Consumption of Common Pool Resources under Altruism and Uncertainty

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Abstract

This paper adresses the consumption of Common Pool Resources. Hardin (1968) proposed that since they are free to consume and limited in quantity, CPRs are consumed inefficiently. However, experiments and research has shown that behavioral factors and uncertainty can reduce over-consumption. In this paper, we develop a model to explain CPR consumption by combining some of these ideas into one model.

Introduction

- Common pool resources (CPRs) are goods that are rivalrous but non-excludable eg. Fisheries, grazing lands, water resources (rivers and lakes).
- This poses an economic problem highlighted in Hardin (1968). Models and experiments so far have been expanded to include altruism, dynamic models and uncertainty separately. This paper tries to combine these into one theoretical model.
- Ostrom (1999) suggested that CPRs are often managed by a local governance structure to reduce inefficiency.
- The role of altruism, inequity aversion, reciprocity and conformity has been studied by Velez et al. (2009). They experimentally verify that these factors play a role in a person's choice in a CPR setting.
- Fischer et al. (2004) conduct an experiment to show that altruism affects inter-generational consumption.
- Building on such research, in this paper we try to develop a model explaining how behavioral characteristics and uncertainty affect CPR consumption.

Research Question

How do individual characteristics and uncertainty affect consumers' choice in a dynamic CPR model?

- Behavioral characteristics include altruism and selflessness/selfishness.
- Uncertainty is in the amount one will be able to consume. Since the resource is limited, one may not be able to consume the amount one intends to.

Main Objectives

1. Presenting a basic one period model.
2. Extending the model to two periods.
3. Adding uncertainty to the two period model.

One Period Model

Defining Variables

- w_i is consumer i's wealth.
- x_i is the amount he spends on private goods (other than the CPR)
- q_i is his consumption of the CPR.
- $\bar{q}_{-i}$ is the average consumption of the CPR of all members of society except i.
- $w_i = x_i + q_i$.
- m_i is the parameter that shows how much he cares about total consumption of the good. This can be thought of as his altruism. $m_i \geq 0$.
- k_i is the extent of his selfishness or selflessness. If k_i is positive, he is selfish. Otherwise he is selfless.

Payoff Function

$$\pi_i = x_i + \ln(m_i(q_i + \bar{q}_{-i}) + k_i(q_i - \bar{q}_{-i})) \tag{1}$$

Optimal Consumption from Best Response Function

$$q_i^*(\bar{q}_{-i}) = \begin{cases} 1 + \frac{k_i - m_i}{k_i + m_i}\bar{q}_{-i} & \text{if } \bar{q}_{-i} \in \left[0, \frac{m_i+k_i}{m_i-k_i}\right] \text{ and } 0 \leq k_i < m_i \text{ or } -m_i < k_i < 0, \\ & \text{or if } k_i < -m_i < 0 \text{ or } k_i > m_i \geq 0, \\ 0 & \text{if } \left(\bar{q}_{-i2} > \frac{m_i+k_i}{m_i-k_i}\right), 0 \leq k_i < m_i \text{ or } -m_i \leq k_i < 0. \end{cases}$$

Two Period Model (No Uncertainty)

Additional variables

- We now add time subscripts
- We introduce savings in period one (which can be negative as well). All wealth is exhausted in period 2.
- An additional unit of q_{i1} saved (consumed) leads to and increase (decrease) in s_{i1} by 1. Thus, $\frac{\partial s_{i1}}{\partial q_{i1}} = -1$

Payoff Function

$$\begin{aligned} \pi_i &= x_{i1} + \ln(m_i(q_{i1} + \bar{q}_{-i1}) + k_i(q_{i1} - \bar{q}_{-i1})) \\ &+ \delta\big(x_{i2} + s_{i1} + \ln(m_i(q_{i2} + \bar{q}_{-i2}) + k_i(q_{i2} - \bar{q}_{-i2}))\big) \end{aligned} \tag{2}$$

Optimal Consumption from Best Response Function

$$q_{i2}^*(\bar{q}_{-i2}) = \begin{cases} 1 + \frac{k_i - m_i}{k_i + m_i}\bar{q}_{-i2} & \text{if } \bar{q}_{-i2} \in \left[0, \frac{m_i+k_i}{m_i-k_i}\right] \text{ and } 0 \leq k_i < m_i \text{ or } -m_i < k_i < 0, \\ & \text{or if } k_i < -m_i < 0 \text{ or } k_i > m_i \geq 0, \\ 0 & \text{if } \left(\bar{q}_{-i2} > \frac{m_i+k_i}{m_i-k_i}\right), 0 \leq k_i < m_i \text{ or } -m_i \leq k_i < 0. \end{cases}$$

$$q_{i1}^*(\bar{q}_{-i1}) = \begin{cases} \frac{1}{\delta} + \frac{k_i - m_i}{k_i + m_i}\bar{q}_{-i1} & \text{if } \bar{q}_{-i1} \in \left[0, \frac{1}{\delta} \cdot \frac{m_i+k_i}{m_i-k_i}\right] \text{ and } 0 \leq k_i < m_i \text{ or } -m_i < k_i < 0, \\ & \text{or if } k_i < -m_i < 0 \text{ or } k_i > m_i \geq 0, \\ 0 & \text{if } \left(\bar{q}_{-i1} > \frac{1}{\delta} \cdot \frac{m_i+k_i}{m_i-k_i}\right), 0 \leq k_i < m_i \text{ or } -m_i \leq k_i < 0. \end{cases}$$

Two Period Model (With Uncertainty)

Additional variables

- We now assume that since the stock of the CPR is limited, an individual cannot be sure that he will be able to consume his optimal q_{it}^*. This is because someone else may consume the good before he can.
- $\tilde{q}_{i1}$ is the quantity that consumer 1 was unable to consume in period 1 due to limited supply of CPR. $\tilde{q}_{i1} \in [0, q_{i1}^*]$.
- From here on, q_{it}^u is the solution with uncertainty and q_{it}^{nu} is without uncertainty.
- We incorporate this by defining $\frac{\partial q_{i2}^u}{\partial q_{i1}^u} = -1$.
- In such a case, if he is unable to consume it in period 1, he will try to consume the leftover in period 2.
- An extra unit of q_{i1} saved (spent) in period one increases (decreases) s_{i1} by 1. Therefore, $\frac{\partial q_{i2}^u}{\partial q_{i1}^u} = -1$.

Payoff Function

$$\begin{aligned} \pi_i^u &= w_i - q_{i1} - s_{i1} + \ln(m_i(q_{i1}^u + \bar{q}_{-i1}) + k_i(q_{i1}^u - \bar{q}_{-i1})) \\ &+ \delta\big(x_{i2} + s_{i1} + \ln(m_i(q_{i2}^{u*}(q_{i1}) + \bar{q}_{-i2}) + k_i(q_{i2}^{u*}(q_{i1}) - \bar{q}_{-i2}))\big) \end{aligned} \tag{3}$$

$$q_{i2}^{u*} = q_{i2}^{nu*} + \tilde{q}_{i1}^u$$

Optimal Consumption from Best Response Function

$$q_{i1}^{u*}(\bar{q}_{-i1}, A_i) = \begin{cases} \frac{1}{\delta(1+A_i)} + \frac{k_i - m_i}{k_i + m_i}\bar{q}_{-i1} & \text{if } \bar{q}_{-i1} \in \left[0, \frac{1}{\delta(1+A_i)} \cdot \frac{m_i+k_i}{m_i-k_i}\right] \text{ and } 0 \leq k_i < m_i \text{ or } k_i < -m_i < 0, \\ & \text{or if } -m_i < k_i < 0 \text{ or } k_i > m_i \geq 0, \\ 0 & \text{if } \left(\bar{q}_{-i1} > \frac{1}{\delta(1+A_i)} \cdot \frac{m_i+k_i}{m_i-k_i}\right), 0 \leq k_i < m_i \text{ or } -m_i \leq k_i < 0. \end{cases}$$

In the above solution, the consumer must work with some expected value of $\tilde{q}_{i1}^u$ to obtain the value of A_i

Conclusions

- At first we find that by introducing multiple periods, a consumer consumes more in the initial periods.
- As we can see, the introduction of the possibility to consume in a future period potentially (and very likely) decreases the consumption in period 1.
- If $\delta(1 + A_i) = 1$, the first period of the game has the same solution as the one period model.
- If $\delta(1 + A_i) > 1$ the consumer actually consumes less in the first period comared to a one period game.
- Thus, the magnitude of A_i determines whether consumption under uncertainty is more or less than in a single period game.

Future Work

- Simulating examples
- Finding alternate ways to introduce uncertainty. This will also include a better representation of the expected $\tilde{q}_{i1}^u$.
- Testing the rhobustness of the model by using other utility functions.
- Designging an experiment to estimate parameters.
- Repeating a similar game with infinite periods.

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