

Do Non-strategic Sanctions Obey the Law of Demand?
The Demand for Punishment in the Voluntary Contribution Mechanism *

Christopher M. Anderson
Department of Environmental and Natural Resource Economics
University of Rhode Island

Louis Putterman
Department of Economics
Brown University

Abstract

The prospect of receiving a monetary sanction for free riding has been shown to increase contributions to public goods. We ask whether the impulse to punish is unresponsive to the cost to the punisher, or whether, like other preferences, it interacts with prices to generate a conventional demand curve. We test the price responsiveness of the demand for punishment by randomly varying the cost of reducing the earnings of other group members following laboratory voluntary contribution decisions. In our design, new groups are formed after each interaction and no subject faces any other more than once, so there is no strategic reason to punish. We nonetheless find significant levels of punishment, and we learn that both price and the extent to which the recipient's contribution is below the group mean are significant determinants of the quantity of punishment demanded. Moreover, punishment is mainly directed at free riders even when it costs nothing to the punisher. However, the propensity to punish egregious free-riding varies considerably within our subject pool, from non-punishers to aggressive punishers.

JEL numbers: C91, H41, D71

Keywords: Public goods, collective action, experiment, punishment, demand.

* The research reported here was funded by National Science Foundation grant SES-0001769. We thank the Rhode Island Agricultural Experiment Station for support of the Policy Simulation Laboratory. We also thank Toby Page for suggestions regarding the design of the experiment, and Dmitri Lemmerman for adapting the computer software used to conduct it.

1. Introduction

The voluntary contribution mechanism is a linear n -person dilemma game that experimentalists use to study, in the laboratory, problems of collective action such as the voluntary provision of a public good. Subjects are put in groups and asked to divide endowments between group and personal accounts. Although the socially efficient outcome is attained when all contribute their full endowment to the group account, individuals maximize their payoff by retaining their endowments, regardless of what others do. In trials, subjects typically contribute an average of over 50% of their endowments in one-shot play or in the initial round of repeated play. In repeated play, contributions then tend to decay toward zero (Ledyard, 1995; Davis and Holt, 1993).

Recently, a number of experiments have been inspired by Fehr and Gächter's (2000a) demonstration that this decay in contributions can be mitigated or reversed by allowing subjects to direct costly monetary punishments at other group members after learning of their contributions. The qualitative findings that many subjects engage in costly punishment, that it is aimed mainly at low contributors, and that contributions accordingly stabilize or rise, has been confirmed by a number of studies including Bochet, Page and Putterman (2002), Carpenter (2000), Falk, Fehr and Fischbacher (2001), Fehr and Gächter (2002), Masclet, Noussair, Tucker and Villeval (2003), Page, Putterman and Unel (2003), and Sefton, Shupp and Walker (2002). Fehr and Gächter (2000b) interpret the evidence as suggesting that substantial numbers of individuals have a propensity to punish free riding, perhaps because it violates a norm of, or a predisposition towards, reciprocity.

While most of these experimental designs make it possible for subjects to interact more than once, so punishment could be motivated by the desire to induce higher contributions in later periods, there is evidence that at least some costly punishment is nonstrategic. For example, many subjects pay to punish free riders in the last period of finitely repeated interactions. And there is considerable punishment in the perfect stranger treatment of Fehr and Gächter (2000a) in which no subject encounters another more than once.

Two characterizations of this nonstrategic behavior have been offered. When A contributes more to the public good than does B, A earns less than B in the contribution stage of their interaction. Given this, it might appear to be irrational for A to further lower his earnings to retaliate against B, if they will not be grouped for future play. According to the first characterization, A may feel so much anger at B that A seizes the opportunity to punish B without pausing to weigh the consequences. Punishment, on this account, is an act that is not amenable to economic analysis, although it needs to be factored into that analysis to adequately predict the outcomes of certain types of interaction. An alternative characterization is that A's desire to punish B is a preference similar to others. Imposing a loss on B will give A satisfaction, and although the feeling of satisfaction is not itself rational, this is equally true of other tastes, and, as with other tastes, the degree of satisfaction anticipated can be reasonably weighed against the cost of acquiring it, to determine the amount that should be purchased to maximize subjective well-being. On this second account, there would be a downward sloping demand curve for punishing free riders just as there is for consuming boysenberry jam or hot fudge sundaes. The desire to punish free riding can then be thought of as a conventional preference.

We report the results of an experiment to test which characterization is more accurate. To study the demand for punishment, we asked subjects to make contribution and punishment decisions at several prices. To rule out a strategic incentive to punish, we used a perfect stranger design. Our experiment provides further evidence that nonstrategic punishment of free riding is common, and it demonstrates that the demand for punishment does obey the Law of Demand. It also sheds light on some related issues. Based on our results, we extend to the case of zero cost punishment the finding that individuals use punishment mainly to reduce the earnings of free riders. We demonstrate a partial violation of the Fehr-Schmidt (1999) inequality-aversion explanation of punishment by showing that punishment occurs even at higher cost to the punisher than to the target. We also detect considerable differences among subjects in the propensity to punish free riders.

2. Experimental Design

To test the extent to which monetary factors are considered in determining the quantity of punishment demanded, our experimental design places subjects in a series of five one-shot

voluntary contribution games with two stages. In the first stage, subjects are anonymously grouped and choose their level of contribution to the public good. In the second stage, each subject learns the contribution levels of other members of her group and her price for each dollar she chooses to reduce the earnings of other group members. Based on this information, each subject chooses the amount she wishes to reduce each other group member's earnings. Her own earnings are reduced by the cost of the reductions she purchases, and by the total amount of reductions purchased for her by the other group members. After each learns her payoff, the subject is assigned to a completely new group, containing no subject she faced in any previous round.

After extra subjects were dismissed (and paid their \$5 appearance fee), 18 subjects were seated in the laboratory, each at a private computer. The experiment moderator read the instructions (in Appendix A) out loud as subjects read along. The instructions were divided into two parts, one for each stage of the game. After each part, subjects calculated the payoffs given hypothetical practice problems to ensure they understood how decisions mapped to payoffs.

The first stage of the game is a standard voluntary contribution mechanism. Subjects were endowed ten experimental dollars at the beginning of each period. In the first stage, each makes an allocation, x_i , to her group's account, and $(10 - x_i)$ to her own personal account. For each member of the three member group, the group account returns $0.6 \sum_{i=1}^3 x_i$, or 0.6 times the total assigned to the group account. Subjects earned this fraction of the group account allocation regardless of how much they themselves contributed to the group account. Therefore, each subject's earnings from the first stage of the game is $\pi_i = (10 - x_i) + 0.6 \sum_{i=1}^3 x_i$. Given this payoff function, it is dominant strategy to set $x_i = 0$ since the private return on a dollar in the personal account is one dollar, but only sixty cents in the group account. Subjects indicated their decisions by typing an integer allocation to the group, x_i into an input box in the experimental software interface. Once all group members made their first stage allocation, the second stage of the game began with each subject being shown how much each other member of the group allocated to the group account. Each was also shown, her (but not other members') private per-unit punishment cost, p_i . In each period, p_i could take on one of five possible values. The five values were 0, 30, 60, 90 and 120 cents in treatment 1; 0, 5, 10, 20 and 30 cents in treatment 2;

and 30, 40, 50, 60 and 70 cents in treatment 3. Each subject faced each of the five values in a random order throughout the five periods, and subjects' orderings were determined independently, so subjects could infer nothing about the prices of others in their group based on p_i . Subjects were told only that their p_i was chosen randomly from among the five values, and that other subjects' prices were equally likely to be each of the five values in any given period. We assigned punishment costs in this way so that those costs could affect the choice of punishment only directly, and not also by influencing the choice of contribution in a given period. Three different sets of punishment costs were used to see whether the same or different qualitative results would hold over different ranges of values.

With the contribution and price information presented, subjects made two decisions, one level of punishment (possibly zero) for each of the other two members of their group. Each subject i indicated her a choice by typing an integer number of units of punishment, r_{ij} , in to a box for each other subject, j , in the group. Subjects may choose any number of punishment units so long as (a) the punishment given to any one subject is not greater than that subject's earnings for the period and (b) the total cost of the units purchased does not exceed π_i , the amount earned by the punisher in the first stage of the game in the same period.

Once all group members make their second stage punishment decisions, each subject learns the aggregate amount he or she was punished by other members of the group, and his or her final earnings for the period. Subject i 's earnings for the period are

$$\text{Earnings}_i = (10 - x_i) + 0.6 \sum_{j=1}^3 x_j - p_i \sum_{j \neq i} r_{ij} - \sum_{j \neq i} r_{ji}$$

The first two terms represent i 's earnings in the voluntary contribution mechanism stage of the game. The third term is the amount i spent punishing other members of her group. The fourth term is the amount i was punished by the other members of her group. Money that is “punished away” is returned to the research fund.¹ If this equation yields a negative number, i 's earnings for the period are set to zero.

¹ The structure of the contribution and punishment stages is identical to that used in Bochet *et al.* (2002) and Page *et al.* (2002) except that in those experiments, groups consist of four subjects, the MPCR is set to 0.4 rather than 0.6,

Subjects participated in this two-stage game five times. After each game, subjects were reassigned to completely new groups, such that they never faced the same subject twice.² This matching protocol ensures there is no strategic benefit to punishment: altering others' behavior will not benefit a subject, for she will never encounter that opponent again, with certainty.³

After the five rounds, subjects answered a debriefing questionnaire with basic demographic information and a narrative description of their strategy in the game. Subjects' earnings were converted from experimental dollars to U.S. dollars at a rate of 1 experimental dollar = \$0.25, \$5 was added as a flat fee for participation, and subjects were paid privately. Earnings averaged \$20.61, with a standard deviation of \$3.58, for sessions which lasted about 75 minutes.

Three sessions of each treatment were run in the Policy Simulation Laboratory at the University of Rhode Island, and one session of each treatment was run in a computer classroom at Brown University. Subjects were recruited from e-mail lists of students who had expressed interest in participating in experiments, from courses, and from on-campus advertisements. Subjects did not necessarily have any training in economics, and, with the exception of a few subjects at Brown, none had experience with similar experiments.⁴

and the punishment cost is uniformly 0.25. Having a fixed cost of taking one monetary unit from the person targeted differs from Fehr and Gächter (2000), in which there is a rising marginal cost of deducting fixed *fractions* of the targeted person's earnings. A fixed cost per monetary unit deducted is used in Fehr and Gächter (2002).

² Five is the maximum number of ways to allocate 18 subjects into groups of three such that no subject is ever grouped with any other subject more than once.

³ During periods 1 through 4, one cannot rule out altruistic motivation to help other participants in later periods. However, the coefficient on a round 5 indicator variable in random effects tobit regression, like that in Table 2, is insignificant, indicating that last-round punishment is indistinct from the first four rounds, controlling for punishment price and target contributions.

⁴ The few exceptions, at Brown, had participated in 10 or 20 period partner-group experiments with a single fixed cost of punishment.

3. Results

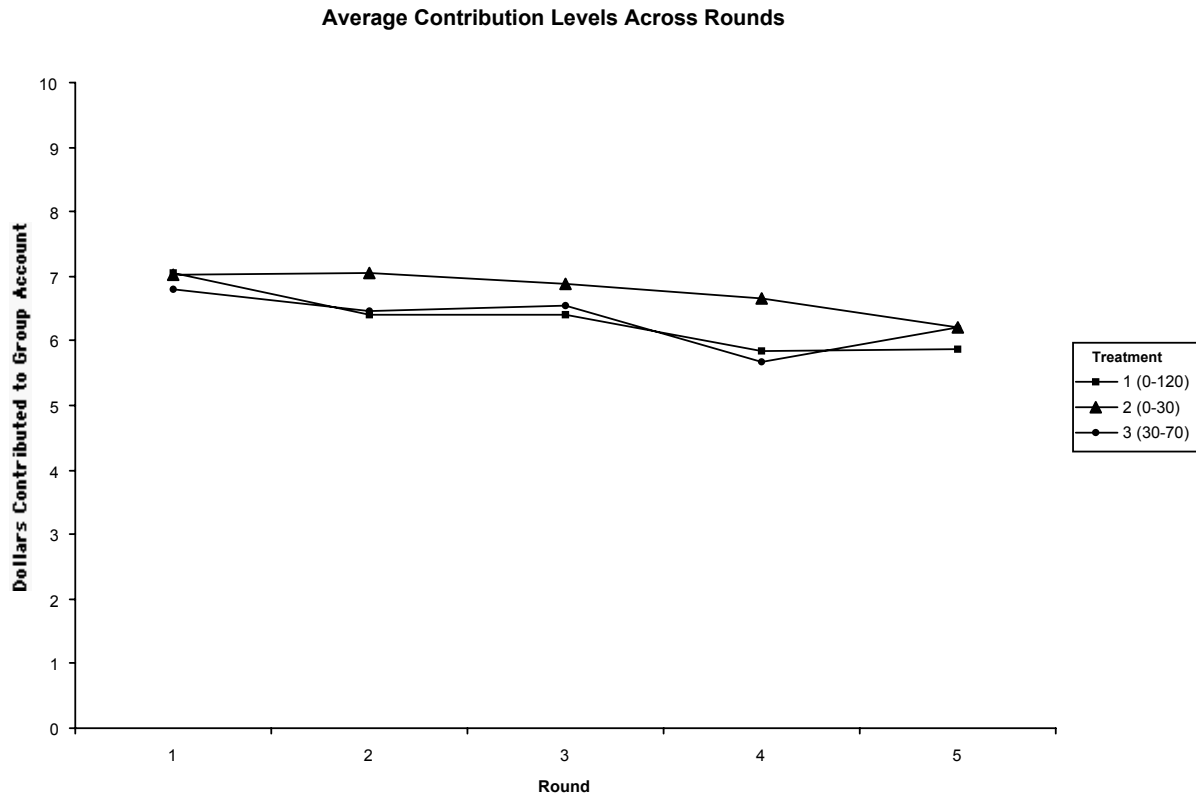


Figure 1: Average contributions to the group account in each round, by treatment

Each of our 216 subjects made five contribution decisions, for a total of 1080 observations. The average contribution in each round is shown in Figure 1, broken down by treatment. Initial contributions average about 70% in all treatments, and, consistent with previous experiments in VCM with punishment, decrease only slightly with repetition, much less dramatically than in voluntary contribution mechanisms without punishment.

In each period, each subject made two punishment purchase decisions, one for each other member of the group, for a total of 2160 observations, 671 (31.1%) of which represented a positive amount of punishment. The effect of punishment price and treatment on the level of punishment can be seen in Figure 2, in which each bar indicates the average amount of punishment each person purchased for each other member of the group in each price treatment condition. Across treatments, there is a trend toward smaller quantities of punishment at higher prices. At a price of zero, an average of over three units of punishment are purchased for each

other group member. For low, positive prices this demand is just under two units (1.95 at five cents, 1.62 at ten cents). As the price rises to 60% of the value of the punishment purchased, demand falls to 0.49 units per period. At the highest price, \$1.20 or 120% of cost to the subject targeted, demand is only 0.38 units for each other group member.

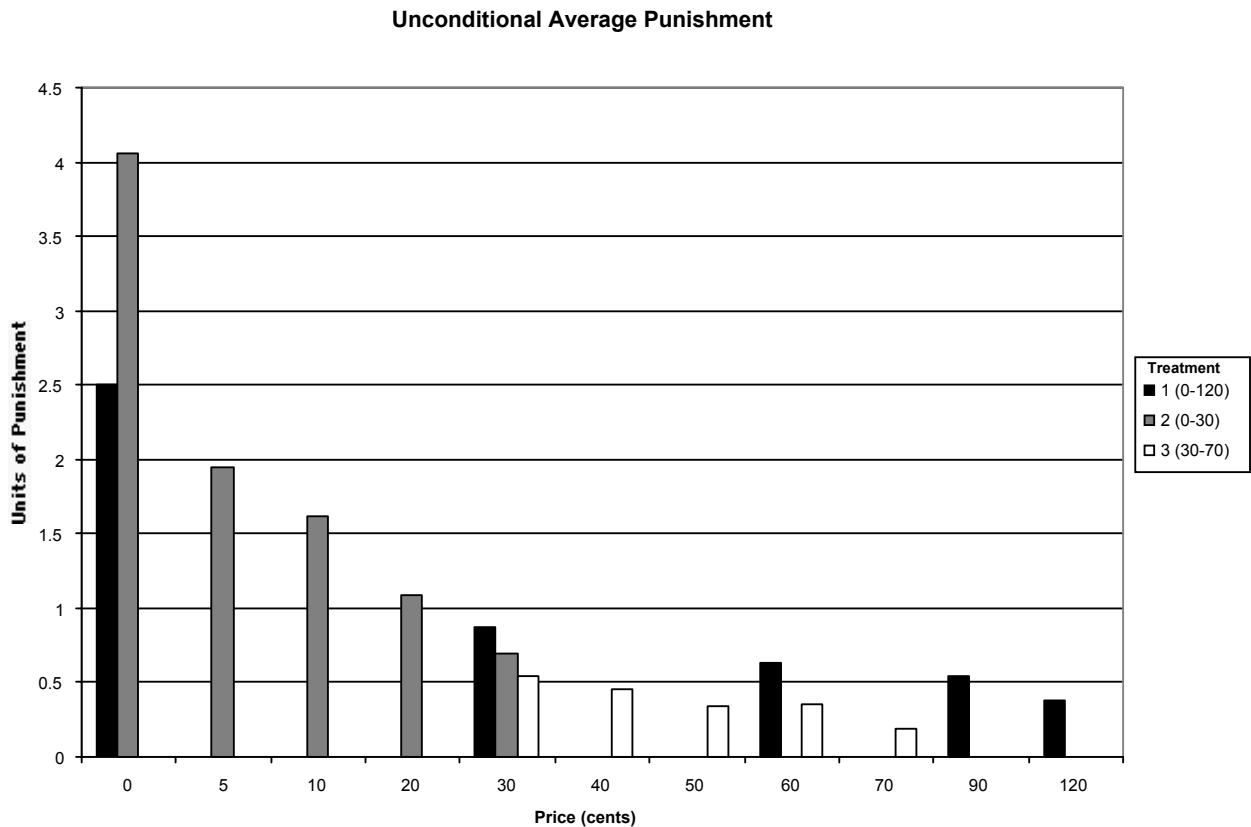


Figure 2: Average number of units of punishment demanded at each punishment price, by treatment

The decrease in punishment across the full range of prices is also apparent on a treatment-by-treatment basis. Treatment 1, represented by black bars at prices 0, 30, 60, 90 and 120 cents shows strong decreasing trend, with the quantity of punishment demanded at each price lower than at the next higher price. Treatment 2, represented by grey bars at prices 0, 5, 10, 20 and 30 cents, shows a similar pattern of decreasing quantity demanded at each price. Treatment 3, represented by white bars at prices 30, 40, 50, 60 and 70 cents, does not exhibit the same strong monotonicity as there is no decrease between prices of 50 and 60 cents, but there is still an overall trend of reduction.

The remainder of the results section attempts to establish the visibly apparent features of the data statistically. The major result, result 2, establishes the statistical link between price and the quantity of punishment demanded. Result 3 shows that, in addition to price, punishment demanded is increased by the target's level of free riding, a regularity result 4 extends to decisions with zero punishment price, and result 5 shows that punishment occurs even when the cost to the punisher exceeds that to the person punished. That the demand for punishment varies considerably through the population is established in result 6 by allowing for different "types" of people. Result 7 relates these punishment patterns to earnings and efficiency differences across treatments.

Result 1. Subjects made use of the punishment opportunity, even when it was costly.

In 2160 punishment purchase observations, 671 (31.1%) represented a positive amount of punishment by 161 different subjects, 74.5% of the subject pool as a whole. In the 1872 observations in which punishment was costly, 147 different subjects (68.1% of the pool) paid from their own earnings to reduce others' earnings 510 times (27.2% of overall opportunities). Therefore, despite a design which ensures that there is no strategic benefit to punishment, positive levels of punishment are still observed at positive prices, replicating previous experimental results.

Having established that punishment occurs, our subsequent investigation focuses on factors which affect, and motivations for, punishment.

Result 2: The level of punishment is decreasing in price, even after controlling for the significant effect of the level of free-riding.

Figure 2 illustrates that the demand for punishment is responsive to price. To establish the statistical significance of this result and investigate related questions, we turn to multivariate analysis. We begin by estimating a regression equation in which the amount of punishment that a subject i gave to a subject j is the dependent variable, and the price to the punisher per unit of punishment is an explanatory variable. Another likely explanatory variable whose effect is not

apparent from the figure is the contribution level of the recipient of the punishment. Fehr and Gächter (2000a) and others cited above found that the potential recipient's deviation from the average of the other group members significantly affected the punishment level. Following Fehr and Gächter, who found a kinked relationship between the recipient's contribution deviation and the amount of punishment received, we enter as separate independent variables the absolute negative deviation from the average contributed by other group members, and the absolute positive deviation from the average contributed by other group members. The first (second) variable takes the value zero if the subject contributed more (less) than the others' average. Because no-cost punishment may behave differently from costly punishment, we include a dummy variable for punishment at zero price. To test whether no-cost punishment is influenced by free riding, we also include an interaction term between the latter dummy and the absolute negative deviation. Random effects tobit regression estimates for the combined sample and for the separate samples of each price treatment are shown in Table 1.⁵

Table 1 shows that the variable of primary interest, Price, has a significantly negative relationship with the number of units of punishment given by i to j , consistent with the Law of Demand. The price variable is not only statistically significant, but also extremely economically significant. For example, an increase in price from forty cents to ninety cents will decrease the punishment expected by a target who has undercontributed by two dollars from 0.40 units to 0.20 units. At an undercontribution of \$5.20, one unit of punishment is expected at a price of 5 cents, but the expected punishment drops to half that at a price of 60 cents.

⁵ The tobit specification is used because the dependent variable, the amount of punishment, is censored at zero. Random effects are included in the model because our data includes ten observations on each of 216 subjects; within subject, these observations are not independent. Result 6 attempts to explicitly model some of the heterogeneity in this panel dataset.

Table 1: Determinants of Punishment

Independent Variables	Units of Punishment R.E. tobit
Average Constant ⁶	-3.242 NA
Absolute Negative Deviation	0.532*** (0.059)
Absolute Positive Deviation	0.078 (0.072)
Price of Punishment	-0.027*** (0.005)
Price=0 Dummy	2.547*** (0.414)
Price=0 × Abs. Neg. Dev.	0.435*** (0.125)
σ_ε	3.191 LL=-2456.79 Wald(16)=422.00***

Random effects tobit model of the determinants of purchasing punishment. Standard errors are in parentheses. Session-specific constants are averaged in the Average Constant. Significance levels noted at * (p<0.10), ** (p<0.05) and *** (p<0.01).

When the price falls to zero, the expected punishment increases by about 0.78 units when the recipient's contribution is the same as the average; increases are larger at higher levels of free riding.

Result 3: The demand for punishment is increasing in the recipient's level of free riding.

Figure 3 shows the average level of punishment associated with each level of negative and positive deviation of own contribution from the average by others in one's group. The figure suggests that punishment increases as contribution falls further below the average by others in one's group.

⁶ A separate constant is estimated for each session. The reported value is the average of these constants. The significance of the session constants varies widely, but all are estimated to be negative.

Average Punishment by Level of Free Riding

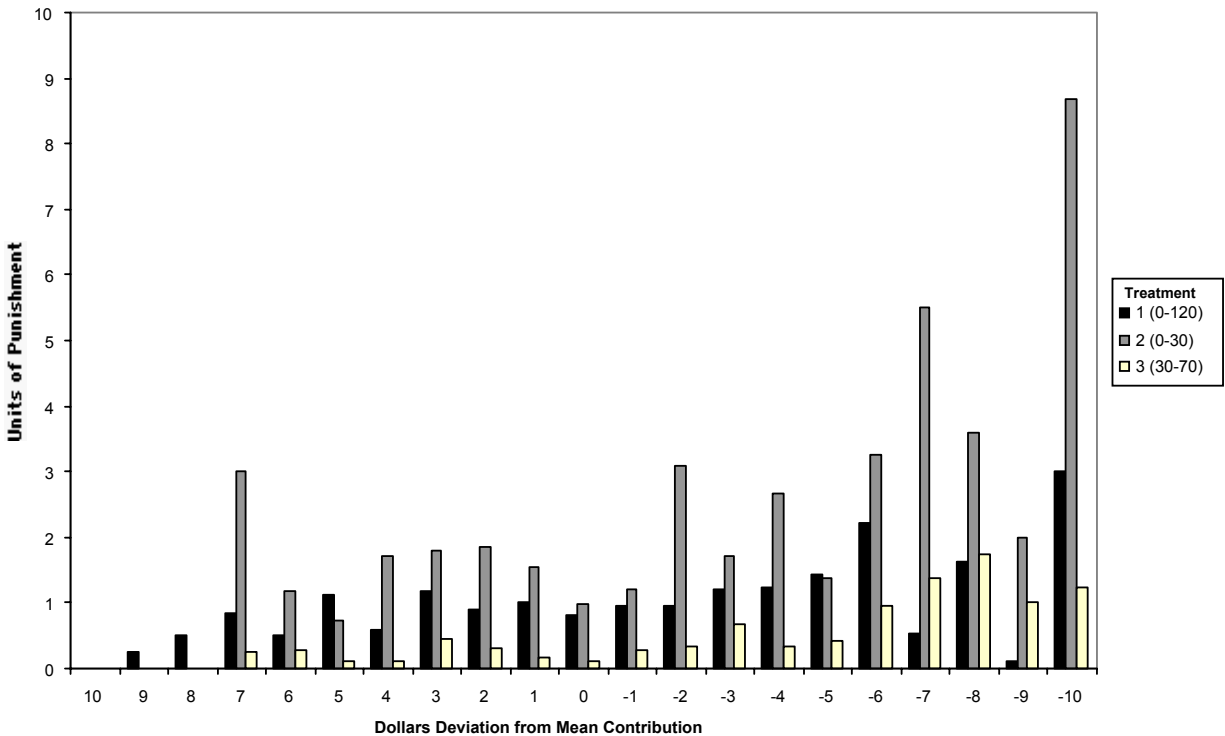


Figure 3: Average units of punishment given by deviations from the mean and treatment

The tobit results in Table 1 provide statistical support for this result. As in Fehr and Gächter (2000a), the coefficient on absolute negative deviation is highly positive, indicating that lower-than average contributors are both more likely to be punished and receive more punishment when they are punished. An increase in free riding from an absolute negative deviation of two to four dollars increases expected punishment from 0.43 units to 0.73 units at a price of 30 cents. At a price of 10 cents, one unit of punishment is expected at an absolute negative deviation of 5.5 dollars, but this decreases to half a unit of punishment at an undercontribution of 2.7 dollars. Carpenter (2000), Falk, Fehr and Fischbacher (2001), Fehr and Gächter (2002), Sefton, Shupp and Walker (2002), and Bochet *et al.* (2002) also report punishment significantly increasing with the deviation of contribution below the average. As in Fehr and Gächter (2000a), the coefficient on absolute positive deviation is insignificant, indicating that once one's contribution was above the average, further increases in contribution did not significantly reduce the probability of punishment.

Average Punishment Demanded

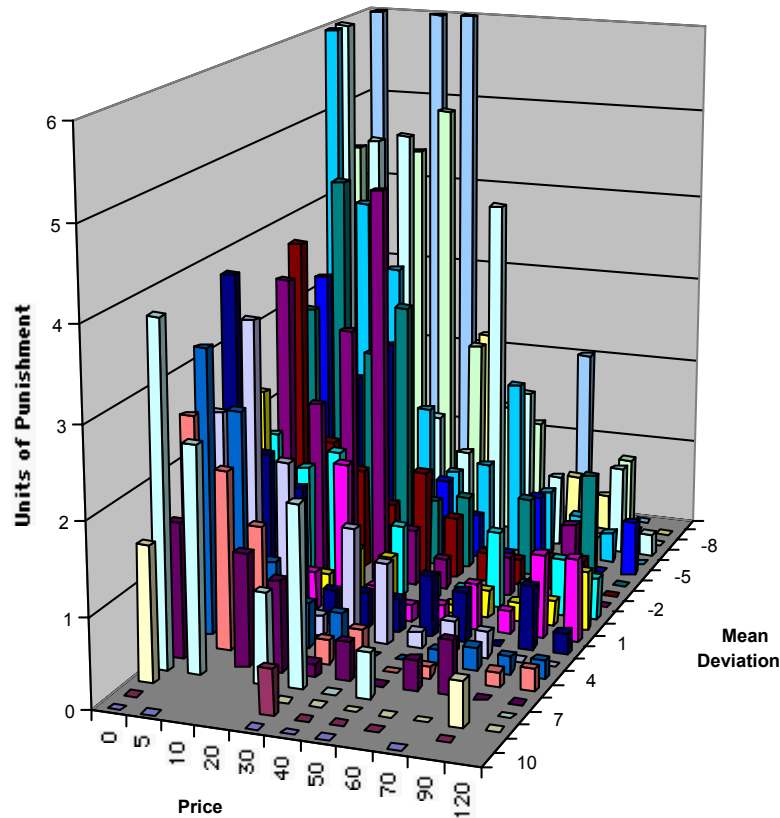


Figure 4a: Average amount of punishment demanded as a function of the target's deviation from the mean contribution of the other two group members and punishment price

Predicted Average Punishment Demanded

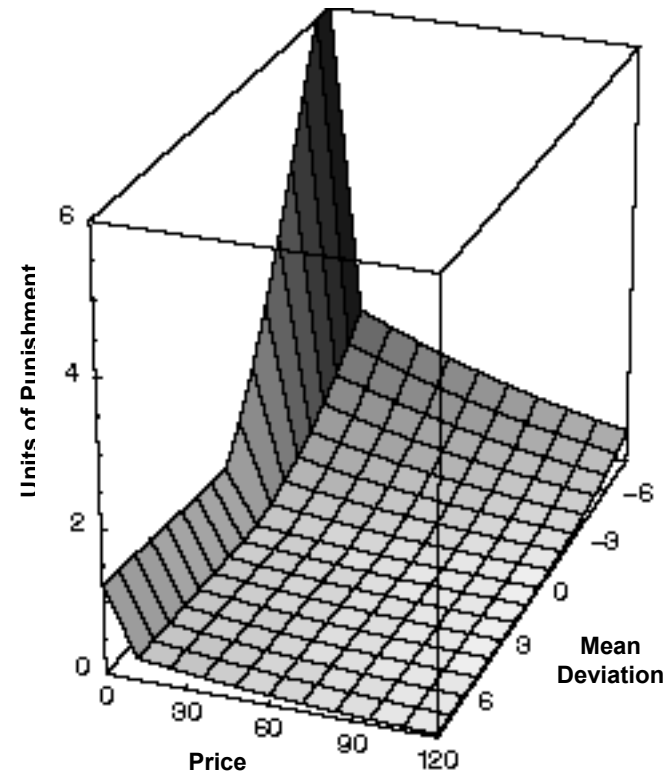


Figure 4b: Predicted punishment as a function of absolute deviation from the mean contribution of the other two group members and punishment price based on the model of Table 1

The significant interdependence of price and free riding shown in results 2 and 3 is summarized graphically in Figure 4. The experimental data, represented in Figure 4a, shows that the most punishment, indicated by the tallest bars, occurs at low prices and high levels of free riding. The expected level of punishment predicted by the tobit model in Table 1, as a function of price and relative contribution, is shown in Figure 4b.⁷ In general, punishment increases as free riding increases at each price, and punishment decreases as prices increase at all levels of free riding.

While standard economic theory predicts no one should punish at positive prices, it makes no prediction when punishment is free. If individuals care only about their own earnings—that is, they have neither altruistic nor envious preferences toward others, nor are they reciprocators or adherents to norms such as “each doing his fair share”—then they would be strictly indifferent about punishing at zero price. Since no extra effort is required to punish (all subjects being required in any case to enter some number, possibly 0, in the relevant space), we might expect to see at zero price a smear of data covering all possible punishment values, zero included, with no particular pattern. The next result shows that consumption of free punishment is not random, but rather related to the level of free riding relative to the group mean.

Result 4: Cost-free punishment is also an increasing function of the recipient’s free riding.

This result is initially demonstrated by the highly significant positive coefficient on the interaction between the zero price indicator and the absolute negative deviation, in Table 1, which is also reflected in Figure 4b. It is further illustrated by the regression of Table

⁷ The apparent discrepancy between the level of punishment in Figure 4a and the predicted level in 4b is primarily attributable to price-mean deviation combinations with high average punishment, but few observations. These cells are given equal visual weight in Figure 4a, but are weighted by the number of observations they represent in the tobit model, and therefore in Figure 4b. The tobit model also predicts extremely large numbers of units of punishment to be very unlikely, although there are several such observations in the data.

2, which considers only the 288 observations at zero price. As in the whole sample, absolute negative deviation is positive and significant, indicating a preference of punishing free-riders. In this model, at zero price, an increase in free riding from two units to four units leads to an increase in expected punishment from 3.26 units to 4.58 units. Taken together, these results suggest that even when punishment is free, people have specific motives for choosing to punish: they dislike free-riding, or have a sense of fairness, or similar other-regarding or normative preferences they will generally not punish if the target has not ‘earned’ the punishment, even though it costs them nothing.

Table 2: Determinants of Punishment when Price=0

Independent Variables	Units of Punishment Tobit
Average Constant	-0.809
Absolute Negative Deviation	1.033*** (0.223)
Absolute Positive Deviation	0.245 (0.241)
σ_ε	6.478
	LL=-620.74 Wald(9)=35.59***

Tobit model of the determinants of purchasing punishment when the price is zero. Standard errors are in parentheses. Session-specific constants are omitted. Significance levels noted at * (p<0.10), ** (p<0.05) and *** (p<0.01).

That the incidence and quantity of costly punishment systematically varies with free riding indicates that punishment, while not payoff maximizing, is not arbitrary or random: subjects may be maximizing a utility function that includes non-monetary components in which punishment is a complement of free riding. A variety of such functions have been suggested, reflecting preferences for altruism, fairness, equity or vengeance (see, for example, Bolton and Ockenfels, 2000, Charness and Rabin, 2002, Cox and Friedman, 2002, Falk and Fischbacher, 1998).

Although it is beyond the scope of our paper to comment on the relative merits of these theories, our experimental design included a partial test of one theory, by Fehr and Schmidt (1999), to which we turn in our next result. Fehr and Schmidt propose that

agents dislike inequality, especially when it is disadvantageous to them. In the Fehr-Schmidt theory, inequality-averse high contributors would punish free riders when the cost to the person punished exceeds that to the punisher, since the free rider earns more than the high contributor prior to punishment and the punishment reduces this inequality. The next result shows that this equity-based theory of punishment is inconsistent with some of our data.

Result 5: A positive amount of punishment is observed at a price greater than \$1.00, most of which is inconsistent with Fehr and Schmidt's equity-based explanation for punishment.

In Treatment I, each subject had one period with a price of \$1.20 to punish another group member by subtracting one dollar from his or her earnings. The average amount of punishment in this condition is 0.381 units of punishment, representing a positive amount of punishment in 23 of 144 decisions by 14 of 72 subjects. In 17 of these 23 cases, the person targeted had contributed the same amount as or less than the punisher, so earnings inequality could only be created or exacerbated by punishment. This suggests that, at least for a subset of our subjects, equity is not the primary motivating factor in the punishment decision.⁸

While the population as a whole is responsive to price and negative deviation of contribution, post-experiment debriefing questionnaires suggest that there was considerable heterogeneity in subjects' punishment strategies. Articulated strategies ranged from people who punished whenever someone contributed below a certain amount or who punished only when the price was zero to people who provided a straightforward argument that punishment did not benefit them, and therefore was irrational. Given this systematic variation, inference based on aggregate data may not fully capture the effect of price variation on punishment.

⁸ A weaker form of the same conclusion could be drawn from Falk, Fehr and Fischbacher's (2001) data, where they observe a significant amount of punishment when the punishment price equals the recipient's reduction in earnings.

To investigate subject heterogeneity with regard to punishment, we apply El-Gamal and Grether's (1995, 1997) estimation-classification algorithm to estimate model parameters for different groups of subjects. The estimation-classification algorithm assumes the choices of each person in the sample are described by a function $F(\theta)$, where θ is a vector of unknown model parameters. Heterogeneity is introduced by allowing that the population contains K segments, or “types” of person, with each type described by one of K different θ s. The θ_k s which describe each type and which subjects are which type are estimated simultaneously. In estimation, person i 's contribution to the likelihood function, given $\Theta=(\theta_1, \dots, \theta_K)$, is the maximum of the joint likelihood of all i 's observations across the K types.⁹ Conventional maximization algorithms can be used to identify the Θ which maximizes the likelihood of the observed data, with care taken to ensure the global maximum is identified in a likelihood function which often has many local maxima.

Result 6: Sensitivity to punishment price and free-riding varies considerably within our sample.

Support comes from Table 3, which reports the two- and three-segment estimation-classification tobit models (single-segment results are in Table 2).¹⁰ Each column of the table reports the estimated coefficients, the proportion of the sample best described by

⁹ The log-likelihood function is

$$\ln L(Y; X | \Theta, K) = \sum_i \operatorname{argmax}_k \{ \sum_t \sum_j \ln L(Y_{ijt}; X_{ijt} | \theta_k) \}$$

where Y are the observed punishment choices, X the independent variables, and $\Theta = \theta_1, \dots, \theta_K$, the parameter vectors for each of the K types. The log-likelihood function is the sum over all individuals of the best log-likelihood of the joint probability of their observed choices, levels of punishment for each other group member j and period t , across the k possible types.

¹⁰ Maximization was carried out using Gauss. To maximize the chance we identified the global maximum among many local maxima, we repeated the maximization from a 1000 starting points randomly drawn from a large neighborhood around a starting vector based on the single-segment parameters, modified to reflect patterns which emerged from debriefing questionnaires.

those coefficients, the proportion of punishment decisions which resulted in punishment, and the average amount of punishment that those in each segment assign to each other member of their group.¹¹ The session-specific constants shared among all segments are suppressed.

The two-segment model divides the population into high punishers and low punishers. Low punishers, 69.0% of the sample, on average, punished in less than one fifth of punishment decisions. The price of punishment and absolute negative deviation highly significantly affect their punishment decisions, but these factors are swamped by a large negative constant. At a price of 30 cents, 0.46 units of punishment are expected from a segment I subject in response to an undercontribution of two dollars.

Table 3: Heterogeneous Tobit Estimates of Determinants of Punishment

	Two-segment		Three-segment		
	I	II	I	II	III
Proportion of Subjects	69.0%	31.0%	30.6%	47.2%	22.2%
Punishment Frequency	18%	60%	4%	32%	67%
Average Punishment	0.76	1.79	0.24	1.19	2.00
Average Constant	-6.237	1.226	-9.764	-2.955	1.904
	NA	NA	NA	NA	NA
Abs. Neg. Deviation	0.983*** (0.114)	0.118* (0.062)	0.565 (0.578)	0.859*** (0.083)	0.012 (0.066)
Abs. Pos. Deviation	0.063 (0.146)	-0.058 (0.070)	-1.659** (0.812)	0.261** (0.109)	-0.046 (0.068)
Price of Punishment	-0.076*** (0.011)	-0.016*** (0.005)	-0.483*** (0.158)	-0.054*** (0.008)	-0.016*** (0.004)
Price=0 Indicator	3.587*** (0.662)	1.490*** (0.424)	6.110* (3.707)	2.652*** (0.578)	1.042** (0.333)
Price=0 × Abs. Neg. Dev.	-0.108 (0.193)	0.523*** (0.112)	-188.433 NA	0.677*** (0.185)	0.588*** (0.140)
σ_ε	6.166	2.560	11.134	4.349	2.396
LL	-2310.12		-2186.63		

Two- and three-segment tobit models of the determinants of purchasing punishment when the price is zero. Standard errors are in parentheses. Session-specific constants are omitted. Significance levels noted at * ($p < 0.10$), ** ($p < 0.05$) and *** ($p < 0.01$).

¹¹ El-Gamal and Grether use a maximum normalized entropy criterion to determine the appropriate K . We do not apply this criterion formally because $K=3$ classifies behavior intuitively and estimation of $K > 3$ is computationally prohibitive.

The second segment, 31.0% of the sample, averages two and a half times more punishment per punishment decision than the low punishers. The high punishers' significantly positive constant suggests a much greater tendency to punish small deviations, leading to more frequent punishment. At a price of 30 cents, 1.59 units of punishment are expected from a segment II subject in response to an undercontribution of two dollars.

Adding the third segment to the model allows a clearer division between subjects who need significant provocation to punish and those who simply never punish. In our debriefing questionnaires, many subjects expressed the view that punishment was irrational (since it cost but could not benefit) or that punishment was simply wrong. The three segment model groups these people, 30.6% of the sample, into segment I. The average punishment level of 0.24 units per punishment decision represents only 26 decisions to punish by 11 of 66 subjects. Six of the 11 only punish at prices of zero or 5 cents, and only three choose to punish in more than one round. All of these observations occur when the zero price-absolute negative interaction is zero, leading to the enormous magnitude and undefined standard error on the zero price-absolute negative deviation interaction.

With non-punishers and near-non-punishers estimated to be in their own segment, the punishers are divided into two segments. Segment II characterizes 47.2% of subjects who are responsive both to free riding and to the price of punishing. The negative constant indicates that this segment forgives contributions somewhat less than the group mean, though significant free-riders are likely to receive punishment. There is also a significant although smaller positive coefficient on positive deviation, indicating that some subjects in this segment punished more those who contributed significantly *more* than their group average. In the face of such subjects, the surest way to avoid punishment would be to contribute the group average while avoiding "standing out" by contributing substantially more.¹²

¹² Bochet *et al.* describe the punishment of high contributors as "perverse" because it tends to discourage contributions, thus working against efficiency. Perverse punishment typically accounts for about 20% of

The estimate of segment III shows the remaining 22.2% of subjects to be aggressive and (from a normative standpoint) somewhat indiscriminate punishers. The significantly positive constant and insignificant coefficients on the contribution deviation terms suggest a considerable propensity toward high levels of punishment, unrelated to the level of free riding. When the price is zero, the level of punishment further increases and, interestingly, becomes sensitive to the level of free riding in the conventional direction, consistent with Result 4.

Taken together, these three segments indicate that a significant portion of the sample does not routinely punish, and almost never does so at positive prices. However, the remaining 70% of the sample does punish. About two thirds of these subjects are primarily responsive to free riding at all prices, and the others punish aggressively at all levels of free riding. Importantly, both punishing groups are responsive to price.

Result 7: Contributions remain higher than is typical with repetition in the VCM without punishment, although there is a mild declining trend in all treatments. Across treatments, contributions tend to be higher but earnings lower when the cost of punishment is lower, reflecting the trade-off between the incentive effect of the threat of punishment, and the toll on efficiency from punishments carried out.

Figure 1 shows the time path of average contributions in each of the three price treatments. All treatments show a statistically significant although economically mild tendency toward lower contributions in later periods. A random effects regression

all instances of punishment in the partner group treatments of Fehr and Gächter (2000a), and Page *et al.* (2003), but is less in Fehr and Gächter's stranger and perfect stranger treatments, evidently because "blind revenge" motive underlies it in partner groups and is absent when group composition changes. Despite the perfect stranger character of the present experiment, punishment of a group's highest contributor (or of a subject tied for that position) nevertheless accounts for 23.1% overall of all instances of punishment, and 22.7% of the instances of punishment at positive prices, in our own data. The higher incidence than in the Fehr-Gächter stranger treatment may be partly attributed to the fact that groups have only three members in the present experiment versus four in theirs and the others cited.

indicates all time slopes are significantly different from zero.¹³ This is consistent with patterns observed in the VCM with punishment in Page *et al.* (2002), but different from that observed by Fehr and Gächter (2000a,2002), who find contributions to rise with repetition.

Turning to the differences across treatments, recall that subjects in a given treatment knew only the distribution of punishment costs, not the particular costs faced by other group members in given periods, so price realizations could not affect current contributions. With the set of possible costs varying among the three treatments, however, the price set could influence the average contribution in a treatment as a whole. Our results suggest that anticipated and actual punishments had small but in some cases statistically significant effects on contributions and earnings. These differences are interesting, because they provide insight into the dilemma that while the presence of a punishment option significantly deters free riding, efficiency may either be increased or reduced, depending on the degree to which the punishment threat must actually be executed and the amount of punishment perversely aimed at high contributors,¹⁴ which never serves efficiency.

Table 4 summarizes the components of contributions and earnings in each treatment. The highest average contributions were in the low punishment price treatment, and the lowest were in the high variance punishment price treatment, with the mid-price punishment treatment in the middle. Contributions in the VCM stage of the game are significantly higher in the 0-30 treatment than in the other two treatments, which are not statistically distinct from each other. Pairwise Wilcoxon signed-rank tests comparing the level of contributions in each treatment show the 0-30 treatment has weakly higher contributions than either the 0-120 or 30-70 treatment (with $p=0.048$ and $p=0.047$ respectively). The

¹³ To confirm statistical significance, we estimated the model $C_i = \sum_{j=1}^3 \{a_j T_{ji} + b_j T_{ji} Period_i\}$, where C_i is i 's contribution, T_j is an indicator variable which equals one if observation i is from treatment j and zero otherwise, $Period_i$ is the period number from which observation i was observed, and a_j and b_j are model parameters. A random effects regression indicates all a_j s and b_j s are significantly different from zero.

¹⁴ See footnote 12.

distribution of contributions in the 0-120 treatment is statistically indistinct from that in the 30-70 treatment, with Wilcoxon test $p=0.98$.

Table 4: Average Earnings, Punishment and Efficiency

	Treatment		
	0-120	0-30	30-70
Average Contribution	6.31	6.76	6.34
Contribution Stage Earnings	15.06	15.41	15.07
Average Punishment	0.99	1.88	0.38
Average Punishment Expenditure	0.32	0.14	0.17
Average Total Earnings ¹⁵	12.44	11.36	13.97
Efficiency	69%	63%	78%

Unlike with contributions, efficiency and earnings differ considerably across treatments. A Wilcoxon signed-rank test of earnings in each period rejects the hypothesis that period earnings in the 30-70 treatment have the same distribution as those in the 0-120 and 0-30 treatments ($p < 10^{-7}$ and $p < 10^{-11}$, respectively); the 0-120 treatment has slightly higher earnings than the 0-30 ($p = 0.04$).¹⁶ The treatment with the highest contributions also has the lowest total earnings because gains from higher contributions are punished away, illustrating the dilemma of punishment (see also Bochet *et al.*, 2002). Punishment is most frequent in the 0-30 treatment, where it is cheapest. It is least frequent in the 30-70 treatment, where there is no low-cost punishment available. In the 0-120 treatment, low cost punishment is available some, but not all, of the time. However, even controlling for price, Figure 2 shows there is less punishment in the 30-70 treatment than at comparable prices in the other treatments. However, a Wilcoxon signed rank test of the data from the 0-120 and 30-70 treatments at the shared prices 30 and 60 does not reject the hypothesis of identical punishment distributions ($p = 0.28$).

¹⁵ Although subjects' period earnings were given a lower bound of zero, the reported average earning statistics assume negative earnings were allowed. This fully captures the effect of punishment and punishment expenditure.

¹⁶ Efficiency is measured as the percentage of maximum possible group earnings, where each person contributes all \$10 to the group account and there is no punishment.

4. Conclusion

This experiment gave subjects in small groups the opportunity to reduce one another's earnings after learning of their contributions to a public good. The game was played five times, each time in a completely new group and with a different price encountered in a random and not pre-announced order. Consistent with other experiments, subjects engaged in costly punishment even though no strategic gain was possible. Also consistent with those experiments, contributions to the public good remained at relatively high levels despite repetition. The amount of punishment was found to be significantly negatively related to its cost to the punisher, and significantly positively related to the amount of free riding (absolute negative deviation from others' average contribution) by the person targeted. Punishment was mainly used to punish free riding even when it cost nothing to the punisher. Some punishment was also purchased even when it cost the punisher more than the person punished, in violation of Fehr and Schmidt's (1999) inequality-aversion explanation for punishment.¹⁷

Concurrent with our research, similar research was undertaken by Carpenter (2003). Carpenter also finds that the demand for punishment is decreasing in its price. His experimental design differs from ours in various ways, including (a) use of a stranger, but not a perfect stranger, protocol, (b) all subjects in a treatment faced the same set of prices in the same pre-announced order, which could thus affect contribution levels, (c) price-penalty ratios which range from 0.25 to four, with much less emphasis on ratios less than one and (d) no zero price. Carpenter's analysis complements ours by isolating income and wealth effects at the set of higher prices designed to generate income effects.¹⁸

¹⁷ Fehr and Fischbacher (forthcoming) recognize that the inequality-aversion theory is only an imperfect approximation, but may be good enough for many purposes and has the advantage of tractability. Our discovery of an empirical exception to the theory should not be seen as ruling out its use in some circumstances in such a spirit.

¹⁸ The coefficients on same-period and cumulative earnings variables in the tobit model of Table 2 are not significant, indicating we have no such income effect. This is likely because punishment is much cheaper, relative to earnings and penalties imposed, in our experiment than in Carpenter's, reflecting the different purposes of the experimental designs.

Apart from reconfirming that subjects will punish free riders at cost to themselves without strategic gain, and that the anticipation and experience of such punishment can help to sustain contributions to a public good, our experiment sheds light on the nature of the preferences that underlie such punishment. Most importantly, our results suggest that subjects obtain definite amounts of satisfaction from punishment, similar to that from other goods, and thus amenable to rational comparison with cost to reach decisions on the number of units to purchase. In the standard terminology of economics, the desire to punish free riders is a taste, not rational in itself, but an unexceptional input to the rational decision calculus. While we have not established definitively why punishment brings utility, we confirmed that it is directed mainly at free riders, and found evidence that the main goal of punishment is not to redress inequalities *per se*. In addition, like tastes for other goods, the taste for punishment varies considerably in the population.

References

- Andreoni, James, 1988, "Why Free Ride? Strategies and Learning in Public Goods Experiments," *J. of Public Economics* 37: 291-304.
- Bochet, Olivier, Talbot Page and Louis Putterman, 2002, "Communication and Punishment in Voluntary Contribution Experiments," Working Paper No. 2002-29, Department of Economics, Brown University, available at <http://www.econ.brown.edu/2002/>.
- Bolton, Gary and Axel Ockenfels, 2000, "ERC: A Theory of Equity, Reciprocity and Competition," *American Economic Review* 90: 166-93.
- Carpenter, Jeffrey, 2000, "Mutual Monitoring in Teams: Theory and Experimental Evidence," unpublished paper, Middlebury College.
- Carpenter, Jeffrey, 2003, "The Demand for Punishment," unpublished paper, Department of Economics, Middlebury College, January.
- Charness, Gary and Matthew Rabin, 2002, "Understanding Social Preferences with Simple Tests," *Quarterly Journal of Economics* 117 (3): 817-69.
- Cox, James C. and Daniel Friedman, 2002, "A Tractable Model of Reciprocity and Fairness," unpublished paper, University of Arizona and University of California Santa Cruz.
- Davis, Douglas D. and Charles A. Holt, 1993, *Experimental Economics*. Princeton: Princeton University Press.
- Falk, Armin, Ernst Fehr, and Urs Fischbacher, 2001, "Driving Forces of Informal Sanctions," Working Paper No. 59, Institute for Empirical Research in Economics, University of Zurich, September.
- Falk, Armin and Urs Fischbacher, 1998, "A Theory of Reciprocity," mimeo, University of Zurich.
- Fehr, Ernst and Simon Gächter, 2000a, "Cooperation and Punishment," *American Economic Review* 90: 980-94.
- Fehr, Ernst and Simon Gächter, 2000b, "Fairness and Retaliation: The Economics of Reciprocity," *Journal of Economic Perspectives* 14 (3): 159-81.
- Fehr, Ernst and Simon Gächter, 2002, "Altruistic Punishment in Humans," *Nature* 415: 137-40.

Fehr, Ernst and Klaus Schmidt, 1999, "A Theory of Fairness, Competition, and Cooperation," *Quarterly Journal of Economics* 114: 817-68.

Ledyard, John, 1995, "Public Goods: A Survey of Experimental Research," pp. 111-94 in John Kagel and Alvin Roth, eds., *Handbook of Experimental Economics*. Princeton: Princeton University Press.

Masclet, David, Charles Noussair, Steven Tucker and Marie-Claire Villeval, 2003, "Monetary and Non-Monetary Punishment in the Voluntary Contributions Mechanism," *American Economic Review* 93 (1): 366-80.

Page, Talbot, Louis Putterman and Bulent Unel, 2002, "Voluntary Association in Public Goods Experiments: Reciprocity, Mimicry, and Efficiency," Working Paper No. 2002-19, Department of Economics, Brown University, available at <http://www.econ.brown.edu/2002/>.

Sefton, Martin, Robert Shupp and James Walker, 2002, "The Effect of Rewards and Sanctions in Provision of Public Goods," Working Paper, University of Nottingham and Indiana University.

Appendix A: Experimental Instructions

The instructions were read aloud by an experimenter as the students followed along on their computer screens.

This is an experiment, funded by a research foundation, to study decision making. You will be earning money in “experimental dollars” during the experiment. At the end of the experiment you will be paid in cash in real dollars. Each experimental dollar is worth a real \$0.25 (twenty-five cents). The amount you earn will depend on your and others’ decisions. The maximum possible earning is \$32.50 (real dollars) and the minimum possible is \$5. You are likely to earn an amount in between. Please make sure you understand the decision process.

Groups

There are eighteen participants in this experiment, and the experiment consists of five decision periods. During each decision period, you will be placed in a group with two other participants, hence a group of three. After every period, you will be put in a completely new group. You will not know the identities of the other two members of your group in any given decision period, nor will you be told their identities after the experiment is over.

Earnings

Each of the five periods in the experiment is structured as follows:

At the beginning of the period each member of your group will receive \$10 (experimental dollars). Each of you must decide how to divide this amount between a group account and a personal account.

The money you assign to your personal account goes directly into your earnings.

An amount equal to 0.6 times the group’s total assignment to the group account goes into your earnings.

$$\text{Earnings} = (\text{amount in personal account}) + (0.6)(\text{total in group account})$$

Every group member earns 0.6 times the total in the group account, regardless of how much they personally put into that account.

The next four screens are designed to help you test your understanding of the experiment so far. Corresponding to each screen, there is a sheet of paper on your desk labeled

Practice 1, Practice 2, etc. We will fill in the first paper worksheet together, then the first screen. Please note that these are practice exercises only, and do not affect your actual earnings in the experiment.

At this point, an experimenter walked subjects through computing their voluntary contribution game payoffs when all three members of the group contribute \$10 to the group account. The exercise is first completed on paper, and then using the experimental software. Following that, subjects computed, on their own using first paper and then the experimental software, their payoffs for the case where every member assigns \$0 to the group account, and for the case where the subject assigns \$5 to the group account, a second member assigns \$5 to the group account, and a third member assigns \$10 to the group account. Once these exercises were reviewed by an experimenter, the instructions resumed.

Consider what would happen in practice 3 if you increase your assignment to the group account by \$1.

Your personal account would go down by \$1, reducing your earnings by \$1.

Your group account would go up by \$1, increasing your earnings by \$0.60, for a net reduction of \$0.40

But each of the other people in your group would increase their earnings by \$0.60, for a total increase of \$1.20 for the others in your group.

Reductions

There is another decision that affects your earnings. Once you learn the others' assignments to the group account, you have a chance to reduce others' earnings, and others have a chance to reduce your earnings. Suppose, in the last example, that you decide to reduce B's earnings by \$3, and C's earnings by \$5. The total amount of reductions you make on others' earnings is therefore \$8.

In most periods, it costs something to reduce another group member's earnings. The cost will vary randomly from one period to another during the experiment. There are five possible costs per dollar of reductions: [0, 5 cents, 10 cents, 20 cents, and 30 cents; varies with treatment]. Each group member is equally likely to be faced with any of these five costs in a given period. Each period, you will be told your own cost for imposing reductions that period, but you will not know the reduction costs facing the other two members of your group, which are likely to be different.

As an example, suppose that in this period it costs you 30 cents for each dollar by which you reduce others' earnings. Then in this example, it costs you $(0.30)(\$8) = \2.40 to impose the total of \$8 of reductions on B and C.

Just as you can reduce others' earnings, others can reduce yours. Suppose B reduces your earnings by \$1 and C reduces your earnings by \$3. The total reduction of your earnings by others is then $(\$1 + \$3) = \$4$. You will learn that your earnings have been reduced by a total of \$4 but you will not learn who has reduced your earnings by what amount, how many group members have participated in reducing your earnings, or what it cost them to make these reductions.

Similarly none of the others will learn whether you as an individual have reduced their earnings, by how much, or at what cost, only the total reductions.

Practice sheet 4 takes you through an example of the reduction process. Let's fill out this sheet together, and then enter the information in the corresponding screen.

The experimenter then led subjects through computing their payoffs when they had chosen to punish others, and others had chosen to punish them. The exercise was carried out first on paper, then using the experimental software.

Your Net Earnings

Your net earnings for a period will be:

$$\begin{aligned} & \text{Amount in personal account} + \\ & (0.6)(\text{Total in group account}) - \\ & (\text{Your cost of reducing others' earnings}) * (\text{Total of your reductions of others}) - \\ & \text{Total of reductions of your earnings made by others} \end{aligned}$$

In this formula, your cost of reducing another person's earnings is the one that is displayed on your screen for that period. If your earnings in a given period are ever negative, they will be reset to zero. Also, the maximum that you can spend on reductions in a given period is the amount of earnings you have for that period before the reduction process begins. Note that each period is independent of the others in that you begin each one with \$10 to allocate, and you can earn as little as zero and as much as \$22 (experimental dollars) in that period, depending on your decisions and those of the others in your group.

Remember that you will be told what your reduction cost is at the beginning of each period, but you will not learn what the reduction costs that face the others in your group are. (That is, knowing your own cost tells you nothing about their costs, since for each of them, any one of the five possible costs is equally likely in any given period).

At the end of the experiment, the net earnings for the five periods will be totaled and converted from experimental dollars to real dollars. Then \$5 will be added for your participation.

Conclusion

It is important that you understand the procedures and formulas that will be used in the experiment. Once the experiment begins, there will be no further discussion, and no communication of any kind among the participants is permitted, apart from the transmission of the decisions by computer. So please review the experiment in your mind now and raise your hand if you have any questions. Once all questions have been answered, the experiment will begin.