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The Review of Cooperation Mechanism of Repeated Game

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ABSTRACT
Cooperation was an essential element in promoting social development in various fields. Social resources could be used in the most efficient way through cooperation. Game Theory created a mathematical framework to simulate cooperation. Therefore, the study of game models could provide people with better understanding of cooperative behaviour and promote cooperation. This paper provided a basic review of the application of repeated game models in cooperation problems. This paper discussed cooperation under different benefit conditions with three repeated game models of Prisoner's dilemma, Stag Hunt Game and the Snowdrift Game. It also provided the mechanisms, personal attributes and strategies to promote cooperation in repeated games. This paper provided theoretical support for solving cooperation problems in reality. Moreover, it provided fundamental information for people to understand how cooperation functions in repeated games.

Keywords: *Repeated Game, Cooperation, Game model*

1. INTRODUCTION

Cooperation was an important part of the operation of human society. The phenomenon of cooperation widely existed in all aspects of biology and human society [1]. At any time of human development, cooperation had played an indelible role in successful events. Therefore, understanding and familiarity with the mechanism and production of cooperation had become an important skill that could guide success [1]. Cooperation referred to the form of social activities produced by cooperation between multiple individuals or groups to achieve common interests [2]. Through cooperation, the power of many individuals could exert a more effective impact than the power of one individual. As a result, the individuals involved in cooperation could gain more benefits. Operation of society was based on a high degree of cooperation between individuals [3]. For example, with a family as a cooperative unit, newborns needed help from their elders to adapt to the world [4]. And, in the societal system of cooperation, people hold various professional positions in society and serve the public [4]. Thus, individuals and groups living in the community had a cooperative relationship with each other, which had become a necessary condition for most people's lives [5].

Game theory is an effective discipline on studying how to promote the emergence and maintenance of cooperation [6]. It creates a mathematical framework to set the specific rules, outcomes and payoffs, and the available strategies in the game. This framework could be used to simulate and deduce the cooperation and competition. In game theory, players rationally choose strategies. When the interest of an individual and that of the collective could not be both satisfied, cooperation could not be established. Game theory could be used to study cooperation in many fields in the real world. For example, in biology, some scholars had studied the stability of cooperation between tumor cells through game theory. This provided insights into preventing the potential evolution of tumor cells [7].

This paper organized cooperation mechanisms with few repeated two-player game models. Three classic game models were used: repeated prisoner's dilemma, repeated stag hunt, and repeated snowdrift.

The concept of Nash equilibrium was first proposed and accurately defined by John Nash in 1950 [8]. Nash equilibrium was the strategy configuration when there's no profitable deviation for both player [9]. There might be more than one Nash equilibrium in a game matrix. With repetition, the player could use strategy to

encourage the outcome of the effective Nash equilibrium.

Prisoner's Dilemma was first conceptualized by Merrill Flood and Melvin Dresher in 1950, and formulated by Albert William Tucker [10]. Prisoner's dilemma reflected the contradiction between individual optimal choice and collective optimal choice. Non-cooperation was inspired when the best strategy for individual was detrimental to the collective. In an infinite repeated prisoner's dilemma, cooperation might occur due to the addition of empirical factors and the possibility of punishment [11,12].

Stag hunt Game was first proposed as a story in Rousseau's "On the Origin and Basis of Human Inequality" [13]. Stag Hunt Game reflected the instability of cooperation due to the risks involved. Cooperation made better payoff, but players might not be willing to take the risk of playing cooperation due to the uncertainty of their opponents' actions [14]. In a repeated stag hunt game, players might be more inclined to cooperate since the addition of experience factor.

The snowdrift game was also known as the chicken game and the eagle-dove game. There was a free rider problem in the snowdrift game, where the free rider might get the produce of the cooperator's work without making any contribution [15]. In the repeated snowdrift game, the player's tendency for cooperating and not cooperating would increase as the number of repetitions increases [6].

This paper aimed to review and organize the mechanisms of cooperation in game theory models. It would be discussed separately with repeated prisoners, repeated stag hunts and repeated snowdrifts. It also covered the strategies and factors that could help on promoting cooperation in games. Incorporating the game models into real-life situations could effectively promote cooperation. It could simply simulate the possible cooperation scenarios in various fields of management of organizations, intergovernmental collaboration, business activities and teamwork in small groups. It could be used as a theoretical reference to improve collective efficiency and productivity in society.

The remainder of this paper was organized as follows: Section 2 analysed the definition of the fundamental concepts of prisoner's dilemma. It included one-staged prisoner's dilemma and repeated prisoner's dilemma. Then, Section 3 briefly reviewed the Repeated Stag Hunt game. Section 4 discussed the repeated snowdrift game. Lastly, the paper's conclusion was presented in section 5.

2. PRISONER'S DILEMMA

Prisoner's dilemma was a game theory model that tells of Two of the prisoners received different terms of imprisonment by choosing whether to confess. The payoff matrix was shown as the following table. In the one-round prisoner's dilemma, the only Nash equilibrium of Prisoner's dilemma was that both players choose to defect. It showed that the player's individual optimal strategy did not align with the collective optimal strategy in this game [16, 17]. In this case, cooperation would lead to the best payoff of the collective, but players must choose to defect.

		Player B	
		Cooperate	Defect
Player A	Cooperate	3,3	1,4
	Defect	4,1	2,2

Figure 1 Payoff matrix of one-round Prisoner's Dilemma.

In the single-round prisoner's dilemma, scholars had found in their previous studies that the principle of mutual benefit, sense of control and risk preference could influence the generation of cooperation to a certain extent [17]. In a repeat game, there was different historical information in the case of repeated rounds, which could become credibility. Or the inducement of cooperation could be provided before the beginning, which could promote the production of cooperation.

In the case of finite repetition prisoner's dilemma, it had been proved by backward induction that finite repeated prisoner's dilemma game had a Perfect Subgame Nash equilibrium of all participants chose to betray in every stage. Dal found that cooperation was larger in infinitely repeated prisoner's dilemma than finitely repeated one. So, the following cooperation strategies were mainly discussed in the infinite prisoner's dilemma [18, 19].

In the 1980s, Axelrod first initiated the study on cooperation in prisoner's dilemma. By running experimental tournaments, scientists found that the winner in the competition used the strategy of "tit for tat". The method of this strategy was to cooperate first, and then imitated the opponent's previous behaviour. However, TFT strategy had its shortcomings. Scientists had found that TFT strategy showed vulnerability in a noisy environment [20, 21].

In order to adapt to noise interference, scholars developed generic tit-for-tat (GTFT) from the criterion of TFT strategy. It could maintain the cooperation between the two parties well under noise interference

[22]. This strategy, like TFT strategy, would cooperate at the beginning of the game despite of the opponent's cooperative behaviour. But when the opponent takes betrayal, GTFT would implement cooperative behaviour according to a certain probability. Under the influence of tolerance of GTFT strategy, the false betrayal caused by noise interference would be tolerated to a certain extent [23].

Meanwhile, Win-Stay Lose-Shift WSLS was also a strategy with certain adaptability to noise A Harvard University professor discovered this superior strategy after numerous computer simulations, in which the method of action was to win and continue and lose and move on. The WSLS strategy had been proven in Robert Axelrod's Tournaments to be effective in maximizing the personal benefit of a player [24].

Additionally, many strategies were proposed by other scholars, such as Exploitation strategy, which was also called zero-determinant strategy (ZD strategy) [25]. It was a kind of strategy based on probability and with one-step memory in repeated games. This kind of strategy could unilaterally design opponents' profits and their own profits, regardless of how opponents' strategies react. It was a linear relationship, so as to achieve their own income was not lower than the opponent's income [26]. Through the ZD strategy, it effectively helped the payoff of a player greater than his opponent in the experiment.

3. REPEATED STAG HUNT GAME

Stag Hunt game was concluded by Brian Skyrms from a story of stag hunt. It describes the conflict between choosing safety and choosing cooperation [27]. The payoff function of each player was shown in matrix below. There were two pure Nash Equilibrium in this game, which were (Stag, Stag) and (Rabbit, Rabbit). The differences were that the former had risk and the latter one is risk free [28]. Therefore, there was a risk of getting zero payoff in to cooperate, so players would choose non-cooperation for safety.

		Hunter B	
		Stag	Rabbit
Hunter A	Stag	10,10	0,4
	Rabbit	4,0	4,4

Figure 2 Payoff matrix of one-round Stag Hunt Game.

In one-round stag hunt game, there had been many solutions such as changing payoff levels, the trust players had on each other, and agents of uncertainties in previous paper [29-31]. In the repeated stag hunt game, the complexity of the of cooperation had increased due to the feasibility of punishment and threat.

A study of personal attributes in the repeated stag hunt game in 2011 had found that patient is an effective factor in promoting cooperation. The experiment had participants played a repetitive game of stag hunt in pairs and take a personality survey after completing it. Patient players were more likely to accept cooperation and achieved greater mutual benefits. In a circular game, players' worries about future earnings influenced whether they would choose to give up the possibility of win-win cooperation in the future to obtain the determined earnings now. The study found that patience was the only effective influence on players' behaviour in the repeated stag hunt game [5, 32].

In 2021, Marsh conducted experiments to prove whether imagery session would affect people's choice. They designed an experiment in which volunteers played stag hunt repeatedly on a computer with AI opponents with listening to an audio clip that encouraged or discouraged cooperation randomly assigned. The results showed that the imagery session does encourage more or less collaboration because the players who listened to the audio with cooperation suggestion had a greater tendency to cooperate and the other players did the opposite. Therefore, they suggested that implicit sessions had subconsciously influence people's cooperative behaviour [33].

In 2009, Omar designed an experiment at repeat the stag hunt game to see if the previously inefficient Nash equilibrium would affect subsequent cooperation [34]. This study complemented a previous study on the same topic in 1991, where the precedent effect was presented [35]. From the observation of the experiment, the probability of cooperation of players in good precedent was 19% higher than the ones with the players in bad one. This study proved that the results of the previous Nash equilibrium could affect people's latter choices, and that the previous play was also promoted by the risk attitude of players [34].

In the year of 2017, scholars had simulated the dynamic evolution of agents in the cyclic network. They built two group stag hunt game with Cellular Automata Model and players were all assumed rational. The study found that the evolution of the game model could be affected by the number of agents in the network. The odd cyclic network and even cyclic network in the evolution would transform periodically. This induced the instability of cooperation on the micro [36].

4. SNOWDRIFT GAME

The snowdrift game model was proposed by John Von Neumann and Oskar Morgenstern in 1944. It told about a scenario in which two drivers were caught on opposite sides of a snowdrift and must choose whether

to shovel the snow or wait. The following figure showed the payoff matrix of a snowdrift game. The two Nash Equilibrium in the snowdrift game was that either (cooperate, defect), or (defect, cooperate) [37]. The snowdrift game illustrated those conflicts of individual interests between players in pursuit of the collective benefits. [38]. Cooperation creates a shared good that might be abused by others, while simultaneously providing some advantages to the cooperator.

		Player B	
		Cooperate	Defect
Player A	Cooperate	1,1	-2,-2
	Defect	2,-2	-3,-3

Figure 3 Payoff matrix of one-round Snowdrift Game.

Previous scholars had shown that the one-shot snowdrift game could be affected by factors such as communication and emotion of players [39,40]. With the addition of repetition in the repeated snowdrift game, players needed to consider strategy and long-term payoffs later in the game.

In 2018, scholars combined the punishment mechanism with the asymmetric repeated snowdrift game. The experiment built a digital simulation with the dynamic theory. It set a penalty mechanism for the final payoff of players, which was to cut the payoff to punish the player for defection. The aim was to study the effect of punishment mechanism on cooperation promotion by analyzing the stability of the cooperation in the model. The classic snowdrift game was a symmetric model, in which both players were equally rewarded for each outcome. Asymmetric models, on the other hand, resulted in unequal payoff for players. It turned out that by increasing the level of punishment, players cooperate more. Which showed that the punishment mechanism could effectively promote cooperation [41].

In 2010, scholars established an evolutionary snowdrift game model by combining it with the self-questioning scheme. This scheme let players found the strategy, which could bring the best payoff in the previous stage and compare it to the actual payoff. And, the player would use the strategy that could maximize the payoff from the previous round. The result showed that the self-questioning scheme could also positively affect the generation of cooperation in the evolutionary snowdrift game [42].

In 2004, scholars found that the persistence of cooperation in the repeated snowdrift game could be inhibited by spatial structure. This study put the model into the spatial lattice and made the neighbouring individuals played a repeated snowbank game. The result of the study showed that cooperation happens more in the well-mixed games than the structured ones. Therefore, spatial structure was detrimental to cooperation in repeated snowdrift games [43,44].

In 2016, some scholars studied the cooperation mechanism of N-person Snowdrift game with consideration of the time cost by using numerical simulations. Greater payoff induced greater time costs. Also, the more cooperators participated in the game, the less time cost each player musted undertake. The study result was that as the number of players increases, the stability level in cooperation declines. It showed the increase in the number of players inhibited cooperation. Meanwhile, the addition of time cost promoted cooperation [45].

5. CONCLUSION

For the cooperation problem in the repeated game, this paper reviewed studies on the generation cooperation of repeated prisoner's dilemma, repeated stag hunt game and repeated snowdrift game. In repeated games, cooperation could be influenced by strategies and influencing factors. Strategies like TFT, GTFT and ALLD effectively promoted cooperation in repeated prisoner's dilemma. Besides, in the stag hunt game, implicit sessions, previous outcome and patience also affected whether players would choose to cooperate. The cooperation mechanism in the repeated snowdrift game was affected by punishment mechanism, self-questioning scheme and time cost factors. In this paper, our review of cooperation mechanism in repeated games might provide a theoretical support for people in promoting cooperation in various fields of society.

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