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Games of corruption: How to suppress illegal logging

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HIGHLIGHTS

- We study an evolutionary game for the illegal logging and the corruption of rule enforcers.
- Harvesters cooperate (log legally) or defect; enforcers are honest or corrupt.
- The dynamics converge either to defecting harvesters or to cooperators.
- The education of enforcers is a potent means of curbing corruption.
- Information on corrupt enforcers enhances the likelihood of cooperative outcomes.

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ABSTRACT

Corruption is one of the most serious obstacles for ecosystem management and biodiversity conservation. In particular, more than half of the loss of forested area in many tropical countries is due to illegal logging, with corruption implicated in a lack of enforcement. Here we study an evolutionary game model to analyze the illegal harvesting of forest trees, coupled with the corruption of rule enforcers. We consider several types of harvesters, who may or may not be committed towards supporting an enforcer service, and who may cooperate (log legally) or defect (log illegally). We also consider two types of rule enforcers, honest and corrupt: while honest enforcers fulfill their function, corrupt enforcers accept bribes from defecting harvesters and refrain from fining them. We report three key findings. First, in the absence of strategy exploration, the harvester–enforcer dynamics are bistable: one continuum of equilibria consists of defecting harvesters and a low fraction of honest enforcers, while another consists of cooperating harvesters and a high fraction of honest enforcers. Both continua attract nearby strategy mixtures. Second, even a small rate of strategy exploration removes this bistability, rendering one of the outcomes globally stable. It is the relative rate of exploration among enforcers that then determines whether most harvesters cooperate or defect and most enforcers are honest or corrupt, respectively. This suggests that the education of enforcers, causing their more frequent trialing of honest conduct, can be a potent means of curbing corruption. Third, if information on corrupt enforcers is available, and players react opportunistically to it, the domain of attraction of cooperative outcomes widens considerably. We conclude by discussing policy implications of our results.

1. Introduction

Although the "tragedy of the commons" is ubiquitous (Hardin, 1968), field research on governing the commons, as well as laboratory experiments on public good games, show that, sometimes, cooperation can be maintained and the tragedy avoided (e.g., Ostrom, 1990; Henrich, 2006; Henrich et al., 2006; Rustagi et al., 2010). In particular, research by Ostrom and colleagues has shown that people are frequently able to discuss, establish, and enforce rules defining a system of punishment for rule breakers (Ostrom, 2000). In her view, institutions are tools for providing incentives to promote cooperation (Ostrom and Walker, 1997; Ostrom et al., 1994). Basic design principles of Ostrom (1990) for social settings that allow long-lasting resource use include the successful establishment of a monitoring and sanctioning system. Such systems provide examples of mechanisms that enforce cooperation by punishing defectors.

The general theory of sanctioning mechanisms has been studied extensively (e.g., Tyler and Degoey, 1995; Nakamaru and

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Iwasa, 2006; Rockenbach and Milinski, 2006; Dreber et al., 2008; Egas and Riedl, 2008; Sigmund, 2007; Casari and Luini, 2009; Nakamaru and Dieckmann, 2009; Kosfeld et al., 2009; Boyd et al., 2010; Baldassarri and Grossman, 2011; Chaudhuri, 2011; Iwasa and Lee, 2013; Shimao and Nakamaru, 2013). In some situations, individual players directly punish defectors (peer punishment; Fowler, 2005; Bochet et al., 2006; Cinyabuguma et al., 2006; Gürerk et al., 2006, 2008; Ertan et al., 2009). Alternatively, players may establish a costly police-like system for punishing defectors, which is specialized on spotting and fining defectors (pool punishment; Yamagishi, 1986; Van Vugt et al., 2009; Kamei et al., 2011; Sigmund et al., 2011; Andreoni and Gee, 2012; Traulsen et al., 2012). For such a system to function effectively, the hired rule enforcers (or inspectors, officers, janitors, sheriffs) have to work properly. In some situations, however, the rule enforcers can be corrupt, accepting bribes from defectors and then refrain from fining them.

Illegal logging is a typical example of how the tragedy of the commons may jeopardize a common good. Since each individual harvester can gain from logging more trees than other harvesters, preventing unsustainable overharvesting requires establishing standards for legal logging. And when the tasks of monitoring and sanctioning harvesters according to those standards are delegated to third parties, corruption may arise. Corruption is known to be positively correlated with illegal logging in many places around the world, including Indonesia, China, Southern Asia, and West and Central Africa (Seneca Creek Associates, 2004). For some countries, such as Cambodia, Indonesia, and Bolivia, indicative estimates of illegal logging even exceed 80% (Food and Agriculture Organization (FAO), 2005; European Forest Institute, 2005). Illegal logging occurs widely and persistently, at both state and community levels (Corbridge and Kumar, 2002; Véron et al., 2006; World Bank, 2006). A statistical analysis of forest management showed that efficient judicial systems deter rule breaking, increase the compliance of harvesting firms, and reduce corruption (Diarra and Marchand, 2011). At the theoretical end, Mishra (2006) discussed a game model in which a public official may siphon off public goods—an unlawful action that is supposed to be stopped by a politician, but may continue if the public official bribes the politician, as well as a major fraction of citizens. These studies underscore the general understanding that corruption tends to ruin joint efforts, leading to resource depletion and distorted distribution.

In this paper, we study conditions and mechanisms for curbing corruption, using very simplified models, rather than realistic models incorporating the many details that may affect corruption in particular situations. We deliberately focus on the simplest possible situations in order to identify the key elements for controlling the corruption of rule enforcers. We thus hope to derive general insights and conclusions that may be applicable to a broad range of other social dilemmas.

Specifically, we consider a situation in which a group of harvesters establish a rule to restrain logging. Hired enforcers monitor the harvesters who commit to the rule and fine defectors who harvest the common forest excessively. We assume that rule enforcers are paid by the harvesters, rather than being funded through an external source or organization: this corresponds to the 'grass roots' institutions studied by Ostrom (e.g., Ostrom and Walker, 1997; Ostrom, 2000). To investigate whether this rule enforcement system can emerge as a social institution in the modeled community, we use replicator dynamics describing social learning occurring through the imitation of successful role models (e.g., Sigmund, 2010). On this basis, we investigate conditions favoring cooperative harvesters and honest enforcers, respectively.

After establishing results for this simple model as a baseline, we extend our analyses in two directions. First, we study a series of models differing in exploration rates among strategies, and second, we investigate the effects arising from the availability of information on corrupt enforcers. The resulting dynamical systems show typical nonlinear behavior, such as a strong dependence on initial conditions, heteroclinic cycles, and stable long-term oscillations. Based on our findings, we conclude that the education of enforcers, as well as information on corrupt enforcers, have the potential to exert profound effects on levels of cooperation and corruption.

2. Model

2.1. Harvesters and enforcers, their strategies and payoffs

Harvesters may log legally and invest efforts into maintaining a forest in a healthy state, so it can sustainably provide ecosystem services benefiting all community members. Alternatively, harvesters may log illegally, harvesting trees in an unsustainable manner to enhance their own incomes. Individually, each harvester has an incentive to engage in the unsustainable harvesting of commonly owned forest trees. If all harvesters do so, however, the forest may eventually be lost, and every member of the community will suffer. This is a typical social dilemma known as the tragedy of the commons (Hardin, 1968). Maintaining the forest in a healthy state requires cooperation, while illegal logging corresponds to defection.

Faced with this social dilemma, harvesters may find it necessary to hire a "rule enforcer", who spots defecting harvesters and fines them. We model this situation in a minimalistic way by assuming that pairs of harvesters can commit to being monitored, and potentially punished, by an enforcer. Alternatively, harvesters might be tempted to bribe the enforcer, so as to enable them to cheat on their co-players with impunity. When a significant fraction of enforcers are corrupt, harvesters may benefit from refusing to commit to paying for an, then often useless, enforcer.

Considering two harvesters forming a pair, we set their baseline payoff to be the one achieved when both defect (illegal logging), and denote it by λ. If one harvester switches to cooperation (legal logging), we assume this improves both harvesters' payoffs by b, measuring the benefits accrued from cooperation, through the improved (i.e., less degraded) ecosystem service. The payoff for a harvester who defects against a cooperating harvester thus is $\lambda+b$. The cooperating player, in contrast, has to pay the cost of cooperation, causing a loss K, which measures the income reduction from restrained logging, and thus resulting in a payoff $\lambda+b-K$. We denote the net cost of cooperation by $c=K-b$, so the payoff of the cooperating harvester is $\lambda-c$. If both harvesters cooperate, each of them benefits from the double improvement of the ecosystem service, and thus obtains a payoff $\lambda+2b-K=\lambda+b-c$. Hence, a cooperator pays a cost c for providing a benefit b for the co-player. A defector, by contrast, refuses to pay this cost, but still receives this benefit, if the co-player cooperates. This payoff scheme is regularly adopted in theoretical studies of the evolution of cooperation: It has the structure of the donation game, which is a special case of the Prisoner's Dilemma game (Sigmund, 2010).

In addition to harvesters that may cooperate or defect and that may or may not be willing to commit to the enforcer service, we also consider conditional cooperators, who are willing to commit and cooperate if and only if their co-players are also willing to commit. Harvesters can only commit jointly; a single player cannot commit, just as a single party cannot sign a bilateral contract. There are thus five types of harvesters: conditional cooperators (at a fraction x_1 in the harvester population), committing cooperators (x_2), committing defectors (x_3), non-committing cooperators (x_4), and non-committing defectors (x_5), with $x_1+\cdots+x_5=1$.