IIFET 2016 Conference, 11-15 July 2016, Aberdeen, Scotland

A game theoretic model of monitoring and compliance in fishery cooperatives

Manuel Bellanger[1], Dan Holland[2], Chris Anderson[3], Olivier Guyader[1], Claire Macher[1]

[1] IFREMER, UMR AMURE

[2] Northwest Fisheries Science Center, NOAA Fisheries

[3] School of Aquatic and Fishery Sciences, University of Washington

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 judgements 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 harvesters managing collectively their fishing activities
- Assigning rights to a group rather than to individuals can facilitate coordination and collective action → *co-management* approach
- Co-op members may be <u>jointly and severally liable</u> for not exceeding collectively assigned fishing rights (*e.g.* in the U.S. and in the E.U.)

Joint & Several Liability

- Members of the same co-op may be jointly and severally liable for not exceeding collective fishing quotas, and sometimes for other violations too (*e.g.* misreporting of catch landings and discards),
  i.e. **the regulator can hold the members of the co-op collectively liable for damages caused by one or more members**.

  → Potential reduction of monitoring costs for the regulator

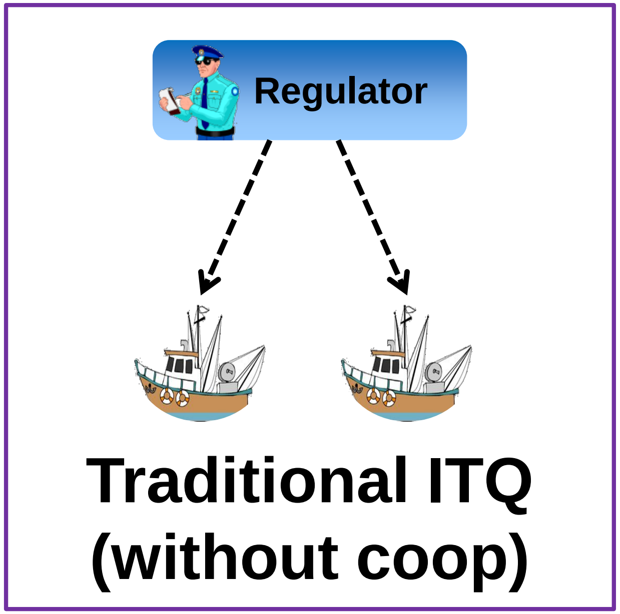
- Co-ops implement an **internal "*compliance regime*"** specified in their contracts/internal agreements, including monitoring (observation, reporting) and penalties

  → Change of traditional deterrence scheme and economic incentives

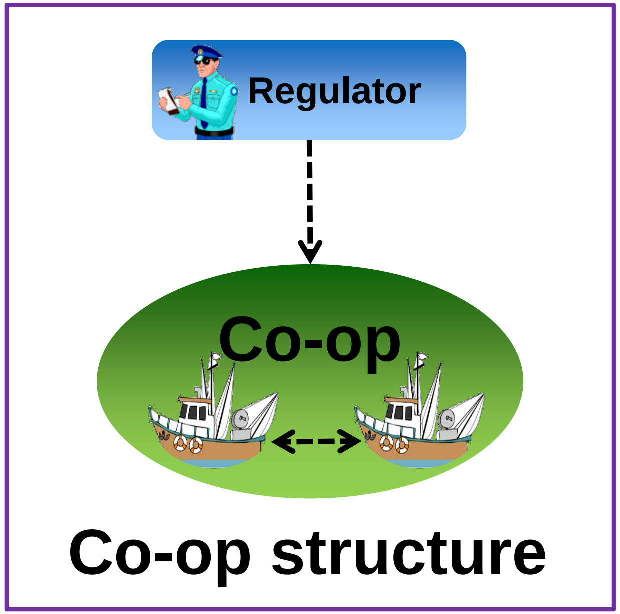
- In some co-op agreements: indemnification against regulator penalties

The model

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



VS



- Unpredictable fishing events: large catches of some species the fisherman does not hold quota for
- Individual fisherman is considering violating for an additional benefit X (trip level decision)

The model

- *Homo oeconomicus* baseline case: Traditional ITQ
  - Regulator has probability p_r of detecting violation, and imposes a fine V_r
  - Individual fisherman complies if and only if: $X \leq p_r V_r$

- Fishery co-op → joint & several liability
  - Fines imposed by the regulator are equally supported by $\boldsymbol{i}$ and $\boldsymbol{j}$
  - The co-op can implement internal monitoring. In the model, we consider that co-op members can “watch” each other.
  - We investigated 2 mechanisms:
    - Scenario 1 - indemnification: By watching $\boldsymbol{i}$ at cost $\boldsymbol{\alpha}$, $\boldsymbol{j}$ can protect self against regulator penalties when $\boldsymbol{i}$ violates with probability $\boldsymbol{p_c}$ (no internal penalty other than indemnification). Indemnification occurs when the regulator detects a violation by $\boldsymbol{i}$ that was also detected by $\boldsymbol{j}$.
    - Scenario 2 - internal penalty: By watching $\boldsymbol{i}$ at cost $\boldsymbol{\alpha}$, $\boldsymbol{j}$ can detect a violation by $\boldsymbol{i}$ and collect a fine $\boldsymbol{V_c}$ from $\boldsymbol{i}$ with a probability $\boldsymbol{p_c}$ (internal penalties are independent of detection by the regulator)

The model

- In scenarios 1 and 2, i chooses among the 4 following strategies:
  - $i(0,0)$: i does not violate and does not watch j
  - $i(0,1)$: i does not violate and watches j
  - $i(1,0)$: i violates and does not watch j
  - $i(1,1)$: i violates and watches j

- Similarly, j chooses among $j(0,0)$, $j(0,1)$, $j(1,0)$ and $j(1,1)$

The model

- The game is presented in normal form (payoff matrix)
- 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: under scenario 1 (no internal penalty other than indemnification), rational economic incentives to comply are not higher than in the ITQ *homo oeconomicus* baseline case.

- Proposition 2: under scenario 2 (internal penalty), symmetric players (*i.e.* such that $X_i = X_j$) have no incentive to effectively implement an internal monitoring system.

- Proposition 3: under scenario 2 (internal penalty) and assuming asymmetric players such that $X_j < \frac{1}{2} p_r V_r < X_i < \frac{1}{2} p_r V_r + p_c V_c$, rational economic incentives to comply increase.

Scenario 1 - indemnification: no internal penalty other than indemnification

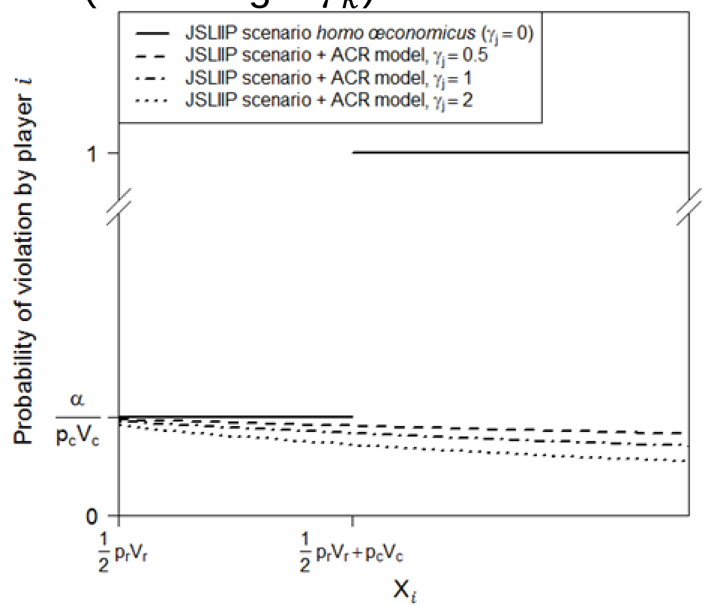
Scenario 2 - internal penalty: the co-op can impose internal penalties independent of detection by the regulator

Social preferences

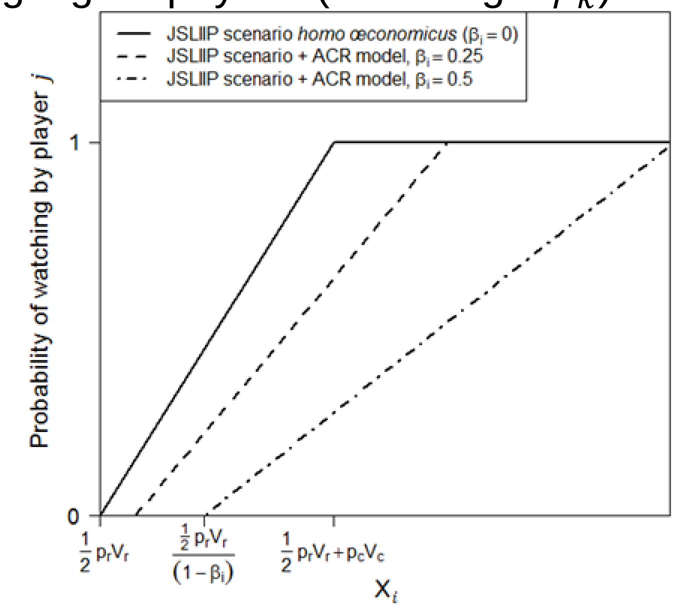
❖ <u>Proposition 4</u>: under scenario 2 (internal penalty), assuming asymmetric players and considering an **inquality aversion model***, the level of compliance increases even more.

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

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).



(a) level of violation by i



(b) level of monitoring by j

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

- Reporting: catch logs and dealers reports required on a timely basis
- Observation: at-sea and dockside observers, electronic equipment
- Penalty structures: graduated sanctions for noncompliance 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.

Thank you for your attention

Manuel Bellanger[1]*, Dan Holland[2], Chris Anderson[3], Olivier Guyader[1], Claire Macher[1]

[1] **IFREMER, UMR AMURE**

[2] **Northwest Fisheries Science Center, NOAA Fisheries**

[3] **School of Aquatic and Fishery Sciences, University of Washington**

*** manuel.bellanger@ifremer.fr**

Backup slides…

Perspectives

- ❖ Empirical elements showing the influence of the compliance regime implemented by co-ops on the behavior of harvesters

- ➢ Direct evidence → difficulty of estimating non-compliance rates

- ➢ Indirect evidence, *e.g.* “observer effect” (**Münch & Demarest 2016**)

  - ▪ In New England sectors, observer coverage rate ≈ 20%

  - ▪ Sector discard rates applied to unobserved trips are based on average observed trip data

  - ▪ Comparison between observed trips vs unobserved trips shows changes in fishing location/landings, indicating potential illegal discards

→ incentives of co-ops to monitor and enforce discards regulations?

Discussion – limitations of the model

- From a *2 players* situation to an *N fishers* co-op

Simplifying assumption: the "*second player*" may be considered as the "*rest of the cooperative*", *i.e*. an aggregation of the other fishermen

→ impacts on the probability of detection and monitoring costs, but analytical results would be essentially similar

→ free-riding issues (monitoring)

→ size of the co-op and social capital

- One-shot game whereas the environment modeled is repeated

- Penalty structure: penalties ramp up for repeated offenses

→ can create asymmetry between players

The model

- Normal form game (payoff matrix)

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

- $i(0,0)$: i does not violate and does not watch j
- $i(0,1)$: i does not violate and watches j
- $i(1,0)$: i violates and does not watch j
- $i(1,1)$: i violates and watches j
- α: monitoring cost
- p_r: probability of detection by the regulator
- V_r: fine imposed by the regulator

Scenario 1 - indemnification: by watching $\boldsymbol{i}$ at cost $\boldsymbol{\alpha}$, $\boldsymbol{j}$ can protect self against regulator penalties when $\boldsymbol{i}$ violates with probability $\boldsymbol{p_c}$ (no internal penalty other than indemnification).

Finding Nash equilibria by eliminating dominated strategies

For example: if $X_j \le X_i < \frac{1}{2} p_r V_r$, we have:

$\boxed{i(1,0)} \prec \boxed{i(0,0)}$ (strategy $i(1,0)$ is dominated by $i(0,0)$)

$\boxed{i(1,1)} \prec \boxed{i(0,1)}$, $j(1,0) \prec j(0,0)$, $j(1,1) \prec j(0,1)$

then $i(0,1) \prec i(0,0)$ and $j(0,1) \prec j(0,0)$

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

Mixed strategy equilibria

Nash theorem => existence of a solution

e.g. if $\frac{1}{2}p_rV_r < X_j \le X_i < \frac{1}{2}p_rV_r + p_cV_c$, no pure" Nash equilibrium

We assign probabilities m, n, l and $1-m-n-l$ to $\boldsymbol{i}$'s strategies.

We assign probabilities p, q, t and $1-p-q-t$ to $\boldsymbol{j}$'s strategies.

Scenario 2- internal penalty		**Player j**			
		$j(0,0)$	$j(0,1)$	$j(1,0)$	$j(1,1)$
Player i	$i(0,0)$ m	p $\begin{cases}\pi_i = 0\\ \pi_j = 0\end{cases}$	q $\begin{cases}\pi_i = 0\\ \pi_j = -\alpha\end{cases}$	t $\begin{cases}\pi_i = -\frac{1}{2}p_rV_r\\ \pi_j = X_j - \frac{1}{2}p_rV_r\end{cases}$	$1-p-q-t$ $\begin{cases}\pi_i = -\frac{1}{2}p_rV_r\\ \pi_j = X_j - \frac{1}{2}p_rV_r - \alpha\end{cases}$
	$i(0,1)$ n	$\begin{cases}\pi_i = -\alpha\\ \pi_j = 0\end{cases}$	$\begin{cases}\pi_i = -\alpha\\ \pi_j = -\alpha\end{cases}$	$\begin{cases}\pi_i = -\frac{1}{2}p_rV_r + p_cV_c - \alpha\\ \pi_j = X_j - \frac{1}{2}p_rV_r - p_cV_c\end{cases}$	$\begin{cases}\pi_i = -\frac{1}{2}p_rV_r + p_cV_c - \alpha\\ \pi_j = X_j - \frac{1}{2}p_rV_r - p_cV_c - \alpha\end{cases}$
	$i(1,0)$ l	$\begin{cases}\pi_i = X_i - \frac{1}{2}p_rV_r\\ \pi_j = -\frac{1}{2}p_rV_r\end{cases}$	$\begin{cases}\pi_i = X_i - \frac{1}{2}p_rV_r - p_cV_c\\ \pi_j = -\frac{1}{2}p_rV_r + p_cV_c - \alpha\end{cases}$	$\begin{cases}\pi_i = X_i - p_rV_r\\ \pi_j = X_j - p_rV_r\end{cases}$	$\begin{cases}\pi_i = X_i - p_rV_r - p_cV_c\\ \pi_j = X_j - p_rV_r + p_cV_c - \alpha\end{cases}$
	$i(1,1)$ $1-m-n-l$	$\begin{cases}\pi_i = X_i - \frac{1}{2}p_rV_r - \alpha\\ \pi_j = -\frac{1}{2}p_rV_r\end{cases}$	$\begin{cases}\pi_i = X_i - \frac{1}{2}p_rV_r - p_cV_c - \alpha\\ \pi_j = -\frac{1}{2}p_rV_r + p_cV_c - \alpha\end{cases}$	$\begin{cases}\pi_i = X_i - p_rV_r + p_cV_c - \alpha\\ \pi_j = X_j - p_rV_r - p_cV_c\end{cases}$	$\begin{cases}\pi_i = X_i - p_rV_r - \alpha\\ \pi_j = X_j - p_rV_r - \alpha\end{cases}$

Mixed strategy equilibria

The expected payoff of player i is:

$$E(\pi_i) = \left(-\tfrac{1}{2}p_rV_r(1-p-q)\right) \times m + \left(-\tfrac{1}{2}p_rV_r(1-p-q) + p_cV_c(1-p-q) - \alpha\right) \times n$$
$$+ \left(X_i - \tfrac{1}{2}p_rV_r(2-p-q) - p_cV_c(1-p-t)\right) \times l$$
$$+ \left(X_i - \tfrac{1}{2}p_rV_r(2-p-q) - p_cV_c(1-p-t) - \alpha\right) \times (1-m-n-l)$$

Scenario 2- internal penalty		Player j			
		$j(0,0)$ p	$j(0,1)$ q	$j(1,0)$ t	$j(1,1)$ $1-p-q-t$
Player i	$i(0,0)$ m	$\begin{cases} \pi_i = 0 \\ \pi_j = 0 \end{cases}$	$\begin{cases} \pi_i = 0 \\ \pi_j = -\alpha \end{cases}$	$\begin{cases} \pi_i = -\frac{1}{2}p_rV_r \\ \pi_j = X_j - \frac{1}{2}p_rV_r \end{cases}$	$\begin{cases} \pi_i = -\frac{1}{2}p_rV_r \\ \pi_j = X_j - \frac{1}{2}p_rV_r - \alpha \end{cases}$
	$i(0,1)$ n	$\begin{cases} \pi_i = -\alpha \\ \pi_j = 0 \end{cases}$	$\begin{cases} \pi_i = -\alpha \\ \pi_j = -\alpha \end{cases}$	$\begin{cases} \pi_i = -\frac{1}{2}p_rV_r + p_cV_c - \alpha \\ \pi_j = X_j - \frac{1}{2}p_rV_r - p_cV_c \end{cases}$	$\begin{cases} \pi_i = -\frac{1}{2}p_rV_r + p_cV_c - \alpha \\ \pi_j = X_j - \frac{1}{2}p_rV_r - p_cV_c - \alpha \end{cases}$
	$i(1,0)$ l	$\begin{cases} \pi_i = X_i - \frac{1}{2}p_rV_r \\ \pi_j = -\frac{1}{2}p_rV_r \end{cases}$	$\begin{cases} \pi_i = X_i - \frac{1}{2}p_rV_r - p_cV_c \\ \pi_j = -\frac{1}{2}p_rV_r + p_cV_c - \alpha \end{cases}$	$\begin{cases} \pi_i = X_i - p_rV_r \\ \pi_j = X_j - p_rV_r \end{cases}$	$\begin{cases} \pi_i = X_i - p_rV_r - p_cV_c \\ \pi_j = X_j - p_rV_r + p_cV_c - \alpha \end{cases}$
	$i(1,1)$ $1-m-n-l$	$\begin{cases} \pi_i = X_i - \frac{1}{2}p_rV_r - \alpha \\ \pi_j = -\frac{1}{2}p_rV_r \end{cases}$	$\begin{cases} \pi_i = X_i - \frac{1}{2}p_rV_r - p_cV_c - \alpha \\ \pi_j = -\frac{1}{2}p_rV_r + p_cV_c - \alpha \end{cases}$	$\begin{cases} \pi_i = X_i - p_rV_r + p_cV_c - \alpha \\ \pi_j = X_j - p_rV_r - p_cV_c \end{cases}$	$\begin{cases} \pi_i = X_i - p_rV_r - \alpha \\ \pi_j = X_j - p_rV_r - \alpha \end{cases}$

Mixed strategy equilibria

The expected payoff of player i is:

$$E(\pi_i) = \left(-\tfrac{1}{2} p_r V_r (1-p-q)\right) \times m + \left(-\tfrac{1}{2} p_r V_r (1-p-q) + p_c V_c (1-p-q) - \alpha\right) \times n$$
$$+ \left(X_i - \tfrac{1}{2} p_r V_r (2-p-q) - p_c V_c (1-p-t)\right) \times l$$
$$+ \left(X_i - \tfrac{1}{2} p_r V_r (2-p-q) - p_c V_c (1-p-t) - \alpha\right) \times (1-m-n-l)$$

i maximize its expected payoff, so partial derivatives with respect to m, n, and l must be 0:

$$\begin{cases} \dfrac{\partial E(\pi_i)}{\partial m} = 0 \\ \dfrac{\partial E(\pi_i)}{\partial n} = 0 \\ \dfrac{\partial E(\pi_i)}{\partial l} = 0 \end{cases} \Leftrightarrow \begin{cases} q = t + \dfrac{X_i - \frac{1}{2} p_r V_r - \alpha}{p_c V_c} & (1) \\ p = 1 - t - \dfrac{X_i - \frac{1}{2} p_r V_r}{p_c V_c} & (2) \\ 1 - p - q = \dfrac{\alpha}{p_c V_c} & (3) \end{cases}$$

=> We derive the probabilities associated with each strategy when players choices are mutually optimal, thus the levels of compliance and monitoring of each player.