Equality seekers or moderate monopolists: Social structure affects the evolution of distributive norms

Kazuaki Kojima[1], Reiji Suzuki and Takaya Arita

Graduate School of Information Science, Nagoya University, Japan
[1]k-kojima@alife.cs.is.nagoya-u.ac.jp

Introduction People in some societies tend to put a greater value on equality in distribution of resources even if they have to pay expensive court costs to achieve it, while people in some other societies tend to aim at a maximal share (the whole) but withdraw readily if any conflict occurs. Nash demand game (NDG) is a one-shot two-player game and has been widely used for modeling such bargaining situations in computational and game theoretic approaches. Each player simultaneously demands a portion of some good. If the total amount demanded by the players is less or equal than available good, each player obtains the claimed request. Otherwise, neither player gets anything. Whereas the studies using NDG can account for why people favor the equal distribution (Skyrms (1996)), it is too simple to deal with various distributive norms. We use the demand-intensity game (DIG) which adds a psychological factor to NDG while maintaining such simplicity that it can be analyzed by the concepts and tools of the game theory (e.g., Kojima and Arita (2012)).

The goal of this study is to clarify the origin and evolutionary dynamics of distributive norms using DIG. Previous studies have shown that population structures tend to promote cooperative behavior by means of cooperative clustering and assortative interactions. We perform the evolutionary simulation focusing on the effect of the population structures on the evolution of distributive norms. We show a surprising result that network structures significantly change the evolutionary scenario. A population distributed over a regular network tends to evolve a strong equality norm. However, as the random links increase in the network, the more we see the scenario in which monopolists occupy the population who ask for the whole but with a moderate or timid intensity. We also find that network structures with some intermediate randomness create an interesting scenario in which several norms emerge in a cyclic manner.

Model DIG is a one-shot game between two players. Each player has values of d and i ($0 \leq d, i \leq 1$) as a strategy $S(d, i)$: $S(d_0, i_0)$ for player 0 and $S(d_1, i_1)$ for player 1. d indicates how much portion of the resource she wants and i indicates the intensity of the demand as shown in Fig. 1.

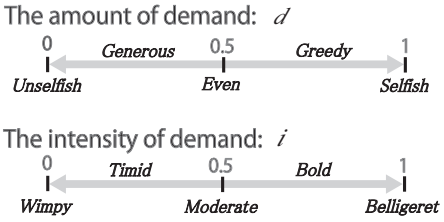

Figure 1: Representation of strategies.

For example, a strategy with $d = 1$ is described as "selfish" while a strategy with $i < 0.5$ is described as "timid."

Player 0's payoff is defined as the following equations (1)-(3). If the aggregated demand between both do not exceed the total resource 1, each player obtains her demand d as a payoff without a conflict. Otherwise, each player obtains a payoff reduced by the conflict cost defined as the mean intensity of them, from the tentative payoff tp considered as follows. The self demand d_0 is separated into two parts: the directly obtained part $(1-d_1)$ and the resting overlapped part (d_0+d_1-1). The latter will be divided at the ratio based on the difference between player's intensities $(1 + i_0 - i_1 : 1 + i_1 - i_0)$.

$$payoff = \begin{cases} d_0 & (if\ \ d_0 + d_1 \leq 1), \\ tp \cdot (1 - cost) & (otherwise), \end{cases} \quad (1)$$

$$tp = (1 - d_1) + (d_0 + d_1 - 1)\frac{1 + i_0 - i_1}{2}, \quad (2)$$

$$cost = \frac{i_0 + i_1}{2}. \quad (3)$$

There are two typical strategies: $d = 0.5$ and $d = 1$. Although debatable, we simply associate the former with "egalitarianism" and the latter with "libertarianism." The ideal society in the sense of equality and efficiency (anyone receives 0.5 in every game) can be achieved by not only egalitarianism norm $S(0.5, *)$ but also "wimpy" libertarianism norm $S(1, 0)$.

Social networks in our model are represented as Moore neighborhood structure on a toroidal square lattice consisting of 100 x 100 nodes each of which has a player. Net-

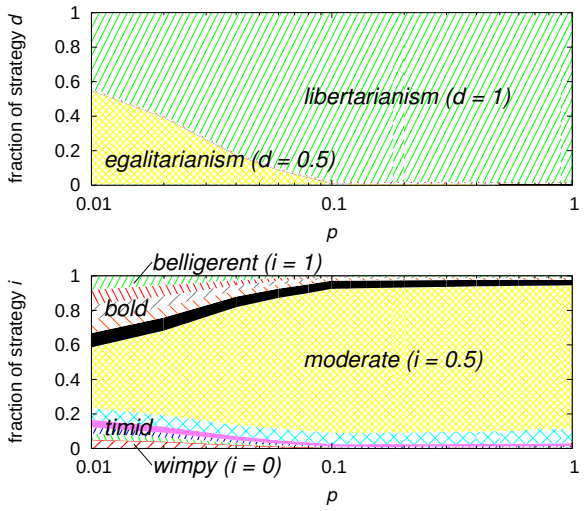

Figure 2: Distribution of the evolving strategies from 1000th to 1500th generations as a function of the rewiring probability p averaged over 100 trials ($w = 1$). Each area corresponds to each strategy value, sorted in order of increasing value.

works are constructed by rewiring each link with a probability p. In each generation of evolution, each player plays DIG with directly connected neighbors. The fitness for player j is defined as $exp[w\pi_j]$ in which w represents the intensity of selection and π_j represents the average payoff. Each player adopts a strategy selected fitness-proportionally from own and all neighborhoods' strategies as a next strategy and then changes d and i to a random value with a low probability 0.05, respectively.

Effects of social structure We conducted evolutionary simulations in which d and i have discrete values from 0 to 1 with a 0.1 resolution. Figure 2 shows the distribution of the evolving strategies from 1000th to 1500th generations ($w = 1$). Although it is not clear from this figure, basically just one strategy always occupied the population as a norm except for some region of p.

We see a clear tendency that as the random links increase egalitarianism disappears and instead libertarianism grows and then every time occupies the population. We also found that egalitarianism was coupled with various intensities, $S(0.5, *)$ and libertarianism was coupled mainly with the moderate intensity, $S(1, 0.5)$.

Furthermore, we found that in a few trials network structures with some intermediate randomness ($p \approx 0.06$) create an interesting scenario in which several norms (including timid or moderate libertarianism and bold or moderate egalitarianism) emerge in a cyclic manner as shown in Fig. 3. It is similar to cyclic dynamics emerging from voluntary interactions in the public goods game or the prisoner's dilemma

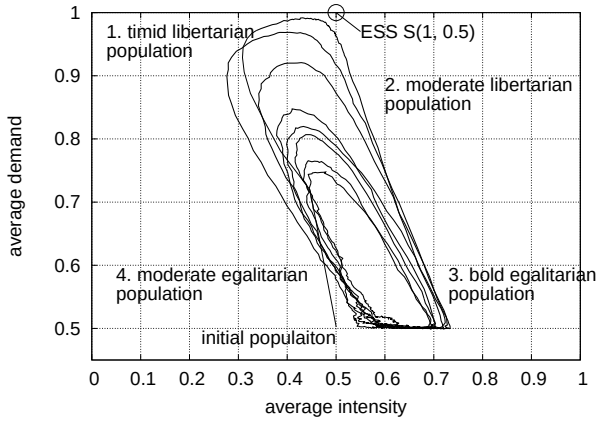

Figure 3: A typical evolutionary trajectory of strategies averaged over each population. Starting from $(0.5, 0.5)$ as mean values of a random population, it drew clockwise circles composed of (1) a growth of the number of libertarians, (2) an increment of the intensities, (3) an increase of the number of bold egalitarians and (4) a decrement of the intensities.

(Hauert et al. (2002), Suzuki et al. (2008)).

In addition, when using networks with strong spatial locality (small p), strong selection (large w) favored the coexistence of egalitarianism and timid libertarianism. Timid or wimpy libertarians, by obtaining a high payoff against any strategy, could survive under strong selection in spite of the advantageous network structure for egalitarianism.

Conclusion We demonstrated that the population structure could strongly affect the evolution of distributive norms by performing the evolutionary simulations using an extended version of the Nash demand game. Specifically, we showed that spatial locality favors equality seekers while randomness in the networks favors "moderate" or "timid" monopolists. This result might offer significant implications to us living in a world where an increasing number of people are connected to each other through social networking although our tendency to connect with similar others should be taken into consideration.

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