Can Incomplete Information Lead to Under-exploitation in the Commons?

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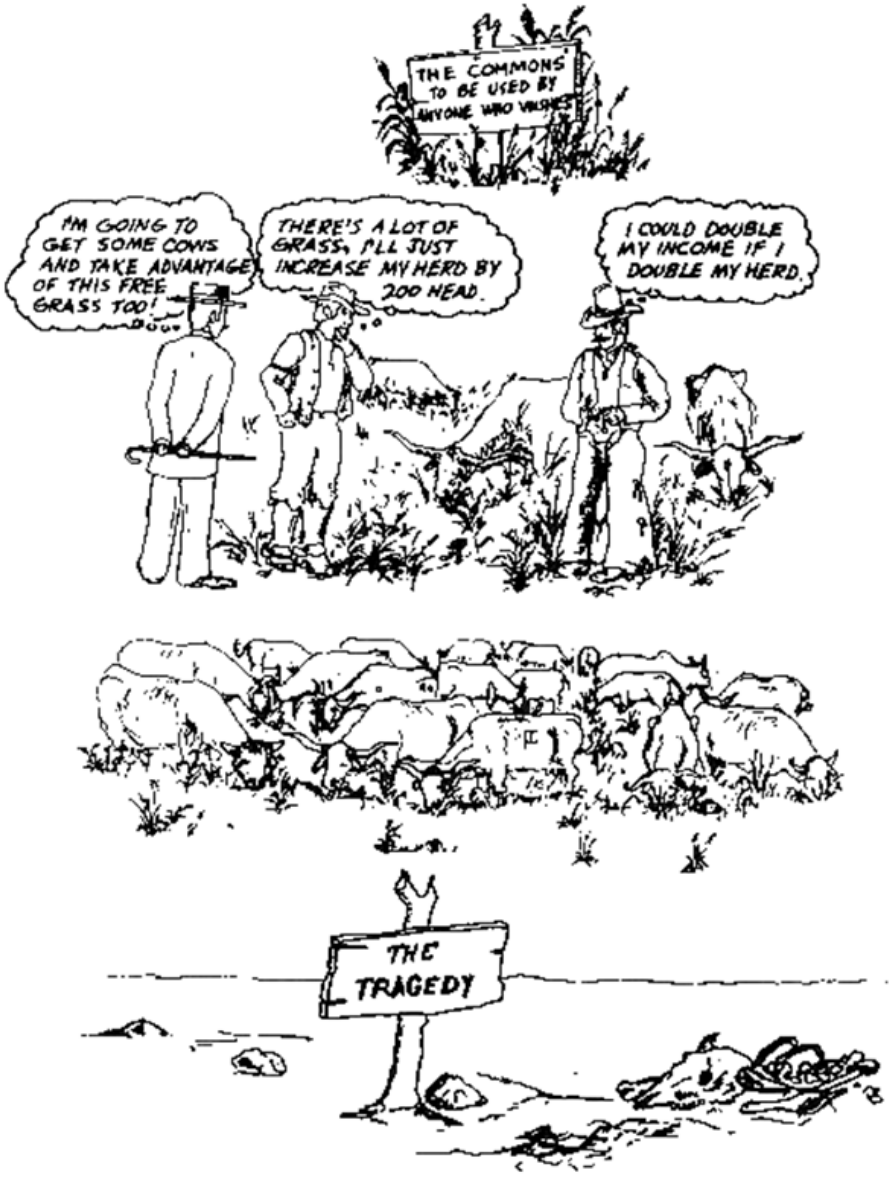
THE COMMONS
TO BE USED BY
ANYONE WHO WISHES
I'M GOING TO GET SOME COWS AND TAKE ADVANTAGE OF THIS FREE GRASS TOO!
THERE'S A LOT OF GRASS, I'LL JUST INCREASE MY HERD BY 200 HEAD.
I COULD DOUBLE MY INCOME IF I DOUBLE MY HERD.
THE TRAGEDY

Introduction

- Tragedy of the commons examines how CPR are prone to *overexplotation*
- Users do not internalize the external effect
- Multiples studies focus on how to prevent overexplotaition
- We analyze a CPR game in a context of *incomplete information*
- The incumbent privately observes the commons' initial stock but the potential entrant does not
- The entrant infers the level of the stock by observing the incumbent's exploitation
- Empirical evidence: Pinkerton and Ramirez (2009) fishing communities in Loreto (Mexico)

Introduction

- How the incumbent's exploitation of the CPR can convey or conceal information
- Under which condition the incumbent's incentives to deter entry can serve as a tool to protect the resource

Outline of the Presentation

- Literature review
- Complete Information
- Incomplete Information in the CPR game
- Comparison under both informational contexts
- Conclusions

Literature

1. Several approaches analyze how to reduce overexploitation in the commons by ...[Ostrom (2009)]
    1. inserting the CPR game into an enlarged structure (repeated games), allowing for perfect/imperfect monitoring. Baland and Plateau (1996)
    2. Similarly, we insert the CPR game into an asymmetric information context.
2. This study also relates to models of entry deterrence in the commons, such as Mason and Polasky (1994), who consider *complete* information.
    1. We consider both complete and incomplete information.
3. The paper also contributes to the literature on signaling when agents' actions impose *intertemporal* externalities.

Model - Complete Information

- Consider a CPR (Fishing grounds, forest) where and incumbent (Firm 1) *initially* exploits the resource
- An entrant (Firm 2) analyzes whether or not to enter
- There are **no** entry barriers
- The initial stock is either low or high $\theta_K = \{\theta_L, \theta_H\}$
- Two-stage game
  - In the first stage, the incumbent decides its appropriation level $x_1 > 0$
  - In the second stage a potential entrant, observing the incumbent's appropriation level, chooses whether or not to join the incumbent.

First Stage

- the incumbent appropriates $x_1 > 0$ with a total cost $c(x_1, \theta_K)$, which is increasing and convex in appropriation, i.e.,. In addition, the marginal cost of appropriation is decreasing in the available stock θ_K, i.e., $c_{x_1\theta} \leq 0$.
  - $c_{x_1} > 0$, $c_{x_1x_1} > 0$ and $c_{x_1\theta} \leq 0$
  - The incumbent is the only agent exploiting the resource, obtaining monopoly profits of $M_1^K(x_1) \equiv x_1 - c(x_1, \theta_K)$ where $K = \{H, L\}$.

Second Stage

- **No Entry:**
  - The incumbent appropriates $q_1 > 0$ obtaining

$$\overline{M}_1^K(q_1; x_1) \equiv q_1 - c^1(q_1, x_1, \theta_K, \beta), \quad K = \{H, L\},$$

- **Entry:**
  - Incumbent and entrant compete for the common resource,

$$D_i^K(q_i, q_j; x_1) \equiv q_i - z^i(q_i, q_j, x_1, \theta_K, \beta), \quad K = \{H, L\},$$

- The regeneration rate of the CPR, $\beta \in [0, 1]$.
  - $\beta < 1$ indicates that the regeneration rate of the CPR does not compensate the reduction of the initial stock (biological regeneration does not offset first-period appropriation).
  - $\beta = 1$ illustrates that the regeneration rate exactly compensates the reduction of the initial stock (biological regeneration offsets first-period appropriation)

Complete information

1. When the initial stock is **low**, the entrant does not enter, and...
    1. The incumbent fully internalizes the effect of first-period appropriation.
    2. No overexploitation of the CPR.
2. When the initial stock is **high**, the entrant enters, and...
    1. 1ST PERIOD: Overexploitation...
        1. because the incumbent ignores external effects.
    2. 2ND PERIOD: Overexploitation...
        1. that is, the standard "tragedy of the commons" emerges.

Incomplete information - Time structure

1. Nature decides the realization of the CPR's stock, either high or low, with probabilities p and $1-p$, respectively. Only observed by the incumbent.
2. The incumbent chooses its first-period effort, yielding an associated first-period appropriation.
3. The entrant observes the incumbent's actions, and forms beliefs. Let $\mu(\theta_H|x_1)$ denote the entrant's posterior belief about the initial stock being high after observing x_1
4. Given these beliefs, the entrant chooses whether or not to enter the CPR.
5. If entry does not occur, the incumbent remains the only agent exploiting the CPR, whereas if entry occurs, both agents compete for the CPR.

Separating equilibrium

- The incumbent selects a particular first-period appropriation level when the stock is high, but chooses a different appropriation when the stock is low.
- We assume that the separating appropriation level x_1^L does not coincide with the low-stock incumbent's appropriation under complete information, $x_1^{L,NE}$.
- Otherwise, the high-stock incumbent could be tempted to pool with the low-stock incumbent
- Entrant's equilibrium beliefs are $\mu(\theta_H|x_1^H) = 1$ and $\mu(\theta_H|x_1^L) = 0$.

Separating equilibrium

- The entrant enters when it infers that the initial stock is high, but stays out when it interprets that the stock is low.
- Incentive compatibility conditions that guarantee the existence of a separating equilibrium. The high-stock incumbent selects its equilibrium appropriation $x_1^{H,E}$ if

$$M_1^H(x_1^{H,E}) + \delta D_1^H(x_1^{H,E}) \geq M_1^H(x_1^L) + \delta \overline{M}_1^H(x_1^L)$$

- The low-stock incumbent selects the equilibrium appropriation of x_1^L if

$$M_1^L(x_1^L) + \delta \overline{M}_1^L(x_1^L) \geq M_1^L(x_1^{L,E}) + \delta D_1^L(x_1^{L,E})$$

Separating equilibrium

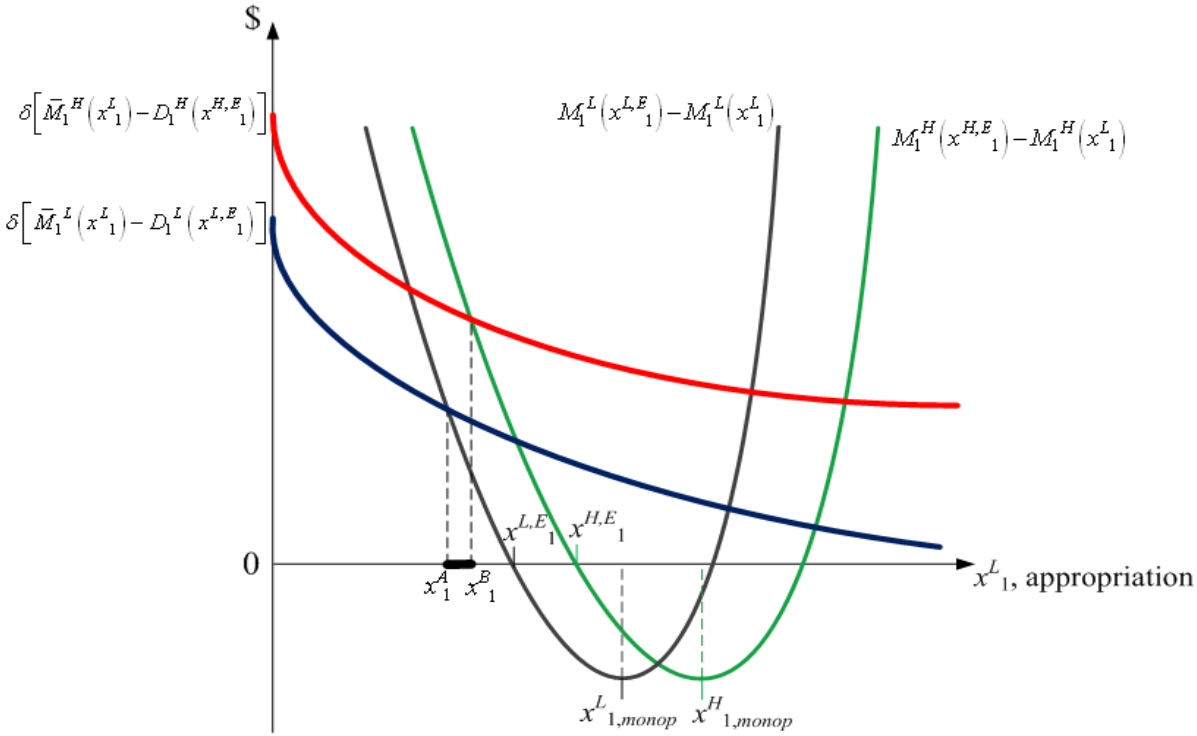

Figure 1. Separating equilibria under $\beta < 1$.

Separating equilibrium

- Consider $\beta = 1$

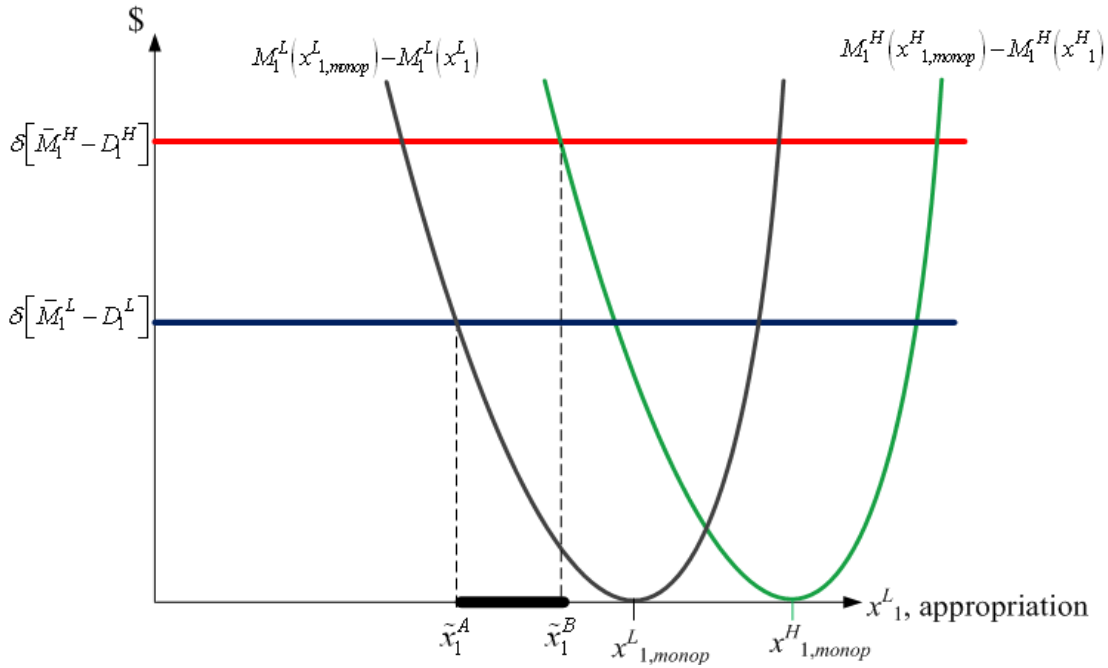

Figure 2. Separating equilibria under $\beta = 1$.

Separating equilibrium

- High-stock: Example about Hudson's Bay Company [Mason and Polasky (1994)
  - Faced with the threat of entry from French furtraders during the 18th century, the company increased beaver harvests.
- Low-stock is low [*underexploitaition]:* The case of the silver hake provides an interesting example of this type of informative signaling.
  - After two decades of intense exploitation by mechanized U.S. and Canadian fishing boats in the North Atlantic from 1960 to 1980, the available stock became significantly depleted. The incumbent fleet has consistently underexploited the resource below its annual sustainable catch since the late 1990s; see United Nations Food and Agriculture Organization.
- *The least-costly separating equilibrium survives the Intuitive Criterion if* $p > \overline{p}(x_1)$, *where* $\overline{p}(x_1) \equiv \frac{-D_2^L(x_1)}{D_2^H(x_1) - D_2^L(x_1)}$

Separating equilibrium

- **Efficiency properties.**

		Separating PBE	Complete Inf.
Low stock	1^{st} Period	x_1^B, underexp.	$x_1^{L,NE}$, soc. optimal
	2^{nd} Period	q_1^m, soc. optimal	q_1^m, soc. optimal
High stock	1^{st} Period	$x_1^{H,E}$, overexp.	$x_1^{H,E}$, overexp.
	2^{nd} Period	$q_1^d + q_2^d$, overexp.	$q_1^d + q_2^d$, overexp.

Pooling equilibrium

- Both types of incumbent select *the same first-period appropriation*, which reveals no additional information about the initial stock to the entrant, deterring entry.
- This is a positive result in terms of overexploitation since entry does not occur;
  - *Incomplete information provides the high-stock incumbent with an "implicit protection right."*
- The **high-stock** incumbent underexploits the CPR.
  - Why? This incumbent reduces exploitation in order to *conceal* its type to the potential entrant, deterring entry.
  - How to promote it? Setting up a quota.

- **Efficiency properties in the separating and pooling equilibria.**

		Separating PBE	Pooling PBE
Low stock	1^{st} Period	x_1^B, underexp.	$x_1^{L,NE}$, soc. optimal
	2^{nd} Period	q_1^m, soc. optimal	q_1^m, soc. optimal
High stock	1^{st} Period	$x_1^{H,E}$, overexp.	$x_1^{L,NE}$, underexp.
	2^{nd} Period	$q_1^d + q_2^d$, overexp.	q_1^m, soc. optimal

Conclusions

1. We consider asymmetric information and signaling in the commons.
2. By doing so, we identify additional forms of inefficiencies that can help ameliorate overexploitation in the commons.
    1. This occurs, in particular, in the pooling equilibrium when the initial stock is high.
3. The tragedy of the commons —present both under complete information and in the separating equilibrium— dissipates in the pooling equilibrium.