

# Emergent Properties of human cooperation under Evolutionary game

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**Abstract:** This essay will introduce the emergent properties of human cooperation under evolutionary selection. The propensity for altruism, punishment, and reward is one of the emergent properties that have co-evolved with cooperation by providing an efficient feedback mechanism. The numerical simulation of an evolutionary agent-based model of repeated agent interactions with feedback-by-punishments is a robust emergent property selected by the evolutionary rules of the model. At the same time, it illustrates emergent cooperation under the other situations such as randomness, and circumstance fluctuations. It also presents the phenomenology of the different phase diagram under different circumstance. There are many phenomenological similarities between the course of emergent states of matter and recent history in China. I will briefly introduce how to use these phases to explain the last few decades of China's history. This essay simplifies the complicated situation for possible future research.

## I. Introduction

It is very interesting that I find a similarity between the society and matter while taking the course 569 *Emergent States of Matter*. There are many phases of matter, gas, liquid, solid, etc., just like phenomena or “phases” of society, from a state of total chaos (Thomas Hobbs), constitutional democracy, direct democracy, authoritarian, dictatorship system to totalitarian (Marxism communist). We can plot the different phases of matter through the P-T diagram. Physicists have found lots of relations between these different phases. I am spending lots of time to try to make a connection between matter and society. I really feel there should be at least a phenomenological relation between them. I can use the basic similarity to interpret many historical events occurring in recent China (1976-2006) and can predict some useful results. Even though I use the similarity between the matter and the society to interpret and predict the phenomena and the essence of the current situation and try to define something analogous to the “pressure” and “temperature” in matter, I cannot establish any basic model for this so-called social-physics or political-physics. I have less ability to do that, so I will review the central ideas of the papers which are included in the reference. I find that

there is a difference between these papers approach and the approach from the physics of emergent states of matter. This is because the emergence of human cooperation and altruism by evolutionary feedback selection [1] is a very different region from physics. The reason is that human beings are so different from the point view of organization. They are not as similar as the atoms in matter. Because I cannot really establish the link between the society and the matter through good models, I will introduce some models to discuss the emergence of human cooperation which is distributed in the references. These are (i) the level of cooperation because of punishment and/or reward[1,2]; (ii) evolution of cooperation as a consequence of environment fluctuation[3]; and (iii) to analyze the cooperation with a binary game[4,5] (iv) randomness enhances cooperation[6]. I will briefly introduce the similarity between society and matter that has been hovering around my brain during the semester.

## II the level of cooperation because of punishment and/or reward

“The potential for cooperation is everywhere in nature, yet evolution seems to rarely take advantage of it” [1]. There are very sophisticated relations among and across the community and society, and many researchers tried to establish different theories to explain the puzzle of human cooperation, and a growing number of experiments show that humans exposure an inclination to both benefit others cooperative “norm-abiding behaviors”[1], and to punish others for norm violations (called respectively “altruistic rewarding” and “altruistic punishment”) [1]. It maintains as a mechanism that the spontaneous cooperation occurring from the individuals, however, as to an organization, there are competition and conflict “between individuals and/or subgroups and of the free rider, to which altruistic punishments/rewards constitute a possible remedy”. [1]

Traditional theory described that individual being is all selfish identity who only care about his own interest, but in reality, individual always show the altruism to the other people who are really not similar to each other. So individual conducts not only self-center but also “inequity adverse” [1],there is the situation that they are not so selfish individualistic identity. Here will introduce the theory which describes the level of cooperation owing to punishment and/or reward. This theory will introduce three different games: third party punishment games, the ultimatum game and altruistic punishment game to give us explanation of the cooperation level through the evolutionary feedback selection and its experiment results. This theory and related experiment results through the numerical simulation of a simple evolutionary agent-based model of repeated agent interaction with feedback display that the propensity to punish can be seen as an emergent property! (Regulation ignites the spontaneous symmetry breaking).

Altruistic was defined that a costly behavior cannot benefit any personal

material gain. From Fehr and Gächter's experiments, they show that the theory of evolutionary feedback selection regards human, as that of any other species, is the result of an evolutionary process, promote better consistency between selfish aim and group efficiency. "Altruism is neither irrational nor rational at the individual level, it's an emotion, mental state that arise spontaneously, promoting socialization, thereby group efficiency, cascading to individual efficiency." [1]

I will rewrite a general formulation of these concepts through the third-party punishment game, the ultimatum game and the altruistic punishment games in the following.

(a) General formulation of the theory of evolutionary feedback selection

Consider  $n$  agents in a social dilemma situation, in which voluntary contributions are needed to obtain some shared end-result, and where the individual rational choice is to free-ride. We denote by  $c_i$ ,  $i=1, \dots, n$ , the contributions of each agent to the common project. Then, the shared end-result is quantified by  $n$  payoffs function  $P_i(c_1, c_2, \dots, c_i, \dots, c_n)$ , which are possibly distinct. After the one-period play, the total wealth of agent  $i$  is therefore  $P_i(c_1, c_2, \dots, c_i, \dots, c_n) - c_i$ . The conditions for a social dilemma to hold is that

$$P_i(0, 0, \dots, 0, c_i, 0, \dots, c_n) < c_i, \quad (1a)$$

$$P_i(c_1, c_2, \dots, c_{i-1}, 0, c_{i+1}, \dots, c_n) > P_i(c_1, c_2, \dots, c_i, \dots, c_n) - c_i \quad \text{for all } i\text{'s}. \quad (1b)$$

Condition (1a) writes that the project does not remunerate sufficiently the individual contributions and thus discourage agents to contribute independently of the actions of the other agents. Condition (1b), which should hold for arbitrary  $n$ -plets  $(c_1, c_2, \dots, c_i, \dots, c_n)$ , states that the rational choice is to free-ride.[1]

After the introduction of punishment opportunity, individual try to find the link to set up the cooperation and they need to find opportunity to do additional thing for public good. Even in common situation people try to find the way to create public goods interaction by high incentives. While the punishment is a costly, social behavior, people try to find the other to eliminate the costly behavior and find the non-punishing strategies and then lessen the degree of cooperation and even annihilate the possibility of cooperation. It will perish the emergent state of cooperation. In this situation, it becomes higher (second) order cooperation problem, and people try to conduct their behavior to avoid being punished, and people still need to pursue long and standing cooperation, it needs to introduce the other mechanisms, one mechanism is providing reputation which need to accumulate and make more contribution to the emergent public relationship. It is a positive feedback system different from punishment, it also create the possibility of emergent cooperation. With the punishment and reputation, cooperation are emergent characteristic under the collective co-evolution with the mechanisms of positive and negative

feedback by using the punishment and reputation under repeated interaction. Here, we introduce the mechanisms of providing the punishment and/or reputation; the agents will react and evolve the change to act on the feedback on the other agents with rewards and/or punishments. The level of reward/punishment is determined by the emergent cooperation which can provide the circumstance that people can feel self-respect and maintain a self-perspective among the community from the other's action and response, in the social interaction people can receive feedback from the other's opinions, attitudes and perceptions among the feeling of their mind. An agent will test the unfairness of the allocation through comparing the difference between the pair wise contributions and pair wise payoffs. It is called the first-person-perspective. Here we just start to consider the mechanism of feedback by punishment, and the mechanism of feedback by reward will reintroduce in the later section. Only we consider the following situations does the mechanism of feedback by punishment arise:

- (i) Identical payoffs but different contribution which occurs randomly in public good interaction or in common tragedy, that kinds of situation are often appeared in global resource sharing. "The level of punishment exerted by an agent  $k$  on an agent  $i$  observing the contributions  $c_i$  and  $c_j$  of two agents  $i$  and  $j$  ( $k$  can also be  $j$  herself) should be an increasing function of  $|c_i - c_j|$ , with the punishment applied to the smallest contributor"[1]. We consider this situation in order to punish the free rider.
- (ii) Identical contributions but different payoffs, usually owing to uncertain random factors or owing to some structural asymmetry. It is usually to describe the situation which have characteristic of the ultimatum and dictator games. "The level of punishment exerted by an agent  $k$  (on agent  $i$ ) observing the payoffs  $P_i$  and  $P_j$  of the two agent  $i$  and  $j$  should be an increasing function of  $|P_i - P_j|$  with the punishment applied to the greatest payoff. Here, the rational is to punish the largest unjustified/unfair endowment".[1]
- (iii) Different contributions and different payoffs, we can use two coefficients to combine both the  $(c_i - c_j)$  and  $(P_i - P_j)$  situations. It is well known that people can get fair share if people cooperate, but people also know they can get more if they do not cooperate but it is unfair to the other people, so usually people will obey the rule and meanwhile people will process a drive to punish the other agents who do not obey the cooperation regulation, it is a long evolution for people to develop the cooperation/defection experiences through many generations.

Here, we can discuss the optimization problem, for example, agent  $i$  compare her contributions with the contributions of other agents and concern about her expectation, she also will concern about the punishment she may have been tolerated from other agents and the punishment she would like to imposed on

the other agents.

Owing to contributors will anticipate punishment, usually cooperation will be stable in this fairness circumstance then more cooperation will emerge. This will lessen the possibility for free-ride to get more profit and we can find the Nash equilibrium in which nobody cooperates. This evolution has experienced many generations via the existence of the feedback mechanism, and it can be adjusted itself to the marginal expected gain and yield a Pareto efficient dynamical fixed point[1].

#### (b) Analysis of a third-party punishment game

From the result of Fehr E. and Fischbacher U. T's experiment, third parties punish allocators at their own cost without any monetary, it shows the nature of human altruism, because they will never meet in the future. It shows that for selfish individual will also empathize with the allocator and consider the possible future gain with/without the potential punishment, then find a possible way to get her maximum expected gain.

#### The ultimatum game

According to the theory of evolutionary feedback selection, the level of altruistic punishment in the ultimatum game is controlled by the allocations distribution and should be highly sensitive to cultural and/or economic difference, so the results are very different among different history and culture, the general situation is a low propensity to cooperate in the ultimatum game should compare with the low rejection rates. Such sensitivity has been observed in laboratory experiments [1].

#### (c) Comparison between the theoretical punishment level and experimental results

According to the theory of evolutionary feedback selection, when an arbitrary agent involve in a group project, in order to get the maximum gain, he should behave in cooperative actions and limit his selfish or self-center stand. It takes many generations to evolve the selfish optimization under the level of feedback provided by punishment. As a result, human unconsciously select a level of punishment to control the selfish separation and to emerge the cooperative factors in an organization. As well as the level of providing the reward, in an organization, one agent is heavily dependent on the other agent and participates in the contribution reciprocally. The different agents have different abilities to settle down the problems which they meet. So the members of an organization sometimes need to be selected for more cooperation to emerge.

There are some difference to analyze the different cultural and/or biological

processes while the selection and transmission of the optimal level of feedback. If we observe some model in different cultural and/or biological processes, in some situations, we can find some groups will evolve spontaneously toward non-cooperative Nash equilibrium.

#### (d) reward versus punishment

As we mentioned earlier, there are other mechanisms to emerge cooperation besides the evolutionary feedback by punishment, one of them are the evolutionary feedback by reward. It shows that any individual participate in and automatically favor in cooperation between humans. There are no costly behaviors. Actually it is in the inverse of the feedback by punishment and technically symmetric. When an agent has done better than expected according to some common standard, the other people will show respect or we can call reward her. It occurs in gift exchange game, trust games, and shared-value game. Here the punishment is replaced by reward.

“Feedback by punishment is probably associated with “negative” emotions, such as anxiety, anger, fear, shame, and guilt, at various degrees either for the punisher and the punished one. In contrast, feedback by reward may trigger different kinds of emotions, such as desire, hope, joy, and pleasure”[1]. And human is so sophisticated that anyone has positive and negative emotion anywhere anytime, so the feedback by reward is as important as the feedback by punishment, as the development of civilization, human needs using more positive emotion than negative emotion to emerge cooperation. It is thus an open question in our mind as to whether feedback by reward has been selected by evolution with intensity similar to that of punishment. And choosing more and more feedback by reward will create a better world?

#### (e) concluding remarks

As we presented in the previous section, the cooperation will emerge through the mechanisms of feedback by punishment and/or reward and/or other factors. And humans pay attention to the fairness and the reciprocity; there are some mutual interactions between individuals. The emergent cooperation created randomly by the strong feedback through punishment and reward. It is also benefit to self-centered individuals. We can explain lots of phenomenon through the theory of reciprocity, the evolution of cooperation is characterized by the reciprocal altruism or direct evolutionary feedback selection.

We also introduced the theory of evolutionary feedback selection which the feedbacks appear through punishments, namely, third punishment, the ultimatum game and altruistic punishment. All the analysis shows that the altruism and selfishness might not be paradoxical behaviors; it is the results of evolutionary selection process via punishment and reward through long many

generations. Owing to the long and many generation evolutionary development, there are some different characteristic properties from different historic and cultural community, and with the increased mutual interaction, the trend is to learn from one another and the multiplier cooperation will emerge, and people will share the common views and reciprocal fairness, especially through law, ethics, and education. The extensive cooperation adjusted by reward-punishment is comprised of co-evolutionary processes, enhancement through the Darwinian selection process.

### III randomness enhance cooperation [6]

Cooperation can be found in everywhere in the real world, from biological systems to economic and social systems. However, we know the altruistic actions contradict Darwinian selection. So “understanding the conditions for the emergence and maintenance of cooperative behavior among selfish individuals becomes a central issue”[6], there are several natural mechanisms of enforcing cooperation have been developed in the last decades.

Recently, Perc published a paper that he introduced the random disorder in the payoff matrix to study the evolutionary PDG (Prisoner’s Dilemma game). It shows that the frequency of the cooperation arrive the maximum at the intermediate disorder which indicated a resonance-like behavior.

This paper showed “the effects of both the topological randomness in individual relationships and the dynamical randomness in decision makings on the evolution of cooperation”[6]. It says that we can find that there is a mechanism of randomness which promotes cooperation similar to a coherence-resonance-like fashion. This is to say that we can find “an optimal amount of randomness, which can induce the highest level of cooperation”[6].

Just like the effects of noise and disorder in the classical stochastic and coherence resonance phenomenon, we can find that both the topological randomness and the dynamical randomness play constructive roles in the evolution of cooperation in the simulation results.

In conclusion, through the study of the effects of both the topological randomness and the dynamical randomness on the evolutionary Prisoner’s Dilemma game, we find that there is an optimal amount of randomness, which is in the leading role of the highest level of cooperation a constructive effect, the simulation results show that a typical coherence-resonance-like behavior exists in the evolution of cooperation. We generally regard that the resonant behavior may play a significant role in the other situations of evolutionary dynamics.

### IV evolution of cooperation as a consequence of environment fluctuations

Whatever from social animals to human beings, they need to find the possible equilibrium between selfness and altruism. Sometime it is not easy

for them to settle down the region of the equilibrium, they feel frustrated to make a decision to live alone or join an organization, even randomly response to the changing environment. Some new emergent states created by the environment fluctuations.

Even in very low level being in the nature, there are some cooperation situation among the creature, in society, people meet cooperation paradox when they are in the situation like Prisoners Dilemma or the third party game, some situations appear that the cooperation have more benefits than selfish to their interests, during that time, emergent cooperation will arise unpredictably.

In conclusion, when individual make a decision to be a member of an alliance, the first point which they need to face is considering the advantage and disadvantages of the alliance, they need to face the cooperation paradox. It restricts the abilities of individual decision making. "It was demonstrated that a population has to pass through a series of different conditions, favoring and suppressing selfishness, in order to development a robust sociability, an exploitative population, characterized by the correlated mutual responses of the cooperate/exploit (rather than homogeneous cooperation or selfishness) type, was shown be stable for a whole range of the Chicken Game "[3]. In this paper, the specific assumption on the individual decision making mechanisms reflects the general mainframe for the analysis of social behavior under the different hypothesis of evolution as a consequence of environment fluctuation.

## V Emergence of cooperation and organization in an evolutionary game

As physicists we would like to study a game in a statistical system which involves large number of agents, and then to observe the emerging collective phenomena and do some simulation and research on these new emerging organizations. Actually we cannot develop a reasonable model now. However there are similar properties of the emerging society. Although the agents just care about their own gain, cooperation and altruistic behavior arise spontaneously sooner or later. Evolution lets these organizations create one new feature (or to annihilate an existing feature) from time to time. The more sophisticated organization, the more emergent cooperation should be existed. Altruistic conductors can create complex organization under the evolutionary condition..

## VI Summary of the emergent cooperation from evolutionary selection rule

From these papers, we have a strong sensation that the emergent cooperation is occurring under some conditions, such as kin selection, retaliating behavior, reciprocity, voluntary participation, development of reputation, or spatial extension, even though some of these conditions are from the temporary fluctuations. These conditions refer to the regulations; it is

related to emergent states of matter under some “pressure” and “temperature”, in some critical point, it occurs from one phase to the other phases. Obviously they are total different because randomly natural law obeyed particles are very different from the self-interest maximum of the individual thinking identity. So to cooperate is not so general from individual to cooperation. And I think if we broaden the field to politics and/or legal system and compare the individual to the whole society, the individual seems more random and it is more similar to the atoms or molecules in the emergent states of matter. I would like to briefly introduce the similarity between the emergent states of matter and emergent order of the society.

## VII How I try to link the similarity between the emergent states of matter and the emergent orders of society

During the course *Emergent States of Matter*, I felt frustrated that I always tried to link the different phases of matter with different political systems in society. When I try to use the superficial similarities to explain and predict the things happening in China, sometimes I can not identify whether it is because of the similarities between the society and matter or if it is my own personal skills giving some explanation and make some prediction.

I usually make the comparison from matter to society with atoms or molecules to individual. When they are in high temperature and lower pressure it is in gas state, it is totally symmetric and with the lowering temperature and/or increasing the pressure, it occurs spontaneously symmetry breaking, from gas to liquid to solid or the other phases, we can find the critical point for the phase transition and the line of phase transition. In society, we also can define “pressure” or “temperature”, but there are different, it is better to assume that there are three axes, one represent power, one represent legal systems, one represent religion or ideology. If there were no regulations from power, legal systems, or ideology, the society would be in chaos, it would be totally symmetric, just like the situation written in *Leviathan* by Thomas Hobbes. When the society adds the dimension of power and/or legal systems and/or regions spontaneous symmetry breaking occurs. There are many social states such as constitutional democracy, authoritarian, dictatorship, totalitarian and the other states, with different critical points, and lines of the states transition and the surface of states transition. I tried to model these situations, however, even though I spent lots of time on these situations, and I try to make some comparison between the matter and society or between atoms and individual, and I find it is very hard to do some experiments under the same controlled conditions. I can make the connection at the phenomenological level. Actually it is relatively easy for me to explain the situation from the “large pressure” from power and ideology just like the solid state in matter, during the period of “Big Cultural Revolution” controlled by despot Mao, all the people lived uniformly, whatever from the uniform to personal thinking, all the other states

were expelled through prison or labor camp or personal committed. It is called totalitarian. After the death of Mao, the “pressure” becomes less and especially during the sharp difference among the top leaders in the CCP(Chinese Communist Party), there were spontaneous emergent states in society, we call it as authoritarian period. During these periods, although the CCP sent some spies to make some space for average people to involve in their internal fight, the spontaneous emergent states (non-government organizations) do not want to obey the CCP. So when the top figures had settled down the difference (somehow like totalitarian), all the members obedient to the new leader, then the new authority usually started or simultaneously started to crack down the new emergent civil organization. That is the mainframe of the current history in China. We can use this model to explain the phenomenon of the “Democracy Wall in 1979”, the fight among the top leaders were between Deng Xiaoping and Hua Guofeng, we can also use this model to explain the phenomenon of “Tian’anmen demonstration in 1989”, the fight among the top leaders were Zhao Ziyang and Li peng, the big man is Deng Xiaoping behind them. Owing to the uncompromised from Zhao with the top leaders in the CCP, the crack down was very harsh, thousands of people were killed and hundred of thousands people were arrested, sentenced, and exiled to the outside of China. We can also explain the phenomenon of “China Democracy Party in 1998”, and “the human rights defenders in 2006 this year”, in 2006, the fight in top leaders in the CCP were between the new leader Hu Jingtao and the previous leader Jiang Zemin, after that, the CCP crack down the human rights defenders’ activities most of which were spontaneously participated in. We can predict the near future in China after the 17 national Congress of the CCP in 2007.

It is true that the situation becomes more and more complicated in China after “the open policy”. There is more and more capitalism occurring in China, people have more and more freedom in social, economic, and cultural rights, but the civil and political rights are seriously restricted. Because of the freedom from social, economic, and cultural aspects, the society is becoming more and more flexible, and the pressure from the CCP becomes weaker and weaker. Sooner or later, the CCP will try to use some harsh measure to keep the serious controlled situation in China, and especially during fights between the top leaders, the CCP always dispatched lot of their spies to control and influence the activities of movement. The CCP tries to prevent the transition happening among the state of authoritarian, the state of chaos, the state of constitutional democracy or new authoritarian. However, owing to the development of the capitalism and the open policy, people have more and more freedom from economic, social, and cultural aspects, the political system of dictatorship of the CCP in China cannot continue for long time. It should transition to another phase. We do not know which phase of governanace will be in China's future, because no one can control all the conditions for the transition.

- Although I currently cannot do the modeling, I still think it is helpful and powerful to make the connection between the matter and society or between the atoms and individuals. It is really useful to give the explanation and make some prediction. Last summer when I was in Germany during August 1-4, 2006, I told one reporter that one of human rights defenders in China would not be arrested at that time. But, after I went to London, United Kingdom on August 5, some other people gave me the new article written by the defender. I could not tell another reporter the same thing which I had just said in Germany, because I found the critical point or the transition line, and once the settle-down between the top leaders in the CCP occurred, another crack down would happen. It did happen during the next month.
- It is very important for physicist to involve in the activities to transition from the dictatorship to constitutional democracy. Some people said that it is Benjamin Franklin to make the US constitution to have the property of “Checks and Balances”; and after that, politics became political science rather than “power strategy”.

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