Journal of Behavioral and Experimental Economics 72 (2018) 67–77

Contents lists available at ScienceDirect

Journal of Behavioral and Experimental Economics

journal homepage: www.elsevier.com/locate/jbee

Instability in the voluntary contribution mechanism with a quasi-linear payoff function: An experimental analysis

Jun Feng[a,*], Tatsuyoshi Saijo[b,c], Junyi Shen[d], Xiangdong Qin[e]

[a] Graduate School of Engineering, Kochi University of Technology, 2-22 Eikokuji, Kochi 780-8515, Japan
[b] Research Institute for Humanity and Nature, 457-4 Kamigamomotoyama, Kyoto 603-8047, Japan
[c] Research Institute for Future Design, Kochi University of Technology, 2-22 Eikokuji, Kochi 780-8515, Japan
[d] Research Institute for Economics and Business Administration, Kobe University, 2-1 Rokkodai, Kobe, Hyogo 657-8501, Japan
[e] Antai College of Economics and Management, Shanghai Jiaotong University, 1954 Huashan Road, Shanghai 200030, China

ARTICLE INFO

Keywords:
Instability
Public goods game
Lab experiment
Voluntary contribution mechanism
Conditional cooperator

JEL classification:
H41

ABSTRACT

We conduct experiments to investigate the convergence of contributions in the voluntary contribution mechanism (VCM) with two quasi-linear payoff functions. One is linear with respect to private goods and nonlinear with respect to public goods; we call it "QL1." The other is linear with respect to public goods and nonlinear with respect to private goods; we call it "QL2." The system with QL1, built on the assumption of self-interested players and myopic Cournot best response dynamics, is not stable, but the system with QL2 has a dominant Nash equilibrium. This theoretical result predicts a "pulsing" of contributions in the VCM with QL1. Our experimental observations demonstrate that individual contributions are certainly converging to the dominant Nash equilibrium in the experiment with QL2. In the experiments with QL1, however, the dispersion of individual contributions increases progressively with repeated trials, and the contributions are still volatile in the experiments' last periods, although we do not find a clearly unstable pulsing in the group's total contribution.

1. Introduction

The voluntary contribution mechanism (VCM) has been investigated by experimental economists for many years in order to understand the public goods provision problem.[1] Most researchers in this field use linear payoff functions such as $u(x_i, y) = x_i + by$, where x_i is a private good of player i, y is a public good, and b is a positive constant. However, several scholars argue that this linear payoff setting cannot represent real-world situations of the VCM environment because the self-interested choice (Nash equilibrium) and the optimal social choice are located at opposite boundaries of the feasible choice set (see, e.g., Sefton and Steinberg, 1996; Laury and Holt, 2008).

One way to address this problem is to adopt nonlinear payoff functions to provide an interior solution for the self-interested choice and the optimal social choice. Thus, two quasi-linear payoff functions are introduced in the literature. The economic rationale of the first payoff function is that private good x_i is money; therefore, its marginal return could be assumed to be constant. However, the marginal return from specific public good y is nonlinear. That is, $\pi(x_i, y) = x_i + t(y)$ (see Isaac et al., 1985; Isaac and Walker, 1991; Sefton and Steinberg, 1996; Isaac and Walker, 1998; Laury et al., 1999; Hichri and Kirman, 2007). We call this "QL1." Conversely, the second payoff function is linear with respect to y and nonlinear with respect to x_i. Thus, the function is $\pi(x_i, y) = h(x_i) + y$ (see Sefton and Steinberg, 1996; Keser, 1996; Falkinger et al., 2000; Willinger and Ziegelmeyer, 2001; van Dijk et al., 2002; Uler, 2011; Maurice et al., 2013; Cason and Gangadharan, 2014). We call this "QL2." The second payoff function is used to model a relatively rare situation in which the marginal return from the private good decreases, whereas it is constant for the public good.

These two designs lead to completely different theoretical predictions. The VCM with QL1 induces multiple static Nash equilibria, which produces a coordination problem. By contrast, the VCM with QL2 induces a unique dominant equilibrium, which is similar to the VCM with linear payoff functions. Sefton and Steinberg (1996) compared contribution levels across QL1 and QL2 environments using a randomly rematched group setting to suppress the feedback from the results of previous periods in the experiments. They predicted that the presence of the coordination problem should partially explain why the average of individual contributions is significantly above the Nash prediction in their design of the VCM with QL1, although their experimental results indicated only a slight difference in contribution levels between the two experiments.

* Corresponding author
E-mail address: cb8226@alumni.sjtu.edu.cn (J. Feng).

[1] See Ledyard (1995) and Chaudhuri (2011) for surveys on experiments regarding the VCM. Bergstrom et al. (1986) discuss the basic theoretical properties of the VCM.

https://doi.org/10.1016/j.socec.2017.12.002
Received 28 October 2016; Received in revised form 2 December 2017; Accepted 3 December 2017
Available online 05 December 2017
2214-8043/

In contrast to Sefton and Steinberg (1996), we are interested in the VCM experiments with QL1 and QL2 using a fixed group setting. Since the fixed group setting transforms the game into a super game, subjects might be motivated to play strategically in such an environment (for details, see the discussion in Sefton and Steinberg (1996)). Furthermore, because the group members are fixed, the feedback from preceding periods contributes to belief formation much more directly in the fixed group setting than it does in the randomly re-matched group setting. Healy (2006) provides experimental evidence that subjects appear to best respond to recent observations in the VCM experiment with QL1 using a fixed group setting.

Recently, Saijo (2014) showed that, if subjects follow the assumptions of self-interested players and myopic best response dynamics, all Nash equilibria are not asymptotically stable in the system of the VCM with QL1.[2] This leads to a pulse of contributions (alternating between contributing nothing and contributing everything). This dynamic analysis predicts that the feedback from repeated trials will worsen the coordination problem in the VCM with QL1. On the other hand, Laury et al. (1999) found that the symmetric Nash equilibrium was a poor predictor of individual contributions and that mean contributions also varied widely among individuals, even within a single experiment. This result was confirmed by Hichri and Kirman (2007). These observations and the instability result suggest a complex interaction among subjects in the VCM with QL1.

Analogous arguments of instability were discussed concerning oligopoly competition in the field of industrial organization (see Cox and Walker, 1998; Rassenti et al., 2000; Huck et al., 2002). Nevertheless, the instability problem in the VCM with QL1 differs from that examined in those discussions. As Andreoni (1995) pointed out, subjects are called upon to generate positive externalities in the VCM environment, whereas they are asked to generate negative externalities in the experiment of oligopoly competition.[3] The positive and negative framing will lead to different effects on cooperation (see Andreoni, 1995; Sonnemans et al., 1998; Cookson, 2000; Bowles and Polania-Reyes, 2012). Cooperative behavior is widely observed in the VCM experiments (for a survey, see Chaudhuri, 2011). Therefore, an investigation in the VCM environment might provide a new understanding of the effect of instability in an environment that includes cooperation.

More importantly, most experimental studies in the field of VCM experiment have used the linear payoff function, which might have failed to capture the real-world instability of the VCM. Therefore, this study investigates that instability and provides dynamic analyses on the convergence of individual contributions in the VCM with QL1 using a fixed group setting. The results of the VCM experiment with QL2 serve as a reference.

In contrast to the observation of a tiny difference in contribution levels between the QL1 and QL2 environments using a randomly rematched group setting in Sefton and Steinberg (1996), our experimental results show a significant difference in the convergence of individual contributions between the QL1 and QL2 environments using a fixed group setting. We find clear evidence that the dispersion of individual contributions decreases, indicating the convergence of individual contributions, and that the absolute changes of individual contributions diminish, suggesting that individual contributions become steady, in the experiment with QL2.[4] Conversely, although we do not find a clearly unstable pulsing in the group's total contribution in the experiments with QL1, our observations show that the dispersion of individual contributions increases progressively with repeated trials and that individual contributions are still volatile in the experiments' last periods. Hence, individual contributions diverge in the QL1 environment. These observations suggest that the coordination problem is not alleviated and that individual contributions are not converging to any equilibrium in the experiments with QL1. Therefore, our main result is that the experimental observations provide supporting evidence for the non-convergence of individual contributions in the QL1 environment using a fixed group setting, but there is still a significant distance between our theoretical instability argument and our experimental observations.

Moreover, consistent with the findings of previous studies, our data show considerable cooperation across players in all experiments. In each experiment, almost 50 percent of the subjects could be considered as following the decision rule of typical conditional cooperators, and about 20 percent of the subjects are weak free riders.[5] Based on this observation, we discuss possible explanations for the distance between our theoretical predictions and the experimental observations in the conclusion.

The remainder of this paper is organized as follows. Section 2 summarizes several theories concerning the VCM with QL1 and QL2. Section 3 presents our experimental design. Section 4 reports the experimental observations. Finally, the last section discusses the results and concludes the study.

2. Theories of the VCM with QL1 and QL2

2.1. VCM with QL1

Suppose that, in an n-player VCM with QL1, all players have the same payoff function and the same endowment E. A simple quadratic specification is the following:

$$\pi_i = E - s_i + aS - bS^2, \tag{1}$$

where a and b are positive constants, s_i denotes player i's individual contribution, and $S = \sum_{i=1}^{n} s_i$ represents the group's total contribution. For this simple game, a list of individual contributions $\hat{s} = (\hat{s}_1, \hat{s}_2, \cdots, \hat{s}_n)$ is a Nash equilibrium if, for all i, $\pi_i(\hat{s}_i, \hat{s}_{-i}) \geq \pi_i(s_i, \hat{s}_{-i})$ for all $s_i \in [0, E]$, where $\hat{s}_{-i} = \sum_{j \neq i} \hat{s}_j$. Therefore, from the first-order condition, the sum of Nash equilibrium contributions is given as

$$\hat{S} = \frac{a-1}{2b}, \quad \hat{S} \in [0, nE]. \tag{2}$$

This result indicates that any combination of individual contributions constitutes a static Nash equilibrium as long as the total contribution equals $\hat{S}$ (Bergstrom et al., 1986).

Anderson et al. (1998) introduce decision errors into this model. They show that, though there is a continuum of Nash equilibria, a unique logit equilibrium exists that is symmetric across players. The equilibrium density is a (truncated at the boundary of the choice set) normal density for the quadratic public goods game (the VCM with QL1).[6] Furthermore, they suggest that the quadratic model can easily be generalized to allow for individual differences in error parameters. The unique symmetric logit equilibrium thus becomes a unique asymmetric logit equilibrium. Moreover, because the distribution is truncated by the boundary of the choice set, the expected contribution of the logit equilibrium is also sandwiched between the symmetric Nash

[2] An intuitive explanation of asymptotic stability is that an equilibrium $\hat{x}$ is asymptotically stable if all nearby solutions not only stay nearby but also tend to $\hat{x}$ (Hirsch and Smale, 1974, p. 180). We provide the formal definition of asymptotic stability in Section 2.

[3] The VCM experiments usually frame the subject's choice as contributing to the provision of public goods, which could benefit other players within the group, whereas the oligopoly experiments usually frame the subject's choice as providing a product, which will lower the market price and result in a disbenefit to others within the group.

[4] Absolute changes are the absolute values of the first-order differences of individual contributions.

[5] Typical conditional cooperators are those players who always try to match the average contribution of others in the previous period and whose contribution is insignificantly different from the average contribution of others. Weak free riders are those whose contribution is significantly below the average contribution of other players in the group and who are affected by the difference between their individual contributions and the average.

[6] See Proposition 3 in Anderson et al. (1998).