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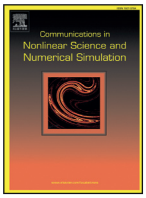

Research paper

Individual vision and peak distribution in collective actions

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People make decisions on whether they should participate as participants or not as free riders in collective actions with heterogeneous visions. Besides of the utility heterogeneity and cost heterogeneity, this work includes and investigates the effect of vision heterogeneity by constructing a decision model, i.e. the revised peak model of participants. In this model, potential participants make decisions under the joint influence of utility, cost, and vision heterogeneities. The outcomes of simulations indicate that vision heterogeneity reduces the values of peaks, and the relative variance of peaks is stable. Under normal distributions of vision heterogeneity and other factors, the peaks of participants are normally distributed as well. Therefore, it is necessary to predict distribution traits of peaks based on distribution traits of related factors such as vision heterogeneity and so on. We predict the distribution of peaks with parameters of both mean and standard deviation, which provides the confident intervals and robust predictions of peaks. Besides, we validate the peak model of via the Yuyuan Incident, a real case in China (2014), and the model works well in explaining the dynamics and predicting the peak of real case.

1. Introduction

The collective action is one of the most fundamental social phenomena with political impacts and societal implications [1–4]. In order to achieve specific common interests or collective goals [3,4], individuals or members of society cooperate together and they participate or get involved into all types of collective actions, such as Strikes, Protests, Rallies, and Demonstrations, such as Occupying Wall Street. So far, methods of statistics [1,5–13], mathematical modeling, and simulations [14–22] have been applied to explore the regularities of collective actions. However, the evolution process and especially the peak of participants have been paid less attention. The peak of participants regularly indicates the largest number of participants mobilized, the largest amount of resources involved, and the highest success probability achieved [4,21,22]. Therefore, the peak is the key factor to predict the success probability or chance of certain collective actions. As the number of participants is positively correlated to the success rate of collective actions [21–24], this work aims to solve the peak mechanism of participants mobilized, improve the model's fitness via adding more factors (heterogeneities) into model's simulations, and validate the model with the data of real case.

Inspired by existing explorations of models such as the threshold model [22,25], standing ovation model [26], network model [27–30], stochastic learning model [31–36], critical mass model [37–39], and freezing period model [40], the peak model of participants has been developed. It is believed that two factors have substantial effects on peaks: (1) Jointness of Supply (J). It measures how the individual payoffs are shaped by the group size N [21,37–39]. Zero jointness of supply

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(J = 0) reduces individual payoffs, discourages participants, and leads to the mobilization problem in larger groups [4,41]. "Pure jointness of supply" (J = 1) does not reduce individual payoffs and therefore encourages more participants [21,38]; (2) Heterogeneity. Heterogeneity reduces the heights of peaks, but homogeneity enhances them. Measured by the standard deviation [7,21,25–27,37], the heterogeneity among individuals makes it harder to organize collective actions, which plays the negative role in mobilizing individuals to participate collective actions [21,23]. Meanwhile, the homogeneity or "homophily" promotes and increases participations of collective actions [21,42,43].

This work continually improves the previous peak model based on these two factors: (1) Jointness of Supply (J). As a key parameter or factor, each collective action has one degree of Jointness of Supply, either static or dynamic. Since 1990, J has been expanded into the unit interval and set as a continuous variable [21,31–33,42,43]. It suggests that a higher J encourages participations and facilitates the emergence of critical mass [21,31,32,37,42]. The peak exists under the condition that $-\infty < J < 1$ [43]. Like the previous work [21], we focus on the commonly seen interval of J ($0 \le J \le 0.4$), because the mobilization of people is problematic while $0 \le J \le 0.4$ and the mobilization is not difficult as $J > 0.4$. Meanwhile, the peak is substantially large and hard to be simulated and visualized as the parameter $J > 0.4$; (2) Heterogeneity. The previous peak model has presented the core idea of how to predict real peaks: (a) the ideal state of complete homogeneity solves ideal peaks, (b) heterogeneity in reality reduces the real peaks from ideal peaks, and (c) simulations and statistical methods are applied to evaluate ideal peaks [43]. There exist multiple sources of heterogeneity, and utility heterogeneity is not enough. Especially, people or group members have different vision abilities in reality. In order to better reflect the real society, the vision heterogeneity is introduced into the revised peak model of participants during the dynamics of participation in collective actions.

2. The peak model

2.1. Vision heterogeneity in net utility

The relationship between individuals' objective payoffs (V_i, scalar) and collective goods (V_g, scalar) mainly explains why people participate and where the collective action has the peak in terms of the number of participants [4,31,37–39]. Therefore, Eq. (1) reflects the relationship between V_i and V_g and how the individuals calculate their net utility. J denotes their relationship, and a higher J encourages more individuals to participate and the peak is higher [43]. The previous peak model indicates that the condition for people to participate is that the net utility (S_i, scalar) should be positive in Eq. (1). Agents will quit as free riders if the net utility is zero or negative [43]. Although several sources of heterogeneities, such as threshold heterogeneity [22,25,32], utility heterogeneity [37,38], and position, coring, or judgment heterogeneity [26] are well investigated, vision heterogeneity is less considered in modeling and simulations of collective actions. Heterogeneity within society members is inevitable [7,21,25,26,27,43], as it is impossible to find two identical people in the world. The individual utility terms, v_i and cost c_i, are both heterogeneous, and their standard deviations (σ_v and σ_c) measure their heterogeneity degrees respectively in Eq. (1).

$$S_i = v_i V_i - c_i = \frac{v_i \cdot V_g}{N^{(1-J)}} - c_i \tag{1}$$

Agents make decisions under different information sets [45], in that they have different visions h_i. Eq. (2) reflects how individuals calculate their net utilities with vision heterogeneities. Limited to social capital and networks [16,17,21,26–30,39,44], personal values and specific angles, positions, roles, and prestige [24,26,37], individuals (participants and free riders) probably perceive and observe different numbers of people in the same collective action. Technically, the individual vision h_i is defined as the percentage or probability of participants in the total population observed by individuals. With different visions h_i, they may see different numbers of people sharing the V_g. Therefore, we include individual visions into the peak model of participants in collective actions. Suppose one certain collective action have one hundred individuals in Fig. 1. Individual One in purple can observe ninety-nine people, so his or her vision is 0.99, i.e. $h_1 = 99/100 = 0.99$; Individual Two in blue sees twenty-one people, and his vision is 0.21, i.e. $h_2 = 21/100 = 0.21$; Individual Three in red perceives six people, so the vision of him or her is 0.06, i.e. $h_3 = 6/100 = 0.06$; The individual 100 is out of the visions or horizons of them. Therefore, S_i includes the vision heterogeneity in Eq. (2), where the individual utility v_i, cost c_i, and vision h_i are normally distributed and their standard deviations (σ_v, σ_c and σ_h) measure their heterogeneities respectively.

$$\begin{aligned} &S_i = v_i V_i - c_i = \frac{v_i \cdot V_g}{(h_i \cdot N)^{(1-J)}} - c_i \\ &s.t.\;\; v_i \sim N\left(v,\ \sigma_v^2\right),\ c_i \sim N\left(c, \sigma_c^2\right), \text{ and } h_i \sim N\left(h, \sigma_h^2\right) \end{aligned} \tag{2}$$

2.2. Behavior rules and parameter settings

Individuals or agents are not making decisions to participate (participants) or not (free-riders) simultaneously, but sequentially instead [16,21,22,32,35,37,43]. Eqs. (3) and (4) demonstrate how agents make dynamic decisions or actions as the group size N_t grows with the time t. In other words, they join the collective action one-by-one if we stretch the time into the infinite tiny units or pieces. Utility v_i, cost c_i, and vision h_i is the internal attributions of individuals and maintain constants