The Emergence of Cooperation Theory in Economics with Special Reference to Evolutionary Game Theory

Smera Elsa Saji

Madras Christian College, India. smerathamarasseril@gmail.com

Abstract: Cooperation can be considered as one of the fundamental aspects of Social life. As like a gum, it binds individuals together and allows the formation of different social structures, organizations, civilizations etc. This paper explains the emergence of cooperation theory in economics with special reference to evolutionary game theory. In evolutionary game theory, mostly there are binary games where players have to choose one of the sides independently. Here players play different strategies based on the past record. The analysing power is limited and the trait of supporting other is always dominated by selfish behaviour. Adaption to the circumstances is also another feature. Thus the evolutionary game theory provides a clear cut picture of how interesting cooperation and competition patterns arises in a society.

Keywords: Cooperation, Coordination, Game Theory

I. INTRODUCTION

The Process of Evolution can be defined as the change in beliefs and norms over time. Human behaviour including economic behaviour can be summed up as the product of changes over a course of time. The complexity economics is a branch which is very helpful in explaining evolution in economic behaviour. Complexity is a dynamic theory which studies how interactions among species create behavioural patterns and how this forces them to change and adapt themselves. In Economics- the firms, consumers, investors etc. always undergo changes and then adapt themselves within an outcome for their survival. Under equilibrium by definition there is no scope for improvement or further adjustment and exploration. But in reality the economy is always open to changes. This can happen either because of some external influence or otherwise by some internal factors. We can see that the economy is not something given and existing but constantly developing as a result of technological innovations and arrangements.

Complexity economy thus sees the economy as in motion and emphasized contingency, indeterminacy, sense-making, and openness to change. A fundamental observation about humans is that we can cooperate to achieve a desired outcome that individuals would not be able to achieve on their own. The cooperation does not occur in every possible situation. The study of why and when cooperation occur cuts across disciplinary boundaries in social science. In the words of political philosopher Brian Skyrms: "the viability of cooperation depends on mutual beliefs, and rests on trust". When sociological researchers focuses on the values such as social orientation, generalized trust, social identities, group membership etc. for defining how cooperation is shaped ,the political scientists and economists give emphasis to rational responses. The scope of cooperation widely varies. It is unlimited. It may occur in the family and between strangers, in matters big and small, and on scales ranging from a small family to society.

II. REVIEW OF LITERATURE

- Robert Axelrod (1980) in his work "Effective Choice in the Prisoners Dilemma" explained a "primer" on how a Prisoner's Dilemma game plays effectively in an iterated situation. To analyse cooperative and competitive behaviour a computer tournament was conducted. Through this he analysed how individuals effectively reacted.
- David B Fogel (1993) in his work "Evolving Behaviours in Iterated Prisoners Dilemma" conducted evolutionary programming experiments to investigate the conditions that promote the evolution of cooperative behaviour in the iterated prisoner's dilemma.
- Eric Van Damme (1994) in his work on "Evolutionary game theory in European Economic Review" describes the main concepts from biological game theory and some modifications that have been suggested to make them more applicable in economic contexts.
- J. Neil bearden (2001) in his work "The Evolution of Inefficiency in a Simulated Stag Hunt" with the help of genetic algorithms he tried to understand how players under risk conditions achieved pareto inefficient and pareto efficient equilibriums.

 DOI : 10.35291/2454-9150.2020.0493

III. OBJECTIVES

- To analyse how individuals pursuing their own interest will act and how this in turn affects the system as a whole.
- To analyse about individual motives and then deduce consequences for the behaviour of entire system with the help of evolutionary game theory.

IV. METHODOLOGY

This is a descriptive type of research. The data have been collected from secondary sources such as books, articles in journals, websites etc.

V. RESULTS AND ANALYSIS

ECONOMY – A COMPLEX SYSTEM

If we define economy as a complex system of rules, then we can define economics as the study of the coordination of these rules and how they change. The vast scenario of economy includes complicated agents such as consumers, firms, banks, investors, government agencies etc. and their actions like buying, selling, speculation, investing, exploring, forecasting, competing, learning etc. These agents will continuously carry out innovation for adapting themselves to the changing surrounding environment. Ancient Economic works reveals a recursive loop, where the aggregate pattern as a reflection of individual behaviour and individual behaviour as a reflection of aggregate pattern in the society. It is this recursive loop that connects with complexity and the complexity is all about formation of structures.

EVOLUTION OF COOPERATION

"The cooperation theory is based upon an investigation of individuals who pursue their own self-interest without the aid of a central authority to force them to cooperate with each other."

Robert Axelrod

In a broader sense, we can define cooperation of individual as a behaviour that is beneficial to actor and recipient. Two unrelated individuals will cooperate only if they get an immediate return from that interaction or otherwise a future benefit from it. The mechanisms such as reward, punishment, ostracism, reputation building etc. are helpful in maintaining and stabilizing cooperation among individuals. Evolution of cooperation refers to the study of how cooperation can emerge and persist. The issue of cooperation can be considered as a central problem with regard to groups, organizations and societies. Any kind of cooperation can be attained through appropriate game theoretic situation called Prisoner's Dilemma. Here Axelrod organised a game where there exists an iterated Prisoner's Dilemma situation. In this game on the basis of actions done by opponents previously, the players will play the game over and over. And the question here was what would be the strategy that could adopt in order to attain the best? In this game, in the initial stage a player cooperates and his further actions always depend on the actions of his opponent. If the opponent started cooperating again the player would do as well. Finally the results showed that the best strategy is the 'tit for tat'. Cooperation remains as a question when selfishness emerges among individuals. Thomas Hobbes gave an interesting explanation to these existing questions. According to his view cooperation could not develop without a central authority and consequently a strong government is necessary.

RELEVANCE OF EVOLUTION OF COOPERATION IN ECONOMICS

Cooperation is important with regard to behavioural interactions, biological evolution, cultural dynamics, economic assistance and collective intelligence. Inclusive fitness theory is considered as the most successful theory till now for explaining the emergence and maintenance of cooperation in biological systems. Yet the emphasis of cooperation has side-lined more economic considerations which mean that dynamics of social interaction was given more emphasis rather than economic principles. In addition, the features that influence the dynamics of cooperation have been studied using different theoretical frameworks and different virtual setting of games with different specific assumptions. Among the different methods used to study the evolution of cooperation, the simplest and most used one is the Prisoners Dilemma. This assumes that if two agents cooperate, both will benefit otherwise there is a relative overall loss or an additional cost to the cooperating agent if another one does not cooperate. Here we simulate an expanded iterated prisoner's dilemma with a range of costs and benefits to the co-operator that reflect more closely known real situations. In this model, Pay out matrices, punishment, benefits, economic synergies triggered by cooperation, and costs of cooperation, are different features that influences the evolution of cooperation. Different types of networks have different effect on the evolutionary dynamics of cooperation. The networks with the strongest effect on the likelihood and speed of diffusion of cooperative behaviour are random networks and small world networks, in contrast to regular reticular networks which have the weakest effect on this dynamics.

EVOLUTIONARY GAME THEORY

In this the application of mathematical methods to biological context can be observed. It later became an interesting area for several researchers in the field of economics, sociology, philosophy etc. As compared to classical game theory, the evolutionary game theory particularly focuses on dynamic strategies.

 DOI : 10.35291/2454-9150.2020.0493

Two Important Approaches:-

1) The concept of an Evolutionary Stable Strategy as the principal tool of analysis.

The problem of the Hawk-Dove game analysed by the Maynard Smith and Price in "The Logic of Animal Conflict" explains this. In this we can see two persons fighting themselves for a particular resource. The value of the resource is fixed as V and the cost of the fight is represented by the letter C. In this game, the HAWK shows a violent behaviour. It is not ready to withdraw without the withdrawal of its opponent or otherwise until it is injured. While DOVE which is always a symbol of peace, withdraws immediately whenever its opponent shows a violent behaviour.

The payoff matrix for the above game is given below:

	Meets Hawk	Meets Dove
Hawk	½ (V-C)	V
Dove	0	V/2

Figure 1.1(a) payoff for Hawk-Dove Game

- When Hawk meets a Dove it is able to capture the entire resource (V).
- When a Hawk meets a Hawk there is equal probability for winning and losing. In this case the average outcome will be V/2 minus C/2
- When a Dove meets a Hawk the probability for getting the resource is null (0).
- When a Dove meets a Dove both will cooperate and share the resource equally (V/2).

2) In the second approach with the help of an explicit model, the properties of the evolutionary dynamics will be analysed.

Prisoner's Dilemma which was framed by Merrill Flood and Melvin Dresher, explains how individuals choose one of two strategies, typically called "Cooperate" and "Defect." The payoff matrix for the Prisoner's Dilemma is given below.

	B stays silent (cooperate)	B betrays (defect)
A stays silent (cooperate)	(1,1)	(3,0)
A betrays (defect)	(0,3)	(2,2)

Figure 1.1(b) payoff matrix for Prisoner's Dilemma

The decisions are made without the awareness regarding the opponent's act. Defection yields a higher payoff than cooperation. The problem is that if both of them defects, then the payoff will be higher. By using the below diagram we can describe it more clearly.

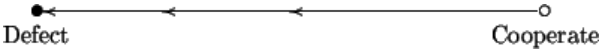

Figure 1.1(c) The replicator Dynamical model of the prisoner's Dilemma.

In the diagram, the non-cooperation between both the individuals will be represented by the left end. The rightmost part of the figure shows a condition where everyone cooperates. The intermediate points between these two represents the situations where some part of the population defects and the remaining cooperates. The rightmost point show an unstable equilibrium when everyone cooperates. The leftmost point indicates the state where people defects are a stable equilibrium. It implies that when a small portion of the population diverges from the strategy defect, then evolutionary dynamics forces them to come back to the original equilibrium condition.

Evolutionary game theory provides means for dealing a number of drawbacks in the traditional theory of games like:

1) The Equilibrium Selection Problem.
2) The problem of hyper rational agents.
3) The lack of dynamical theory

PROBLEM OF COORDINATION

Coordination is defined as an act of arranging or putting things in order. Economics primarily focuses on the outcomes that may result from coordination and any failure in coordination may lead to disequilibrium. In everyday life we see numerous ways in which coordination is affected. The custom of driving vehicles on one side of a road is an example for this. There are different ways of Coordination. In some, players find strategies that are part of the same equilibrium. In some other, there exists multiple equilibriums and there are also strategies which results in a disequilibrium outcome. The problem for the players is to achieve the right equilibrium when all players agree on what is the best equilibrium.

COORDINATION GAMES

In a coordination game both the players will mutually benefit by working together. When participants work together for the benefit of all, the solutions to problems are cooperative solutions. The challenges in a cooperative game for each individual participant is to determine what course of action will provide the most benefit to all of the participants in the game. That course of action, in turn, will also provide the most benefit for each individual participant.

❖ BATTLE OF SEXES

Battle of the sexes used by Cooper can be considered as a typical coordination game where the preferred equilibrium provides a player with a high payoff of 600, while the less preferred equilibrium only yields 200. There are two Nash equilibria for this game: (Baseball, Baseball) and (Opera,

 DOI : 10.35291/2454-9150.2020.0493

Opera). In addition, there is an equilibrium involving randomisation, where both the man and woman choose their preferred activity with probability 0.75. In this manner, each person is indifferent between the two options since each yield a payoff of 150 on average (0.75 * 200= 0.25 * 600 = 150).

		Man	
		Opera	Baseball
Woman	Baseball	(0,0)	(200,600)
	Opera	(600,200)	(0,0)

Figure 1.1(d) Payoff matrix of Battle of Sexes Game

PRISONER'S DILEMMA

Prisoners Dilemma is a game which was designed to represent a conflict of interests in the form of individual and group decision-making. On the other hand, this game shows Nash equilibrium solution. Here, two suspects are arrested, but the police do not have enough information for a conviction. Police incarcerate two persons in two separate cells, so that there is no connection between them. Two prisoners are faced with two options; remain silent or confess the crime. If both remain silent, both go free after a short time due to lack of evidence for conviction. If either of two prisoners confesses the crime and the other one remains silent, the silent prisoner is sentenced to five years while another goes free. If both persons confess, through their cooperation with police, they are sentenced to three year.

Players' payoff can be shown by negative numbers that represent years of imprisonment. Since each player's payoff is negative, results are rating as positive values for each state. In this situation, while one player gains his best payoff (three), the other one will be faced with his worst (zero). It means confess on opponent's silence (free riding behaviour) provides the highest utility.

		Player 2	
		Cooperate	Defect
Player 1	Cooperate	(2,2)	(0,3)
	Defect	(3,0)	(1,1)

Figure 1.1(f) Payoff matrix of Prisoner's dilemma

Equilibrium: In this game, each player has a dominant strategy (3> 2 and 1>0). Mutual defection (DD) is Nash equilibrium, because players do not have incentive to move. Mutual cooperation (CC) is Pareto optimal, where group utilities maximize. Here Pareto optimal solution is not equal to Nash equilibrium.

STAG HUNT

The stag hunt is a story that became a game about social cooperation. The game is based on the discussion from the philosopher Jean-Jacques Rousseau. In this game, players choose between strategically safe (defection) and risky actions (cooperation). Stag Hunt which is also called as "assurance game" and "trust dilemma" have multiple Nash Equilibrium.

ASSUMPTIONS

- There is no communication between the two hunters.
- The stag yields more than hare.
- Both hunters are rational and equally informed.

Here, each hunter has the probability of hunting either a hare or otherwise deer. The chances of getting a hare are independent of what others do. As compared to hare deer is more valuable. The chances of getting a deer by oneself are very low. But with an increase in number of hunters the probabilities for successful deer hunt increases.

		Hunter 2	
		Hunt Stag	Hunt Hare
Hunter 1	Hunt Stag	(a, a)	(c, b)
	Hunt Hare	(b, c)	(d, d)

Figure 1.1(g) Payoff matrix of Stag Hunt

$$\text{If } a \geq b \geq d \geq c$$

If both the players cooperate, the chances for getting the large prize (stag) are more. A person can capture a hare without considering what the other does.

Let's assume hunting a hare gives a payoff of 3, hunting the stag gives a payoff of 5 to each one, and hunting nothing gives a payoff 0. According to this game, if a player chases a hare, he is guaranteed a payoff of 3. On the other hand, if a player hunts the stag, the reward he gets depends on the other person's act. If the opponent also picks stag, then the stag is hunted and each gets a reward of 5. Instead If the other person selects hare, then the player doesn't gets any reward.

THE MATRIX FOR THE GAME

		Player 2	
		Hunt Stag	Hunt Hare
Player1	Hunt Stag	(5,5)	(0,3)
	Hunt Hare	(3,0)	(3,3)

Figure 1.1(h)

Players in these states do not have any incentive to move, where both have access to hunting. If both hunt stag or otherwise if both hunt rabbit, then they will reach in a high payoff and low payoff equilibrium respectively.

 DOI : 10.35291/2454-9150.2020.0493

Uncertainty about the other player's action may prevent them to take such strategic risk. If one of them doesn't cooperate then picking stag involves a risk. The picking of hare doesn't involve any risk because it doesn't depend on the other person's act. So a player who selects hare takes no risk but he loses the reward which he can attain, if he hunted stag. One has to choose what is most beneficial to him by considering the other person's choice. In this game there are two Nash Equilibria (occurs when both players picks the best responses). Here there are two situations:

i. In case if one hunts stag then it is better to pick stag over hare by the other. This outcome will be Pareto Optimal or Socially desirable Outcome. It is the equilibrium as a result of mutual cooperation.
ii. Consider if the other person picked hare. Now, it is more sensible to pick hare rather than stag. The hare equilibrium is called Risk Dominant. It is the equilibrium of mutual defection since it involves less risk.

Here there are 2 Nash equilibria- both hunting stag and both hunting hare. In the stag hunt, the decision of one player always depends upon his assumptions regarding what his opponent does. The two equilibriums shown above can be considered as a comforting solution as it demonstrates self-interested motivations can produce social cooperation.

VI. CONCLUSION

Cooperation is a fundamental aspect of biological systems. The origin of different organisms from unicellular ones, human societies etc. are few of the countless examples of complex systems that depend on cooperative interactions. There are varieties of means through which cooperation can be developed. The study on Evolution of Cooperation with reference to evolutionary game theory helps us to understand the conditions under which people can move from risk dominant outcome to socially desirable outcome. The strategy of how benefits foster formation of cooperation can be better analysed and interpreted by a variety of techniques which include reducing cooperation costs, increasing trust among others etc. Evolutionary game theory is a very diverse subject and still a very active field of research. The adaptive or evolutionary game theory has focused on the behaviour of simple algorithms and strategies as they play out in strategic contexts. The different aspects mentioned in this article show that even simple models of cooperation can lead to complex and diverse outcomes. It suggests that the mathematical models are crucial to advance our understanding of evolution.

REFERENCES

[1].Robert Axelrod (1984) The Evolution of Cooperation, Basic Books, New York.
[2].William Poundstone (1992) Prisoner's Dilemma, Anchor Books, New York.
[3].Brain Skyrms (2004) The Stag Hunt and the Evolution of Social Structure, New York.
[4].Martin J. Osborne (2004) An Introduction to Game Theory, Indian Edition, Oxford University Press.
[5].Massimo Salzano, Alan Kirman (Eds) (2005) Economics: Complex Windows, Springer.
[6].J.McKenzie Alexander (2009) Evolutionary Game Theory, Stanford Encyclopedia of Philosophy.
[7].W. Brain Arthur (2015) Complexity and the Economy, Oxford University Press.
[8].Robert Axelrod (1980) Effective Choice in the Prisoner's Dilemma.
[9].David B. Fogel (1993) Evolving Behaviour in the Prisoner's Dilemma, Evolutionary Computation.
[10]. Xin Yao and Paul J. Darwen (1996) An experimental Study of N-Person Iterated Prisoner's Dilemma Games, Informatica.
[11].Smith, John Maynard (2005)Evolutionary Game Theory, Theoretical Economics.

 DOI : 10.35291/2454-9150.2020.0493