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DOI
10.1007/978-3-030-61503-1_36

Publication date
2021

Document Version
Final published version

Published in
Advances in Social Simulation - Proceedings of the 15th Social Simulation Conference, 2019

Chapter 36
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Introduction

Common-pool resources (CPR) are shared resources that can be at the risk of depletion as a result of over-use [1]. To avoid the *Tragedy of the commons*, users can build institutions for collective action, i.e., systems of rules and enforcement mechanisms that allow for collective management and use of those resources [2]. In other words,

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P. Ahrweiler and M. Neumann (eds.), *Advances in Social Simulation*, Springer Proceedings in Complexity,
https://doi.org/10.1007/978-3-030-61503-1_36

such institutions are the collection of rules-in-use that emerge as a result of collective decision making of entitled users [3]. The cooperation among the members of an institution for collective action can enable the sustainable governance of resources. However, these members are heterogeneous in different way, possibly affecting their level of cooperation. In commons literature, heterogeneity is defined as diversity in wealth, power, cast, preferences, income among commoners [4, 5].

While theoretical research suggests that inequality can have a positive influence on collective action [6], some empirical studies have highlighted the negative effect of heterogeneity on collective action [4, 7]. Agent-based modeling is a suitable method to deal with complexity and ambiguity of these social systems [8] where modeling multiple factors and parameters under different conditions is needed. Yet little work on this topic has been done using agent-based modelling. In this paper we propose a model that investigates how heterogeneity (here defined in terms of wealth inequality) shapes individuals' behavior with regards to participation in collective action.

Model Description

We extend an existing, empirically validated model of the emergence of institutions for the management and use of CPRs, when agents collectively exploit a resource using both individual strategies and an endogenously-generated institutional rules [9]. Resource grows according to $\Delta R = rR\left(1 - \frac{R}{K}\right)$ formula, where K is the carrying capacity and r is the reproduction rate. At the beginning agents randomly select an action-condition as a strategy when no institution exists and follow that strategy to extract "energy" from the resource, where energy represents their wealth. If agents are not satisfied with their energy level, they change their strategy. Later on in the time, the agents vote on an institutional rule, which is basically the most popular individual strategy and everyone must comply with the selected institution. If a number of people (above a threshold) are not satisfied with the institution, a new one is selected.

Our goal is to analyze the relation between overall wealth inequality among the members and cooperation. We hence modified the original model to allow for different levels of wealth inequality at the setup and defined cooperation in two different ways: (1) participation in voting to establish the institutional rules [10] and (2) cheating, i.e., not complying with the collectively chosen institutional rule. Following previous findings [11], cooperation is linked to the local visible wealth gap. More specifically, agents are linked in a social network and tend to decrease their cooperation when they see a significant wealth gap between themselves and their neighbors, i.e., their probability of cheating is increased and the probability of participating in voting is decreased. Note that this effect only depends on the local level of inequality (i.e., between neighboring agents), while it is independent of the global inequality.

To define institutional rules and individual strategies, we use ADICO grammar [12]. In the ADICO grammar A denotes Attributes: specifies subject, to whom a strategy or rule applies; D refers to Deontic: determines how an action is done (prohibition, obligation, and permission); I represents Aims: identifies the actions toward which Deontic applies; C indicates Conditions: under which conditions or, when, where, and how a strategy or rule applies; and O denotes Or Else: determines specific punishments to be applied when an agent acts in violation of the institutional rules.

The resulting model was implemented in Python using the Mesa library. The model includes the following components.

- **Agents**. An initial random energy between 1000 to 2000 units is assigned to each agent. Each agent records his current and best strategies (coded using the ADICO grammar), along with its location, neighbors, and energy level.
- Best strategy: the agents always save the strategy that has led them to a greater consumed resource. This parameter is updated during the simulation (based on new institutions or strategies). This depicts a simple learning behaviour based on history.
- Strategy change: happens when the agent's energy is less than a threshold. The change can follow three different procedures: copy from a neighbour, randomly select another strategy (innovation), or choose the best strategy of the agent (learning).
- Each agent has a confidence level and innovativeness level. The former increases the chance of using the best strategy in the next round, and the latter increases the chance of coming up with completely new strategy.
- **Institutional rules**. Also coded following the ADICO framework.
- Cheating: if the agent finds a significant gap between its energy and the average energy of his neighbours, it may cheat (i.e. not comply with the established institution and act based on his own current strategy).
- Voting: agents who observe a gap between their energy and the average energy of their neighbours have a lower probably for participating in voting.

Results

As mentioned before, we define cooperation as voting and cheating tendency which take place when there is an institution in place. Therefore, we only look at the runs which have emerging institution (151 out of 200 total independent runs). To measure the level of cooperation value, we count the number of agents who have participated in voting AND complied with the established institution, then divide that with the total number of agents.

We used the Gini-coefficient to evaluate the final wealth inequality (i.e. energy) distribution of agents. The Gini-coefficient is distributed between 0 and 1, with larger values meaning greater inequality. As shown in Fig. 36.1, when $0.2 < = \text{Gini}$, in almost all the simulation runs, inequality leads to lower cooperation. This means the collaboration is lower when we have wealth inequality. But as we move to zero on x dimension, $\text{Gini} < 0.2$, we have less density and we cannot see a stable relationship

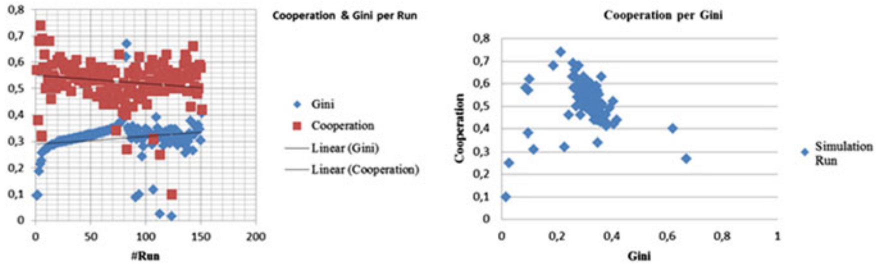

Fig. 36.1 Cooperation-Gini

between cooperation and the Gini. It seems when we have agents with similar levels of energy (Gini < 0.2), the cooperation behavior of agents do not follow the same trend.

We analyze the correlation between Gini (as inequality factor) and cooperation in 200 simulation runs. Although we cannot see significant correlation when we consider all instances with emerging institution ($r = -0.0298$), significant correlation is shown when we analyze the results with significant final inequality (i.e., $0.2 \leq$ Gini in 143 runs). We have density of instances where the Gini is between 0.2 and 1, the result is significant at $p < 0.05$ and there is a tendency for high Gini scores (more inequality) to go with low cooperation scores and vice versa ($r = -0.555$).

Conclusion

The goal of this research was to study the relation between inequality and cooperation in CPR settings. While it seems trivial that there is a negative correlation between the two, some research suggests the opposite. Yet, our model suggested the negative correlation. The model shows that inequality has a negative correlation with cooperation in the management and use of CPRs. Cooperation was defined through participation in setting up the institution for the management of the CPR, and compliance with the institution once it is in place. Our next step is to highlight the interplay between these two paths, and identify mechanisms that could be empirically tested. We aim to step up our analysis from cooperation to collective action in general.

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