Sustainable cooperation in Village Opera based on the public goods game

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A B S T R A C T

Many scholars have devoted to study how to improve the level of cooperation and amount of mechanisms have been presented. However, what makes cooperation sustainable? Village Opera is a kind of public cultural activities in southern China and has been on until now. It is a good example that cooperation can maintain a long time and the pattern of Village Opera is similar to public goods game(PGG). So we investigate Village Opera by PGG. To better understand the process of evolution in Village Opera, we introduce three types of agents into our spatial PGG. Through numerical simulations, we find We find that reputation can promote cooperation and reputation is influenced by habitual preference(β). Moreover, the key is that demand or tradition can maintain the cooperation level when reputation is disappear in Village Opera.

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1. Introduction

Village Opera is a kind of traditional public cultural activities mainly in southern China. In general, the pattern of this activity is that villagers voluntarily donate money to invite opera troupe and all people in the village can enjoy the performance. Initially, a few of villagers will contribute their money. The donors are always some rich and influential people. No matter what their purposes are, these behaviors have improved their reputation and influence by donation. Subsequently, more and more villagers are willing to donate money with the rise of Village Opera. Now, most of villagers are willing to contribute to Village Opera and the form of this activity evolves into crowd funding. Here are the problems: How does the pattern of Village Opera evolve into crowd funding? And what makes people voluntary to cooperate and maintain the sustainability of cooperation?

We find that the pattern of Village Opera is similar to Public goods game(PGG).So we here aim to investigate one of the potential mechanism of Village Opera and find the reason why cooperation can be sustainable in PGG.

The problem of maintaining public goods that everybody could free to use emerges in many social dilemmas [1–5]. Therefore, for researchers, it becomes a long lasting pursuit to promote cooperation. Evolutionary game theory has become one of the most prevalent methods to investigate cooperation in all kinds of social

dilemma situations [6]. PGG is regarded as a multi-person prisoners dilemma game. In a typical PGG, individuals who choose cooperation must contribute c to the common pool, while defectors do not. The total contribution is multiplied by a factor r, and then distributed equally among all group members. Here we can find that defection is always the optimum strategy. Cooperation has become a social dilemma [7–10].

Customarily, the agents who participate in a PGG are identified as rational and self-interested. However, the formation of Village Opera told us that cooperation is existent and people are not totally rational and self-interested. Massive studies have indicated that no matter for what purpose, many people are willing to make sacrifices for public goods. To explain the emergence and maintenance of cooperative behaviors, many solutions or mechanisms of promoting cooperation have been proposed [11–18]. The influence of emotions on decision-making in PGG has been indicated by some researchers [19,20]. And some researchers have investigate the influence of publishing the list on cooperation level [21,22]. Xiaoping Zheng et at. introduced that heterogeneous investments and rationality of small groups could promote cooperation [23,24]. The environment factors [25], coevolution of strategy and ability [26] and individual behavior [27] also could influence the evolution of cooperation. Meanwhile scholars proposed that cooperation can be promoted if people are being watched [28]. Here we research cooperation by reputation. Reputation has also been found that it can promote cooperation in PGG [29–33]. People build up good reputation or a positive image score by helping others [34–36]. The empirical study of Milinski showed that when human vol-

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unteers alternated with indirect reciprocity games and this alternation produced a high level of cooperation in PGG [37]. And Semmann et al. showed that reputation is a driving force for cooperation in PGG and sustains public resource [38]. People are more likely to make more contributions and these extra donations can enhance their reputations [39]. And heterogeneous investment exerts an important influence in PGG [40–42]. Actually, it is very similar with Village Opera. There are some people who are rich will donate to the Village Opera. Generally, there are two reasons for their behaviors. One is that they are volunteer for charity and the other is that they want to build up good reputation by charitable donations. In order to simplify the model, we only discuss the people who donate more money because of the second reason. They can obtain an amount of benefits by their good reputation which is called long-term interests [43]. However, the donators will not always contribute more donations to public goods in the real world. Their reputation cannot increase infinitely [44]. So that they will reduce the amount of their contributions in the future. Furthermore, their reputations will change with the amount of the donations. However , people will form demand for the public goods with time accumulating. Just like Village Opera, villagers are willing to cooperate because of their demand and tradition. So we use the method of evolutionary game to investigate the development of Village Opera.

As mentioned above, in Village Opera, some people are willing to contribute more due to acquire reputation from others. These minds make them cooperate and their behaviors can exert an influence on their neighbors so that cooperation can be remarkably promoted. Nevertheless, the marginal utility of their donations will be decreasing gradually. And neighbors will slowly accustom to their behaviors because of diminishing sensitivity [44], which means the increment of their reputation is on the decrease. Hence, they will reduce their donations in the future. At that time, agents would change their strategies because of this situation. The donators may be regarded as defectors. And their influence would decrease with the diminution of their donations. However, the previous cooperation make people form the demand of the public goods or the tradition of the public cultural. The demand or tradition makes people tend to be more cooperative and maintains the sustainability of cooperation.

So far, a large body of literature show that when agents choose cooperation, their reputation would be good in second order social norms [17] or increase a fixed value to the former value. However, in reality the increment of the reputation of people is becoming smaller with time. It means the reputation always has an extremum. People live in a real contacting network. They have different connections with different people. So when different networks intertwine, it would influence the cooperation level because of the change of overall payoffs [45]. And, in fact, reputation could bring benefits in different networks. This is how it works: If A is generous to B, and C is observing this, C expects A to also be generous to him, and will therefore pick A in a future coalition. Equally, if A is being nasty to B, observer C would want to avoid dealing with A in the future. Reputations matter a great deal in these social exchange networks, and it might pay off to develop an altruistic reputation because being seen as an altruist would create opportunities unavailable to non-cooperators [46].

Furthermore, the reference selection for strategy updating of previous researches only focus on the receiving payoffs of their neighbors or themselves [47]. It is far away from the realities under a couple of real world circumstances. In reality, Individuals not only consider the payoffs they could gain from others, but also take their own needs and the utility of the public goods into account when they make decisions in PGG. Just like Village Opera, people are willing to cooperate because it becomes a kind of traditional culture and form a kind of demand for this public culture.

Depending on this situation, we here extract a PGG model with three types of agents from Village Opera. We suppose that three types of agents are distributed randomly on a square lattice [48–53], including investor (R), cooperator (C), defector (D). Investors are the persons who would contribute to Village Opera. They are always cooperative, but they can independently change their donations by themselves. They will contribute more at the beginning of the spatial PGG and reduce the contribution in the future. Their reputations will increase when they give extra donations. On the contrary, it will decrease when they reduce their donations. The value of their reputations will be influenced by a parameter β, which we call it habitual preference. It denotes that the degree of the influence of investors by additional contributions or the decrement. Notably, the purpose that investors contribute more is to obtain long-term interests so that we can regard their reputations as their benefits in PGG. Based on above hypotheses, we primarily focus on researching the importance of investors, and observing the impacts of habitual preference, the number of Rs and the variation of donations on evolution of cooperation in Village Opera.

This paper is organized as follow. We introduce our model in Section 2. The numerical simulation results have been shown in Section 3. Conclusion is provided in Section 4.

2. The PGG model with three types of agents

We simulate our model with three types of agents (Rs, Cs and Ds) on a $L \times L$ regular lattice with periodic boundary conditions. We assume that N agents are randomly distributed on the square lattice. Every agent i has k neighbors. Initially, the fraction of Rs are dynamic in order to satisfy experiment demand. Other agents are regarded as Cs and Ds with equal probability. Meanwhile, each agent will make decision simultaneously.

Every agent attends $G = k + 1$ PGG groups [54] and calculates a payoff according to the following formula:

$$
\begin{aligned}
P_i &= \sum_{j \in \Omega_i} P_i^j + R_i = \sum_{j \in \Omega_i} \left(r \frac{c_i n_i^j}{k_j + 1} - c_i \right) + R_i \\
&= \sum_{j \in \Omega_i} \left(r \frac{c_C R n_C R^j + c_C n_C^j}{k_j + 1} - c_i \right) + R_i
\end{aligned}
\tag{1}
$$

where $r(1 < r < N)$ stands for a synergy [55]; Ω_i denotes the set of PGG groups in which agent i participates. j is one of the set of PGG groups. n_i^j means the total number of cooperators in PGG group j, n_{CR}^j and n_C^j indicate the number of Rs and Cs in PGG group j respectively. k_j is the number of neighbors of central agent in PGG group j. $c_i(c_C R = u, c_C = 1, c_D = 0)$ indicates the donation which is contributed by agent i. R_i is the reputation of agent i. $\frac{R_i}{50}$ is the long-term benefit which agent i obtain by reputation. Only Rs have the these benefits.

Additionally, Rs, who want to pursue reputation, always cooperate and contribute u to the group and their reputation can be increased with the time. Their strategies are difficult to be changed by others. However, Cs and Ds are easier to be influenced by Rs. So agent Cs and Ds will update his strategy with the following probability by selecting his neighbor j [54]:

$$
W\left(c_i \leftarrow c_j\right) = \frac{1}{1 + \exp\left(\frac{P_i - P_j}{K}\right)}
\tag{2}
$$

Where K denotes the impact of ambient noise, and we set $K = 0.1$ here based on previous studies. According to this formula we can know the agent with higher payoff will be chose with high probability.

On the beginning, we assume that Rs contribute $u = 2$ to the group and their reputation will increase with time, but the increments of the reputation decrease with time. In the real-world systems, the individuals who like Rs cannot obtain the reputation