** Indicates significance at 1% level.

Table 5 – Likelihood of punishing player j

Dependent variable: Change in contribution between periods t and t+1, ($c_i^{t+1} - c_i^t$)				
	(1)	(2)	(3)	(4)
Asymmetric	0.34	0.35		
	(0.45)	(0.41)		
Three	0.25	0.22	0.08	0.74
	(0.43)	(0.39)	(0.52)	(0.45)
Strong	0.11	0.23	0.10	0.42
	(0.56)	(0.55)	(0.58)	(0.56)
Punishment inflicted to i in t	0.30***	0.08	0.30***	0.08
	(0.03)	(0.08)	(0.03)	(0.08)
Average contribution of others in t	-0.00	0.09**	-0.00	0.09**
	(0.04)	(0.04)	(0.04)	(0.04)
Period	-0.31***	-0.15**	-0.31***	-0.15**
	(0.06)	(0.07)	(0.06)	(0.07)
Asymmetry Level: 1.5			0.75	-0.43
			(0.71)	(0.65)
Asymmetry Level: 3			0.23	0.15
			(0.51)	(0.46)
Asymmetry Level: 5			0.22	1.08**
			(0.67)	(0.53)
Constant	2.02***	-2.07***	2.08***	-2.25***
	(0.69)	(0.59)	(0.70)	(0.57)
Observations	434	491	434	491
Subject Variance	1.40	0.00	1.41	0.00
	[0.67]	[0.00]	[0.67]	[0.00]
Group Variance	0.00	0.10	0.00	0.00
	[0.00]	[0.29]	[0.00]	[0.02]
Log Likelihood	-1141.20	-1361.91	-1140.93	-1359.89

Linear regression, Regressions (1) and (3) are run for subjects who in period t contributed less than the group average, Regressions (2) and (4) are run for subjects who in period t contributed more than the group average, Estimation was done in STATA 10.1 using GLLAMM with random effects at the individual and group level, and adaptive quadrature, Standard errors are in parentheses, Squared brackets include the covariance of the random effects, *** Indicates significance at 1% level, ** Indicates significance at 5% level.

Table 6 – Evolution of contributions

Dependent variable: Earnings of player $i, (\pi_i^2)$					
	(1)	(2)	(3)	(4)	(5)
Asymmetric	0.54	0.57	0.26	0.26	
	(1.28)	(1.26)	(1.27)	(1.27)	
Three		1.26	1.26	0.01	0.27
		(1.22)	(1.22)	(1.32)	(1.55)
Strong			1.25**	1.25**	1.25**
			(0.51)	(0.51)	(0.51)
Period				0.37***	0.37***
				(0.07)	(0.07)
Period*Three				0.23**	0.23**
				(0.10)	(0.10)
Asymmetry Level: 1.5					0.78
					(1.96)
Asymmetry Level: 3					-0.68
					(1.47)
Asymmetry Level: 5					1.43
					(1.86)
Constant	25.03***	24.40***	24.40***	22.35***	22.22***
	(1.02)	(1.18)	(1.18)	(1.23)	(1.28)
Observations	1320	1320	1320	1320	1320
Subject Variance	1.69	1.69	1.44	1.67	1.67
	[0.63]	[0.63]	[0.60]	[0.60]	[0.60]
Group Variance	11.50	11.10	11.16	11.16	10.62
	[3.10]	[3.01]	[3.01]	[3.01]	[2.87]
Log Likelihood	-4120.66	-4120.13	-4117.24	-4065.55	-4065.80

Linear regression, Estimation was done in STATA 10.1 using GLLAMM with random effects at the individual and group level, and adaptive quadrature, Standard errors are in parentheses, Squared brackets include the covariance of the random effects, *** Indicates significance at 1% level, ** Indicates significance at 5% level.

Table 7 – Determinants of earnings

Figure 1: Evolution of Contributions

Figure 2: Punishment as a function of deviation from the contribution of peers

Figure 3: Punishment likelihood as a function of deviation from the contribution of peers

Figure 4: Evolution of Earnings

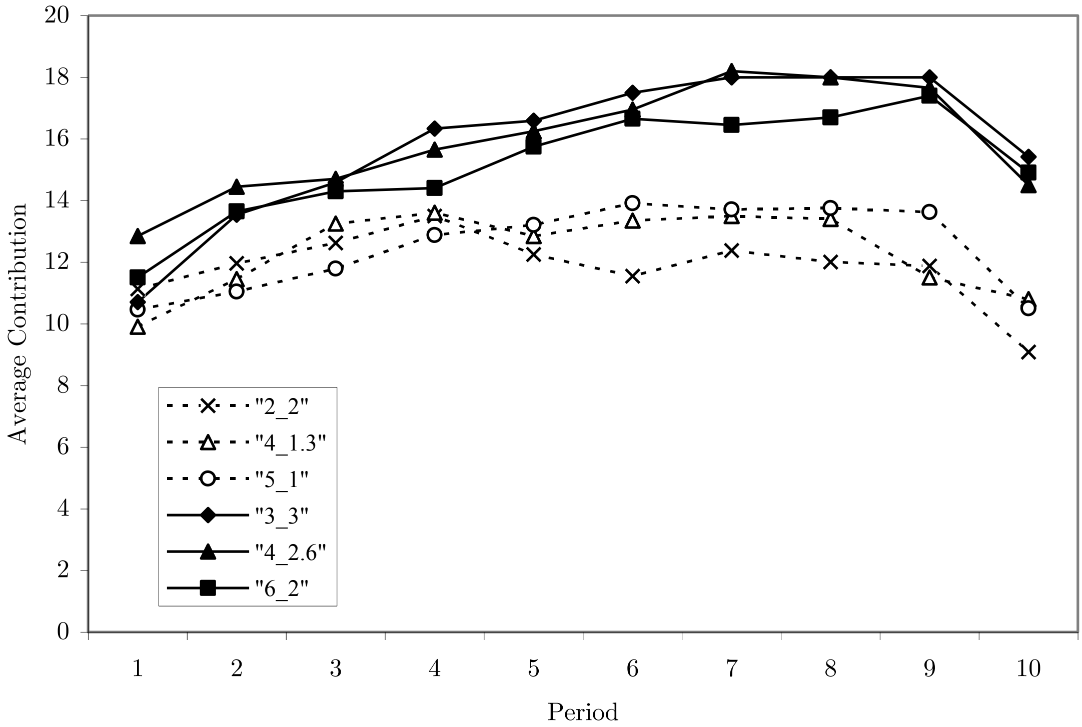
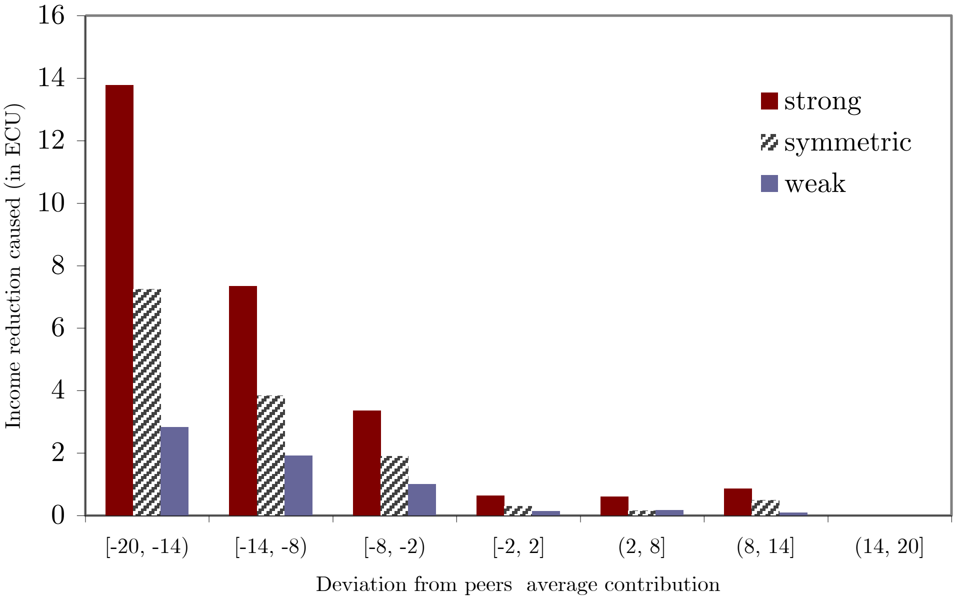


Figure 1



16
14
12
10
8
6
4
2
0
Income reduction caused (in ECU)
strong
symmetric
weak
[-20, -14)
[-14, -8)
[-8, -2)
[-2, 2]
(2, 8]
(8, 14]
(14, 20]
Deviation from peers average contribution

Figure 2

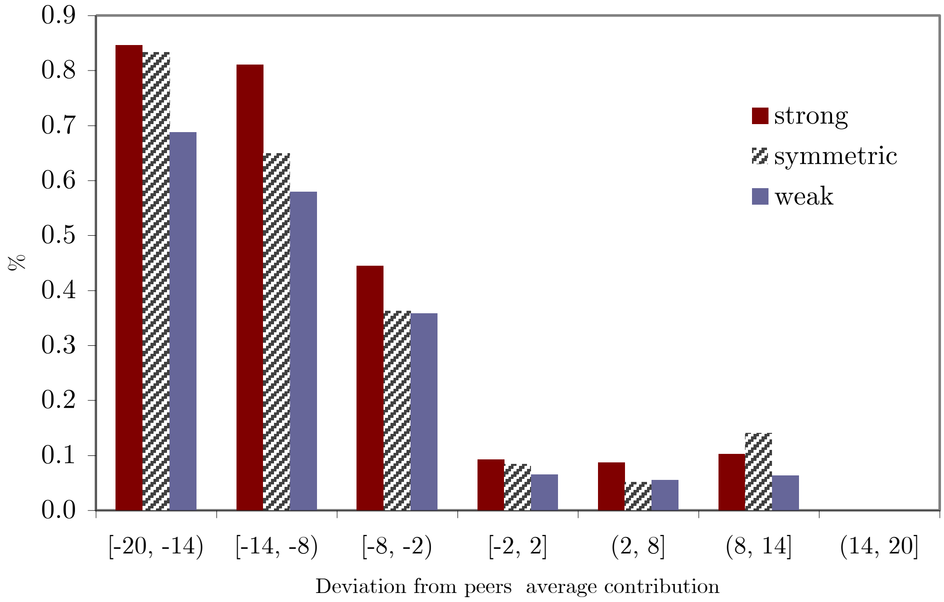

0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
%
strong
symmetric
weak
[-20, -14)
[-14, -8)
[-8, -2)
[-2, 2]
(2, 8]
(8, 14]
(14, 20]
Deviation from peers average contribution

Figure 3

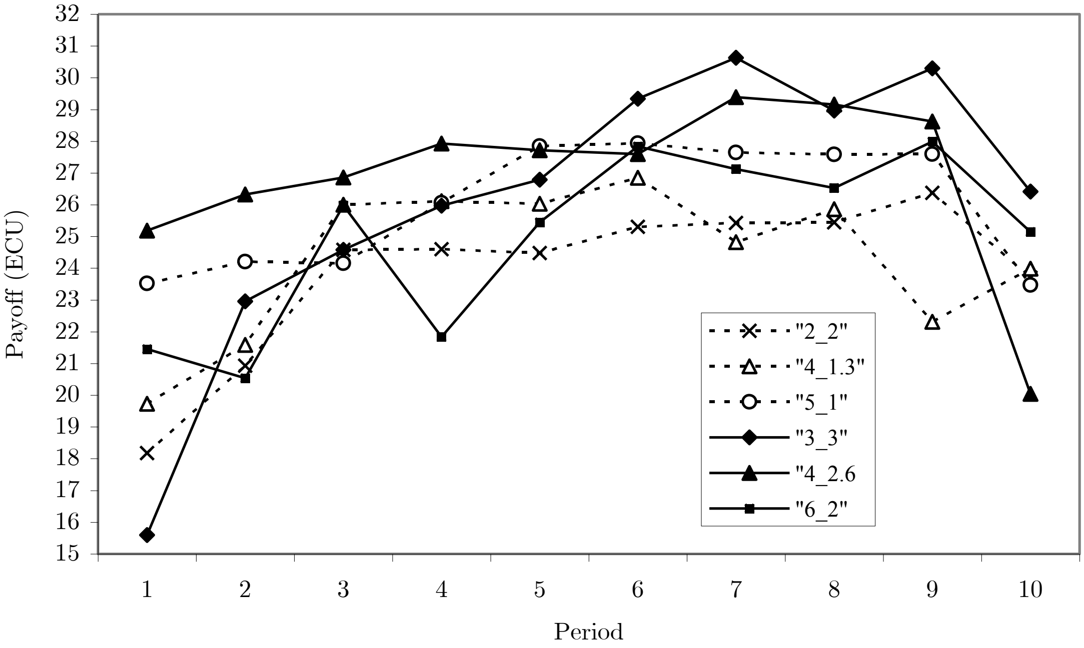

32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
Payoff (ECU)
1
2
3
4
5
6
7
8
9
10
Period
"2_2"
"4_1.3"
"5_1"
"3_3"
"4_2.6
"6_2"

Figure 4