The co-evolution of social institutions, demography, and large-scale human cooperation

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Background

During the Neolithic period humans underwent a transition from living in small groups of hunter-gatherers, to large groups of agriculturalists. This transition involved groups overcoming various social dilemmas, including collective defense of settlements, and the construction and usage of shared irrigation systems. Solving these dilemmas would allow groups to expand to a much larger size. To successfully resolve them, groups would need to create institutions that support large-scale cooperative behavior.

Following Hurwicz (1996), we define institutions as political game forms that generate the rules of economic interactions. In our context, institutions are political game forms that determine the payoff structure of individual actions in a social dilemma situation. For example, institutional rules might determine how much water an individual may take from an irrigation system, when they must contribute labor to the maintenance of the system, and what the sanctions will be for not following these rules (Ostrom, 1990). The political game form is then the process of bargaining between group members that generates these rules. This is likely to be costly for the individuals that take part, since bargaining over institutional rules takes time and effort that individuals could otherwise spend on directly gaining material payoffs. Consequently, forming institutional rules carries transaction costs for the individuals involved (Ostrom, 1990). Political game forms can take various shapes, ranging from an egalitarian form that accounts for the preferences of all group members, through to a despotic form in which the rules are set entirely by the preferences of a leader. In the context of the origin of agriculture, the political game form was likely to start out as an egalitarian process, since the archeological and anthropological evidence implies that pre-agricultural hunter-gatherer groups were egalitarian in terms of both resource equality and group decision-making (Price, 1995; Boehm, 1999).

Here we model the co-evolution of individual strategies in the social dilemma with individual preferences for the institutional rules.

Objectives

Using simulation modeling, we investigate how social institutions can co-evolve with demography to produce a transition from small- to large-scale cooperative groups. We determine conditions under which individuals that invest into creating institutions can invade a population of asocial individuals.

Methods

We use a demographically explicit model of a structured population of individuals that live on discrete resource patches connected by migration (Wright's 1931 island model). Each patch can contain both social individuals that create institutional rules, and asocial individuals that remain outside of an institution. Interactions within social groups begin with a political game form that generates institutional rules, followed by an economic game form that uses these rules and that determines material payoffs. Individuals carry two evolving cultural traits that are passed vertically from parent to offspring, subject to a small mutation (or innovation) rate. The first trait determines whether they either a) remain asocial, b) join a social group on their patch and contribute to a common good (cooperate in the economic game form), or c) join a social group but do not contribute (defect in the economic game form). The second trait is the individual's preference for the institutional rules, i.e. its strategy in the political game form. Specifically, this is a preference for the proportion of its group's common good that should be invested into sanctioning non-contributors. A group's institutional rules thus specify how much is invested into sanctioning non-contributors. These rules are constructed from an aggregation of the individual preferences of social group members. The remainder of the common good not assigned to sanctioning is invested into technology that increases the carrying capacity of the group, for example an irrigation system. Social individuals (both cooperators and defectors) pay a fixed cost for having an institution,

representing the transaction costs of negotiating and bargaining over institutional rules. Asocial individuals do not take part in either the political or economic game forms, and hence do not pay any costs but also have no opportunity to increase their carrying capacity.

Results

We present a summary of the results here – full results of the study are presented in Powers & Lehmann (2013). The main finding is that social individuals are able to invade a population of asocials, and establish institutional rules that select for high levels of cooperation, provided that group size (carrying capacity) is initially small. The benefits of cooperation then produce sufficient common good to raise carrying capacity, and hence drive an increase in group size. Crucially, once institutional sanctioning is established, it is able to maintain cooperation even as group size subsequently becomes very large. Successful institutional rules allocate most of the common resources to increasing the group's carrying capacity, while investing just enough into sanctioning to prevent defection from being favored. The evolutionary stability of these rules requires a structured population, such that groups with these rules grow to the largest size, and export their institutional rules to other groups through excess production of migrants. This creates a process of competition between institutional rules. By contrast, in an unstructured population there is only one set of institutional rules, and so institutional rules cannot be a source of differential individual fitness. Consequently, individual preferences for the institutional rules are not under selective pressure in the case of an unstructured population.

Conclusions

Sanctioning institutions most easily evolve in small groups, but can then maintain cooperation even as the benefits of cooperation cause groups to markedly expand in size. This transient process can help to explain the transition from small- to large-scale cooperative societies.

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