

Comparison Between Classical Game Theory and Evolutionary Game Theory Focused on Prisoner's Dilemma

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ABSTRACT

Game theory is the study of multiple individuals or teams using related parties in the game to implement strategies under certain constraints. Prisoner's Dilemma is a classic example of people using game theory for analysis. This paper compared the classical game theory and evolutionary game theory through searching information from various authoritative sources, to summarize and present some relative knowledge. The final conclusion is that evolutionary game theory is better than classical game theory when they are used for analyzing real life problems.

Keywords: *classical game theory, evolutionary game theory, prisoner's dilemma*

1. INTRODUCTION

There are many materials that have studied classical game theory, but few people compare it with evolutionary game theory. Thus, this essay was written for making a comparison between classical and evolutionary game theory. This paper was done through collecting literature in order to compare classical and evolutionary game theory from history, development, applications and assumptions. Game theory considers the predicted behavior and actual behavior of individuals in the game, and studies their optimization strategies. In the classical game theory, and that the participants play the game with complete information. Evolutionary game theory no longer believes that humans are super-rational gamers. On the contrary, people believe that humans usually achieve game equilibrium through trial and error, which is shared by the principles of biological evolution. There are many games that scientists could use game theory to predict and estimate the results, one of the most famous game is prisoner's dilemma.

Prisoner's dilemma is a classic example in game theory. The situation was that two people have different choices. Each of the choices connect the two people's results. The two theories can have different presentation on this game. This essay will make a comparison between these two game theories focused on the prisoner's dilemma.

1.1. The Two Theories

The histories, developments and utilization aspects were different between the two theories. Classical game theory has longer history than evolutionary game theory. Classical game theory developed through changing the range of the standard and focused on the philosophy and political

science. Evolutionary game theory focused on the different section of the economics including the analysis on social institutional change, industrial evolution, stock market and so on. Thus, the application of the two theories are different.

1.1.1. The Development of Classical Game Theory

In 1713, the first known discussion of game theory appeared in a letter. James Waldegrave provided a maximization of a two-people version of a card game [1]. Game theory became a unique field when John von Neumann published a paper in 1928. In 1944, he worked with Oskar Morgenstern and published the book, *Theory of Games and Economic Behavior* [1]. At this time, the study on game theory mainly focused on the cooperative game theory (Cooperative game refers to the game played by some players in the form of alliance and cooperation) [1]. In 1950, the first discussion of the prisoner's dilemma emerged [1]. John Nash developed the Nash equilibrium (if the strategy chosen by any player is optimal in the case that the strategy of all the other players is determined) [1]. In the 1950s, many concepts of game theory were developed [1]. Until now, the game theory has been applied in many fields, such as International Relations, Political Science, Economics, International Science and so on.

1.1.2. The Development of Evolutionary Game Theory

Marshall indicated that the concept of evolution is more complex than static [2]. Alchian suggested replacing the concept of profit maximization, which is a kind of way that the manufacturer uses all sorts of sale means to maximize

profits, with the concept of natural selection (In the long run, only those companies that can respond to and successfully adapt to changes in the financial and business environment can survive) in economic analysis [2]. This view provided an idea for the development of evolutionary game theory [3]. The "explanation of group behavior" of Nash (It is not necessary to make an assumption that the participants have adequate understanding about the overall game structure, nor are they required to have the desire and ability to make any complex reasoning. Nash equilibrium can still be reached by only assuming that the participants can accumulate empirical information about the relative advantages when different pure strategies are implemented) is the earliest theoretical result that contains relatively complete evolutionary game thought [2]. The development of evolutionary game theory benefited from Smith and Price's basic concept of evolutionary game theory -- Evolutionary Stable Strategy (The intuitive meaning of the definition is that when a system is within an evolutionary stable equilibrium range of attraction, it can resist small external shocks.) [2]. In the 1980 s, with the deepening of the research on evolutionary game theory, many economists put the evolutionary game theory is introduced into the field of economics [2]. Since the 1990s, evolutionary game theory has entered a new stage [4]. Weibull systematically and completely summarized the evolutionary game theory, including some recent theoretical research results [2].

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1.2. The Comparison between Two Theories

There are similarities and differences between two theories. The histories, hypothesis, and applications in daily life are variable between two theories. However, both of the theories use model or other mathematical techniques to analysis the games.

1.2.1. The Similarities between Two Theories

Both of the theories research about the competition contradiction in everyday life in the form of game, and uses mathematical and logic methods to analyze the procedure law of things. They all form important fields in Economics.

1.2.2. The Differences between Two Theories

Classical game theory assumes that participants are completely rational and have consistent preferences. Participants can get an optimal scheme under the given conditions [2]. Classical game theory assumes that the behavior main body has the perfect rational thinking, which means behavior main body is always in their own best interests as the goal, with a variety of environment, the pursuit of self-interest maximization of judgment and decision-making ability, has the interaction in the presence of game environment perfect judgment and ability to predict, and will not make mistakes, not impulsive, no reason [3]. In addition, one of the most central assumptions in game theory is the "common knowledge" assumption of both players, that is, all players are rational, and all players know that all players are rational, and so on to infinity [3]. Evolutionary game theory abandons the assumption of complete rationality. According to Darwin's evolution theory and Lamarck's genetic theory, from the system theory, the adjustment process of organizational behavior is regarded as a dynamic system, in which the behavior of each individual Describe the relationship with the group separately [1]. Evolutionary game theory assumes bounded rationality for participants, therefore, these individuals do not possess the "omniscience and omnipotence" of the actors in game theory, and cannot obtain optimal results in economic activities instantaneously [1]. The classical game theory ignores the question of time and emphasizes the equilibrium of the instantaneous question [4]. In evolutionary game theory, time plays a very important role [2]. In the process of evolution, the behavioral subjects constantly modify and improve their behaviors, imitate successful strategies and so on [2].

1.3. The Theories Focused on Prisoner's Dilemma

Prisoner's dilemma is a classic example in game theory. The situation was that two people have different choices which was shown in the introduction section. Each of the choices connect the two people's results.

1.3.1. Classical Game Theories Focused on Prisoner's Dilemma

The matric below can directly display the choices. Prisoner's dilemma was named from the situation below. Two prisoners who worked together were arrest by the police and could not communicate with each other. If neither of them reveals the situation of the others, both of them would be imprisoned for one year since the evidence was insufficient [2]. If one of them report the others, the whistleblower will be released at once; the silent person shall be sentenced to 10 years' in prison for non-cooperation. If they report each other, they will be sentenced to 8 years' custody because the evidence is

conclusive [2]. Let's name the prisoners "Player I" and "Player II" and establish a model. The matrix below can directly display the choices.

For Player I, even though he doesn't know which choice Player II makes, he knows that whatever choice Player II makes, he chooses to confess is always optimal. Apparently, by symmetry, Player II would also choose to "confess," and both would be sentenced to eight years in prison. (Confession, confession) is a dominant strategic equilibrium, which is the Nash equilibrium.

Table 1: Matrix for Two Players

		Player-II	
		confess	refuse
Player-I	confess	8, 8	0, 10
	refuse	10, 0	1, 1

1.3.2. Evolutionary Game Theories Focused on Prisoner's Dilemma

For example, if you have a group of animals that compete with each other, over the course of evolution, would it be easier to survive in large size (which is more aggressive, but also eats more) or in small size (which is less aggressive, but also eats less)? Another matrix was used for analysis.

We assume that the ratio of (1-x) is Small and the ratio of (x) is Large. Then we know:

The Fitness of Small: $5(1-x) + x = 5-4x$

The Fitness of Large: $8(1-x) + 3x = 8-5x$

Thus, when X is relatively in small amount, Fitness of Small < Fitness of Large, Small is not a evolutionarily stable strategy [5]. Because if that group is Small, then over the long course of evolution, Some Small will become Big, gain more Fitness and have more advantages, and gradually become dominant in this group, which means Small will gradually die out [5].

Obviously, we know that when x is large, it's basically comparing 3x with x (because 1-x goes to 0), and it's clear that a small animal's invasion is bound to fail because of $3x > x$ [5]. Thus, (Large, Large) is the Nash equilibrium [5].

Table 2: Matrix for Two Group of Animals

		Beetle-2	
		Small	Large
Beetle-1	Small	5, 5	1, 8
	Large	8, 1	3, 3

1.4. Suggestion

In the previous section, there are two tables related to the topic. The Nash equilibrium is different for the two different situations. The reason is that people consider the natural development of the species instead of only consider the benefit for the two players from their own perspectives. It is better for people to use evolutionary game theory to analyze problems since evolutionary game theory include time factor and dynamic process. Human beings are also evolving. Analyzing the problem using evolutionary game theory would be closer to the fact. On the contrary, classical game theory can be a simplified model for people to refer to when making decisions. Since there are game participants, there must be game rule makers. A deep comprehension of the essence of competitive behavior helps people evaluate and master the connection between things in the competition, and it is more convenient for people to devise and modify the rules, so that it will eventually operate according to people's expected goals. People should separately use different game theories in appropriate situations.

2. CONCLUSION

The distinction between evolutionary game theory and classical game theory is that evolutionary game theory does not require the participants to be completely rational and does not require complete information. Evolutionary game theory is a theory combing game theory analysis and dynamic evolution process analysis. In methodology, it is different from game theory in that it focuses on static and relatively static equilibrium, and emphasizes dynamic equilibrium. Evolutionary game theory, originated from the theory of biological evolution, is an important analysis method of evolutionary economics, and has progressively developed into a new field of economics. Focused on prisoner's dilemma, whereas classical game theory deals more with the relative benefits of individual strategy, evolutionary game theory deals with strategy changes as evolutionary forces change within a population over longer time scales. People should separately use different game theories in appropriate situations.

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