Managing the commons with heterogeneous actors: What do we know we don't know?

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Context

The discussion of CPR management often assumes monitoring is feasible, but is not always the case:

- **Cost Prohibitive**: "Hirst Decision" (2016) made it illegal to provide water well permits in WA if the well interferes with protected waterways or senior water rights holders. But monitoring of the construction of new wells is cost prohibitive.
- **Political Conflict**: Border disputes in the South China Sea make monitoring difficult. Illegal fishing is estimated to account for half of total fish harvests in that area (Sumaila and Cheung 2015).

Literature (1)

- **Suleiman and Rapoport (1988)** and **Rapoport and Suleiman (1992)**: If appropriations are anonymous then they are larger. Stock size uncertainty also increases appropriation mean and variance. Expectation equilibrium if players are boundedly rational.
- **Budescu, Rapoport, and Suleiman (1990)** and **Budescu, Rapoport, and Suleiman (1995)**: Heterogeneity (in ability to profit) leads to higher and more variable appropriation levels, but notions of fairness come into play.
- **J. M. Baland and Platteau (1997), 1998, 1999**: Harvesting model analogous to Cournot competition, where greater inequality leads to more efficient use of the CPR. Heterogeneous in ability to invest.

Literature (2)

- **Faysse (2005)**: Four types of heterogeneity: (1) social position, (2) ability to invest, (3) ability to profit, (4) exit options.
- **Apesteguia (2006)**: Even with payoff uncertainty, players will arrive at a Nash Equilibrium if they have a chance to learn.
- **Aflaki (2013)**: If appropriations above stock level lead to continuous decrease and stock uncertainty is about likelihood instead of size, ambiquity leads to less appropriation.

Research Question

Does firm heterogeneity change the implications of different policy tools when firm costs are private information?

Policy Tools

- Community management: agents can pay to inspect other agents. If the inspected agent is in violation, they pay a fine to the inspecting agent (Casari and Plott 2003).
- Regulator management: (1) regulators apply a high flat fee to all agents if total harvests exceed the optimal level, (2) unmetered agents pay a high flat fee, metered agents pay per unit harvested (Tarui et al. 2008).

Research Contribution

- Extends Aflaki (2013) to examine harvest uncertainty due to lack of information about agent's efforts and strategic implications of agent heterogeneity.
- Consider the implications for heterogeneity on CPR management approaches.

Model (1)

Firms compete in a CPR game in which they choose an effort e_i and earn a harvest that depends on their own effort, the total effort of all firms, and the size of the resource. Firms are heterogeneous in cost c_i and types are not private information, so that the expected profit of a firm is

$$\Pi_i(e_i, e_{-i}, S) = e_i \mathbb{E}_{e_{-i}} h(e_i + e_{-i}, S) - c_i e_i$$

where the price of the harvest is normalized to one. e_i is the firm effort invested in harvesting, $e_{-i} = \sum_{j \neq i} e_j$ is the (expected) total effort of all other firms, and S is the size of the stock. The marginal cost c_i is constant and varies according to firm type.

Model (2)

Assumption 1: The harvest deterioration function $h(e, S)$ reflects increasing difficulty of harvest as total harvests increase, so that it is increasing in S and decreasing and convex in total harvest e.

The corresponding BRF $e_i(e_{-i})$ maximizes expected profits, and the marginal profit is given by

$$
\begin{aligned}
m(e_i, e_{-i}) &= \frac{\partial \Pi_i(e_i, e_{-i}, S)}{\partial e_i} \\
&= \mathbb{E}_{e_{-i}} \left[e_i h_1(e_i + e_{-i}, S) + h(e_i + e_{-i}, S) \right] - c_i.
\end{aligned}
$$

The expectation equilibrium effort is e_i^* that solves $m(e_i, e_{-i}) = 0$.

Functional Form

If there are only two firm types, a low-cost and high-cost type, and $h(e,S) = S - \lambda e$ is a linearly decreasing deterioration function, then in the two-firm case the BRF for each type is

$$e_L(e_H) = \frac{1 - \lambda(1-p)e_H - c_L}{2\lambda(1+p)} \quad e_H(e_L) = \frac{1 - 2\lambda p e_L - c_H}{2\lambda(1+(1-p))}$$

A Flat Fee

Following J. M. Baland and Platteau (1998), a flat fee is charged to all firms if total effort exceeds some optimal effort e^o.

$$\Pi_i(e_i, e_{-i}, S) = \begin{cases} e_i \mathbb{E}_{e_{-i}} h(e_i + e_{-i}, S) - c_i e_i & \text{if } e \leq e^o \\ e_i \mathbb{E}_{e_{-i}} h(e_i + e_{-i}, S) - c_i e_i - T & \text{otherwise.} \end{cases}$$

Non-Monitored Fee

Each firm can accept monitoring and pay per harvest unit t, or pay a flat fee, yielding the following profit function.

$$\Pi_i(e_i, e_{-i}, S) = \begin{cases} (1-t)e_i \mathbb{E}_{e_{-i}} h(e_i + e_{-i}, S) - c_i e_i & \text{if monitored} \\ e_i \mathbb{E}_{e_{-i}} h(e_i + e_{-i}, S) - c_i e_i - T & \text{otherwise.} \end{cases}$$

Community Investigators

Following Casari and Plott (2003), firm i can pay a cost ξ to inspect firm j. If $e_j > e^o$, then j pays a fine $F(e, S)$ to i. If not, firm i is out the cost of inspection. $F(e, e^o) = \gamma(e - S)$ so that the fine grows with the disparity.

Work to be Done!

- Two-stage strategic implications
- Solutions and comparison

Thanks!

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