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Partner selection and emergence of the merit-based equity norm

Hirofumi Takesue

Graduate Schools for Law and Politics, The University of Tokyo, Law 3rd #407, 7-3-1, Hongo, Bunkyo, Tokyo 1130033, Japan

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A B S T R A C T

The merit-based equity norm is a widely observed principle of fairness in resource distribution, in which the resources acquired by each individual are expected to be proportional to the contribution. Despite the empirical significance of this principle, theoretical progress in evolutionary explanations of the fairness norm has been limited to an egalitarian norm. In this study, we examined the effect of partner selection on the evolution of the merit-based equity norm in a simple bargaining game. Our agent-based model demonstrates that the merit-based equity norm emerges when the agent can choose to continue the current partnership based on the bargaining result, whereas the egalitarian norm arises in a random matching situation.

1. Introduction

In the last few decades, evolution of cooperation is among the most actively studied areas in the natural and social sciences (Nowak, 2006; Rand et al., 2013). Combinations of theoretical and experimental work produced valuable insights (e.g. Hoffman et al., 2015; Jordan et al., 2016). For the maintenance of beneficial cooperation, the mechanism on the division of the resource, which motivates individuals to continue the current collaboration, is quite important (Melis, 2013). Utilizing simple bargaining situations, such as the Nash demand game (Nash, 1953), ultimatum game (Güth et al., 1982) and dictator game (Forsythe et al., 1994), researchers have accumulated ample evidence to suggest that fairness plays a large role in the division of resources (Camerer, 2003; Güth and Kocher, 2013; Nydegger and Owen, 1974; Schelling, 1963; Yaari and Bar-Hillel, 1984). Compared with self-interest-based models, theoretical models that consider fairness preferences can better explain these experimental results (Bolton and Ockenfels, 2000; Fehr and Schmidt, 1999). In addition, neuroscience studies have elucidated the neural mechanisms underlying fair behavior (Civai et al., 2012; Dawes et al., 2012). Although these bargaining models are proposed to investigate human behavior, they are also applied to our close relatives, such as the chimpanzee, and stipulate the comparative research (Brosnan and de Waal, 2014; Jensen et al., 2007; Kaiser et al., 2012; Proctor et al., 2013).

Many models have been proposed to explain the ultimate cause of the preference for fair division in a bargaining situation. One approach emphasizes that the ability to select an interaction partner is the key to the evolution of fairness. Some models assume that people actively choose partners based on specific criteria (André and Baumard, 2011a; Chiang, 2008; Debove et al., 2015b), whereas others assume the occurrence of assortative matching (Carpenter, 2002; Shirata, 2012; Skyrms, 1994). Reputation formation can also support the evolution of fairness by preventing future partners from making greedy decisions (Nowak et al., 2000). Other scholars have noted that introducing an erroneous choice that deviates from the "optimal" strategy can lead to the emergence of fairness (Carpenter, 2002; Gale et al., 1995; Rand et al., 2013; Young, 1998). The effect of spatial (network) structure has also been intensively investigated (Alexander, 2000; Page et al., 2000; Szolnoki et al., 2012a, 2012b). In addition to these evolutionary (learning) models, other models that incorporate somewhat sophisticated players have been proposed (Ellingsen, 1997; Güth and Pull, 2004). In most of these studies, *fair division* was defined as a "half split". In other words, fairness is equivalent to egalitarian distribution in this context. The exception is limited to Debove et al. (2016b), whose relationship with our work will be discussed in the last section. However, in the actual world, a half split does not fully explain the fairness norm in resource distribution, and the fields of philosophy and economics have a long tradition of debate regarding the meaning of fairness (Konow, 2003).

The situation gets complex particularly when contribution to the production of resource is considered. Human children are more likely to share rewards equitably with the unlucky partner who gains less rewards after the collaboration task compared to the no-work condition whereas chimpanzees are not (Hamann et al., 2011). This implies that human children apply different criteria of fairness according to the contribution toward the rewards. Moreover, in acquiring food, human children prefer to work together rather than to work individually whereas chimpanzees are indifferent (Bullinger et al., 2011; Rekers et al., 2011). These results suggest that sharing of the food after the collaboration explains the high-level cooperation in humans compared

E-mail address: hir.takesue@gmail.com.

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to our close relatives (Melis, 2013; Tomasello, 2009) and it is quite important to understand how individuals consider the contribution and reach consensus on the resource division.

The merit-based equity principle is a traditional criterion of fairness that dates back to Aristotle in philosophy. According to the merit-based equity norm, the output share received by each person should be equal to each person's own input (contribution) share (Adams, 1965). Equity norm-based distributional fairness determinations require information about the *worthiness* of each individual. The equity norm does not affect the results of *typical* bargaining experiments wherein people bargain over the division of “manna from heaven”. Because people are not responsible for the output, egalitarian and equity norms make identical predictions (half split).

We can confirm the explanatory power of the merit-based equity norm by introducing the concept of responsibility for the resource. For example, the influence of the equity norm can be observed in an experiment in which the bargaining stage is preceded by a “production” stage. In these experiments, the contribution of each person to the production of the goods affects claims with respect to bargaining and subsequent distribution (Cappelen et al., 2007, 2010; Cherry et al., 2002; Gantner et al., 2001; Oxoby and Spraggon, 2008). Recent experiments show that children at an early developmental stage understand the merit-based equity norm (Baumard et al., 2012; Chevallier et al., 2015). In addition, anthropological observations that hunters in some groups share food in accordance with contributions to the hunt suggest that the merit-based equity norm is not limited to some specific culture (Gurven, 2004). Notably, the influence of the equity norm can be observed beyond small-group situations; for example, support for the welfare spending depends on the judgement of the “deservingness” of welfare recipients (Bowles and Gintis, 2000; Fong, 2001; Petersen, 2012; Petersen et al., 2012). These observations request framework, which can explain *both* equity and egalitarian norm.

In this study, we utilize agent-based modeling to show that partner selection framework (Baumard et al., 2013) can explain the evolution of the merit-based equity norm in a simple bargaining game. In this framework, egalitarian norm emerges in the absence of the opportunity for the partner choice. Researchers have shown that partner choice is a useful framework in explaining the evolution of cooperation (Aktipis, 2004; Fu et al., 2008; Hruschka and Henrich, 2006; Izquierdo et al., 2010, 2014; Vanberg and Congleton, 1992) and fairness (André and Baumard, 2011a, 2011b; Chiang, 2008; Debove et al., 2015b). We assume that agents will continue to interact with the current partner if they reach consensus and will dissolve the interaction if negotiation fails. This simple mechanism belongs to *post-interaction* partner selection and can be implemented by agents without complex cognitive abilities; in other words, agents do not have to remember others' past decisions nor anticipate the behavior of the new partner (Izquierdo et al., 2010). Our model considers exogenous productivity to incorporate each agent's contribution in the resource to be divided. Unlike an ordinary game, wherein agents divide a fixed amount of resources, the total amount of resources depends on the agents' productivity. Our interest lies in observing the effect of partner selection on the interest given by agents to their own degree of contribution when determining claims in bargaining games.

2. Model

To investigate the evolution of the fairness norm, we conducted an agent-based simulation wherein a fixed number of agents were paired to play a (modified) Nash demand game. In a standard Nash demand game, two agents bargain over a unit of resource. The strategy in this game is the demand on the resource. Both agents gain what they demand if the sum of the demands of the two agents does not exceed one and gain nothing otherwise.

In this simulation, we introduce the agent's productivity to consider the contribution to the resource. As a result, the resource size for each pair differs according to the agent's productivity. In addition, rather than assuming pure random matching, the results of the bargaining game and exogenous shock determined whether each pair continued or dissolved their current relationship. Agents whose partnerships dissolved were randomly paired in the subsequent period (see Fig. 1 for an outline of one generation of the simulation). After a fixed number of bargaining games, the agents reproduce in a manner proportional to their accumulated payoff.

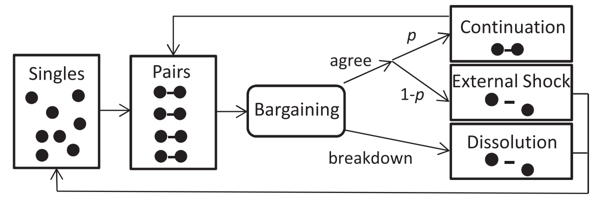

Fig. 1. Sequence of events. This process was repeated L times in one generation.

2.1. The game

In our modified Nash demand game, each agent received exogenous productivity and strategy variables that determined their claim in the bargaining game. Unlike a typical game, the amount of resources to be divided depended on each agent's productivity (r_i). We assume that r_i independently follows a standard uniform distribution U(0, 1). The amount of resources for the pair i and j (R_{ij}) is defined as the sum of the agents' productivity.

Each agent claimed a portion of the resources (partly) based on their own contribution. Agent i's s claim is calculated as follows:

$$d_i = \left(b_i \frac{r_i}{R_{ij}} + (1 - b_i)s_i\right)R_{ij}$$

where b_i denotes the weight on equity and s_i denotes the unconditional demand (we omit the subscript j from d). In this equation, r_i/R_{ij} represents the agent's own contribution share to the resource. If b_i=1, the agent exactly claims what he or she originally contributed (i.e., perfect adherence to the merit-based equity norm). If b_i=0, equity is totally ignored, and an unconditional demand variable (s_i) solely decides the agent's claim; in other words, the agent makes his or her demand in the same manner described for the ordinary Nash demand game. The values of two variables are defined so as to range between zero and one. Our interest lies in the evolution of the population means of b_i and s_i.

The payoff from one bargaining game is defined as that described for the Nash demand game. If agent i reaches a consensus with agent j ($d_i + d_j \le R_{ij}$), he or she acquires the demanded resource (d_i). If the negotiation breaks down ($d_i + d_j > R_{ij}$), both agents do not gain anything. Note that the main result does not change if we utilize another payoff function. In some studies (Ellingsen, 1997), agents who reach the consensus acquire $R_{ij}\frac{d_i}{d_i + d_j}$ so that no resource is left on the table. We confirmed that the main results remain the same under this specification.

2.2. Timeline in one generation

In one generation, the following events are repeated L times (Fig. 1): (i) Pair construction: pairs are randomly constructed from single agents. Note that all agents are single at the outset of the generation. (ii) Game: all agents play the game described above with the partner and gain a (non-negative) payoff. (iii) Continuation of the pair: if the pair reached consensus in the game ($d_i + d_j \le R_{ij}$), the pair is retained. If the pair fails to reach consensus ($d_i + d_j > R_{ij}$), the pair breaks up and the agents become single again. (iv) Exogenous dissolution of the pair relationship: to investigate the effect of a long-