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Abstract:
Possibility of cooperation for sustainable use of the commons is investigated in an analytical setting of evolution game with two-stage constituent game. Players are rational individualists, but classified into long-run type and myopic type in terms of the length of time-horizon. As the long-run type grows, the more cooperative use becomes possible. The long-run type has a payoff advantage over the myopic type, but the latter has to pay adaptation cost for transformation to the former. Possibility of cooperation depends on the relative magnitude among adaptation cost, relative payoff advantage, and physical environmental factors.

Journal of Economic Literature Classification Number: C72, QOO.

List of Symbols:

L

M

R (gothic)

R' (dash, gothic)

A (gothic)

A ' (dash, gothic)

A" (two dash, gothic)

J_0 (gothic, subscript zero)

J_A (gothic, subscrict A)

$J_{A''}$ (gothik, subscript A")

$J_{R'}$ (gothik, subscript R')

0 (gothic, zero)

u_L (subscript L)

u_M (subscript M)

a (gothic)

a' (dash, gothic)

a_0 (subscript zero)

å (gothic, dot)

a^* (gothic, superscript asterisk)

a_* (gothic, subscript asterisk)

a(0) (gothic, the value of a at zero)

b (gothic)

e

p

p^* (superscript asterisk)

p_* (subscript asterisk)

λ_1 (subscript one)、 λ_2 (subscript two)、 λ' (dash) α 、 β 、 γ 、 δ

η_1 (subscript one), η_2 (subscript two)

1. Introduction

Cooperative use of common pool resources is a necessary condition for survival of any community. As Hardin(1968) pointed out, however, any community consisting of rational egoists is apt to non-cooperatively overuse them. The problem of the commons is one of the prisoner's dilemmas, and therefore, we can not escape from the pessimistic logical conclusion in respect of the possibility of voluntary cooperation, as long as players are assumed to be rational egoists. On the other hand, we can ubiquitously observe cooperative behaviors on a voluntary basis in our daily life, even if our community is a large organization according to the Olsonian logic. This is because some types of players can take into consideration the effects of their today's actions on tomorrow's survival conditions, but at the same time other types do not pay due attention to this today-tomorrow relation. The former types can refrain from indulging themselves in unlimited deviation and choose cooperative behavior today, if it is expected that the present cooperative behavior can assure them of some sufficient compensation at later stages. The latter types, on the other hand, stick to the present deviating behavior, as long as it ensures them of the present maximum payoff. It is because any community actually consists of a mix of both kinds of types that we observe ubiquitously cooperative as well as non-cooperative behaviors at the same time.

In this paper, we stick to the behavioral hypothesis of the rational egoist or individualist in the sense that players are willing to "reasonably" seek only their own selfish-interests. "Reasonably" means no systematic errors or no mistakes in their calculating payoffs. In order to describe the various types of players mentioned above, however, we suppose that all of those rational individualists are classified into two types in terms of the difference of time-horizons to calculate their payoffs. According to this classification of the rational individualists, the former type of player, that is, the player taking into consideration the today-tomorrow relation, can be recognized as one with a long time-horizon and is called long-run type of player (L-type). On the other hand, the latter type of player, one paying no consideration to this relation, can be recognized as one with a short time-horizon and is called myopic type of player (M-type). When players are involved in a finite-stage game, the L-type of player takes into consideration the interrelationship among stages and tries to maximize the total payoff of all stages. When the best strategy includes cooperative actions at earlier stages, that type of player may ostensibly look like an altruistic type of person in spite of having sought only his or her own selfish-interests. On the other hand, the M-type of player is not concerned with the present-future relationship, and therefore, takes in interest only in the payoff at each stage separated from subsequent stages. This type of player has been a typical image of the traditional egoist. In this respect the traditional notion of the rational egoist has been too narrowly confined.

As the bonded-rational approach pointed out (Simon, 1955; Simon, 1956), the assumption of the rationality is not realistic. In this paper, however, we stick to this assumption for the following reasons: Firstly, the assumed finite-stage game in which players are involved is not so complicated one as not to be able to find optimum solutions for it. When the players are put in the setting of evolutionary process, however, the rationality is not assumed. If a type of player in the setting of evolution game models were assumed to be able to take into consideration the outcomes of evolutionary processes, we should say this type of player is a super long-run type or a saint type. We do not assume such extremely a long-run type of player in this paper. Secondly, the assumption of the rationality plays a crucial role in establishing new social systems such as laws and constitutions. That assumption is required to avoid any loophole in those social systems. Even if it takes some information cost to make any rational calculation and the decision makers have to be contented with some bounded rational decision in the case of that cost' being big enough, it is still true that they try to make perfectly a rational decision, provided that investment in the required information is believed to be rewarding enough.

In order to fill the gap between the pessimistic logical conclusion of the prisoners' dilemma game and the ubiquitous counter-examples against it in large communities occupied with rational individualists, we present, in this paper, an evolution game model with two-stage game as its constituent game. A large population of players is randomly matched in pairs to play this constituent game successively in each period. The first stage of the constituent game is a prisoner's dilemma game describing an incentive to the free-riding use of the commons. The second stage depends on the outcome of the first stage play. If the commons is cooperatively made use of at the first stage, the productivity or quality of the commons can be improved at the second stage, and the cooperative use becomes the dominant strategy at the second stage game. If it is non-cooperatively overused at the first stage, on the contrary, the second stage is a different or another prisoner's game, and the productivity or quality at the second stage declines to a desperate level in the worst case where non-cooperative use brings about only a negligible positive payoff. The L-type of player knows about this long-run physical nature of the commons, and hopes to choose the strategy of twice-repeated cooperative actions, because it brings the maximum total payoff to that type of player. However, he or she may be cheated at the first stage. Then, they suppose their opponents to be the M-type, and at the second stage they choose non-cooperative action to avoid being cheated again. On the other hand, the M-type of player always believes that he or she is concerned with a prisoner's dilemma game, and therefore, chooses non-cooperative strategy at each stage.

Up till now, non-egoistic or altruistic types of players have been introduced into evolution game models in order to derive the possibility of voluntary cooperation in large communities (Witt, 1985; Guth and Kliemt, 1995; Banerjee and Weibul, 1995). All of them have the common character that all players have the same length of time-horizon, and therefore, cooperative strategy can not be derived from the egoistic behavioral assumption. On the other hand, the bonded rational approach has been also introducing non-egoistic types of behaviors

(Auman, 1981; Neyman, 1985; Rubinstein, 1986; Binmore, 1987; 1988, Binmore and Samuelson, 1992). They assume some programmed behavior patterns ***ad hoc,*** and do not explain how these are derived on an axiomatic basis. They also assumed that the time-horizons are the same, and so they had to assume non-egoistic behaviors in order to derive cooperative relations.

From the assumptions of the above constituent game model, therefore, it can be guessed that when the L-type can grow to the majority of the community, the cooperative use of the commons can be more often observed. Here, we need mention the assumptions on learning and adaptation. Regarding the learning, we cannot assume the sophisticated learning (Milgrom and Robert, 1991) or the rational learning (Kalai and Lehrer, 1993; Jackson and Kalai, 1997; Sandroni, 1998), because we assumed away the super long-run types of players mentioned above. In what follows, We assume that each player follows a simple adaptive learning procedure, Cournot' dynamics. According to this assumption, each player is given data on the population share and average payoff of each type at the end of each period, and based on the data, he or she makes the model of new social environment surrounding him or her and decides on how to adapt to it on the assumption that the situation in the last period is transposed to the next period.

As to the adaptation, however, it is here required to be suitable for a human but not biological evolution game model, because we quite often face with the problem of choice on types "in one generation" but not "over generations". Actually we can not select our own species, but we can change our types, except for some innate ones, by our own effort, even in one generation. Each type has its own strategies, from which each player chooses the best one by reason, but is not programmed to only one strategy.

"In human conflicts, strategies are chosen by reason to maximize the satisfaction of human desires. ...Strategies in animal conflicts are naturally selected to maximize the fitness of the contestants." (Maynard Smith, 1974, p.212)

In some evolution game models with two species (Taylor, 1979; Cressman and Dash, 1991; Cressman, 1995), however, the term species has been used in the same meaning as the term type. The players in those models are programmed to some types or phenotypes, and cannot change them in one generation. In this paper, we try to model the case that all players belong to one species but can change their types in one generation. In order to model the idea of human adaptation in one generation, we modify the Replicator dynamics, and some cost element is introduced to it in this paper. It can be often observed that the payoff of a long-run type of person exceeds that of a myopic type. At the same time, it is well known that it is very difficult for the latter type to change to the former type in spite of the payoff advantage of the former type over the latter type. It is because of some serious cost barrier why it is so difficult. It takes some cost and energy, such as investment in education, training and R & D, for the myopic type to change to the long-run type. We call this cost ***adaptation cost.*** Only when the payoff advantage of the L-type over the M-type exceeds the adaptation cost, the latter type can begin imitating the former type. Of course, the adaptation cost may take other forms such as social pressure (Witt, 1986). We examined such a case in Ueda and Uno (1997).

Finally, we take into consideration the fact that the payoff structure of constituent game changes from period to period. It is usually the case that the so-called myopic behaviors are often in conflict with keeping natural and social environment in good condition. If the M-type continues to increase its population share through social adaptation process, accordingly, the quality of natural and social environment can be expected to deteriorate. We suppose that this deterioration is expressed by decrease in payoffs of the constituent game in successive periods. In order to concrete this idea, it is assumed in this paper that when the population share of the M-type surpasses a critical point, deterioration process of payoff structure is set in motion.

From the examination of the dynamic relation between the quality of the commons and the population share of the L-type, we derive the result that the possibility of voluntary cooperation for sustainable use of common pool resources depends on the relation among the payoff advantage of the L-type of player, the adaptation cost, and the physical nature of the common pool resources. It is further derived that the bigger the payoff advantage of the L-type, the smaller the adaptation cost is and the more renewable the commons are, then the higher the possibility of the voluntary cooperation is.

It may be expected that owing to the existence of the adaptation cost and the vulnerability of the payoff structure, such a community easily falls down to the worst mix of the M-type's growing to the majority and desperately deteriorated quality of the commons. In the sixth section of this paper, we will mention about a possibility of drastic change in the adaptation cost. That cost may change to drastically a low level in the situation that natural and social environments deteriorate so badly. We classify communities into survival types and non-survival types in terms of the possibility of a drastic decline in the adaptation cost.

In what follows this paper is organized as follows: In the next section, we explain basic assumptions on the constituent game and the types of players. In the third section, the technical relations between payoff structure and the population share of L-type are explained. The social adaptation process is discussed in the fourth section. The dynamic processes are analyzed in the fifth section. In the sixth section, a possibility of drastic decline in the adaptation cost is investigated. Basic conclusions and results are summarized in the last section.

2. Constituent Game and Classification of Types

In this section basic assumptions on players' types and constituent game are explained. The constituent game is a two-stage game. All players are randomly matched in pairs successively in each period (As to justification for random matching models, see Boylan**(1992),** and Gilboa and Matsui**(1992)**), and each pair plays the constituent game. Each player belongs to the L-type or M-type, but does not know about types of his or her opponent players before the game. After the first stage, the types are known.

The L-type of player tries to maximize the total payoff of the constituent game with two stages. They know that when both players choose cooperative actions at the same time in the constituent game, the total payoff is maximized. Therefore, they stick to cooperative behavior at the second stage, if then-opponent players are found out to be the same type at the end of the first stage. When they are cheated at the first stage, however, they recognize the opponent players to be the M-type, and therefore choose non-cooperative action at the second stage in order to avoid more loss. The M-type of player takes no account of the future stages, and therefore always tries to maximize the payoff of each stage game independently.

The L-type of player represents persons who are more sensitive to any external effect or any environmental change, and / or have more knowledge on scientific cause-effect relations. Social leaders usually come out from such a type of community members. However, they should not be recognized as a non-selfish type of person. They are also selfish interest seekers. However, they are differentiated from other types of selfish persons in that they seek their long-run self-interests but not myopic ones. On the other hand, the M-type of player is a myopic self-interest seeker. Only such a type of selfish person has been usually recognized as a selfish person. According to our classification, however, both types are self-interest seekers. Difference between them lies only in difference of time-horizons, even if it can be agreed that the L-type of selfish person should be given higher esteem. According to our classification of individualists, therefore, we do not have to either deviate from the basic behavior assumption of economics or rely on any altruistic types of persons in order to derive cooperative behaviors.

The first stage of the constituent game is a prisoner's dilemma game (Table-1). The payoffs in Table-1 denote those of raw player. The payoff structure of the table corresponds to the outcome of joint use of a plot of common pool resource. The technical nature of the common pool resource is described in Figure-1. The ordinate of Figure-1 denotes gross product and cost, and the abscissa the level of inputs to a plot of the common pool resource. The gross product is subject to a logistic function type (Clark, 1990), reflecting a sensitivity to overuse. The cost function is assumed to be linear, according to which each unit of input requires e units of cost in terms of the output. If each player can cooperate in resource use and put each input level at C, then total net output is maximized, 2a, which is shared equally. If one player deviates and puts D level of input under the condition that his or her opponent player sticks to C level of input, then the total net output , λ_1 a, of the input level of (D + C) is appropriated exclusively by the deviator. Here, $1< \lambda_1 < 2$. When both players deviate at the same time, the total net output from 2D is $2\lambda_2$ a, which is shared equally. Here, $0 < \lambda_2 < 1$. In order to emphasize the merit of cooperative use, we assume $\lambda_1 + \lambda_2 < 2$.

The second stage of the constituent game depends on the outcome of the play of the first stage. If both players deviate at the first stage, then they have to play another prisoner's dilemma game with deteriorated payoffs at the second stage (Table-2). The payoff structure of Table-2 corresponds to the physical nature of a plot of common pool resource, described in Figure-2. The relative output relations are essentially the same as Figuere-1, but the productivity has drastically declined after the overuse at the first stage. Therefore, a' is less than a, and the net output of two deviators is assumed to be negligibly small.

On the other hand, if both players cooperate at the first stage, then the productivity of the plot can be preserved at the second stage, and they can have the more optimistic prospect of the future productivity of the common pool resource (Table-3). Subtraction of b from the second raw in Table-3 reflects this optimism for future survival condition[1].

Finally, when the outcomes of the first stage show other combinations of actions, the second stage is assumed to return to the first stage game (Table-1). This assumption is for simplicity.

At the end of the first stage, the L-type of player has perfect information on actions chosen by his or her opponent partner. When either of matched pair is found to have chosen non-cooperative action at the first stage, the L-type of player chooses non-cooperative action at the second stage. It is because he or she believes that his or her partner is the M-type, or that even if this partner were the L-type, the pair knows then that the second stage falls to the prisoner's dilemma game. As some laboratory experiments show (Kelly and Stahelski, 1970), rational individualists respond to any non-cooperative behaviors of their opponent players by rejection to being deceived again.

The outcomes of the constituent game for the L-type and M-type are summarized in Table-4 and Table-5, respectively. The inequality, $\lambda_1 + \lambda_2 < 2$, gives the L-type an incentive to bring about twice-repeated cooperation, because the total payoff of the twice repeated cooperation is the maximum in all feasible outcomes. It depends on partners' type whether or not L-type of player can achieve this maximum payoff.

The payoff of the L-type is bigger than that of the M-type in a weak sense, irrespective of whether expected or realized ones. From this payoff advantage of the L-type, it may be expected that this type can grow to the majority of the community according to the Replicator dynamics. However, we have to take into consideration other factors to investigate social adaptation process.

3. Dynamic Change of Payoff Structure

Natural and / or social environment of any community can not be considered to be constant from period to period, as mentioned in other models of common pool resources (Ostrom et al., 1994; Sethi and Somanathan, 1996). It is observed that the more non-cooperative actions, the worse the quality of the environments. We suppose in what follows that the quality of natural and social environment deteriorates in proportion to the share of non-cooperative relation in each period. Or, it may be supposed that the quality of environment improves itself in proportion to the share of cooperative action in each period.

Let p and 1- p denote the population share of the L-type and M-type in a period, respectively. Then, the population share of cooperative relation is equal to p^2, and that of the case of one cooperative action is equal to $2p(1 - p)$. Therefore, the share of all cooperative actions is equal to $2p - p^2$. Thus we can suppose that payoffs change in accordance with Eq. (1).

$$da/dt = (2p - p^2 - \alpha)a \tag{1}$$

where α is a positive parameter.

When α is less than one, a can increase itself over p exceeding a critical point, $1 - (1-\alpha)^{1/2}$, until p goes up to one (Figure-3). This case corresponds to renewable common pool resources. On the contrary, when α is more than or equal to one, a can keep, at the best, its magnitude at the same level, only when p is equal to one (Figure-4). This case corresponds to non-renewable common pool resources.

Therefore, α plays a role to provide a critical value to divide common pool resources into renewable and non-renewable ones. To the latter type of common pool resources, we can not apply the idea of any economically optimal use. Absolute ban on non-cooperative actions is the necessary condition for preservation of those resources. The idea of some ecological radicals corresponds to such a case.

4. Evolutionary Change of Types

According to the basic assumptions of the section 2, the L-type of player begins with cooperative action at the first stage of each constituent game. On the other hand, the M-type of player chooses non-cooperative strategy at every stage game. Only when a matched pair is both the L-type, twice-repeated cooperation is achieved. When the L-type is matched with M-type, the former obtains a deceived payoff at the first stage, but Nash payoff at the second stage. Each player is expected to play 100 p per cent of the L-type of players and 100 (1 –p) per cent of M-type of players in each period. Then, each type of players obtains some average payoff in each period. At the end of the period, they can know the average payoff of each type. They have to respond to their observation. In this section, we investigate how each type of player adapts to a change in social environment.

Let u_L and u_M denote the average payoff of the L-type and M-type, respectively, in a period under the condition that the population share of the L-type is p. The values of them are given by Eq.(2) and Eq.(3), respectively.

$$u_L = 2\,a\,p + \lambda_2\,a\,(1-p) \tag{2}$$

$$u_M = (\lambda_1 + \lambda_2)\,a\,p + \lambda_2\,a\,(1-p) \tag{3}$$

The payoff advantage of the L-type over M-type is defined by $u_L - u_M$. According to Eq.(2) and (3), it is equal to $(2 - \lambda_1 - \lambda_2)\,a\,p \geq 0$. If, therefore, players adapt their types only to this payoff advantage in accordance with the so-called natural selection, as shown for example in Maynard Smith (1982), Weibul(1995), and Hohbaur and Sigmund (1988), then L-type grows to the majority of this community sooner or later.

In our evolution game model, however, each player as a person but not as a programmed phenotype, has to decide on whether and how to adapt to the new environment. Then, it usually costs some time and energy for persons to change their types for adaptation. It takes some serious cost, in particular when they have to improve their ability. Educational investments to obtain higher specialty, or surrender of vested interests are examples for the cost. Without overcoming this cost-barrier, any person can not change his or her type, even if some payoff advantage is found out in changing to a new type. We call the cost for transformation from the M-type to L-type *adaptation cost*, denoted by δ.

We suppose that only when the payoff advantage can exceed the adaptation cost, the population share of the L-type can increase itself. This idea of evolutionary change of types is shown in Eq.(4).

$$dp/dt = (\gamma a p - \delta) p \tag{4}$$

where δ is a positive parameter, and γ is defined to be equal to $2 - \lambda_1 - \lambda_2$.

As can be guessed from Eq.(4), the adaptation cost is a crucial factor in evolutionary process of the population share of each type. Unless the payoff advantage of the L-type can exceed the adaptation cost, this community tends to be occupied only with the M-type of players. However, the movement of both p and a is interrelated with each other, as shown in Eq.(1) and Eq.(4). In the next section, we examine the dynamic nature of these two equations.

5. Stability Analysis

We have now two differential equations, Eq.(1) and (4), expressing the dynamic process of the productivity of common pool resources, and the evolutionary process of the population share of the L-type, respectively. The dynamic movement of this system depends on parameter values; α, δ, and γ. We classify the following analyses into two cases according as the value of α.

(5-1) $0 < \alpha < 1$: Renewable Case

The phase diagram of this dynamic system is shown in Figure-5. The ordinate shows the population share of the L-type, p, and on the other hand, the abscissa, the productivity of common pool resources, represented by a.

There are two economically meaningful stationary points; 0 =(0, 0), and A=(a^*, p*), where $a^* = \delta / \gamma \{1-(1-\alpha)^{1/2}\}$, and $p^* = 1-(1-\alpha)^{1/2}$, respectively.

The Jacobians of the differential equations evaluated at 0 and A, denoted by J_0 and J_A, are shown by Eq.(5) and (6), respectively.

$$J_0 = \begin{bmatrix} -\alpha, & 0 \\ 0, & -\delta \end{bmatrix} \tag{5}$$

$$J_A = \begin{bmatrix} 0 & 2(1-p^*)a^* \\ \gamma(p^*)^2 & 2\gamma a^* p^* - \delta \end{bmatrix} \tag{6}$$

As shown in Eq.(5), the real parts of both characteristic values of J_0 are negative. Thus, the stationary point 0 is stable according to the linearization theorem. On the other hand, the real parts of two characteristic values of J_A take opposite signs, and thus the stationary point A is a saddle point. Therefore, we can derive the following conclusions: (i) When the initial points lie to the northeast of A, this community tends toward situations where the productivity of common pool resources is improving and the population share of the L-type is increasing. (ii) When the initial states start from other points, this community tends toward 0, where it is occupied with the M-type of players and the quality of environment falls to the worst.

It depends on the relative magnitude of parameter values, α , δ ,and γ ,whether a bliss situation of (i) can be achieved or not. The bigger γ , and / or the smaller α and δ , then the higher the possibility of achieving the bliss, and vice versa.

When α is equal to zero, any points denoted by (a, 0) for a $\geq$ 0 are stationary. They are stable, because, of two characteristic roots of J_0 with α being equal to zero, one is positive and another is zero. Though the quality of environments can remain the same in this case, there is no possibility of the L-type's growing to the majority.

(5-2) $\alpha \geq 1$; Non-Renewable Case

It is enough to examine the case of α being equal to one. The phase diagrams for this case are shown in Figure-6 and Figure-7. The former corresponds to the case of δ / γ being less than a(0), and the latter the opposite case, where a(0) is the value of a at the initial point. The stationary points are; the origin 0 and the line R, where R passes the point, A' = (δ / γ , 1), with δ / γ as its slope. The origin is a stable point, but R is unstable, because, of two characteristic roots of the Jacobian evaluated at A', one is zero but another is positive.

The dynamic movement of the differential equations with α being equal to one depends on the relation between a(0) and δ / γ , as can be seen in Figure-6 and 7. When a(0) $\geq \delta / \gamma$, any initial point on the right side of the line R tends toward the quasi-bliss situations where the L-type grows to the majority but the productivity of common pool resources remains the same (See Figure-6). On the other hand, when a(0) $< \delta / \gamma$, there is no possibility of the L-type's growing to the majority. This community converges to the worst end where it is occupied exclusively with the M-type of players and the productivity of common pool resources declines to zero (See Figure-7).

In the case of non-renewable resources, the best our community can do is at most to keep their quality at the present level. Only when the initial quality level is high enough, and / or the initial population share of the L-type is high enough, the productivity of the resources can be kept. This is a social and natural background of ecologically radical ideas.

6. Possibility of Decline in Adaptation Cost

Until the last section, we have assumed that the adaptation cost is constant in evolutionary processes. However, when our community is plunged into a crisis in survival conditions owing to worsening quality of natural and social environments, it may be possible for the adaptation cost to drastically decline relatively to the payoff advantage. In this section, we investigate this possibility.

As a first step, we take up the case that when the quality of environment declines to a critical level denoted by a_0, the adaptation cost drastically declines to zero. On the other hand, it is assumed that when a is larger than a_0, the adaptation cost increases in proportion to the difference between a and a_0. These ideas are shown in Eq.(7).

$$\delta = \begin{cases} \beta(a - a_0), & \text{for } a - a_0 > 0 \\ 0, & \text{for } a - a_0 \leq 0 \end{cases} \qquad (7)$$

where β is a positive parameter.

When the quality of environment deteriorates down to a critical point, then the first priority of all players is put on their survival conditions. This is why the adaptation cost can be assumed to suddenly drop to zero in the region of a below the critical level denoted by a_0.

Eq.(1), (4) and (7) have two kinds of stationary points. One corresponds to the case for $a \leq a_0$, and another for $a > a_0$. The former is the line R' and the latter, A" in Figure-8, where R' = $(0, p_*)$, $0 \leq p_* \leq 1$, and A" = $[\beta a_0 / \{\beta - \delta(1-(1-\alpha)^{1/2})\}, 1-(1-\alpha)^{1/2}]$.

The line R' is a stable line, as can be shown by the Jacobian evaluated at (0,0),

$J_{R'}$ of Eq.(1), (4), and $\delta = 0$, but the point A" is a saddle point, as can be shown by the Jacobian evaluated at A" and its eigen values of Eq.(9). Actually, we can easily confirm that $\eta_1 + \eta_2 > 0$ and $\eta_1 \eta_2 < 0$, where η_1 and η_2 are two eigen values of J_{A^*}.

$$J_{R'} = \begin{bmatrix} -\alpha & 0 \\ 0 & 0 \end{bmatrix} \tag{8}$$

$$J_{A^*} = \begin{bmatrix} J_1 & J_2 \\ J_3 & _4 \end{bmatrix} \tag{9}$$

where

$J_1 = 0$,

$J_2 = 2\ (1 - p_*)\ a_*$

$J_3 = \ \gamma\ (p_*)^2 - \beta\ p_*$

$J_4 = 2\gamma\ \ a_*\ p_* - \beta\ (a_* - a_0)$

$p_* = 1 - (1 - \ \alpha)^{1/2}$, and

$a_* = \beta\ a_0 / \{\beta - \delta\ (1 - (1 - \alpha)^{1/2})\}$.

When the quality of environmental conditions deteriorates badly enough, that is, when a declines below the critical value a_0, the majority of this community can be occupied with the L-type of players in the end. This situation can be a starting point for an inner revolution, which leads to the establishment of new constitutions to restore survival conditions. This community is called a survival type. On the contrary, in other types of communities where the adaptation cost does not change enough, the origin, 0 =(0, 0), remains only one stable stationary point. These communities tend to a ruinous situation, and are called a non-survival type. The minority members sensitive to the worsening of environmental conditions can not help choosing exodus strategies. Legendary stories on Noah's ark in some regions have such a social background.

7. Summary and Conclusions

Up till now, some different behavioral assumptions from the rational individualism have been introduced into evolution game models in order to derive the possibility of voluntary cooperation in large communities. Bounded-rationality and altruistic types of players are typical examples among them. In this paper, however, we stuck to the behavioral assumption of the rational individualism, but classified all rational individualists into two types in terms of the difference of their time-horizons. According to this classification, players with long time-horizon can choose ostensibly altruistic behaviors, even if they are rational self-interest seekers. It can be guessed, therefore, that if players with long time-horizon can grow to the majority, cooperative relations can be observed more often, and that as long as they have payoff advantage, other types may try to follow that type.

However, it was taken into consideration that as long as human players with myopic time-horizon try to change their types in one generation but not over generations, they have to overcome some cost called adaptation cost. Unless the payoff advantage of the players with long time-horizon can exceed the adaptation cost, the myopic type of players can not try to change their type in spite of the possibility of obtaining bigger payoff. It is because of this cost that myopic types of persons usually remain myopic.

It is often observed that the rnore myopic users of any common pool resources, the worse the quality of them. In this paper, we examined dynamic relations between the quality of common pool resources and the population share of players with long time-horizon. According to the examination, the evolutionary possibility of cooperative use of common pool resources depends mainly on the following three factors:

(i) the payoff advantage of players with long time-horizon, represented by ***y*** ,
(ii) the adaptation cost, ***8*** , for myopic players to change to long run type, and
(iii) the technical nature of the common pool resources, represented by ***a*** .

The bigger *y* is, and the smaller 6 and a are, then the higher the possibility of cooperative use.

It is difficult to expect any communities with high adaptation costs to be able to evolve to a cooperative community, even if cooperative behaviors can show some payoff advantage over non-cooperative behaviors. It may be more difficult in the case of communities with non-renewable resources. We need public policies to reduce the adaptation cost, such as education or training programs to improve specialty, and subsidies for R&D programs to promote structural change of corporations, which can also make surrender of vested interests easier.

In the last section, we mentioned about some possibility of inner revolutions in deteriorating process of the quality of natural or social environment. Communities are classified into survival type and non-survival type depending on the possibility of drastic decline in the adaptation cost in the face of the aggravation of environmental conditions. However, the discussions in that section were incidental, and require more refined treatment.

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Footnote 1

For example, many consumers nowadays intend to be loyal to environment-oriented or community-oriented companies. That is because, even if they do not have perfect insight into relation between their present consumption behaviors and future environmental conditions, they can gain some satisfaction from any better prospect of future survival conditions contributed, even if little, by their present behaviors.

When L-type can not have so good a prospect of their future survival conditions, that is, when $\lambda_2 a - b > 0$ in Table-3, the second stage game of Table-3 does not have a dominant strategy. In this case, belief on partner's types plays a crucial role, as Ueda and Uno (1997) showed.

Figure-1

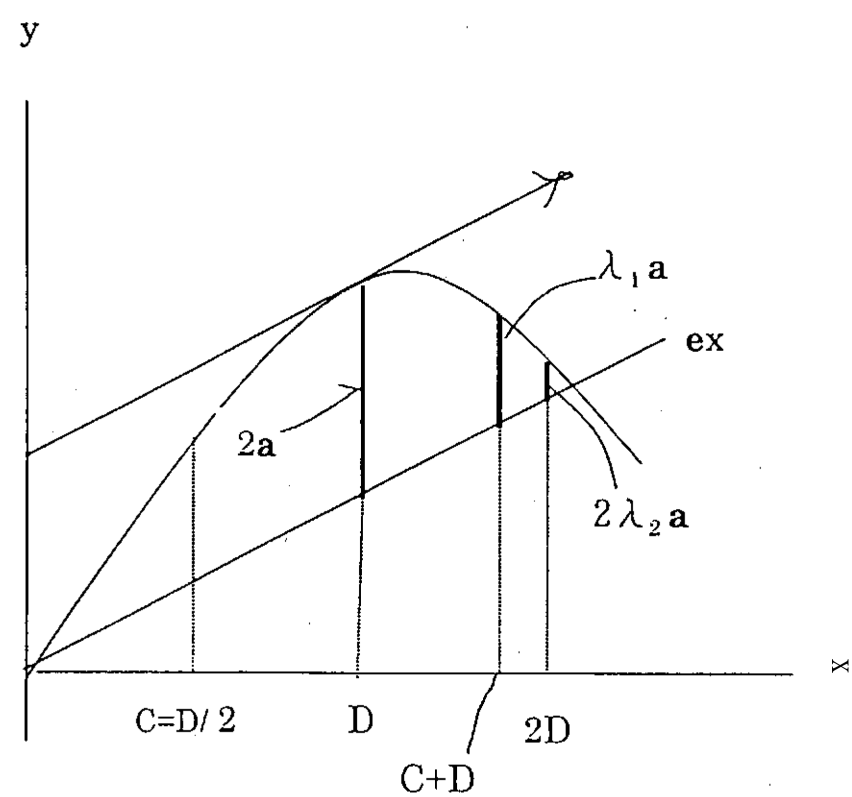

Figure-2

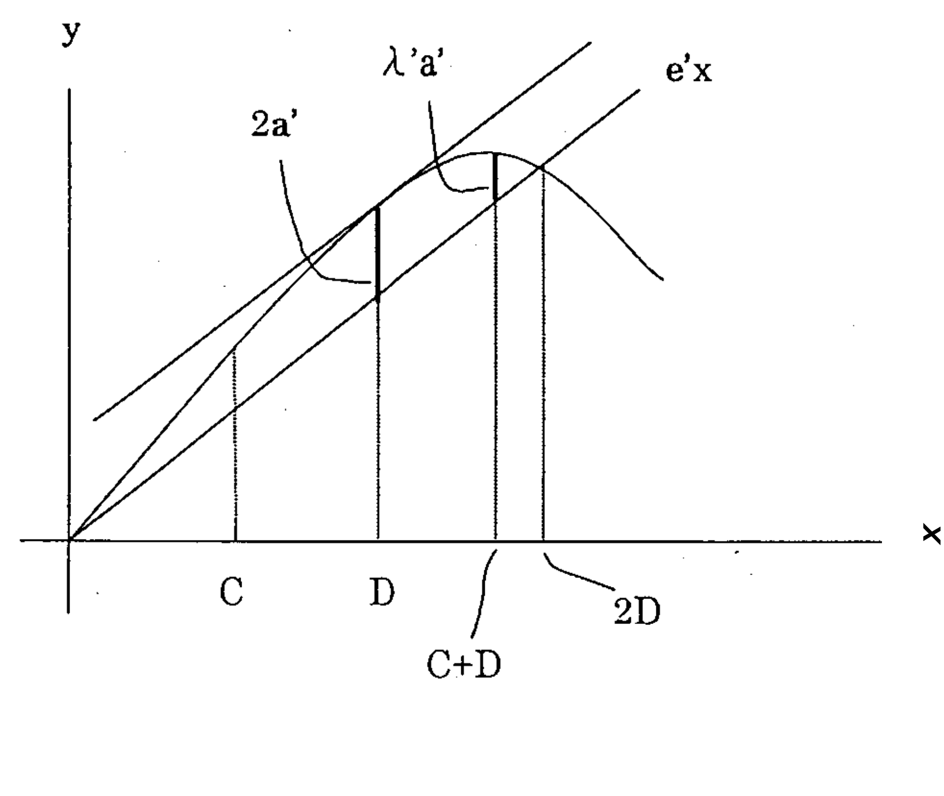

Figure-3

$(0 < \alpha < 1)$

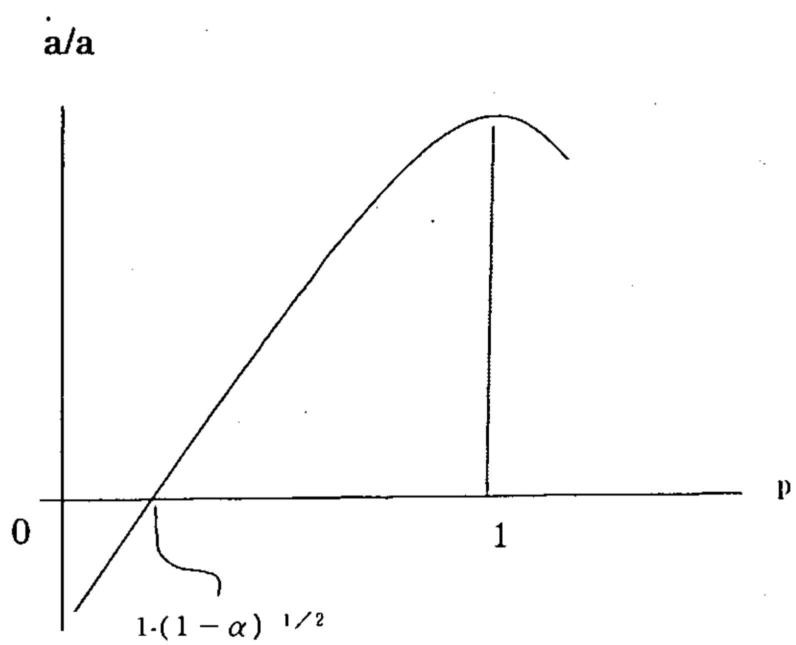

Figure-4

$(1 \leqq \alpha)$

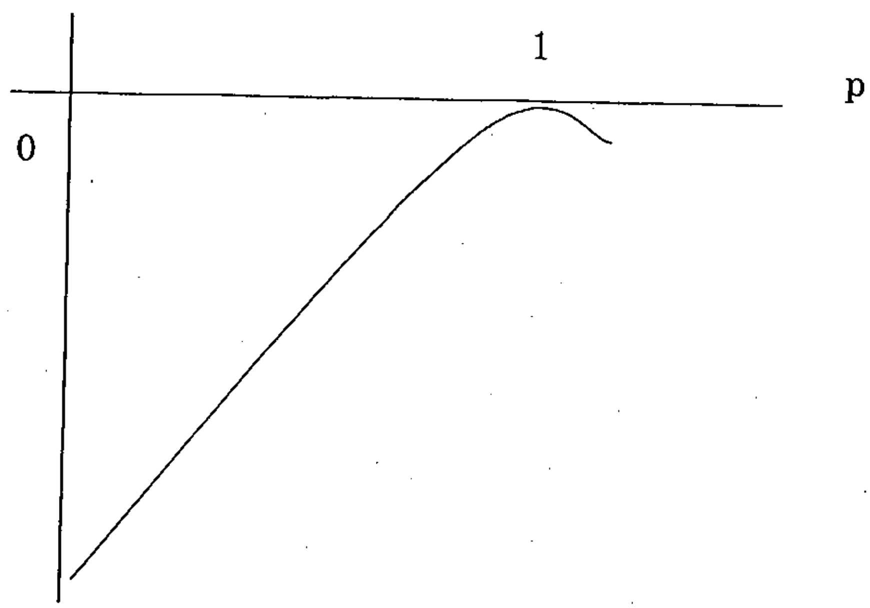

Figure-5

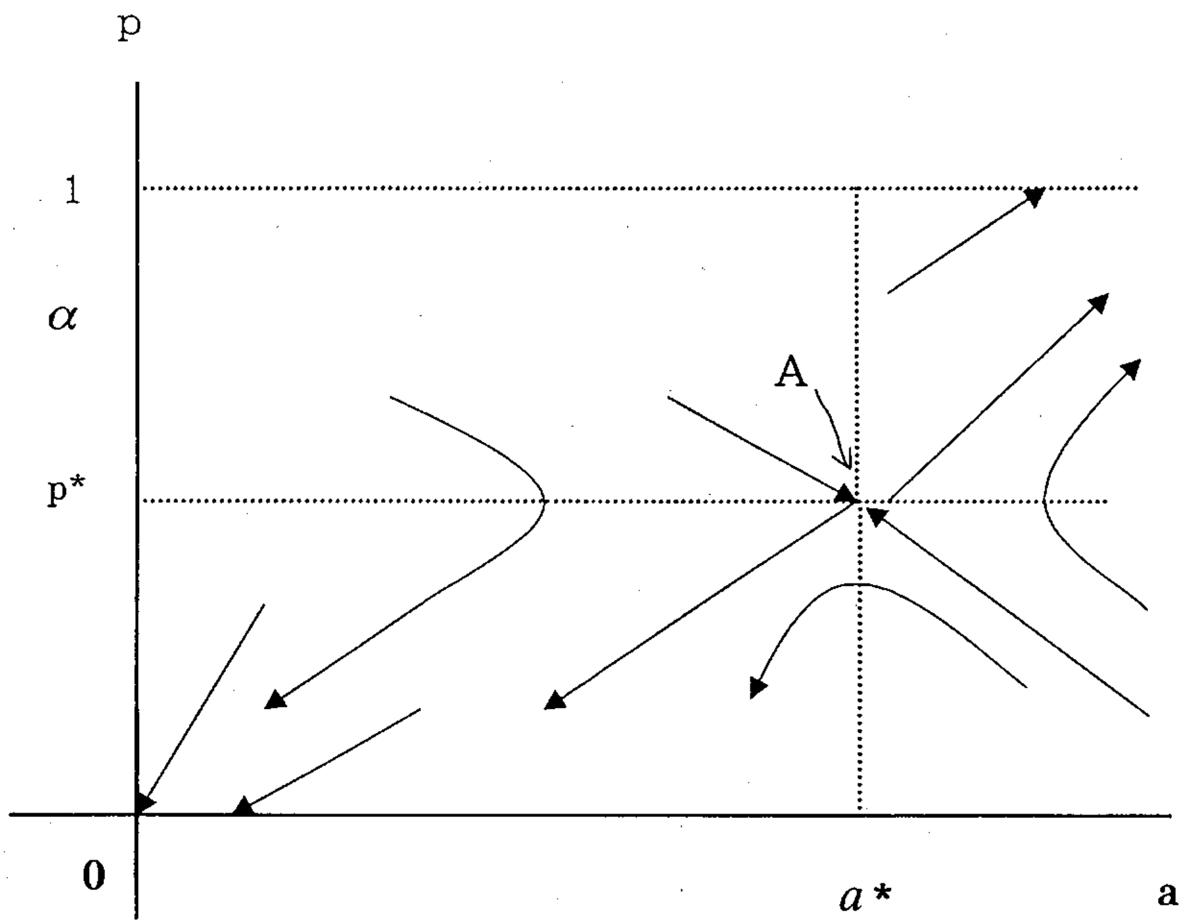

Figure-6

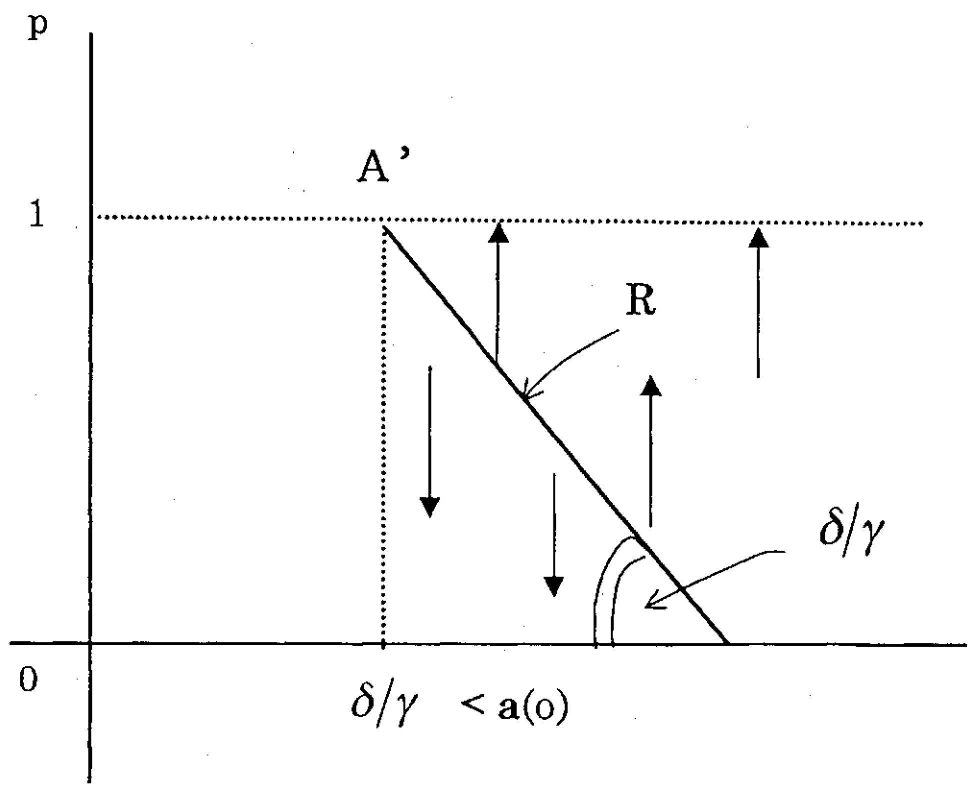

Figure-7

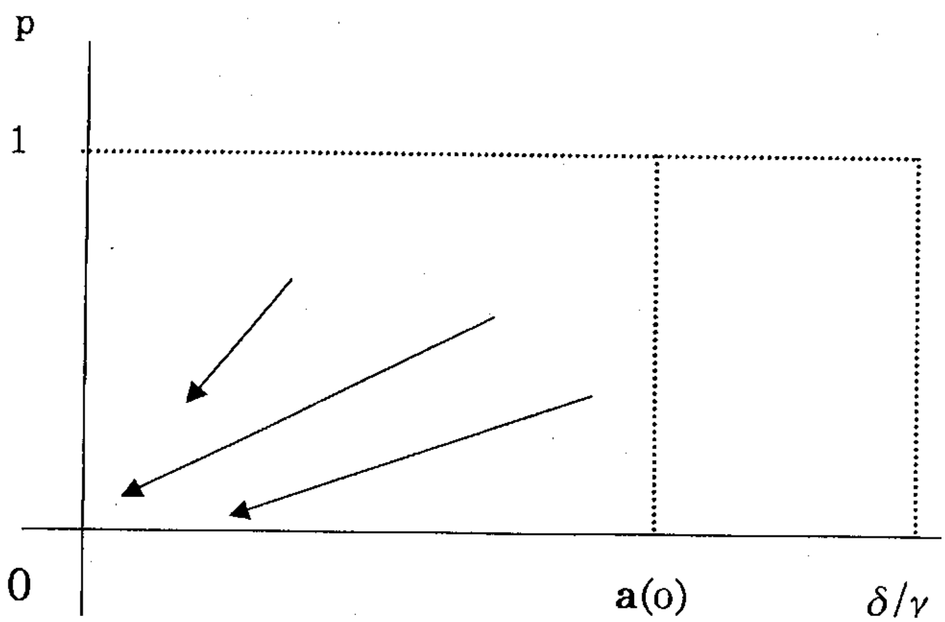

Figure-8

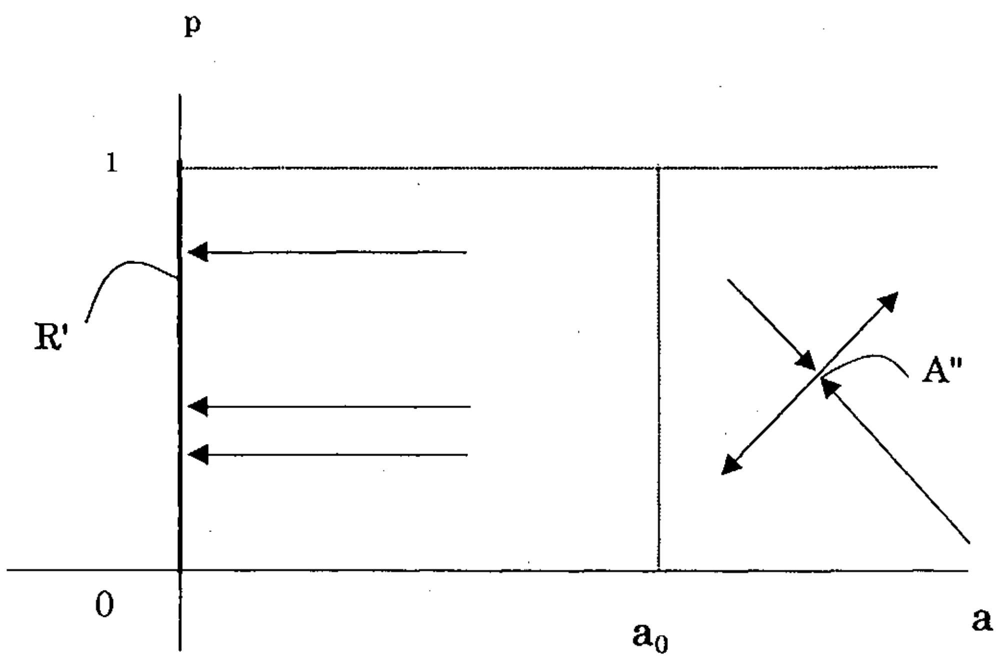

Table-1

$1 < \lambda_1, \quad 0 < \lambda_2 < 1, \quad \lambda_1 + \lambda_2 < 2$

	Cooperation	Non-cooperation
Cooperation	**a**	0
Non-cooperation	λ_1**a**	λ_2 **a**

Table-II

$1 < \lambda'$, $a' < a$

	Cooperation	Non-cooperation
Cooperation	**a'**	0
Non-cooperation	λ' **a'**	0

[

Table-III

$\lambda_1 \mathbf{a} - b < \mathbf{a}, \quad \lambda_2 \mathbf{a} - b < 0$

	Cooperation	Non-cooperation
Cooperation	**a**	0
Non-cooperation	$\lambda_1 \mathbf{a} - b$	$\lambda_2 \mathbf{a} - b$

Table-IV

Outcomes of the L-type (Row Player)

	Cooperation	Non-cooperation
Cooperation	**2a**	λ_2**a**
Non-cooperation	$(\lambda_1+\lambda_2)$**a**	λ_2**a**

(Actions are those of the first stage)

Table-V

Outcome of the M-type (Row Player)

	Cooperation	Non-cooperation
Non-cooperation	$(\lambda_1+\lambda_2)\mathbf{a}$	$\lambda_2\mathbf{a}$

(Actions are those of the first stage)