The Analysis and Solutions to the Free Riding Phenomena Existing in Corporations with Three Game Theory Models

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Abstract: Free-riding phenomena in cooperation requires powerful tools to address it. Game theory method is defined as the analytical concept of dealing with decision-making process in various sciences. This paper summarizes the methods of using game theory to solve the problem of free riding problem in cooperation. This paper will introduce the basic concepts of game theory method, so that readers are familiar with the principles of game theory. In addition, three models of game theory, including the boxed pig game, the public goods game and the snowdrift game, will be studied. In addition, it will review the different types of game theory methods in cooperation free riding problem to achieve the decision-making process. The main research contribution of game theory to hitchhiking applications is studied and discussed in detail.

1. Introduction

In the social sciences, the free-riding problem is a type of market failure that occurs when those who benefit from resources, public goods such as public roads or hospitals, or services of a communal nature do not pay for them or under-pay. Free riders may continue to access or use it without paying for the good. (Either directly through fees or tolls or indirectly through taxes) [1]. Thus, the good may be under-produced, overused or degraded. The presence of free-riders causes this prosocial behavior to deteriorate, perpetuating the free-riding problem [2]. For teams, an inefficient management of free riding could be destructive because the management failure will seriously affect the achievement of team goals, and will have a negative impact on both free-riders and the ones who contribute [3].

To solve the problem existing in the interval of the working process of cooperation, one of the mainstream methods for studying is Game Theory. Game Theory is a research technique that can explore how people maximize their benefits in the situation which will influence others when someone acts [4]. Game Theory is useful in reality such as analyzing the rate of attendance in university based on the game between students and teachers. Free riding problem occurs when teachers don't register the students and students don't attend in class. Progress test and random quiz will be the solution because they can lead registration to be the positive target for teachers. It can improve the effect of registration and the rate of attendance will increase [5]. Under the circumstances of introducing Game Theory for solving the free riding dilemma, the status quo of cooperation being inefficient could be changed into strongly competitive [6]. Boxed pig game, public goods game and snowdrift game are three of classic cases of game theory which can admirably explain why free riding phenomena exists in group. The result of Nash equilibrium of these games will show the incentive of individuals that free riding

Nash equilibrium is mentioned in the concept of game theory, which defines the situation that all players had made their best decision and players do not tend to deviate from their decision. The Nash

equilibrium shown in boxed pig game, public goods game and snowdrift game all make the cooperative members tend to free ride.

The aim of this paper is to provide a comprehensive review of applications of game theory approaches to the solution of free riding problem in three specific models. This paper reviews the knowledge of game theory in some paper to solve the free riding problem. Also, various proposed model in recent publications will be shared to clearly discuss the free riding problem.

The remainder of this paper is organized as follows: Section 2 provides boxed pig game approaches in recent studies. A brief review on the public goods game will be prepared in section 3. Section 4 analyzes the snowdrift games approached from various points. Finally, the paper will be concluded in section 5.

2. Boxed Pig Game

Boxed Pig Game describes how the weak establish correct strategies to receive best payoff when they experience the pressure from the strong. The situation of the Boxed Pig Game involves two pigs, a small pig and a big pig, who tend to eat food in the crib. From the payoff matrix below, the Nash equilibrium is big pig pedaling and small pig waiting for another one to pedal. Thus, small pig is the free riding.

As shown in Table 1, under the premise of big pig selection action (pedal), small pig chooses to wait, small pig can get 4 units of pure income. Big pig gets 6 units, pay 2 units of cost, and get 4 units pf income. When they reach the food tank at the same time, small pig gets 1 unit and big pig gets 5 units of pure income (pay 4 units of cost). In the case of big pig chooses to wait, if small pig pedals, small pig can only eat 1 unit. Then small pig will not be able to meet the cost, and the pure income is -1 units. If small pig also chooses to wait, then the piglet's income is zero, the cost is also zero. Therefore, waiting is better than pedaling for small pig.

Table.1. Definition of boxed pig game

	Pedal	Wait
Pedal	5,1	4,4
Wait	9, -1	0,0

Some paper studied the free-riding problem in enterprises where the payoff of excellent employees and lazy employees were same and it would lead to a low production efficiency for enterprises [7]. Scholars believed that establishing a good incentive mechanism could solve it. Team leaders should break down work based on internal management goals, determined the performance of each team member, and rewarded or punished them accordingly. In this system, slackers would lose their rewards. Through experiments, the author believed that this mechanism can effectively help enterprises to solve the free-riding problem.

Free-riding problem also existed in the scientific research team [8]. In scientific research team, free riding was shown by the negative strategy of ordinary members and not-optional strategy of strong members. Scholars suggested that the team should increase profits to stimulate the members to achieve ideal win-win result. The increase in profit might contribute to increase the incentive of cooperation among the members in the team, which meant the free riding problem could be solved. However, in this study, they did not prove their conclusion through experiments, but only theoretical analysis.

Some scholars paid their attention to the free-riding phenomenon in advertising competition called spillover [9]. In advertising game, free riding incentive was shown by waiting until other providers started advertising. Author suggested that increasing advertising resource comparison ratio could help service providers tolerate opponents free riding and service provider chose to cooperate on advertising and vice versa. However, spillover improved short-term profits at the expense of the long-term profits.

Hence, service providers might not choose to cooperate and increasing advertising resource comparison ratio will promote cooperation in a certain degree.

Similar like advertising competition, website management also faced the free-riding problem [10]. In website management, free riding phenomenon could be seen when small plates on the website created false news in order to get profit. The decision to publish false news always made small plates pay less than big plates, and get similar profit compared to big plates. Authors thought there would be best public welfare when website could delete the small plate's self-interest action. However, the problem is how to fully detect selfish behaviour. Therefore, deleting the false news could prevent free riding problem to some extent.

Some scholars analysed boxed pig game exists in global carbon emission [11]. The reasonable annual carbon dioxide emission was fixed. But developed countries forced developing countries to reduce carbon emission and developed countries could emit more carbon dioxide as a free riding. The solution was to decrease the cost of emission and increase the cost for free riding (wait until developing countries cut emission) in order to stimulate the enthusiasm for countries. Because of the improvement of boxed pig game model, emission reduction was always the best strategy for developing countries and developed countries, free-riding phenomenon was solved.

In ecological protection of trans-regional lake water resources, Free-riding phenomenon was shown by lower enthusiasm from weak region [12]. Weak region could always get the highest benefits when they waited until strong region took actions. Through theoretical analysis, the author suggested the establishment of a reasonable compensation mechanism for ecological protection. This mechanism required government to take incentive policies such as cost sharing mechanism, sharing effect evaluation mechanism. Strong region and weak region might cooperate under the protection of reasonable mechanism so that weak region might give up free riding.

3. Public goods games

Lindal made one of the earliest achievements of public goods theory in the middle of last century. In this model, N players independently choose to put a portion of their initial funds into a public pool without recognizing the choice of other players. The funds invested in the public pool will be multiplied by a factor r $(1 < r < N)$ as the 'public good', which will then be distributed equally to all players. Each player also gets the portion of the initial funds that is not invested in the public pool. Assuming that a player's initial funds are b and the portion invested in the public pool in ci, the player's final payoff is:

$$\frac{r\sum_{i=1}^{N} ci}{N} + bi - ci \tag{1}$$

Although cooperation brings the highest payoff to the group, the only Nash equilibrium is $ci = 0$. Therefore, everyone in this model will not contribution and want to be a free-riding, which lead to a Nash equilibrium.

In addition to the free-riding strategy, the second-order free-riding phenomenon was proposed when direct punishment is implemented [13]. This punishment was to use individuals to pay for private expenses and others would be a free-rider to get a bigger fee. Indirect reciprocity could lead to indirect punishment of free riders for being excluded from continuous social communication. Indirect reciprocity occurred when an individual was involved in future cooperation in order to help others maintain their reputation. In this case, there would be no second-order free riding. As a result, the phenomenon of second-order free riding in collective action would be alleviated.

In the industry, large enterprises were implementers which have free-riding behavior when implementing selective incentive for small enterprises [14]. To solve this problem, businesses would take lead in those willing to take unilateral action and use these people to influence free-riders to think that whether continue to free ride. When there were enough leaders in this model demonstration mechanism, free riding phenomenon could be effectively solved.

Some paper suggested that the peer punishment mechanism could be used to solve the free-riding problem in public goods game [15]. However, retaliation or anti-social behavior by free riders could occur when this mechanism was implemented. In their experiment, they compared support-present condition and no-support condition and found that using a leadership support system could suppress this behavior. Punishment was imposed on free riders through the leadership so that there was no more acts of revenge between peers.

An improved model called spatial public goods game was proposed to explore how reward affected on the evolution of cooperation [16]. This model defined different types of neighbors which had different strategies and simulated their behavior. They found that second order free riding still occurred when the ratio between the benefit and the cost of rewarding was lower than punishment, which meant that defection had been dominant. Scholars thought if the benefits of the reward could offset the cost or were expensive enough, the cooperators would defeat the defectors in an indirect territorial battle. However, if the benefit of reward for winner was not comfortable enough to offset the cost, the winner would not be considered as a rewarding cooperator. Therefore, players would prefer to cooperate when indirect territorial battle was used with reasonable value of reward.

4. Snowdrift Game

The snowdrift game model was proposed in 1997 by mathematicians Chalet and Yicheng Zhang. It revealed the contradiction between individual rationality and group rationality [18]. The situation of the Snowdrift game involved two drivers who were trapped on opposite sides of a snowdrift. Each had the option of staying in the car or shoveling snow to clear a path. The payoff matrix of this model clearly showed that (Betray, Cooperate) and (Cooperate, Betray) were Nash equilibrium. Therefore, free riding phenomenon existed because no one wanted to cooperate.

Table.2. Definition of snowdrift game

	Cooperate	Betray
Cooperate	300,300	200,400
Betray	400,200	0,0

Some scholars studied how to make people cooperate in the multi-player snowdrift game. The author explained N-player snowdrift game by using the example of the construction of a church [19]. The cost of generating benefits was borne by all and the more people participate in the construction, the lower the average cost would be. Total benefits were shared with every member. Free riding problem occurred because some people wanted to get the benefits with lower effort. Therefore, free riders might not work hard in the construction. Authors explained that it needed to make enhancement of coordination in order to increase the equilibrium fraction of cooperators. Therefore, free riding problem in snowdrift game would be remitted.

In a repeated snowdrift game, the evolution of cooperation was an important problem [20]. In a repeated snowdrift game experiment, free riders working with cooperating people could get good reputation and cooperating people working with free riders would get bad reputation. Repeated game promotes the game less aggressive because more and more people would know the harms of free riding after many games. So, the author suggested that free riding problem would be solved by indirect reciprocity in iterated snowdrift games.

To find out whether adding the time cost could promote cooperation in the snowdrift game, some scholars used simulation to prove it [21]. They defined the time cost as a delay caused by each member hesitating or not participating in shoveling. The result was that adding time cost could solve the snowdrift problem by giving the people incentive to shovel the snow because less cost would exist if they shoveled the snow. Hence, the free riding problem in the snowdrift game could be effectively relieved by putting in the time cost.

Some scholars made research about whether punishment can promote the cooperation, players could punish free riders by paying a small fee to impose a larger fine on the cheat [22]. The result was that punishment promoted the cooperation among players due to the punishment was efficient when it reduced a free-riding's payoff below the population average. At this point, the target did best to contribute rather than free ride. Therefore, punishment could effectively resolve the free-riding problem in snowdrift game.

5. Conclusion

The application and corresponding solution of free riding problem involve in game theory is provided in this review, which includes boxed pig games, public goods games and snowdrift games. The Nash equilibrium shown in these three game models is free riding, so members will tend to be uncooperative without exploring the solution of the problem. Exploring a variety of mitigations of free riding will promote the equilibrium to likely change into cooperation. Combining the data provided in the literature with the solution ideas can effectively bring inspiration to solve the problem of free riding.

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