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Specialisation and wealth inequality in a model of a clustered economic network

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Abstract

In this paper we present an agent-based model of specialization, exchange and inequality within a clustered social network, with implications for the economic effect that contact with colonizing groups may have had on prehistoric indigenous populations.

Keywords: Agent-based modelling; Complex networks; Exchange; Kin networks; Mesolithic-Neolithic transition; Power laws; Prehistoric trade; Wealth inequality; Social networks

1. Introduction

An important economic phenomenon in prehistory is the emergence and maintenance of exchange networks between different specialists. The principle of *comparative advantage* in economics means that two economic actors are likely to do better by producing different products as specialists and trading with each other than by producing both products themselves in isolation. Specialization and exchange benefits so generally that the related behaviours may have been integral to early hominid evolution [26].

For this paper we used computer simulation to explore how an exchange network coevolves with the changing specializations of the agents within it. Through simulation, we can keep track of who is connected to whom through a mapping of the network and the specializations of each agent, and we can test the effects of simplified individual motivations for exchange, the make-up of the initial population of agents, and abstract representations of basic ideological dispositions such as the belief in private ownership.

Our computer simulation is vastly oversimplified compared to real human exchange networks, in which we are looking for patterns that emerge on their own under a significantly wide range of parameters and initial conditions. For example, modern networks of wealth [27,5] sexual partners [23] and others [1] often self-organize due to a simple tendency for the rich to get richer, such that each agent tends to acquire additional elements roughly in proportion to the number it currently has. A striking similarity among these networks is that the probability distribution of the number of connections each agent has follows a power law:

$$P(k) \sim 1/k^{\alpha}, \qquad (1)$$

where α is positive and P is the probability that an agent has k connections with other agents. Qualitatively, the power law means that most of the agents in the network have only a few connections, while a few inevitably emerge with orders of magnitude more.

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Power-law distributions of wealth are ubiquitous for a wide range of economic scales [27,5]. Among pastoralist societies, for example, several ethnographic studies show differences in livestock ownership spanning two orders of magnitude [10,22,24,11,15,4]. For the Somali and Ariaal groups, Fig. 1 shows that the distribution of wealth per family, as measured in livestock, approaches a power-law form. Apparently, owners of large herds preferentially acquire additional livestock through the advantages of wealth itself [15,29,30].

1.1. Computer simulation of economic specialization

With the agent-based computer simulation described below, we aim to test whether specialization and wealth inequalities are natural, self-organizing qualities of a small-scale economy. Agent-based modelling allows us to test hypotheses for complex systems in the social sciences [8,12–14], including in archaeological studies of hunter-gatherer subsistence [19–21] and late prehistoric settlement [18]. Computer-simulated *agents* might represent individual people, households or villages that, importantly, have the ability to interact purposefully with their environment and with other agents [2,9]. In successive "time steps", the general sequence of an agent-based simulation is (a) each agent acts according to its rules and local environment; (b) the 'world' (the states of agents and their landscape) is changed according to the sum of all agent actions; (c) agents react to their new environment, and so on. The power of agent-based modelling lies in the iteration (repetition) of these agent interactions over many time steps, which may produce predictable patterns on the large scale, even as the details of the occurrences on the small-scale are unpredictable.

Being simple, our model gives us a chance to run multiple simulations to test how several parameters affect specialization, exchange and wealth inequality within a simplified social network.

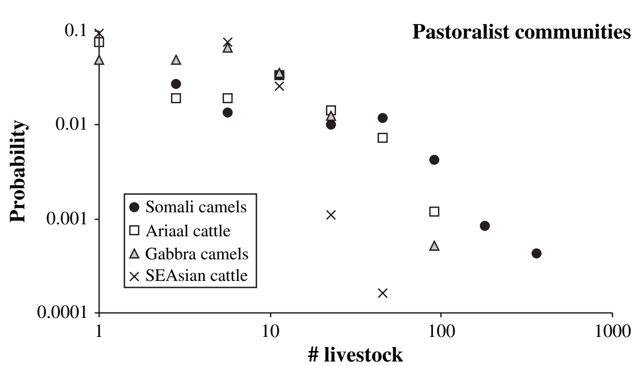

Fig. 1. Livestock ownership in pastoralist societies, as shown by distributions on a plot with logarithmic x- and y-axes. After [4], Fig. 2.6.

2. The model

Our model, programmed in Java and run on the agent-based platform RePast (v. 2.0; http://repast.sourceforge.net/), involves a network of agents who consume, produce and trade two different commodities. In an abstract version of a social network represented by dots and lines, the agents and their connections do not represent physical space, but rather "relational space" depicting which agents are accessible to each other for trade in a localized zone of interaction. Built upon an already-tested social network model [17], described below, our own model runs so that each agent, represented as a network node (Fig. 2), produces and consumes its own combination of two distinct products – product "A" and product "B" (we capitalize the names of model parameters – the trading of which between agents is represented by links in the network). Below, we first describe the social network model [17] and our modification of it for our own simulation, followed by our results and the effects of different parameters.

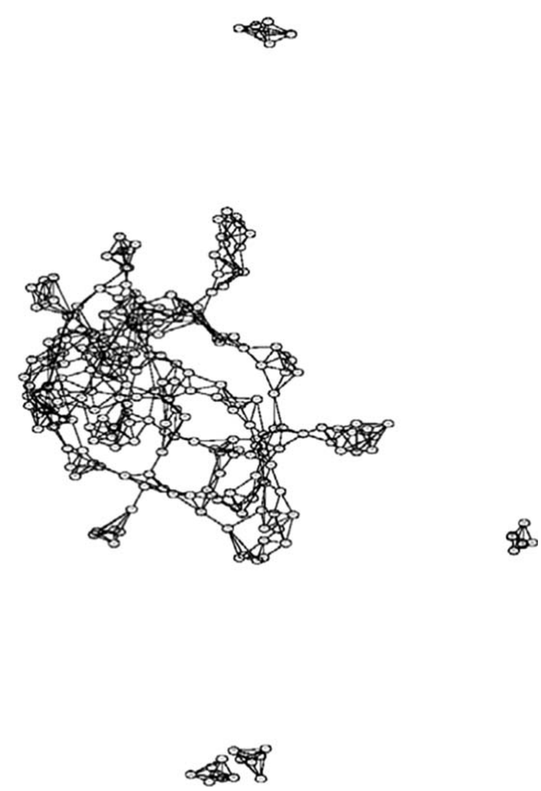

Fig. 2. Sample network generated by the Jin et al. [17] model, using the default values for the variable parameters and constant values of the fixed parameters listed in Table 1. From [17], Fig. 6.