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A game theoretic model of monitoring and compliance in fishery cooperatives

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Economic model of deterrence-compliance

- ***Becker 1968: utilitarian model of individual compliance behavior***

$$V_i = f(X_i, \theta_i)$$

V_i: Violation rate

X_i: Expected illegal gains

θ_i: Expected penalty (probability of detection and sanction, penalty level)

Traditional economic incentives predominate in compliance decision in fisheries
Sutinen and Gauvin 1989; Sutinen et al. 1990; Furlong 1991; Kuperan and Sutinen 1998; Nielsen and Mathiesen 2003; Hatcher and Gordon 2005; Van Hoof 2010

Levels of monitoring-penalties are insufficient to ensure adequate deterrence

… applied to fisheries:

- ***Sutinen & Kuperan 1999: enriched model including personal normative judgments and social influences***

$$V_i = f(X_i, \theta_i, L_i, S_i)$$

L_i: Legitimacy

S_i: Social preferences

Cooperative systems and co-management can bring legitimacy, enhance social norms
Ostrom 1990; Jentoft 1985, 1989; Berkes et al 1996; Eggert and Ellegård 2003; Nielsen and Mathiesen 2003; Van Hoof 2010

Fishery cooperatives / Producer Organizations

- Key players in the governance of many fisheries around the world
- Groups of fishers that collectively hold rights to manage their members' fishing activities
- Assigning rights to a group rather than to individuals can facilitate coordination and collective action → *co-management* approach
- Group members may be jointly and severally liable for not exceeding collectively assigned fishing rights (*e.g.* in the U.S. and in the E.U.)

Joint & Several Liability

- Liability regime under which members of a group are mutually responsible for the damages caused by one or more members
  - ➢ applied in environmental pollution cases (Superfund sites)

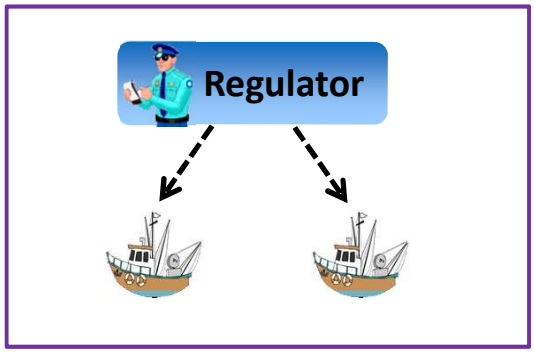
    (Kornhauser and Revesz, 1994)

- Can be applied to fishery co-ops for quota violations, misreporting…
  - ➢ regulator can take away catch privileges from the co-op (e.g. in the US, in France…)

- Co-ops implement an **internal "*compliance regime*"** specified in their internal agreements, including monitoring (observation, reporting) and penalties
  - ➢ change of traditional deterrence scheme and economic incentives

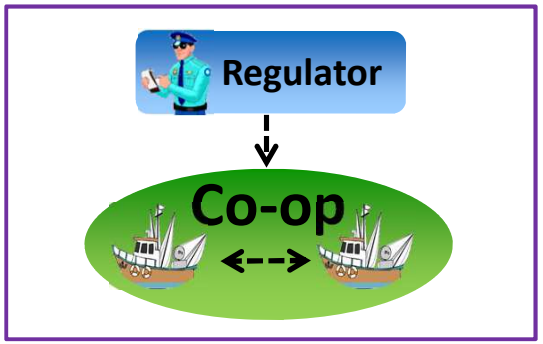
The model

- 2 individuals (i and j), forming a co-op or not



Baseline case
Traditional ITQ (without co-op)

VS

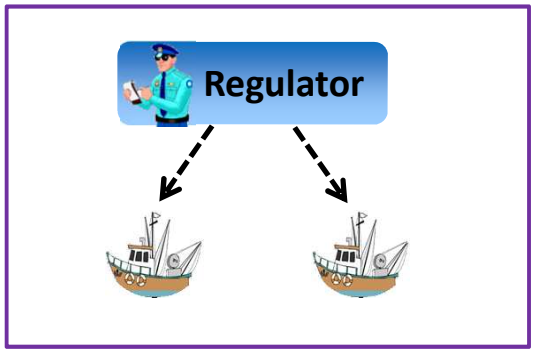


Joint & Several Liability
Co-op structure

- Individual fisherman is considering violating for an additional benefit X (trip level decision)
- Regulator has probability p_r of detecting violation, and imposes a fine V_r
- The co-op can implement internal monitoring: co-op members can "watch" each other at some cost α

The model

- 2 individuals (i and j), forming a co-op or not



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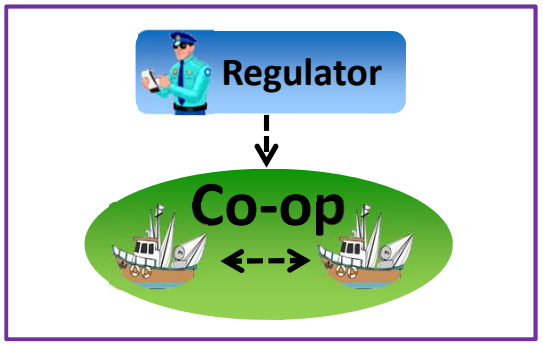


Joint & Several Liability

Co-op structure

Each fisher has 2 possible choices:

- comply (i.e. not violate)
- violate for an additional benefit X

Individual fisher complies if and only if: $X \leq p_r V_r$

Each fisher has 4 possible choices:

	not watch	watch
comply	(0,0)	(0,1)
violate	(1,0)	(1,1)

The model

- 2 individuals (i and j), forming a co-op

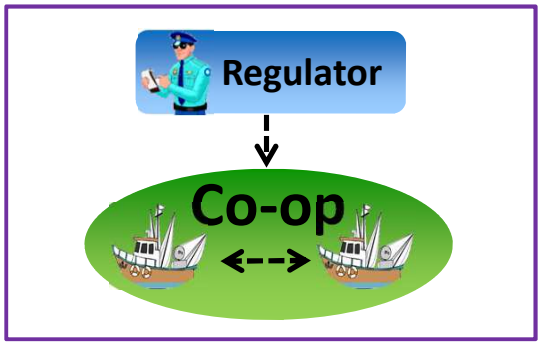
- Fines imposed by the regulator are equally supported by ***i*** and ***j*** (joint and several liability)

- 2 alternative monitoring-penalty mechanisms within the co-op:

  scenario 1: internal penalties are limited to indemnification

  scenario 2: internal penalties are independent of detection by the regulator

- Symmetric players: $X_i = X_j$
- Asymmetric players: $X_i > X_j$



Joint & Several Liability

Co-op structure

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The model

- Normal form game (payoff matrix)

		Player *j*			
		$j(0,0)$	$j(0,1)$	$j(1,0)$	$j(1,1)$
Player *i*	$i(0,0)$	$\begin{cases}\pi_i = 0\\ \pi_j = 0\end{cases}$	$\begin{cases}\pi_i = 0\\ \pi_j = -\alpha\end{cases}$	$\begin{cases}\pi_i = -\frac{1}{2}p_r V_r\\ \pi_j = X_j - \frac{1}{2}p_r V_r\end{cases}$	$\begin{cases}\pi_i = -\frac{1}{2}p_r V_r\\ \pi_j = X_j - \frac{1}{2}p_r V_r - \alpha\end{cases}$
	$i(0,1)$	$\begin{cases}\pi_i = -\alpha\\ \pi_j = 0\end{cases}$	$\begin{cases}\pi_i = -\alpha\\ \pi_j = -\alpha\end{cases}$	$\begin{cases}\pi_i = -\left(\frac{1}{2}p_r(1-p_c)\right)V_r - \alpha\\ \pi_j = X_j - \left(\frac{1}{2}p_r + \frac{1}{2}p_r p_c\right)V_r\end{cases}$	$\begin{cases}\pi_i = -\left(\frac{1}{2}p_r(1-p_c)\right)V_r - \alpha\\ \pi_j = X_j - \left(\frac{1}{2}p_r + \frac{1}{2}p_r p_c\right)V_r - \alpha\end{cases}$
	$i(1,0)$	$\begin{cases}\pi_i = X_i - \frac{1}{2}p_r V_r\\ \pi_j = -\frac{1}{2}p_r V_r\end{cases}$	$\begin{cases}\pi_i = X_i - \left(\frac{1}{2}p_r + \frac{1}{2}p_r p_c\right)V_r\\ \pi_j = -\left(\frac{1}{2}p_r(1-p_c)\right)V_r - \alpha\end{cases}$	$\begin{cases}\pi_i = X_i - p_r V_r\\ \pi_j = X_j - p_r V_r\end{cases}$	$\begin{cases}\pi_i = X_i - \left(p_r + \frac{1}{2}p_r p_c\right)V_r\\ \pi_j = X_j - \left(p_r - \frac{1}{2}p_r p_c\right)V_r - \alpha\end{cases}$
	$i(1,1)$	$\begin{cases}\pi_i = X_i - \frac{1}{2}p_r V_r - \alpha\\ \pi_j = -\frac{1}{2}p_r V_r\end{cases}$	$\begin{cases}\pi_i = X_i - \left(\frac{1}{2}p_r + \frac{1}{2}p_r p_c\right)V_r - \alpha\\ \pi_j = -\left(\frac{1}{2}p_r(1-p_c)\right)V_r - \alpha\end{cases}$	$\begin{cases}\pi_i = X_i - \left(p_r - \frac{1}{2}p_r p_c\right)V_r - \alpha\\ \pi_j = X_j - \left(p_r + \frac{1}{2}p_r p_c\right)V_r\end{cases}$	$\begin{cases}\pi_i = X_i - p_r V_r - \alpha\\ \pi_j = X_j - p_r V_r - \alpha\end{cases}$

Scenario 1: internal penalties are limited to indemnification

- α: monitoring cost
- X: additional benefit from non-compliance
- p_r: probability of detection by the regulator
- V_r: fine imposed by the regulator
- p_c: probability of detection by the co-op

	not watch	**watch**
comply	(0,0)	(0,1)
violate	(1,0)	(1,1)

The model

- Each player makes decisions independently (non-cooperative game)
- They know the equilibrium strategies of the other player (perfect information)
- Preferred strategies are obtained by computing the Nash equilibria ("*best mutual responses*")
- Level of violation by i = sum of the probabilities associated with strategies $i(1,0)$ and $i(1,1)$ in the "mixed strategies equilibria" (if no pure solution)

- We first focus on traditional economic incentives.
- Social preferences are then integrated through an *inequality aversion* model drawing on **Fehr and Schmidt 1999**

The model

- Proposition 1: if internal penalties are limited to indemnification, joint and several liability does not increase economic incentives to comply (as compared to the traditional ITQ baseline case)

- Proposition 2: if internal penalties are independent of detection by the regulator, symmetric players (*i.e.* such that $X_i = X_j$) have no incentive to effectively implement an internal monitoring system.

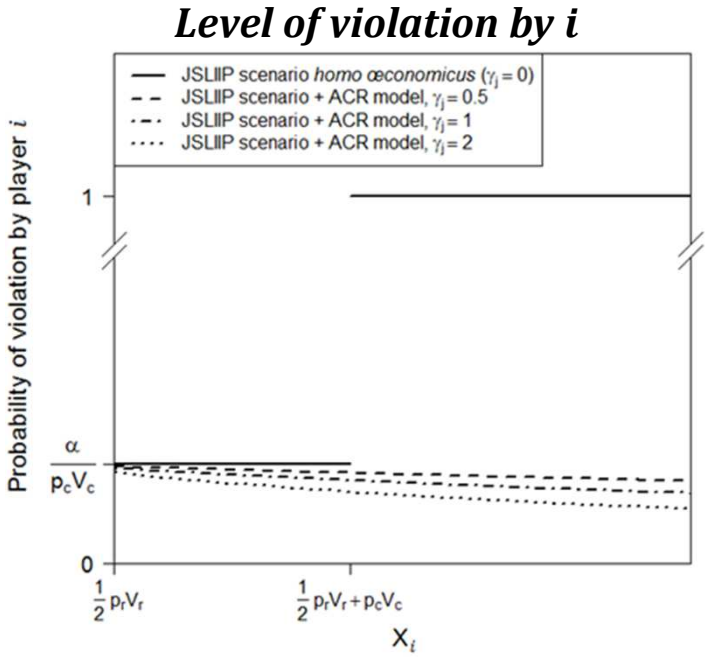
- Proposition 3: if internal penalties are independent of detection by the regulator, and assuming asymmetric players s.t. $X_j < \frac{1}{2} p_r V_r < X_i$, rational economic incentives to comply increase.

Social preferences

- Proposition 4: if internal penalties are independent of detection by the regulator, assuming asymmetric players and considering an **inquality aversion model***, the level of compliance increases even more.

$$*\begin{cases} U_i(\boldsymbol{\pi}) = \pi_i - \beta_i \times \max(\pi_i - \pi_j, 0) \times \rho \\ U_j(\boldsymbol{\pi}) = \pi_j - \gamma_j \times \max(\pi_i - \pi_j, 0) \times \rho \end{cases} \quad \text{with} \quad \rho = \begin{cases} 1 & \text{if } i \text{ misbehaved} \\ 0 & \text{otherwise} \end{cases}$$

and with $0 \leq \beta_k < 1$ and $\beta_k \leq \gamma_k$, $k = i, j$. Players dislike having lower payoffs than other (with weight γ_k) and also dislike having higher payoffs (with weight β_k).



- X_i : potential benefit from non-compliance
- α : monitoring cost
- p_r : probability of detection by the regulator
- V_r : fine imposed by the regulator
- p_c : probability of detection by the co-op
- V_c : fine imposed by the co-op

Discussion – policy considerations

- Cooperative-based catch share systems with joint and several liability enable the regulator to take away catch privileges from the entire cooperative

  → may effectively create a penalty much larger than could be recovered with an individual fine

  → can increase the level of compliance for a given enforcement expenditure

- The regulator cannot only rely on having the cooperatives ensure that there is compliance

- When effectively implemented, internal monitoring-penalty mechanisms have the potential to significantly reduce non-compliance

Discussion – internal agreements of cooperatives

- How do fishery cooperatives structure their internal agreements to implement their *compliance regime* in reality?

  → Several examples in the US and in the EU

- Observation: at-sea and dockside observers, electronic equipment
- Reporting: catch logs and dealers reports required on a timely basis
- Penalty structures: graduated sanctions for non-compliance with cooperative rules, including overharvest monetary penalties, loss of quota units, stop fishing orders, and expulsion
- Indemnification against penalties due to actions of other members may be specifically included or excluded in internal agreements.

  Note: important because it could negate joint and several liability by protecting co-op members from actions of other members.

Discussion – empirical evidence

- Case of Dutch fisheries: co-management regime involving co-ops with joint and several liability laid on top of a pre-existing ITQ system

- Introduction of co-management groups
  - allowed reduction of monitoring costs for the regulator by 45%
  - reduced the number of registered infringement by 90%

  (Van Hoof, 2010)

Perspectives

- Investigate further the specifics of how joint and several liability is applied in fisheries
- Comparison of liability regimes in fishery cooperative programs worldwide
- Examine incentive effects of alternative liability regimes to inform institutional design of cooperative-based catch share systems

Thank you for your attention

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