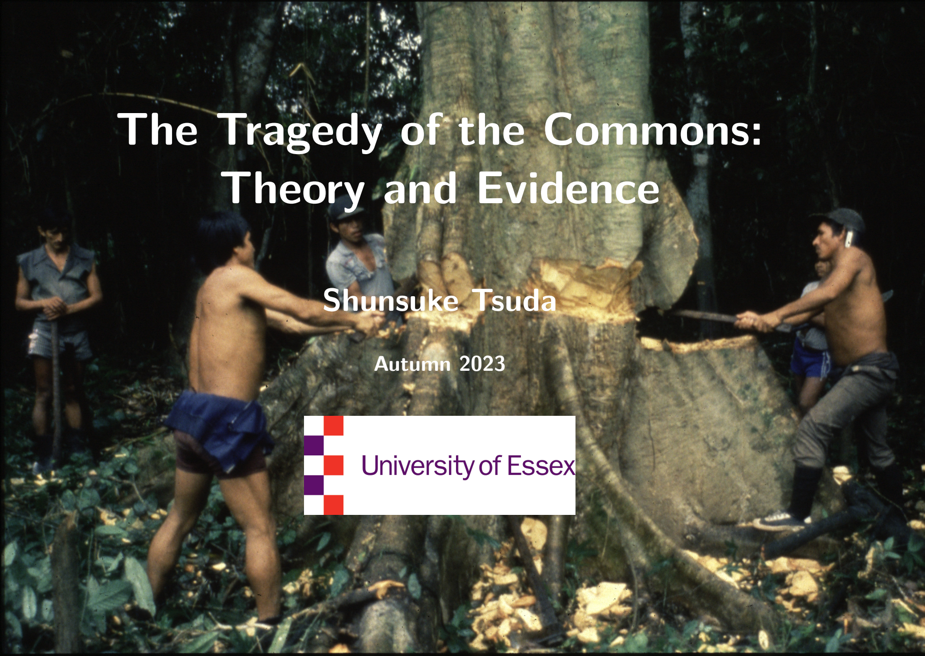

The Tragedy of the Commons: Theory and Evidence

Shunsuke Tsuda

Autumn 2023

University of Essex

Common-Pool Resources (Commons)

Recall from the week 2 lecture:

	Excludable	**Non-excludable**
Rivalrous	Private goods	**Common-pool resources (Local commons)**
Non-rivalrous	Club goods (Congestible resources)	Public goods

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Common-pool resources (a.k.a open-access resources or commons):

- E.g. forests, fishery, grazing lands, irrigation water, coal,...
- Other examples?
- Sources of market failure
- Particularly important in developing economies

Vicious Cycle between Poverty and Environmental Degradation

- The poor in rural areas often depend for their daily livelihood on local commons
- The local commons also provide some insurance for the poor (e.g. as a fallback source of food and fodder in bad crop years)

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  - Silting and increasing toxicity of rivers and ponds
  - Depletion of aquifers
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More erosion of local commons $\Rightarrow$ ...

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- How can we describe this situation formally (mathematically)?
- What are possible solutions?

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Elinor Ostrom won the Nobel Prize in 2009 for her field-based qualitative work which documented when the tragedy of the commons does and does not occur. Read Ostrom (1990) if interested.

Readings

Theory

Bardhan & Udry (1999) Ch. 13; Wydick (2007) Ch. 4

Rustagi et al. (2010)

"Conditional Cooperation and Costly Monitoring Explain Success in Forest Commons Management"

Ryan & Sudarshan (2022)

"Rationing the Commons"

Model of Common-Pool Resource Exploitation: Setup

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- Examples of common-pool resources and inputs:
  - Resources: forest (and forest products) & Inputs: labor
  - Resources: fish stock & Inputs: fishing net/boats

Villager- and Village-Level Profits

- p: input cost
- Profit of villager i:

$$\pi_i = \frac{k_i}{K} f(K) - pk_i \tag{1}$$

i.e. Villager i obtains a revenue proportional to his input level (k_i) relative to the village's overall input level (K)

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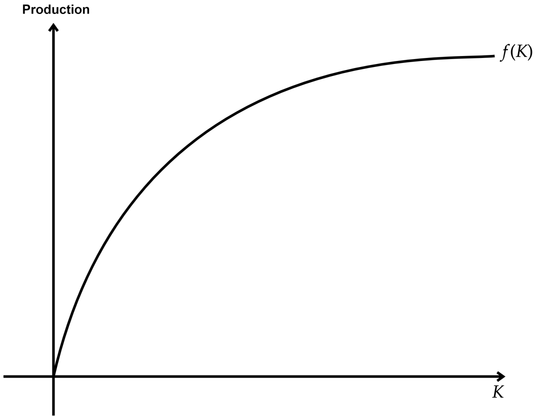
- Total profit in the village:

$$\pi = \sum_{i=1}^{N} \pi_i = f(K) - pK \tag{2}$$

Village-Level Production



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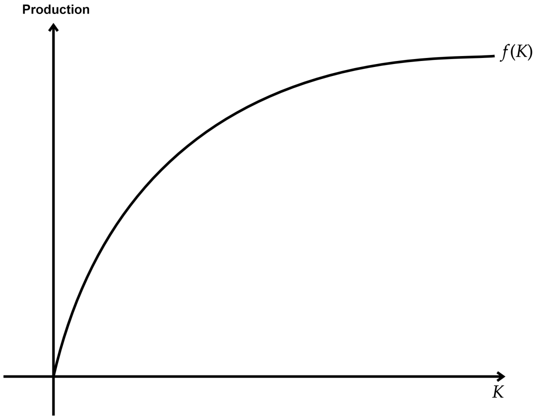

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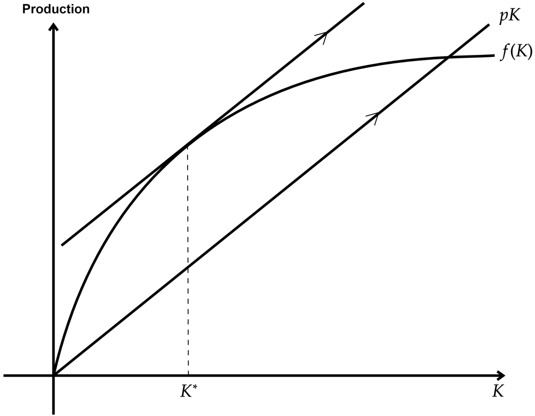
$\Rightarrow$ Marginal product = $f'(K) < \frac{f(K)}{K}$ = Average product for any K

Optimal Resource Use for the Village



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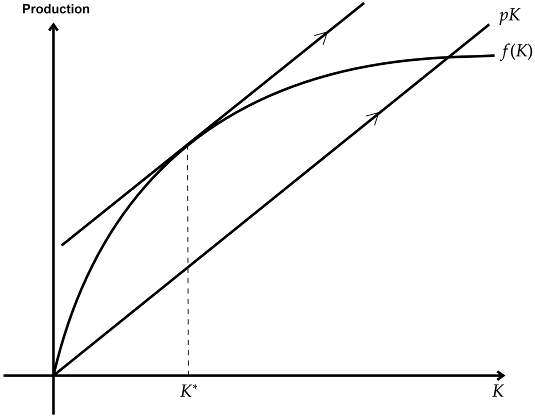

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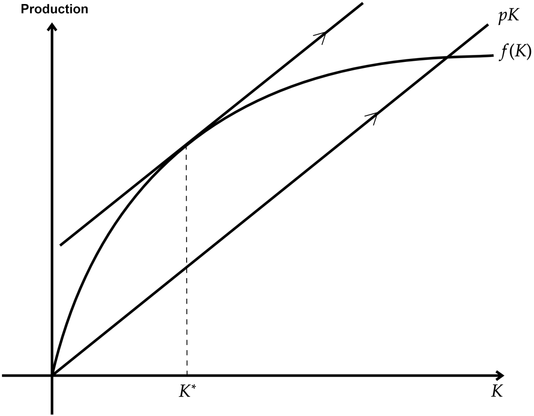

- Taking the derivative of (2) w.r.t. K yields $f'(K^*) = p$
- K^*: optimal input level where marginal product $=$ marginal cost
- Assume homogeneous villagers
  $\Rightarrow k^* = K^*/N$: optimal input level by each villager

Each Villager's Problem Without Cooperation across Villagers

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- Assume that villagers do not cooperate and that actions of others are given to each villager:

$$\frac{\partial k_j}{\partial k_i} = 0 \quad \forall j \neq i \tag{3}$$

- This non-cooperative environment is the key to the tragedy of the commons

Review of Basic Differentiations

Product rule:

$$\frac{d}{dx}u(x)v(x) = u(x)v'(x) + u'(x)v(x)$$

Chain rule:

$$\frac{d}{dx}f(g(x)) = f'(g(x))g'(x)$$

Then:

$$\begin{aligned}
\frac{d}{dx}\frac{u(x)}{v(x)} &= \frac{d}{dx}u(x)(v(x))^{-1} \\
&= u'(x)(v(x))^{-1} + u(x) \cdot (-1)(v(x))^{-2}v'(x) \\
&= \frac{u'(x)v(x) - u(x)v'(x)}{(v(x))^2}
\end{aligned}$$

These techniques suffice to solve each villager's profit maximization problem

Overexploitation without Cooperation across Villagers

- Recall villager i's profit from (1): $\pi_i = \frac{k_i}{K} f(K) - p k_i$
- Differentiating w.r.t. k_i yields:

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\frac{d\pi_i}{dk_i} &= \frac{f(K)}{K} + \frac{k_i}{K} f'(K) - \frac{k_i}{K^2} f(K) - p \\
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$\Rightarrow$ Villager i has an incentive to increase k_i over k^*: **Overexploitation**

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$$\frac{1}{N} f'(\hat{K}) + \frac{N-1}{N} \frac{f(\hat{K})}{\hat{K}} = p \tag{5}$$

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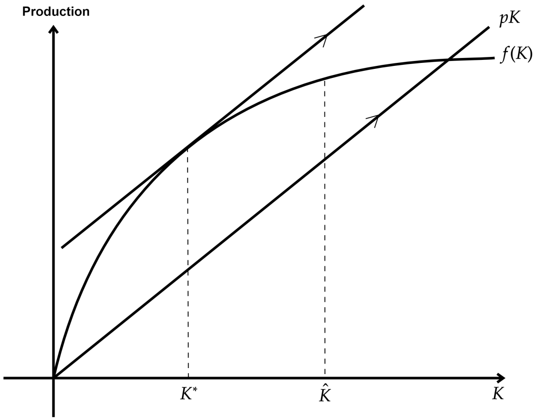
$\Rightarrow$ $\hat{K} > K^*$: **Overexploitation in the non-cooperative equilibrium!**

Overexploitation without Cooperation across Villagers



- K^*: optimal total input level that maximizes the total profit in the village
- $\hat{K}$: total input level in the non-cooperative equilibrium in which each villager maximizes his own profit

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- When a villager increases his input to the commons, this contribution to production is reflected in the **marginal** product
- In contrast, rewards for his increased inputs to the commons are based on the **average** product
- This wedge between the marginal and average product drives him to overexploit the commons
- However, if someone in the village overexploits the commons, it reduces the revenue of other villagers, and thus others will also become willing to exploit the commons more

The Tragedy of the Commons: Summary

- In general, **"the tragedy of the commons"** indicates the situation where the private cost of using a resource being less than its social cost leads to over-exploitation in the common-pool resources
- This is also a well-known case of environmental **externality**

Underinvestment in Maintenance of Common-Pool Resources

- Underinvestment in management, maintenance, and repair of the commons could also lead to resource degradation and depletion
- This is a similar situation to the tragedy of the commons

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- Resource dynamics:

$$\begin{aligned} K &= \bar{K} - \delta \bar{K} + \Delta K \\ &= \sum_i k_i \\ k_i &= \bar{k}_i - \delta \bar{k}_i + \Delta k_i \end{aligned}$$

  - $\bar{K}$: Stock of the commons in the previous period
  - k_i: Amount of the commons maintained by villager i's investment
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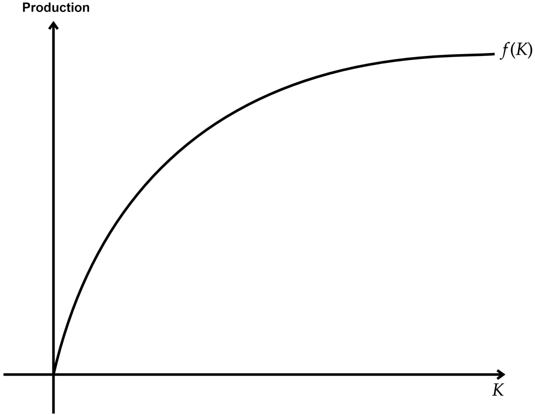
Village-Level Production



$f(K)$: Value of product from the use of resources

Villager- and Village-Level Profits (in the Current Period)

- p: input cost
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$$\pi_i = w_i f(K) - p\Delta k_i \tag{6}$$

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E.g. Maintaining irrigation facilities in Indian villages
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- Total profit in the village:

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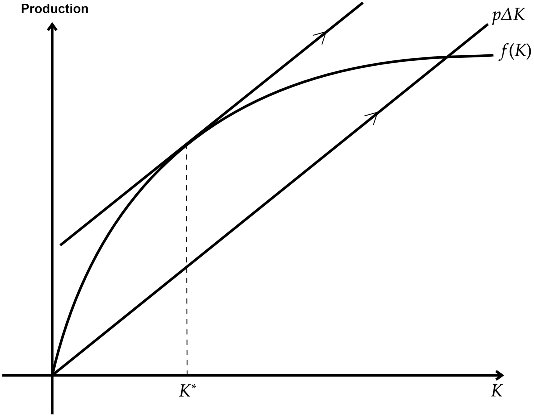
Optimal Investment in Maintenance for the Village



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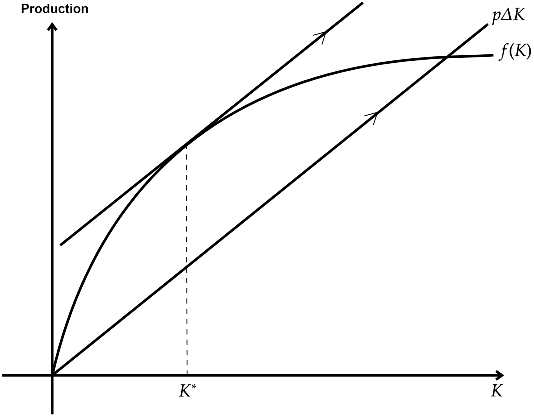

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Underinvestment without Cooperation across Villagers

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$\Rightarrow$ $\hat{K} < K^*$: **The free-rider problem!**

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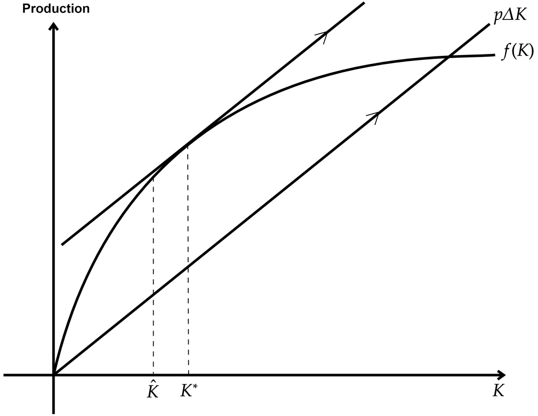
- **Intuition**: Each villager does not have an incentive to make the optimal investment, since the benefits from cooperating in investing in the commons are spread across everyone (while the individual marginal cost is p)

Underinvestment without Cooperation across Villagers



- K^*: optimal total maintained resource stock that maximizes the total profit in the village
- $\hat{K}$: total maintained resource stock in the non-cooperative equilibrium in which each villager maximizes his own profit

State Control or Privatization to Achieve Efficiency?

State control:

- Nationalize and use common-pool resources to maximize social benefits?
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Privatization or taxes:

- $\hat{K}/N$, the input level per villager under the tragedy of the commons, decreases as p, the input cost, increases
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$\Rightarrow$ Focus on the role of the **community**, which lies between the state and the individual

Cooperation under the Community (Model of Common-Pool Resource Extraction)

- Recall villager i's profit from (1): $\pi_i = \frac{k_i}{K} f(K) - pk_i$

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- Suppose that the community imposes a rule on everyone that everyone in the village behaves the same way

i.e. instead of (3), assume $\frac{\partial k_j}{\partial k_i} = 1 \; \forall j \neq i$

- Suppose also that everyone expects everyone to abide by the rule

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- Suppose also that everyone expects everyone to abide by the rule
- Then, with homogeneous villagers such that the input share of each villager will be constant and $1/N$, the FOC of villager i's problem becomes:

$$\begin{aligned} \frac{1}{N}\Big[f'(K) + \sum_{j \neq i} f'(K)\frac{\partial k_j}{\partial k_i}\Big] - p &= 0 \\ \Leftrightarrow \frac{1}{N}\Big[f'(K) + (N-1)f'(K) \cdot 1\Big] - p &= 0 \\ \Leftrightarrow f'(K) &= p \end{aligned}$$

The optimal level of resource extraction is achieved!

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i.e. If someone invests more, then other villagers must also increase their investments according to their relative distribution rates

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The optimal investment in maintaining the commons is achieved!

How Can the Community Sustain Cooperation?

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- Suppose all villagers agreed on a rule that each villager uses $k^* = K^*/N$ in each period (in the resource extraction model)

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For simplicity, let's look at games played by two players

One-Shot Two-Players' Games and Nash Equilibrium

		Player 2's action	
		Conserve	Overexploit
Player 1's action	Conserve (C)	(3, 3)	(1, 4)
	Overexploit (O)	(4, 1)	(2, 2)

- Two players simultaneously choose their actions *for one period*
- Numbers in (,) represent two players' payoffs:
  - If player 1 and 2 choose O and C, then they obtain 4 and 1
  - If both players choose C, then both of them obtain 3

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  - If player 1 chooses O, player2's payoff is higher by choosing O
  - If both choose O, no player has an incentive to deviate
  - Therefore, **(O, O) (i.e. both choose O) is NE**
  - Choosing action O is a **dominant strategy**, since choosing O yields a higher payoff whichever action the other player chooses

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- This dilemma characterizes the tragedy of the commons

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- However, **(C, C) yields higher payoffs (3, 3) for both players but cannot be achieved in NE!**
- This dilemma characterizes the tragedy of the commons
- In general, this game is also called the "prisoner's dilemma"

Q. Is there any way that could achieve the socially-optimal outcome (3, 3) by playing (C, C)?

Repeated Games with Punishments

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"Grim Trigger strategy":

1. Agree to cooperate and play C at the beginning and continue C as long as the other has also been playing C
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Compare present-valued payoffs with a discount factor $\rho < 1$ given that both players follow the grim trigger strategy (with $T \to \infty$):

- Present-value from C: $3 + 3\rho + 3\rho^2 + 3\rho^3 + \cdots = \frac{3}{1-\rho}$
  - Let $S \equiv 3 + 3\rho + 3\rho^2 + 3\rho^3 + \cdots$
  - Then, $\rho S = 3\rho + 3\rho^2 + 3\rho^3 + \cdots$
  - Subtracting the second from the first $\Rightarrow S - \rho S = (1 - \rho)S = 3$

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Each player has an incentive to play C if $\frac{3}{1-\rho} > 4 + \frac{2\rho}{1-\rho} \Leftrightarrow \rho > \frac{1}{2}$

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NE: Both follow the grim trigger strategy and start with C if $\rho > \frac{1}{2}$
$\Rightarrow$ **The socially-optimal outcome is achieved!**

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- With infinite punishments, each player had an incentive to play C if $\frac{3}{1-\rho} > 4 + \frac{2\rho}{1-\rho} \Leftrightarrow \rho > \frac{1}{2}$
- This implies that, if $\rho > \frac{1}{2}$, there exists a finite punishment periods T^* such that:

$$3 + 3\rho + 3\rho^2 + 3\rho^3 + \cdots + 3\rho^{T^*} \geq 4 + 2\rho + 2\rho^2 + 2\rho^3 + \cdots + 2\rho^{T^*}$$

$\Rightarrow$ **NE**: Both follow the grim trigger strategy and start with C if $\rho > \frac{1}{2}$ & $T > T^*$

Generalization

		Player 2's action	
		Conserve	Overexploit
Player 1's action	Conserve (C)	(s, s)	(v, r)
	Overexploit (O)	(r, v)	(t, t)

- The prisoner's dilemma is characterized by $r > s > t > v$
- The commons extraction is realistically characterized by $2s > r + v$
- Under the grim trigger strategy with infinite punishments, play C if:

$$
\begin{aligned}
s + \rho s + \rho^2 s + \rho^3 s + \cdots + &> r + \rho t + \rho^2 t + \rho^3 t + \cdots \\
\Leftrightarrow \frac{s}{1-\delta} &> r + \frac{\delta t}{1-\delta} \\
\Leftrightarrow \delta &> \frac{r-s}{r-t}
\end{aligned}
$$

Governing the Commons: The Top-Down Approach

A "sheriff" monitors common-pool resource users:

- m: the fraction of the time he catches violators
- F^* a fine violators pay if they are caught

$\Rightarrow$ $f \equiv mF$: the expected fine

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Player 1's action	Conserve (C)	(s, s)	$(v, r - f)$
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Consider again a one-shot game

- $r - f > s \Rightarrow$ (C, C) is a NE:
- & also $t - f > v \Rightarrow$ (C, C) is a unique NE

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But again, the top-down approach entails a monitoring issue

Self-Governance and the Sheriff (Elinor Ostrom)

Ostrom focuses on the information advantages of the commons users to avoid the difficulty of monitoring in the top-down approach → PS9

Coordination Game

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  - One-shot game has **only one NE** that does not achieve cooperation
- Another view is that the relevant costs and benefits of collective action may often be more favourable to the possibility of cooperation

$\Rightarrow$ **Coordination game**

  - One-shot game has **multiple equilibria**, one of which achieves cooperation while another of which does not achieve cooperation

One-Shot Coordination Game

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Q. But, which equilibrium will be selected?

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Q. But, which equilibrium will be selected?

- It depends on prior expectations of each player's action
- Forming mutual expectations of cooperation may be facilitated with pre-play communication and the opportunities for mutual reassurance

Prisoner's Dilemma vs. Coordination Game

Prisoner's dilemma game

	Conserve	Overexploit
Conserve (C)	(3, 3)	(1, 4)
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- NE of the static game: (O, O)

Coordination game

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- (Pure strategy) NE of the static game: (C, C) & (O, O)

N-Player Assurance Game

- Imagine a village consisting of N villagers
- In many cases, coordination may become effective only if the number of cooperators reaches a critical mass
- $b(j)$: benefits to each villager when j villagers voluntarily contribute to a local public good (e.g. maintenance and management of an irrigation system)
- c: fixed cost that each contributor incurs
- Assume:
  - Increasing returns to scale (IRS) in the provision of the public good: $b'(j) > 0$, $b''(j) > 0$
  - $b(1) < c$: each villager does not contribute alone

N-Player Assurance Game

	Payoff to i if the number of other contributors is			
Player i's action	$N-1$	$N-2$	$\cdots$	0
Contribute	$b(N)-c$	$b(N-1)-c$	$\cdots$	$b(1)-c$
Not contribute	$b(N-1)$	$b(N-2)$	$\cdots$	0

- There exists N^* such that $b(N^*)-c > b(N^*-1)$

$\Rightarrow$ Given IRS, $b(j)-c > b(j-1)$ for all $j > N^*$

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- **Herd behavior and the commons**:
  - Incentives to cooperate depend on how many others cooperate
  - Important role for community leadership to mobilize a sufficient number of contributors and set the assurance process rolling

Application to the Problem of Pollution and Global Warming

The incentive problem illustrated by the Tragedy of the Commons can also be applicable to the pollution problem

- X, Y: two countries sharing a border, each of which chooses whether to abate pollution or not to abate pollution

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- Pollution abatement comes to a cost of 7 to the abater
- It is assumed to be a public good so that abatement by either country confers benefits of 5 to both countries
- If both abate, both experience benefits of 10 and a cost of 7

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		Pollute	Abate
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	Abate (A)	(-2, 5)	(3, 3)

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A similar framework can also help understand why there seems to be too much CO_2 emissions

Readings

Theory

Bardhan & Udry (1999) Ch. 13; Wydick (2007) Ch. 4

Rustagi et al. (2010)

"Conditional Cooperation and Costly Monitoring Explain Success in Forest Commons Management"

Ryan & Sudarshan (2022)

"Rationing the Commons"

Summary

Data:

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- Experimental measures of conditional cooperation and survey measures on costly monitoring
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Findings:

1. Groups vary in conditional cooperator share
2. Groups with larger conditional cooperator share are more successful in forest commons management
3. Costly monitoring is a key instrument with which conditional cooperators enforce cooperation

Experimentally Measuring Conditional Cooperation

Public goods (PG) game:

- Two players from the same user group are randomly paired in a one-shot anonymous interaction
- Each player receives six bills of one Ethiopian Birr ($\approx$ daily wage)
- Each player decides on his contribution to a PG
- Total contribution is multiplied by 1.5 and distributed equally among the two players irrespective their individual contributions

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This game constitutes a cooperation dilemma:

- Players together are best off if both contribute their entire endowment to the PG
- However, each player's earning is maximized by contributing zero to the PG independent of the other player's contribution
  (Individual cost of contributing one bill to the PG is one but the return is only 0.75)

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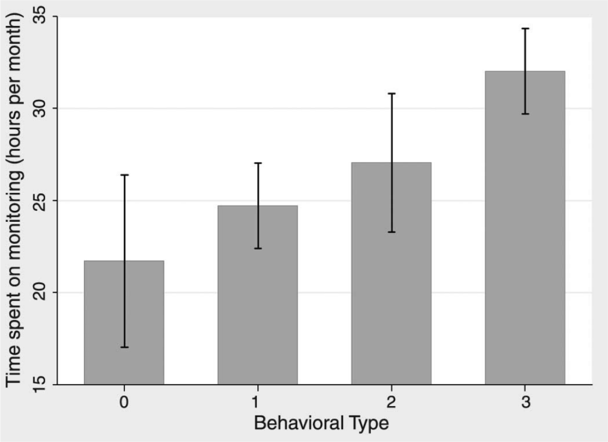
Determining payoffs:

- At the end, a die was rolled to determine the player for whom the 1st decision is taken
- This is matched with the 2nd decision of the other player to determine payoffs

Conditional cooperation in the PG game is associated with actual monitoring practice

Fig. 2. Average time spent on monitoring by behavioral types. Behavioral types are as follows: 0, free rider; 1, other types; 2, weak conditional cooperator; 3, conditional co-operator. Mean ± SEM per type.



Conditional cooperation in the PG game is associated with actual forest management outcome

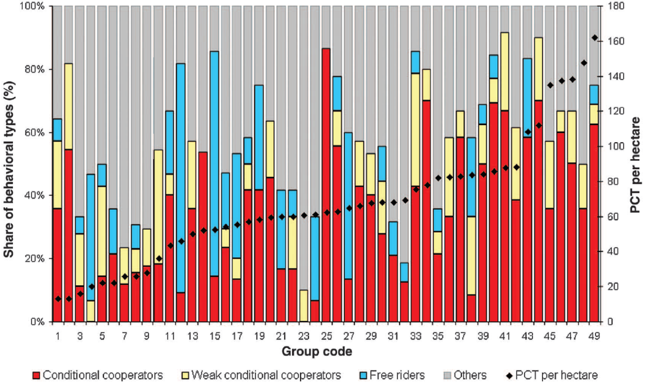


Fig. 1. Forest management outcome as measured in potential crop trees (PCT) per hectare and the relative shares of the main behavioral types in a group. The groups are sorted by PCT. Each bar represents a group engaged in the management of forest commons identified by its numerical code. There is large variation in the forest management outcome (min = 13, max = 161.9, SD = 35.2) and in the share of conditional cooperators (min = 0%, max = 86.7%, SD = 21.5%) and free riders (min = 0%, max = 72.7%, SD = 17.2%) across groups.

Readings

Theory

Bardhan & Udry (1999) Ch. 13; Wydick (2007) Ch. 4

Rustagi et al. (2010)

"Conditional Cooperation and Costly Monitoring Explain Success in Forest Commons Management"

Ryan & Sudarshan (2022)

"Rationing the Commons"

Motivation

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    - Ostrom (1990) illustrates institutions successful in governing the commons by balancing efficiency and equity **at a local scale**
    - Homogeneity across villagers also simplified the model analysis

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- However, **these local institutions cannot scale to meet large commons problems with heterogeneous users**
  - See Dietz et al. (2003) for detailed discussions about the scalability
- For **large-scale** problems, a common policy option is to **ration the commons**: setting a coarse rule to ensure that access to the commons will be fair, if not efficient

This Paper

Q. What is the loss from allocating with rules instead of markets?

- How rationing the commons shape the efficiency and equity of agricultural groundwater use in Rajasthan, India

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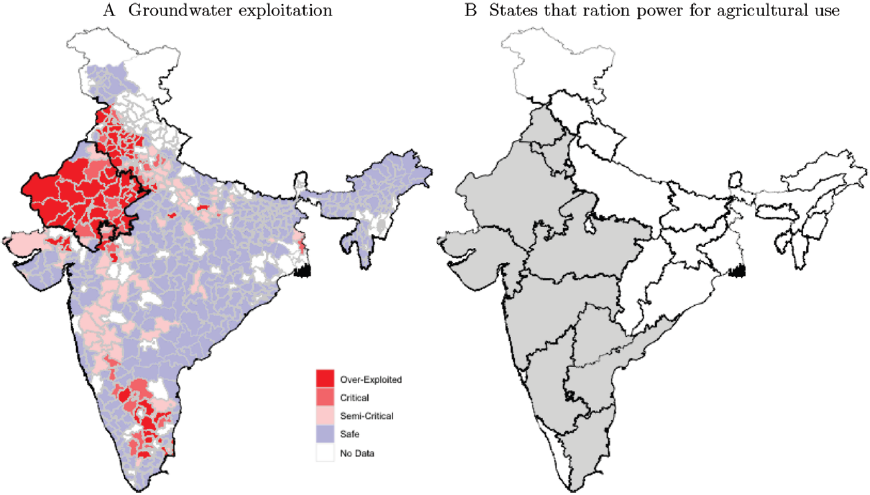
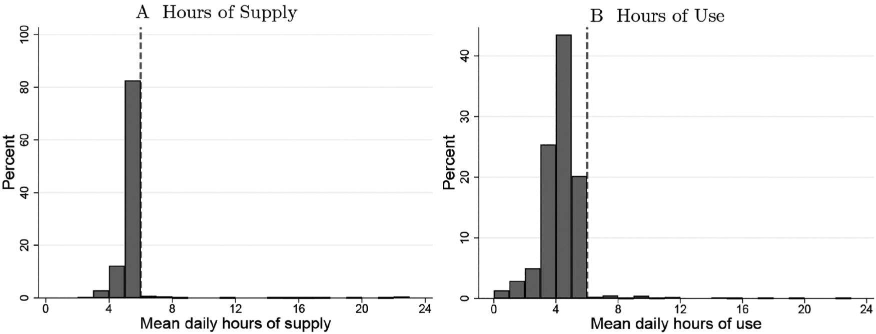
- Rationing binds on input use, such that farmers, despite trivial prices for water extraction, use roughly the socially optimal amount of water on average
- The ratoning regime is still inefficient, because it misallocates water across farmers, lowering productivity
- Pigouvian reform would increase agricultural surplus by 12% of household income yet fall well short of a Pareto improvement over rationing

Context: Groundwater Depletion and Rationing



- Groundwater depletion in India is faster than anywhere in the world
- Rationing has been adopted by many large Indian states

Electricity Rationing to Manage the Commons



- Groundwater in India is the commons: no price and no property rights
- Farmers use electricity mostly for the groundwater irrigation purpose
- Data: Original survey of agricultural households in Rajasthan
- Rationing: restrict the electricity access up to 6 hours per day

Estimating the Marginal Benefit of Increasing the Ration

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An alternative way:

- Recall: electricity is used only as a means to extract water
- The marginal return to water (measured by the well depth) is a "sufficient statistic" for the benefit of an increased electricity ration

Estimating the Marginal Benefit of Increasing the Ration

- Water extraction function:

$$W_i(\bar{H}, D_i) = \rho \frac{P_i \bar{H}}{D_i}$$

where D_i: well depth & P_i: (exogenous) pump capacity

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- Then, the marginal benefit of increasing the ration $(\bar{H})$ is:

$$\begin{aligned}
\sum_i \frac{d\tilde{\Pi}_i(W_i(\bar{H}, D_i))}{d\bar{H}} &= \sum_i \frac{d\tilde{\Pi}_i}{dW_i} \frac{dW_i}{d\bar{H}} \\
&= \sum_i \frac{d\tilde{\Pi}_i}{dW_i} \Big(- \frac{dW_i}{dD_i} \frac{D_i}{\bar{H}} \Big) \\
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\end{aligned}$$

i.e. Use variation in groundwater depth to mimic the effects of (nonexistent) variation in the ration

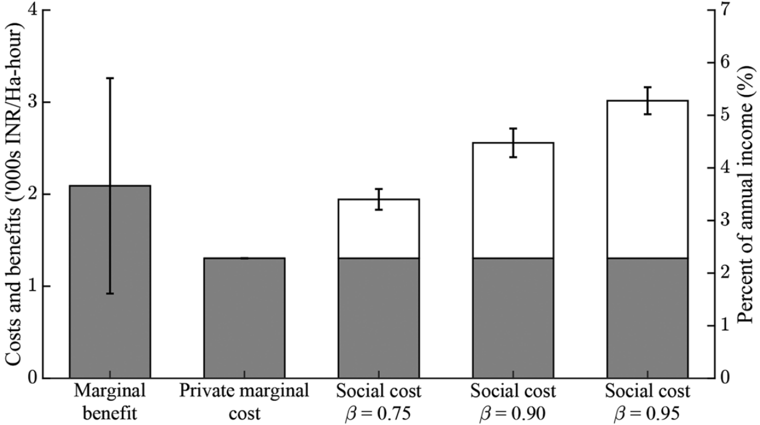
Estimating the Marginal Benefit of Increasing the Ration

HEDONIC REGRESSIONS OF PROFIT ON WELL DEPTH

	OLS		IV-PDS	
	(1)	(2)	(3)	(4)
	A. Total Profit (INR 1,000/ha)			
Well depth (1 SD = 187 feet)	.68	−2.74*	−8.44***	−6.95***
	(1.25)	(1.56)	(2.41)	(2.63)
Toposequence		Yes	Yes	Yes
Soil quality controls		Yes	Yes	Yes
Subdivisional effects		Yes	Yes	Yes
Plot size effects		Yes	Yes	Yes
Mean dependent variable	−5.06	−5.06	−5.06	−5.06
Candidate instruments			419	1,728
Instruments selected			16	18
Unique farmers	4,008	3,999	3,999	3,999
Farmer-crops	8,991	8,973	8,973	8,973

- To estimate farmers' returns to water, use plausibly exogenous variation in groundwater conditions, based on the geology of aquifers
- Also, estimate the private and social marginal costs, including the cost of power and the opportunity cost of water (details omitted)

Marginal Benefits vs. Costs of a 1-hour Increase in the Ration



- The status quo ration is at a roughly optimal level or somewhat too high
- Contradicts the common view about agricultural groundwater use in India: too low electricity prices and too much use of water
  (If so, the marginal benefit should be lower)

Counterfactual Policy Simulations

Quantify the surplus gains under:

- the optimal rationing
- the Pirouvian reform which equalized the price of power to the social marginal cost
- (cash transfers back to farmers using government revenues from the Pigouvian pricing)

To implement counterfactual simulations, we also need to estimate parameters of farmers' production function (details omitted) because we need to predict farmers' behavior under "counterfactual" policies which we cannot directly observe

Counterfactual Production and Social Surplus

	Rationing		Pricing	
	Status Quo (1)	Optimal (2)	Private Cost (3)	Pigouvian (4)
	A. Profits and Social Surplus			
Profit (INR 1,000)	18.72	16.64	19.39	12.90
Unpriced power cost (INR 1,000)	5.35	4.21	.00	−4.64
Water cost (INR 1,000)	5.33	4.18	9.24	4.94
Surplus (INR 1,000)	8.04	8.25	10.15	12.60
	B. Input Use			
Land (ha)	.69	.69	.69	.69
Labor (person-days)	54.81	54.81	54.81	54.81
Capital (INR 1,000)	16.58	15.54	20.79	17.81
Water (1,000 L)	1,590.65	1,248.65	2,758.34	1,475.47
Power (kWh per season)	1,010.20	793.95	1,517.26	768.16
Hours of use (per day)	5.95	4.67	10.63	5.84
	C. Output and Productivity			
Output (INR 1,000)	52.78	49.46	66.15	56.68
Gain in output from status quo (pp)		−6.3	25.3	7.4
Gain in output due to input use (pp)		−6.2	18.7	.9
Gain in output due to productivity (pp)		−.0	6.7	6.5

- Small changes in surplus and production under the optimal ration
- Large surplus gain under the Pigouvian reform

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- The average water extraction is nearly the same
- Large increase in productivity (the last row)

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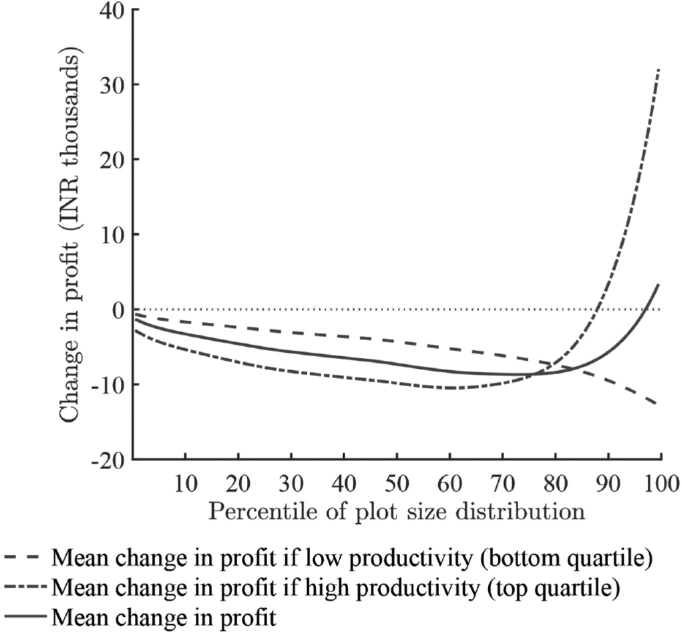
  $=$ the residual increase in output not due to average changes in the level of input use
  $=$ the increase in output due to only the reallocation of capital and water inputs from low-productivity to high-productivity farmers
- **The surplus loss under rationing is due to the misallocation of water across farmers rather than aggregate overexploitation of water (as commonly thought)!**

Farmer Heterogeneity in Response to the Pigouvian Reform



Distributional Effects of the Pigouvian Reform: The Efficiency-Equity Trade-Off Exists

	Transfers				
	Rationing	Pigouvian			
	None (1)	None (2)	Flat (3)	Pump (4)	Land (5)
	A. Inequality under Different Transfer Schemes				
Mean profit (INR 1,000)	40.76	28.10	28.10	28.10	28.10
+Mean transfer (INR 1,000)	.00	.00	21.76	21.76	21.76
Mean net profit (INR 1,000)	40.76	28.10	49.86	49.86	49.86
Standard deviation net profit (INR 1,000)	71.23	78.71	80.47	81.50	84.22
	B. Change from Rationing Regime due to Reform				
Share who gain		.09	.74	.66	.61
Conditional on gain in profit:					
Mean ex ante profit		132.72	33.63	36.82	40.11
Mean change in net profit		25.97	16.61	19.11	22.58
Mean land (ha)		3.49	1.45	1.50	1.61
Mean depth (feet)		211.62	277.59	293.24	275.73
Mean productivity (percentile)		55.60	46.42	49.40	45.78
Share who lose		.91	.26	.34	.39
Conditional on loss in profit:					
Mean ex ante profit		31.61	60.86	48.51	41.76
Mean change in net profit		−16.51	−12.08	−10.58	−11.58
Mean land (ha)		1.31	1.69	1.54	1.36
Mean depth (feet)		295.48	316.89	277.38	306.52
Mean productivity (percentile)		49.99	62.00	52.65	57.73