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The tragedy of commons and free mobility

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Abstract

We characterize free mobility equilibrium in a common pool resource setting with two localities. We find that adopting a decentralized management in just one locality increases agents' welfare not only in the regulated locality but in the unregulated locality as well.

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1. Introduction

We study the common pool resource (CPR hereafter) problem with free mobility, i.e. agents move across localities without cost as in a Tiebout (1956) economy[1]. The focus of this paper is to extend the CPR model to situations where agents in multiple localities are free to choose their place to live and extract resources. Ostrom (1990) highlights the importance of clearly defined boundaries for successful self-governance in the commons. However, in and out population migration may be a significant factor in resource use across communities. Examples of commons with multiple locations include international fisheries or pasturelands under extensive grazing.

We consider two possible management regimes for each locality, both in exogenous and endogenous institutional settings. In some localities common resources may be unregulated. Alternatively, resources may be regulated by a sanctioning mechanism where mutual monitoring and sanctioning opportunities allow agents to obtain the socially optimal use level[2]. Casari and Plott (2003) study a decentralized sanctioning[3] system called “Carte di Regola” for managing the common properties in Alpine villages. We consider this sanctioning system as an example of an institution that has a historical precedence and that has been shown to restore the efficiency in closed communities. The research question is: How does free mobility affect the performance of the sanctioning system? If one locality is regulated and the other is not, would the sanctioning institution withstand the migratory pressure from the neighboring unregulated locality? Would it be possible to prevent “the tragedy of the commons” (e.g., Hardin, 1968)?

To characterize a free mobility equilibrium, we use the Tiebout equilibrium concept defined as a partitioning of agents into localities, where no single agent wants to move from the current position to join the other existing localities (e.g., Tiebout, 1956, Westhoff, 1977).

We find that a locality with sanctions can sustain the efficient use level and prevent over-use under free mobility as long as the community adjusts its harvesting target in response to migratory pressure from the unregulated locality and evasion from sanctions is impossible. Moreover, the locality with no regulation experiences a positive externality from the regulated locality because the latter accommodates more people. We also show that if the institutions are endogenous, i.e. agents in each locality vote for the regulatory regime, the sanctioning system is adopted as long as it is Pareto-improving.

[1]See Scotchmer (2002) for the review of literature on local public good economies.

[2]Sanctions have been shown to resolve social problems in CPR, public good, and truth-telling settings (e.g., Casari and Plott, 2003, Fehr and Gächter, 2000, Sánchez-Pagés and Vorsatz, 2007).

[3]In this sanctioning system, villagers agreed among themselves and set up a contract with the approval of the regional government, called “Carte di Regola”. The contract specified a system for monitoring and sanctioning those exceeding the agreed upon and publicly known use level. The village court could sentence over-users extracting above the harvesting limit. Violators paid a fine in proportion to the extra use. Any community member could report a violation. The share of the fine usually went to the person discovering the violation which encouraged monitoring.

Previous studies on the resource allocation across multiple sites focus on the private property rights. De Meza and Gould (1992) study a two-sector economy with N sites and a fixed amount of labor mobile among sites and between sectors, but assuming costly enforcement. Unlike our paper, they find that enclosure introduced as an alternative regime to the open access may bring inefficient outcomes because of either too much or too little enforcement of private property rights. Chichilnisky (1994) finds resource allocation inefficiency with trade between two asymmetric regions, where one region has ill-defined property rights and the other maintains private property rights of the resource use. Similar to our paper, this model of the effect of trade on the resource use examines a two-locality situation. However, management regimes are treated as exogenous. Threshold models of renewable resource management (Copeland 2005) consider endogenous management regimes, in that the resource is open access until the benefits of resource management are below the fixed cost of maintaining the institution. Once the threshold has passed, resource management is adopted. These models also find a possible welfare-reducing effect of trade. Sanchirico and Wilen (1999, 2005) develop a dynamic model of optimal spatial resource management, which captures fish movement according to their biological patterns as well as fishermen's migration in response to changes in profitability. Yet, they ignore the institutional aspect since all localities are assumed to have open access. None of the above studies exploit a decentralized sanctioning mechanism as an alternative institution in the economy with multiple sites.

2. Basic CPR Model

As a benchmark, we review the basic CPR model with one locality. A finite number N of identical agents with endowment e each, simultaneously decide on the amount of harvest x_i from the common pool, where $i \leq N$ is the agent's index. Let $X = \sum_{i=1}^{N} x_i$ be the total appropriation, and $f(X)$ be a concave production function. For simplicity, we assume $f(X) = a \cdot X - b \cdot X^2$, where a and b are positive constants. The cost per unit of harvest is denoted by c. Then each agent $i's$ profit is given by $\pi_i = e - c \cdot x_i + (x_i/X) \cdot f(X)$.

2.1 Unregulated locality

If the locality is unregulated, denoted by U, then the total appropriation in the symmetric Nash equilibrium is given by (i.e. Falk et al., 2002):

$$X^U = (a - c) \cdot N/b \cdot (N + 1) \tag{1}$$

which is higher than the social optimum defined as follows:

$$X^{opt} = (a - c)/2 \cdot b \tag{2}$$

if $N > 1$. Let $x^{opt} \equiv X^{opt}/N = (a - c)/2 \cdot b \cdot N$ denote per capita social optimum. From equation (1) the Nash equilibrium per person profit in the unregulated locality is given by $\pi_i^U = e + (a - c)^2/b \cdot (N + 1)^2$.

2.2 Locality with sanctions

The model with sanctions (Casari and Plott, 2003) assumes that the community restricts per agent harvesting to the threshold amount, λ, which targets the socially optimal harvesting level. We assume identical agents, perfect and costly monitoring, and no possibility of sanction evasion. There are two steps in the CPR sanctioning game. Once the harvesting threshold in the regulated community is set according to the population level, each agent i decides on a harvesting level, x_i. Next, after observing total group use, each agent may choose to inspect other agents. By paying inspection fee, k, the inspector may obtain exact information about the harvesting decision of one other member. In the case of simultaneous inspections by multiple agents, one person is randomly chosen as the inspector. Harvesting beyond the threshold costs an individual a fine payment if any other member of the community discovers the excessive use. The model assumes perfect enforcement, so that the fine is collected with certainty once the excessive user is detected. For each excess harvested unit a person pays a unitary fine, h. The total fine, $(x-\lambda)\cdot h$, is a direct transfer to the inspector who discovers the exceeded use. We use index R for the regulation, i.e sanctions. Therefore, when locality is regulated by the sanctioning mechanism the agent i's profit is given by $\pi_i^R = e - c\cdot x_i + (x_i/X)\cdot f(X) - I_i m_i + \sum_{j\neq i} I_{ij}(m_j - k)$, where $I_i = 1$ if $\sum_{j\neq i} I_{ij} > 1$, and $I_i = 0$ otherwise. Here m_i is the fine that agent i pays if inspected by agent j, where $i \neq j$ and $m_j - k$, is the revenue generated by agent i from monitoring of agent j. $I_{ij} = 1$ if i inspects j and $I_{ij} = 0$ otherwise. Casari and Plott (2003) establish the following:

Proposition 1 *Suppose a locality has a sanctioning mechanism, where the threshold is set as* $\lambda = x^{opt} - k/h - \varepsilon$, *with* $\varepsilon > 0$ *small enough and the unit fine is set as* $h = a - c - x^{opt}\cdot(N+1)\cdot b$. *Then this mechanism supports the socially optimal level of harvesting as the subgame perfect Nash equilibrium,* $X^R = X^{opt}$. *In this equilibrium, every agent inspects and is being inspected with certainty.*

From equation (2) the equilibrium per person profit in the regulated locality is given by $\pi_i^R = e + (a-c)^2/b\cdot 4\cdot N - k$. Note that, for any given population size $N > 1$, $\pi_i^U(N) < \pi_i^R(N)$ as long as k is small enough[4]. Therefore, each agent prefers the sanctioning regime to no regulation.

3. CPR free mobility equilibrium

Now consider two communities with identical production functions, $f(X)$. Let the total population of the two localities be N. We assume free mobility, but perfect enforcement of sanctions within the regulated locality, and examine two cases: exogenous and endogenous institutions.

[4]The monitoring cost has to satisfy $k \leq (a-c)^2/b\cdot(1/4\cdot N - 1/(1+N)^2)$.

3.1 Exogenous institutions and free mobility

First, we assume that regulatory regimes in each locality are exogenous. Also, we assume that the harvesting threshold in a regulated locality is set optimally and adjusts perfectly to the population level in the locality: $\lambda = \lambda(N^R)$, as defined in Proposition 1. Further, the inspection cost is low enough so that the benefits of the sanctioning mechanism outweigh the costs of adopting it in a regulated locality for any population level $N^R \leq N$.

Consider a game where agents are free to move from one location to the other. First, each agent chooses the locality j, $j \in (U, R)$, in which to harvest. Then, agents choose their harvesting levels. The inspection decisions in the regulated locality then follow. In order to obtain predictions with free mobility across two localities, we use the notion of Tiebout equilibrium (Greenberg and Weber, 1986) often referred as a free mobility equilibrium[5]. The free mobility equilibrium is a partition of population of agents into localities, where no single agent wants to move from the current position to join the other existing locality. In the free mobility equilibrium, two conditions must hold: (i) all localities are inhabited and each agent's action is individually optimal within each locality; (ii) no agent wants to move, i.e. each agent's profit in a chosen locality is at least as high as the identical agent's profit in the other locality.

For our purposes, we need to add sequential structure to the model. Hence, we solve for the free mobility equilibrium as the subgame perfect Nash equilibrium of the game, where the first stage involves location choice and the second stage involves harvesting decisions (followed by monitoring decisions in the locality with sanctions). In equilibrium, the agents choose the localities in anticipation of the outcome of CPR game in the locality with no regulation and the outcome of the sanctioning mechanism in the regulated locality. Given that all agents are identical, the equilibrium then requires that agents split into two localities in a way that per agent profits across two localities are equalized, so that no agent wants to move.

It is straightforward to show that given all agents are identical, under symmetric regimes agents split equally between two localities. With no regulation, both communities over-use the resource. With the sanctions, both communities obtain the social optimum.

Interesting results are derived for the asymmetric institutions case, where one locality adopts the sanctioning mechanism and the other locality is unregulated. The free mobility equilibrium is characterized as follows:

Proposition 2 *In the free mobility equilibrium with identical agents in one regulated and one unregulated locality, the locality with sanctions accommodates more people than the unregulated locality, $N^R > N^U$. Introduction of the sanctioning mechanism in one locality constitutes a Pareto improvement.*

[5]Two equilibrium concepts, Tiebout equilibrium and the core of coalition structure, are used in local public goods models. Conley and Konishi (2002) present a Migration-proof Tiebout equilibrium as a refinement of the core concept.

Proof: Note that in equilibrium, by the identical agents assumption, $\pi_i^R = \pi_i^U$, otherwise an agent would want to move to the locality with higher profit. To prove that $N^R > N^U$, we need to show that cases $N^R = N^U$ and $N^R < N^U$ both lead to a contradiction. Let N be the total population, $N^R + N^U = N$.

First, assume $N^R = N^U = N/2$. Refer to section to see that if $N^R = N^U = N/2$, then $\pi_i^R(N/2) > \pi_i^U(N/2)$, which contradicts the equilibrium condition of "no one wants to move" ($\pi_i^R = \pi_i^U$).

To show that $N^R < N/2 < N^U$ also cannot be an equilibrium, note that $\pi_i^R(n)$ and $\pi_i^U(n)$ are both strictly decreasing in population, n, residing in own locality: $\pi_i^R/\partial n = -(a-c)^2/4 \cdot b \cdot n^2 < 0$ and $\pi_i^U/\partial n = -2(a-c)^2/b \cdot (n+1)^3 < 0$. This implies that $\pi_i^R(N^R < N/2) > \pi_i^R(N/2) > \pi_i^U(N/2) > \pi_i^U(N^U > N/2)$. Contradiction. Hence, $N^R > N^U$.

To show that π_i^R and π_i^U both increase as compared to no regulation in either locality, note that without regulation the population in each community would be $N/2$ with profits $\pi_i^U(N/2)$. Then by the monotonicity of the profit schedule in n, $\pi^U(N^U < N/2) > \pi^U(N/2)$, and by the equal profits' condition, $\pi_i^R(N^R) = \pi_i^U(N^U) > \pi_i^U(N/2)$. Done.

This result indicates the importance of decentralized regulation and its impact on the neighborhood locality. We can show that the results are easily generalizable to any number of localities. As the number of localities with sanctions grows, the whole system Pareto improves. This is because in the regulated locality per person profits increase due to the sanctioning mechanism, while in the unregulated localities per person profits increase due to smaller population, hence lower appropriation.

3.2 Endogenous institutions and free mobility

Now consider internal equilibrium (voting with the ballot) where each community decides on the regulatory structure by majority voting (e.g., Fiorina and Plott, 1978). We show that the regulatory regime can be sustained for both localities in a subgame perfect Nash equilibrium. Again, everyone chooses a locality first. Next, each member of the community votes either for sanctions or no sanctions in their locality, and the outcome is determined by majority voting. Third, each agent decides on his/her harvesting level. In the communities with the sanctioning regime, monitoring decisions follow.

Proposition 3 *In the voting equilibrium, agents vote for sanctions in both localities. The population sizes in both localities are identical,* $N^{R1} = N^{R2} = N/2$.

The result easily follows from the identical agents assumption. By the median voter theorem (e.g., Downs, 1957) the outcome of the majority voting is the median voter's preferred institution. By assumption, $\pi_i^R(n) > \pi_i^U(n)$ for any $n \leq N$ since monitoring costs are low. Therefore, sanctions are preferred to no sanctions.

4. Conclusion

Our analysis of the CPR problem with free mobility and exogenous institutions reveals that the locality with the sanctioning system maintains the socially optimal use level even under migratory pressure as long as harvesting targets are adjustable according to the population level. Moreover, a positive externality is captured if we introduce sanctions in only one locality. This suggests that decentralized regulatory mechanisms for managing commons such as fisheries, grasslands, forests, irrigation systems may be introduced gradually. With an endogenous choice of institutions, where agents choose between no regulation or sanctioning system by majority rule, equilibrium yields institutions with sanctions in both localities as long as monitoring costs are low. Thus, we find that decentralized sanctioning mechanism with perfect enforcement may be Pareto improving. This contrasts with De Meza and Gould (1992) study where an enclosure may be inefficient due to costly enforcement of property rights. Our model has several extensions. In reality, users may trespass and appropriate resource both in their own locality where they do live and in the other locality. Then agents, who do live in the unregulated locality and harvest in the regulated locality, will have no punishment, which may ignite "race to the bottom" in both localities. This mirrors the local public good provision with spillovers (Bloch and Zenginobuz, 2006). Another extension relates to costly mobility, i.e. migration decision creates additional costs in comparison with free mobility. Also we may relax an assumption of identical agents in cost, which may bring interesting sorting dynamics with respect to voting outcome (Gurerk et al. 2006). Depending on the distribution of types, equilibrium may yield sanctions or no sanctions. Further, heterogeneity of agents in other-regarding preferences may trigger antisocial punishment (Herrmann et al. 2008) which may lower the welfare of the community.

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