Deterring Extraction from the Commons: Evidence from an Experiment

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Introduction

Regulation of common property resources like fisheries or wildlife is often carried out through quotas on harvest levels. For example, catch share programs are implemented in many countries, like the US and Norway, to reduce overfishing. Such externally administered programs need to be enforced through mechanisms that can provide different incentives for individuals to bring their behaviour closer to socially optimal levels.

The existing literature has mixed findings regarding the effectiveness of deterrence in strategic choice environments where individual actions impose externalities on others [1, 2, 3, 4]. This paper provides new evidence by disentangling (i) the relative effects of probability and severity of sanctions while controlling for individual risk attitudes, and (ii) the effects of changing quota regimes and fee-bate mechanisms. Moreover, the paper builds evidence by measuring heterogeneity in treatment effects on different types of strategic agents that are typically identified in social dilemma settings.

Method

An incentivized laboratory experiment is used to identify the relative effects of deterrence parameter combinations and quota regimes, while keeping expected penalties the same. The experiment is designed as a linear extraction game where individuals are matched with 3 others to form groups of 4. Each group has access to a shared "group fund" (the common resource) and a private "individual fund". Transferring money from the former to the latter benefits an individual and imposes a negative externality on others in the group. Individual i's earnings in each round of the experiment is determined by:

$$\pi_i = e + h_i + \frac{M}{N}\sum_{j=1}^{N}(h_{max} - h_j) \qquad (1)$$

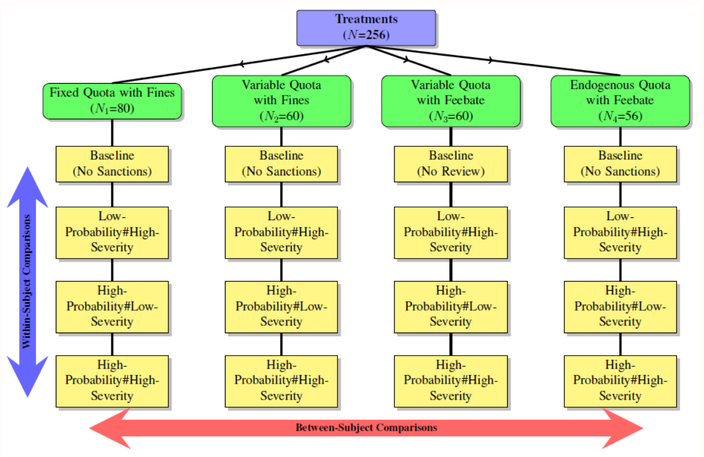
where $e + h_i$ represents the value of i's individual fund while $\frac{M}{N}\sum_{j=1}^{N}(h_{max} - h_j)$ represents the value accruing to i from the common fund. As long as $M/N < 1$ in this game, each individual should extract the maximum possible to maximize their own payoff, while the social optimum is to extract nothing.

Using this setup, monitoring and fines/rewards are implemented through experimentally varying deterrence parameters and quota regimes while ensuring that an individual experiences all deterrence parameter combinations (within-subject), and only one quota regime (between-subject). Deterrence parameter combinations are designed to keep the expected penalty constant to facilitate an apples-to-apples comparison between equivalent increases in probability and severity. Moreover, it can be shown that as long as $1 - \alpha p > M/N$, the optimal Nash strategy remains at full extraction. Each individual plays 20 rounds of the extraction game.

Four probability-severity (p, α) combinations are used for within-subject comparisons: (i) (0,0), (ii) (0.125,2), (iii) (0.25,1), and (iv) (0.25,2). Combinations (ii) and (iii) keep the expected penalty or reward constant, conditional on harvest level. Five rounds of each of the four combinations are implemented, while randomizing the order between rounds, ensuring that differences in harvest levels are not confounded with order effects.

Each individual is randomly assigned to one of 4 quota regimes. In the first regime, the quota is fixed at the social optimum, i.e. zero harvest. The second regime sanctions individuals who harvest more than their current group's average level in the previous round. The third regime implements a fee-bate scheme where individuals who harvest more than their group's average harvest level in the previous period are sanctioned and those who harvest less are rewarded. The fourth regime implements an endogenous harvest norm by using a fee-bate mechanism where individuals who harvest more than their group's current period average are sanctioned while those who harvest less are rewarded. This mechanism follows the mechanism for public good contributions proposed and tested in [7].The experiment design and sample sizes are summarized in Figure 1.

Figure 1: Experiment Design.

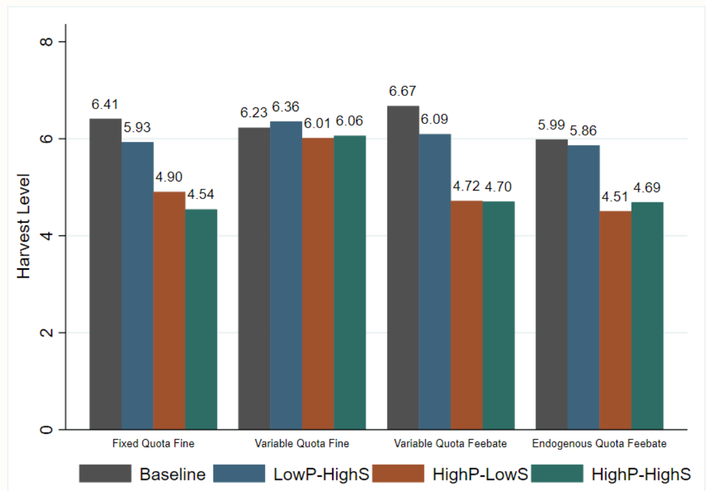


After the extraction game, each individual participates in an incentivized lottery task that measures their degree of risk aversion [5]. A total of 256 subjects participated in the experiment over 13 sessions. The average earnings was $23.78 over all rounds of the extraction game, and $2.09 from the risk task.

Results

Figure 2 shows the average levels of harvest from the common pool for each of the treatment conditions in the experiment.

Figure 2: Average Harvest Levels by Treatment



Effects of Deterrence (Within-Subjects)

The effect of deterrence parameters under alternate quota and feebate regimes are estimated by regressing individual harvest level on treatment indicators, and a set of individual covariates, including risk attitudes, gender, age, and so on. The results are in Table 1 below, with the text highlighted in red indicating the coefficients of interest that test for differences in harvest levels between equivalent penalty function conditions. Note that separate regressions are estimated for each of the 4 quota regimes.

Table 1: Effect of Probability and Severity

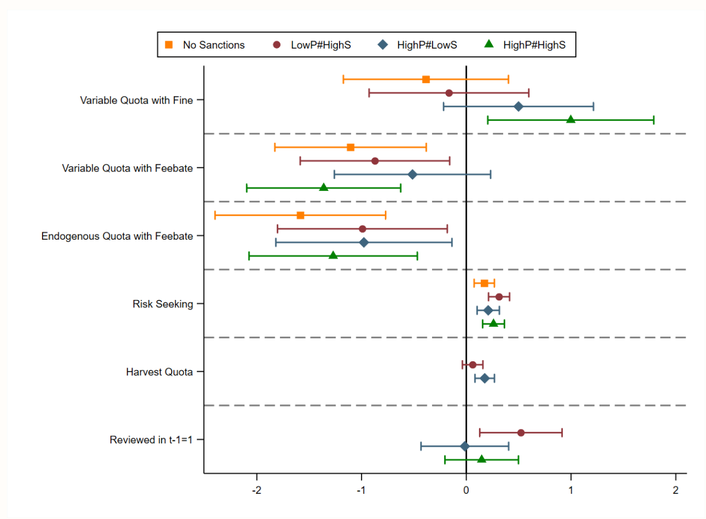
Panel Regression (Outcome: Harvest Level b/w 0 and 10)				
	Fixed Quota Fines Only	**Variable Quota Fines Only**	**Variable Quota Feebate**	**Endogenous Quota Feebate**
Baseline Average Harvest	6.560	6.227	6.673	5.986
Low-P#High-S (1)	-0.681**	-0.489	-1.008***	-0.877**
	(0.3174)	(0.3105)	(0.3365)	(0.3968)
High-P#Low-S (2)	-1.630***	-0.788***	-1.774***	-1.999***
	(0.2870)	(0.2786)	(0.3630)	(0.4188)
(2) - (1)	-0.949***	-0.298+	-0.766**	-1.122***
	(0.2563)	(0.1601)	(0.2623)	(0.2594)
High-P#High-S	-2.102***	-1.095*	-2.427***	-2.490***
	(0.3485)	(0.4615)	(0.5268)	(0.6216)
Observations	1520	1140	1140	1064
Subjects	80	60	60	56

Wald tests of differencces in coefficients between the LowP#HighS and HighP#LowS treatment conditions confirm that an increase in probability is approximately twice as effective at reducing harvest from the common pool than an equivalent increase in severity.

Effects of Quota Regimes (Between-Subjects)

Turning to between-subject tests of the effects of alternate quota and feebate regimes, Figure 3 plots the coefficients and 95% confidence intervals from regressions of harvest level on quota regime indicator, degree of risk-seeking, the level of the exogenous quota and whether an individual was reviewed in the previous round. Separate estimations are performed for each combination of deterrence parameters.

Figure 3: Effect of Quota Regimes

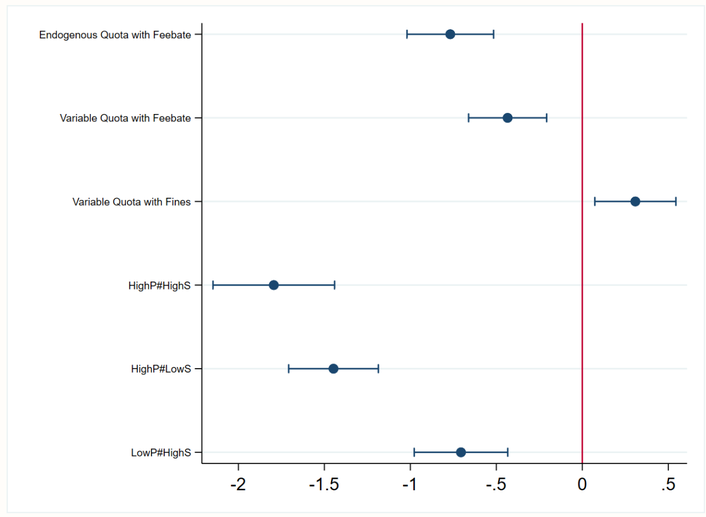


Compared to the Fixed Quota with Fines regime, harvest levels are lower under both regimes with fee-bates in all deterrence parameter combinations. This indicates that a combination of fines and rewards is more effective than a regime that only penalises harvest levels that are higher than the norm without rewarding harvest levels that are lower than the norm, and hence closer to the socially optimal level.

Joint Effects of Enforcement and Quotas

Bringing the two previous analyses together, the marginal effects of each of the treatment conditions and 95% confidence intervals are plotted in Figure 4.

Figure 4: Joint effects of deterrence and quota regimes.



The figure reveals that deterrence has a greater impact, than the quota regimes, *ceteris paribus*. Moreover, an increase in probability remains the greater deterrent than equivalent increases in severity.

Heterogeneities by Subject Type

In social dilemma settings, prior work has identified three distinct types of behaviour – free riding, altruism and conditional cooperation. Free riders and altruists do not respond to other group members' behaviour and extract more and less, respectively. Conditional cooperators change their extraction levels in proportion to others' behaviour. Using baseline behaviour in the experiment (adapting procedure of [6]) to categorize each individual and then interacting their category with treatment, the effects of deterrence and quotas by behavioural type are shown in the table below.

Table 2: Heterogeneous Effects by Subject Type

	Free Rider	Altruist	Conditional Cooperator	Free Rider	Altruist	Conditional Cooperator
	Fixed Quota Fines Only			**Variable Quota Fines Only**		
Low-P#High-S	-2.412***	3.865***	-0.268	-1.145*	-0.152	-0.426
High-P#Low-S	-2.752***	1.350*	-1.303**	-1.817***	0.174	-0.550+
High-P#High-S	-4.069***	2.614***	-1.636***	-1.987**	0.0266	-1.178*
	Variable Quota Feebate			**Endogenous Quota Feebate**		
Low-P#High-S	-1.400**	-0.562	-0.932*	-2.606***	0.224	-0.502
High-P#Low-S	-3.032***	1.304***	-1.363***	-4.264***	0.000675	-2.050***
High-P#High-S	-4.087***	0.165	-1.905***	-4.427***	-0.564	-2.258*

Sanctions and rewards are most effective in reducing harvest by free riders. Their effects are lower on conditional cooperators. Altruists sometimes respond to monitoring by increasing their harvest levels – indicative evidence of crowding out of intrinsic motivation.

Conclusions

The experiment has three main findings. First, the probability of being monitored is a more effective deterrent against socially suboptimal extraction than an equivalent increase in the severity of sanctions. This suggests that policies that leverage a higher likelihood of detecting socially detrimental behaviour is more effective at reducing such behaviour compared to more severe fines conditional upon being detected. Second, a mechanism that combines fines with rewards is more effective at promoting pro-social behaviour than one with fines alone. This result was shown in the context of positive externalities [7], but this paper is the first to show this in the domain of negative externalities. Finally, monitoring mechanisms are most effective on individuals who are more likely to free-ride on others' actions – suggesting that such mechanisms should be targeted to specific contexts where unconditional free-riding behaviour is the norm.

References

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