Management of the Global Commons: Problems with Property Right Approach

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1. Introduction

According to the Olsonian logic of group actions, large groups consisting of selfish members are doomed to difficulty in achieving their common interests owing to free-riding incentive[1]. The global commons is one of the common interests of the large group, actually of the largest groups. However, we can ubiquitously observe the appropriators of the global commons are negotiating on social contracts to preserve it. Any of the social contracts does not allow the signatories to freely access to the global commons. Ofcourse, any player can not adapt to the requirements for the preservation of the global commons so suddenly. As a compromise, the tar-get level of restoration of the commons' quality has been a focal point of the negotiation on the social contracts. The management of the global commons is at such a level of achievement now.

In the light of this situation of the global commons' management, we face with two problems to be solved. First, we have to explain why the pessimistic conclusion of the Olson's group theory can be refuted on the same methodological basis, methodological individualism, as that theory. Secondly, we have to be able to propose policy designs for better management of the global commons.

In examining the first problem, we have to reexamine the behavioral assumptions of the Olson's theory. Here, it should be pointed out that any of group interests is achieved only when two processes are cleared; organizing process and providing process. The goal of each process corresponds to the constitutional contract and the post-constitutional contract, respectively, stipulated by Buchanan (1975). Even if the second process can be cleared from the view point of cost-benefit calculation, providing work for collective goods is not implemented unless the group is organized for negotiation beforehand. It often takes serious cost to get through the organizing process in the case of large groups. Regarding the burden sharing in that cost, all members have incentive to free-ride on others' burden.

If, however, political entrepreneur's can enter the market for organizers, the organizing process can be cleared by the leadership work of the political entrepreneurs. The political entrepreneur is a rationally individualistic type of organizer of group

[1] Olson (1965).

actions. When he or she can anticipate some reward, separated from the direct benefit from collective goods, sufficient to compensate present organizing' work for its cost, he or she can take on the organizer's work. That's why many of the common interests for large groups, such as the establishment of governments and national unions, have been attained up till now. Olson could not take up the political entrepreneur as an independent necessary condition for the organizing process. Therefore, he had to rely on other factors such as the "selective incentives" in order to explain the collective actions of large groups as an exception.

Here, it should be noted that the cost of the organizing work heavily depends on the types of the direct beneficiaries of collective goods. We emphasize that although all players are a selfish individualist, their[1] time-horizons are various.[2] Players with long time-horizon seek their' long run self-interests, but on the other hand, those with short time-horizon myopic self-interests. The pessimistic logical conclusions of not only the Olson's theory but also the logic of commons' tragedy assume only the myopic type of the selfish-individualist. When, however, we take into consideration the coexistence of the long run type of selfish individualist, it is expected that the more of this type in any group, the less cost it takes to organize the group into concerted actions.

According to rationally individualistic calculation of the political entrepreneurs, therefore, even the largest group can achieve its common interests, if those entrepreneurs can anticipate rewards for their organizing work, and at the same time if the long run type of group member is expected to grow to a sufficiently big share of the group. In this paper, we apply this logic to the emerging international social contracts for preservation of the global commons. Each country is recognized as the representative of the majority member's of that country, and behaves as the long run type or myopic type in the international social contract game.

If all of the country-player's are the representatives of the long run individual players, they can willingly join in negotiation for the preservation of the global commons. They play an infinitely repeated game of which players belong to a small group, and therefore can comply with some sub-game perfect strategies without sword. We conjecture that the system of "community management" or "self-governance" implicitly assumes such a social background[3].

[2] Ueda (1999), Ueda & Uno (1997).

[3] Ostrom (1990), Ostrom et al. (1992), Ostrom (1998).

However, only a part of the country-players are the long run type up till now. Here, the second problem of how to manage the global commons becomes important, because the myopic type of country-player has no incentive to join in negotiation process. Regarding the emission of greenhouse gasses, for example, the country-players of long run type are concluding a contract on the maximum level of allowed emission, exclusive of the other types of country-players. They belong to the "privileged group," and therefore can obtain the direct benefit from their group action, sufficient to compensate for then direct cost burden. However, some means such as tradable-pennits regime under planning do not give proper incentive to the development of innovative technologies and the participation of the myopic type of country-player. In this paper, it is proposed that super-advance markets for expected reduction in emission should be designed to give incentive to the development of those technologies, and that the effort of afforestation and reforestation by the myopic players themselves should be allowed to be traded in the permits-market

Finally but not the least, we emphasize that the concept of the property rights to the global commons should be reexamined. We propose the concept should be defined on the basis of the survival right of the human species as a whole. It means that the survival condition for not only the present but also future generation should be taken into allowance. The country-player's of all types are equally responsible for the light of the future generation, and therefore have no right of aggravating the global commons' quality. According to this definition, the initial assignment of the right should be in proportion to the national income of each country, but emissions accumulated in the past should be taken the responsibility of by the past emitters. The developed countries should take responsibility for the great part of the past emissions. However, the atonement for the "past crime" must be conceptually separated from the present cost burden for the future generation.

This paper is organized as the following: The second section explains why the collective actions of large group can be successfully organized. In the third section, a model is presented to explain the tragedy of the global commons and the possibility of cooperative preservation. In the fourth section, the problems of tradable-permits regime are discussed. The last section summarizes the main conclusions.

2. Logic of Group Actions and the Global Commons

According to the Olsonian logic of group actions, it is derived logically that it is difficult to preserve the global commons because it is the common interests for large groups. We can, however, observe that some international social contracts for preservation of the global commons are being concluded. Nowadays, the main concern with the global commons is moving from how to organize the cooperative actions of group members to how to manage the system to preserve the commons. So, first of all, we have to explain why and how the pessimistic logical conclusion from the Olsonian group theory could be evaded. For this purpose, we have to reexamine the characteristics of the global commons, and the implicit assumptions of the Olsonian group theory.

(2-1) Some Criteria to Classify the Commons

The global commons such as the atmosphere and global climate has some specific characteristics, which are of technological or sociological nature. Owing to those characteristics, it has been difficult to make designs to preserve the global commons. In this subsection, we discuss on criteria to classify the commons, in order to make clear the characteristics of the global commons. Here, the commons is in general defined as common property resources appropriated under open-access system.

First of all, the common property resource (abbreviated as CPR below) has the common characteristic that if it is appropriated under open-access system, it has external effects. These effects are classified further into static and dynamic one. The static externality means the negative effect of one's selfish action on others' payoff. Without binding contracts, it invites strategic human relations among appropriators of CPR. On the other hand, the dynamic externality means damage to CPR at later-stages suffered by appropriators' myopic actions at the present stage. It reflects an intertemporal relation between today's action and tomorrow's quality of CPR. The appropriators have to take into consideration not only the static but also dynamic externality in order to preserve CPR. It usually takes some time for the dynamic externality to be perceived by the majority members, because it takes long time to learn it from experience. It takes long to perceive the dynamic externality of, in particular, the global commons such as the atmosphere and climate owing to its technical nature. The static externality can be overcome by attaining Parato optimality, but some survival conditions must be met in order to overcome the dynamic externality.

Secondly, CPRs are classified in terms of the possibility of reproduction. Many of

extracted mineral resources belong to the group of non-reproductive CPRs. Other CPRs such as forests, marine resources, and atmosphere are reproducible under proper management system. The global commons shares some of the characteristics of the reproducible group. Either positive effort such as planting or restraint of unlimited appropriation is required for the reproduction. However, accumulated emissions are of irreversible character, for which only some of the players should be blamed. It should be taken into allowance in negotiation on social contracts to preserve the quality of CPR.

Thirdly, the size of appropriators plays a crucial role to preserve CPRs. If the group is small in terms of the Olson's definition, and if the game played by the group is repeated long enough, then the CPR may as well be managed under voluntary systems without authorized enforcement. Those commons has been called the local commons. On the other hand, it is difficult to organize the group actions for cooperative management of CPRs in the case of large groups. We have been calling these CPRs the global commons according to the popular terminology.

Fourthly, the commons are classified in terms of the difference of time-horizon among appropriators. We should keep it in mind that even if all players are of a selfish type, the time-horizon of each player is various. The shorter the time-horizon is, the more difficult to take into allowance the dynamic externality. In this paper, we classify players into two types in terms of the time-horizon; long-run type and myopic type.

The global commons has the technical characteristic that though the dynamic externality causes serious damage to survival conditions for the human species, it is, owing to the technical nature of the global commons, difficult to perceive the dynamic effects by learning from daily experience compared with other types of CPR. Furthermore, it has the sociological characteristic that according to the Olsonian logic of group actions, it is actually difficult to organize cooperative actions to achieve the sustainable use of it. This last conclusion is derived from the implicit assumption that all appropriators have the same myopic time-horizon. However, the time-horizon is various from person to person, even if all persons are recognized as a selfish type. As the next subsection shows, this is one of the crucial factors to overcome the logical conclusion of the Olsonian group theory.

(2-2) Collective Actions and Political Entrepreneurs

The cost to provide for collective goods should be divided into two. The first is the direct

cost for providing the goods for beneficiaries after collective actions are successfully organized. The second is the ex ante or preparatory cost required for organizing; collective actions. These two types of cost are not explicitly separated in the Olsonian group theory, which led to the pessimistic conclusion based on the individualistic assumption.

It should be emphasized that even if the direct cost is less than the direct benefit obtained from the collective goods itself, they can not be provided without solving the problem of the ex ante cost. It is because some organizing work is required for leading group members into cooperative actions before providing the collective goods. It should be noticed that collective goods are not provided not because of the direct cost problems but more often because of the ex ante cost problem. Someone must play organizer's role to lead the expected beneficiaries of collective goods into group agreement. It takes some cost for any person to play the organizer's role. The larger the group size is, *ceteris paribus,* the more expensive this cost is. Therefore, it is impossible for any rational individualist to take up the organizer's role, if he or she can not expect any reward for the cost for organizing activity. Every rational individualist has an incentive to free-ride on other persons' organizing activity.

The problem of the ex ante cost or organizer's cost is serious, but on the other hand we can ironically find a key factor to logically derive the cooperative actions of large groups in the ex ante cost itself. If it is admitted that it is because of the expectation of insufficient reward for the organizing activity itself that the collective goods of large groups are not provided, we can conjecture that if some sufficient reward for the organizing activity is expected, some person may stand up to take up the organizer's role. We call those individualistic organizers the political entrepreneur according to popular terminology. According to our conjecture, the political entrepreneurs get ready to enter the emerging market of organizers, when they are freed from the expectation of "free" work. Why could any government be at last built in spite of its being the collective goods for one of the largest groups? It is because organizers can expect they become full-time officials after successful organizing activity. Why could national unions be organized in spite of their large size? It is because the organizers could expect full-timer's salary. Why was it difficult to organize national unions for consumers? It is because the organizers had to be satisfied with respectable but free work. By separating the ex ante cost from the direct cost of the collective goods, we can logically derive the possibility of cooperative actions of large groups without

appealing to the so-called selective incentives.

(2-3) Possibility of Group Actions to Preserve the Global Commons

It takes some time for the majority of community members to learn the effects of greenhouse gasses on climate change from daily experience. Until these effects are perceived, the global commons is not recognized as a contributor to utility. If the worsening process of the commons' quality is not checked, however, it gets to a critical level at some point of the worsening process. At this point, the global commons can be recognized as a benefactor to utility.

After this recognition, however, it depends on player's type whether or not the dynamic externality is taken into account at the time of decision making. Since the myopic type of player does not take into consideration any payoff obtained in the future, he is not interested in any dynamic externality, even if he could perceive it. In the case of the long-run type of player, however, she takes it into allowance, if its serious effects can be perceived.

When the long-run type grows or is expected to grow to the majority of community members, the political entrepreneurs can enter the emerging market of organizers where they supply organizing service for providing the collective goods. Actually, those political entrepreneurs may take various occupations such as environmental activists and politicians with environmentally conscientious voters as their political supporters. When those political entrepreneurs can join in governing parties and/or policy supported by them is adopted by the government, then this community (country) as a whole can be recognized as a long-run type of player of wider international community.That is, when each community (country) is recognized as a player of inter-communal (international) society, the former is recognized as a player of the game played in the latter. It may be admitted that the developed country is now such a country-player of long-run type as to have the individual players of long-run type as the majority, but that developing country is a country-player of myopic type whose majority members are the individual players of myopic type.

If the players of long-run type consist of a finitely small number, and the dynamic external effects of their present actions are perceived to be influential enough, then they belong to the *privileged groups* according to the Olson's concept. Then they can organize themselves into cooperative actions to achieve their common goods. As long as they belong to a small group, and play an infinitely repeated game, some

combination of cooperative strategies of the stage game can be voluntarily played under renegotiation-proof condition.[4]

3. Basic Model

In this section we construct a model to explain the main logic of the last section. For this purpose this section is divided into two parts. The first part deals with the problem of group actions of a large group such as nation community. In the second part the problem of cooperative actions of a small group such as a group of developed countries.

(3-1) Group Actions of a Large Group

It is assumed to there be many players in a large community. All players are a selfish individualist. However, they are classified into two types; the long run and myopic type. The type is classified in terms of difference in a parameter value. It is an acceptable ceiling value of accumulated emission at the level of which the global commons is recognized as a benefactor to utility. We assume that the ceiling value of the long-run player is lower than that of the myopic player. It is because the long-run type of player puts higher evaluation on the future survival conditions than the myopic player does, and therefore the former perceives the information on the emission accumulated by the time of decision making more seriously than the latter. This is a presumption to approximately describe the difference in tune-horizon.

Assumptions on utility function. The utility of each player is assumed to be a function of private goods, the quality of the global commons, and effort to abate the emission of greenhouse gasses. We assume only one type of private goods, which plays the role of *numeraire.* The private goods bring about positive benefit, but on the contrary, the effort of abatement inflicts negative benefit. It is emphasized here that the global commons can not affect the utility by the time that the emission is accumulated up to the ceiling value. From that time, the global commons is recognized as a benefactor. The utility function is assumed to be quasi-linear, which is defined by Eq.(1).

$$(1)\quad U_i(y_i, z_i, S) = y_i + V_i(z_i, S), \qquad i = 1,2,\ldots, n.$$

[4] Refer to Farrell and Maskin (1989) regarding renegotiation- proof.

U_i is the utility level of i-th player. y_i and z_i denote the consumption level of private goods and the effort for abatement of emission of i-th player, respectively. S denotes the quality of the global commons. It is noted in advance that only after the deterioration of the global commons' quality gets to a critical value, S can work as an independent benefactor to the utility.

From the assumption of the quasi-linearity, V_i is a strictly concave function. From the above definition, $\partial V_i / \partial S > 0$, for $S \leq$ a critical value, and $\partial V_i / \partial z_i < 0$. It is assumed that $V_i(0,0)$ is equal to zero.

Assumptions on the quality of the commons: Here we suppose that the quality of the global commons depends negatively on the accumulated amount of greenhouse gasses emitted without treatment. Each type of player has an acceptable ceiling to that accumulated emission. Let E_L and E_M denote the ceiling value of the long run type and the myopic type, respectively. E_L is lower than E_M. We assume that one unit of consumption (production) technically brings about θ_y units of emission, and that one unit of abatement effort reduces θ_z units of emission. When i-th player consumes y_i units of the private goods, and spends z_i units of effort on reduction of emission in t period, then his net emission in this period, $e_i(t)$, is defined by Eq.(2).

$$(2) \quad e_i(t) = \theta_y y_i - \theta_z z_i \qquad i = 1,2,\ldots\ldots n.$$

Each player is subject to an income constraint shown in Eq.(3).

$$(3) \quad I_i = y_i + c z_i \qquad i = 1,2,\ldots\ldots n,$$

where I_i means the income level of i-th player, and c is the cost of one unit of abatement effort in terms of *numeraire*.

The accumulated emission up to t-period amounts to $\sum_i \int^t (e_i + e_{-i})\, dt$. The quality of the global commons in t-period, S(t), is approximated by Eq.(4).

$$(4) \quad S(t) = E - \sum_i \int^t (e_i + e_{-i})\, dt, \quad E = E_L \text{ or } E_M.$$

Substituting Eq.(2) and (3) for Eq.(4), Eq.(5) and (6) are derived.

(5) $S(t) = E(t) + \sum_i \int (c\theta_y + \theta_z) z_i \, dt$

(6) $E(t) = E - \sum_i \int \theta_y I_i \, dt$

It is noted that E(t) continuously declines, as time passes.

Optimization: When each player maximizes his utility, he has two control variables, y_i and z_i subject to the income constraint. However, we can reduce them to only one variable, z_i by substituting Eq.(4) for the maximized equation. Then the maximized Eq.(1) is changed to Eq.(7).

(7) $U_i = (I_i - cz_i) + V_i(z_i, E(t) + \sum_i \int_t (c\theta_y + \theta_z) z_i \, dt), \quad i = 1,2,\ldots,n.$

On maximizing U_i, we have to classify it to two cases depending on the value of E(t). We assume here that while E(t) is positive, the quality of the global commons does not affect the utility, but that once E(t) declines to zero, the quality of the global commons becomes the concern of that type of player and therefore a benefactor to the utility.

While E(t) has positive value, Eq.(7) changes to Eq.(8) according to the above assumption.

(8) $U_i = (I_i - cz_i) + V_i(z_i), \qquad i = 1,2,\ldots,n.$

The optimization of Eq.(8) leads the maximizing effort, $z_i(+)^*$, to zero (See Figure-1). It is because as long as the player has no concern about the quality of the global commons, his optimal strategy is to set the effort of abatement at zero level.. The higher E is, for the longer period players with that E stick to the zero effort level as the result of their optimization. Therefore, the myopic player sticks to the zero effort longer than the long run type.

On the contrary, when E(t) gets down to zero at some point, the quality of the global commons is perceived to be a benefactor to utility. Then, the form of the utility function to be maximized changes from Eq.(8) to Eq. (7). The necessary and sufficient condition for maximization of Eq.(7) is shown by Eq. (9).

(9) $dV_i / dz_i = \partial V_i / \partial z_i + (c\theta_y + \theta_z) \partial V_i / \partial S = c, \quad \text{for } i \in L,$

where L is a set of the long run players. Let $z_i^*(t)$ denote the optimizer of Eq.(7). It is easily proved that the less $V_i(0, S(t))$, the higher the value of the optimizing z_i (See Figure-2).

Even if, after E(t) gets down to zero, the players of long run type are willing to spend a positive effort level on the abatement of emission, E(t) itself continues to decline because the myopic players do not recognize the global commons as a benefactor to their utility. Whether or not $z_i^*(t)$ increases depends on which of E(t) or the abatement effort of the long run players is more influential on S(t) in each period. If the former factor is more influential, $z_i^*(t)$ is raised, and vice versa.

Static externality: $z_i^*(t)$ was derived from the maximization of the utility of i-th long run player. When, however, each player of the long run type maximizes the sum of the utilities of all long run players, the objective function subject to the same income constraint changes to Eq.(10).

$$(10)\ \sum_i U_i(z_i, S) = \sum_i (I_i - cz_i) + \sum V_i(z_i,\ E(t) + \sum_i \int^t (c\theta_y + \theta_z) z_i\, dt)$$

From the condition for maximum, Eq.(11) is derived to determine the Parato optimum level of abatement effort.

$$(11)\quad \partial V_i / \partial z_i + (c\theta_y + \theta_z) \sum_i \partial V_i / \partial S = c$$

Denoting the Parato optimum level of effort by $z_i^p(t)$, it is proved from comparison of Eq.(11) with (9) that $z_i^p(t)$is bigger than $z_i^*(t)$. This means that at each point of time the abatement level of emission is higher under cooperative system of decision making than under non-cooperative system. The static externality among the long run players is corroborated.

Dynamic Externality: S(t) decreases at the rate of $\sum_i \theta_y I_i$, and increases at the rate of $\sum_i (c\theta_y + \theta_z) z_i$ at each point of time. As long as the latter effect is surpassed by the former effect, accordingly, the quality of the global commons is worsened at the next point of time, even if some positive effort was spent at the previous point of time. Therefore, other criteria than the Parato optimality is required in order to overcome the dynamic externality, if $\sum_i (c\theta_y + \theta_z) z_i^p(t)$ is less than $\sum_i \theta_y I_i$. We denote by $z_i^d(t)$ the effort level to set the former to be equal to the latter, which satisfies Eq.(12).

$$(12)\quad \sum_i \theta_y I_i = \sum_i (c\theta_y + \theta_z) z_i^d(t), \qquad \text{for } \sum_i z_i^d(t) > \sum_i z_i^p(t).$$

In what follows, we assume the case that $\sum_i z_i^d(t) \leq \sum_i z_i^p(t)$, that is, the case that social contract to achieve the Parato optirnality can overcome the dynamic externality at the same time.

Possibility of group actions. Let's suppose here that there is a number share of long run players. When this number share of the long run players can financially support at least, one political entrepreneur, he or she can enter the emerging market of organizing service. If that share is small yet, the situation is similar to an incipient stage of group actions, at which those actions can be organized only by some self-sacrificing volunteers, if any. They may be called a saint type with very long run time-horizon, but we assume away such a type in this paper. When, however, the number grows to the majority of the community, it becomes possible to adopt environmental policy in long run players' favor as a government policy. At this point of time, the will of the long run players can become the social will. We explain the above logic along the line of the model constructed above in this sub-section, except for arrangement of the long run players.

If it is assumed that each player of the long run type is arranged continuously in order of the level of E_t, beginning from the lowest, the number share of the long run players continues to increase, as $(nI\theta_y)t$ continues to rise owing to perpetual economic activity. This is because each of the long run players is assumed to perceive the crisis of the global commons from the data on $(nI\theta_y)t$. Here, it should be noted that income level is assumed to be the same for all players for simplicity. We can suppose, therefore, that as long as the long run player perceives the crisis of the global commons along the line mentioned above, the long run type grows to the majority of this community in the end. If the proportional system of representation is assumed, then at that time, political entrepreneurs representing the interests of the long run players can manage to take power.

This conclusion is based on the assumption that when the quality of survival conditions for human beings falls to a critical level, they expect a dangerous result from the present situation, and that at that point they put positive evaluation on their effort to stop the deteriorating process. Such a change of attitude begins from the long run player with the lowest level of E_L. The dynamic process of the growth of the long run type is shown in what is following:

At each point of time, the change in the quality of the global commons depends on the relative difference between the positive effect of abatement effort and the negative effect of economic activity. This relation is approximately shown in Eq.(13) to (16).

$$(13)\quad S(t) = E - \int \sum_{i} I\,\theta_{y}\,dt = E - (n\,I\,\theta_{y})t \qquad \text{for } t < t_{L}$$
$$- \int \sum_{i} I\,\theta_{y}\,dt + \int (c\,\theta_{y} + \theta_{z})\,z^{*}(t)dt, \quad \text{for } t \geq t_{L}$$

where t_L means the time when $\int \sum_i I\,\theta_y\,dt$ grows just to E_L, the lowest level of E.

$$(14)\quad dS/dt = \gamma\,(Z^{*}(t) - I), \quad \text{for } t \geq t_{L}$$
$$-I, \qquad \text{for } t < t_{L}$$
$$(15)\quad Z^{*}(t) = \sum_{j} \int (c\,\theta_{y} + \theta_{z})\,z^{*}(t)\,dt, \qquad \text{for } t \geq t_{L}, \quad j \cdot \text{long run type}$$

$$(16)\quad I = \sum_{i} \theta_{y} I = n\,\theta_{y} I$$

Eq.(14) means that as far as the positive effect of abatement effort of the long run players is less than the negative effect of economic activities of all community members, the quality of the global commons is aggravated further at that point of time. $Z^*(t)$ is the sum of the positive effect of the abatement effort of the long run players at the time of t. I, derived from Eq.(16), means the total negative effect of the economic activities of all members at each point of time. It should be noted here that $z^*(t)$ is the same value for all long run player at each point of time.

Since the number share of the long run players was assumed optimistically to increase in proportion to the data value on $(n\,\theta_y I)t$, the long run players could grow to the majority in the end. As long as, however, $Z^*(t)$ is less than $n\,\theta_y I$, the worsening process of the commons' quality can not stop under non-cooperative system. So, under the government representing the will of the long run players, the cooperative level of emission abatement is enforced on all individual players of any type, if that effort level can ensure each player against the crisis of the global commons. However, it is impossible for each country to protect itself from that crisis only by itself in the case of the global commons. We have to go beyond country border.

(3-2) Social Contracts for Preservation of the Global Commons

When the government of each country stands for the will of the long run players, we can suppose that it behaves as a player of international community. In this sub-section,

we assume that each player of an international game is the government representing the majority will of each country. When the governments take over player's role, transaction cost, monitoring cost, and punishment cost do not influence decision making so much as in the case of individual players. This is because negotiators dispatched by each government are supported by the overhead cost of each country. We call the government standing for the long run players of the country government-player of long run type. On the contrary, the government representing the myopic majority is called government-player of myopic type. We assume in this sub-section that each government belongs to either of those two types, and that it does not change its type. Furthermore, we assume that each of the long run governments is symmetric and that if all of the long run governments can make a cooperative effort for abatement, it becomes technically possible to stop the worsening" process of the quality of the global commons. On the other hand, they can not stop the worsening process under non-cooperative system of decision making.

Now, let's suppose there are n players, of which l counties are of the long run type, and that the long run players have the same income level. At any point of time, approximate indicator of the commons' quality, S(t), is assumed to take negative value under the non-cooperative system of decision making. That is, Eq.(17) is assumed to hold at any point of time.

$$(17)\quad S(t) = -\int^{t}\sum_{i} I_i\ \theta_y + \int^{t}\sum_{j} (c\,\theta_y + \theta_z)\, z^{*}(t)\, dt\ < 0, \quad \text{for } t \geq t_L$$

where i is a suffix for all players from 1 to n, and on the other hand, j is a suffix for the long run players.

The assumption that the worsening process of the global commons' quality can not stop under non-cooperative system is described by Eq.(18).

$$(18)\quad \sum_{i} I_i\ \theta_y\ >\ \sum_{j} (c\,\theta_y + \theta_z)\, z^{*}(t), \quad \text{for any } t.$$

On the contrary, the assumption that the cooperative actions of the long run players can ensure themselves against the worsening process is shown by Eq.(19).

$$(19)\quad \sum_{i} I_i\ \theta_y\ \leq\ \sum_{j} (c\,\theta_y + \theta_z)\, z^{p}(t), \quad \text{for any } t.$$

$z^*(t)$ is derived from the first order condition for the maximization of U_i with respect to z_i, which is shown by Eq.(20).

$$(20)\quad dV_i/dz_i = \partial V_i/\partial z_i + (c\theta_y + \theta_z)\,\partial V_i/\partial S = c, \quad \text{subject to } z_1 = z_2 = \ldots = z_i.$$

On the other hand, $z^p(t)$ is derived from the first order condition for the maximization of $\sum_i U_j$ with respect to $z_i(t)$, which is given by Eq.(21).

$$(21)\quad d\textstyle\sum_j dV_j/dz_i = \partial V_i/\partial z_i + (c\theta_y + \theta_z)\sum_j \partial V_i/\partial S = c, \quad \text{subject to } z_1 = z_2 = \ldots = z_i.$$

Comparing Eq.(20) with (21), it can be shown that $z^p(t)$ is larger than $z^*(t)$ (See Fig-3).

If the above game played by the long run players is only finitely repeated, each player has incentive to deviate from the cooperative effort level under the condition that other long run players stick to the cooperative effort level. The optimal effort level of deviating strategy is derived from Eq.(22).

$$(22)\quad dV_i/dz_i = \partial V_i/\partial z_i + (c\theta_y + \theta_z)\,\partial V_i/\partial S = c, \quad \text{subject to } z_j = z^p(t) \text{ for } j \neq i.$$

Let z_i' denote the optimal effort level of deviating strategy subject to $z_j = z^p(t)$ for $j \neq i$. It is proved that $z_i' < z^* < z^p$, and that $U_i(z_i') > U_i(z^p) > U_i(z^*)$ (See Fig.4).

Therefore, all of the long run players are involved in a prisoner's dilemma game, if the stage game is only finitely repeated. Is it, however, realistic for each long run player to conjecture that it plays some finitely repeated game in appropriating the global commons? It is not realistic, until some countries can find other places to live than on the earth. As long as all players have to live inside a closed boundary, they accept the reality that they are doomed to play an infinitely repeated game. Accordingly, we may assume that the long run players believe they play an infinitely repeated game.

Now, we can suppose that the long run players commit themselves to the cooperative effort for abatement of the greenhouse gasses. Each of them has to accept the effort level of $z^p(t)$ per period as obligation. While they are executing that policy, they have incentive to avoid being punished following any deviating behavior in the

infinitely repeated game.[1] This is the present situation of the global commons. However, when the non-signatories increase the volume of emission owing to continuing economic growth, the signatories can not treat all of emission only by their own effort at some point of time. When such a risk is anticipated, we have to devise some incentive designs by which the non-signatories are stimulated to participate in burden sharing for preservation of the global commons.

4. Tradable Emission-Permits

According to the logic of the last section, a finite number of the long run players can make a social contract that stipulates the obligatory effort level of abatement for each player to commit to. We assume implicitly that the problem of monitoring be overcome through checking data on consumed fossil energies. However, we did not mention about how each player manages to reduce the emission of the greenhouse gasses. We assumed only that each player has to spend some resources on fulfilling the obligation. With respect to effects on emission abatement, market system is more efficient than tax system. The latter system allows emitters to shift tax burden onto product prices without any effort of abatement, unless the tax burden is so heavy that the emitters can not shift it fully, or that a shift to more energy-efficient technologies is cheaper than paying the tax. In this section, we introduce the market regime of tradable permits into the model constructed in the last section. Furthermore, we examine the effects of that regime on incentive to the development of break-through technologies and the participation of the myopic players.

(4-1) A Model of Tradable Permits

If all signatories are perfectly symmetric, then there is no possibility for any emission permit to be traded among them. In this section, accordingly, we have to drop the assumption of symmetric players, and we assume that the cost for abatement effort is various from player to player. All of the long run players are ranked in order of the cost of abatement effort without losing generality, but it is assumed that there exists a player whose cost is the average of all players' costs.

[5] Of course, the punishment has to meet the renegotiation-proof condition. See Farrell & Maskin (1989), Fudenberg & Mskin (1988), and Barrett (1994a, 1994b).

Suppose that the obligatory level of effort is determined on the basis of the cost information of the average player ranked in the middle of the scale. Then, a half of the players belong to those with higher costs than the average, and other half with lower costs. Let $z^{ob}(t)$ denote the obligatory effort level at the period t, determined on the basis of the average player's cost. Then, for the players with higher costs the marginal costs corresponding to this effort level are higher than the corresponding marginal benefit, but on the other hand, for those with lower costs the marginal costs are lower than the marginal benefit. If all players on both sides of the average cost level are allowed to trade the abatement effort among themselves, the players with higher costs can fulfil their obligation at cheaper cost than by their own effort expenditure. And those with lower costs can obtain additional revenues by selling their effort to the former players (See Figure-5). It should be noted, it was assumed that the right of emission was equally assigned to each player.

According to the Fig.5, z^d is determined at the point that the marginal cost of the average player, denoted by c^d, is equal to the marginal benefit which is assumed to be the same for all players of the long run type. The optimal effort level for the player with lower cost, denoted by z_i^d, is bigger than z^d. On the contrary, the optimal effort level for those with higher cost, denoted by z_j^d, is smaller than it. Therefore, the latter type of player has incentive to buy the amount of $(z^d - z_j^d)$, and the former type to sell the difference of $(z_i^d - z^d)$. The price of emission permits will settle to some points between c_i and c_j. Where to settle depends on the competitiveness and bargaining system of the permits-market.

(4-2) Incentive to develop innovative technologies

The market regime of tradable emission-permits under discussion is confined to a type of player and a type of trade object. Only the long run players can enter the market for trade of permits. As long as, however, the obligatory level of abatement effort is determined by the maximization of total utility of market players, it is done on the basis of existing technologies, the level of which are approximately shown by $c_1, c_2, \ldots, c_i$. According to Nordhaus (1990), cutting the greenhouse gasses by 10 to 20 per cent can be attained at modest cost, which means that the marginal cost can be assumed to be constant in that range of reduction. However, drastic reduction such as 60 percent needs over $300 billions per annum in the world. It means that we have to suppose the marginal cost curve of reversal L shape. Under the market regime where the initial

assignment of the obligatory level of emission abatement is determined by consensus on the maxirnization of group interests, all players may be given some incentive to refine the existing technologies to attain a modest level of emission reduction. But they are not given sufficient incentive to develop break-through technologies, because it needs a consensus on higher obligatory level of emission abatement.

It takes long time and heavy cost to develop the so-called break-through innovative technologies, and if the gestation period is long enough, the market for permits under discussion can not take into allowance the present cost for the development of those technologies. In this sub-section, we propose an idea to give incentive to the development of those technologies.

We suppose that the gestation period of R&D for the break-through technologies is much longer than the period of any advance market for emission-permits. Let T denote the gestation period. Each player has to continue to spend the cost of C on the R&D project in each period, until it can be brought to fruition at the end of the period T. It is expected, however, that the cost of abatement effort drastically declines from the existing level of c^d to a new level of $c^{d'}$ after the period T onward. Therefore, the obligatory level of abatement effort is expected to jump up from the existing level of z^d to a new level of $z^{d'}$ (See Fig-6).

According to the above presumption, the expenditure of C in each period deserves an increase in the abatement effort of all members from the period of T onward. The value of this increase in terms of *numeraire*, denoted by $Z^d(T)$, is shown by Eq.(23).

$$(23)\quad Z^d(T) = c\int_T^{\infty} (z^{d'}(t) - z^d(t))\, l\, dt.$$

If the cost of C for R&D could be somehow convertible to $Z^d(T)$, the developers are given incentive to launch innovative projects for the development of innovative green technologies. For this purpose, some super-advance market should be designed, where C is traded for the future abatement effort. In order to set up such a market, agencies to evaluate the technical possibility of R&D projects have to play crucial role. $Z^d(T)$ should be discounted according as the evaluation.

One of the serious problems of market regimes under consideration or under planning nowadays is that developed countries with higher energy-efficiency have higher marginal costs than with lower energy-efficiency. This is because the former countries have been pur-suing energy-efficient technologies up till now, and therefore

do not have enough room to achieve further efficiency in the field of the existing technologies. However, they have higher possibility of developing the innovative technologies, thanks to accumulated effort of R&D expenditure on clean technologies, and therefore the jumping-up point of their marginal cost is lower than that of the countries with less energy-efficiency (See Fig-5). Even so, however, the obligatory effort level does not exceed that jumping-up point because that obligatory level is determined by social contract on the maximization of the group interests. Accordingly, the development of innovative technologies is not given any incentive under the above market regime, whilst it continues to give the countries with less-developed technologies incentive to indulge themselves in the less-developed situation.

CO_2 tax, in spite of its aiming at abating emissions, allows emitters to shift the tax burden onto product prices, unless the tax level is so high that the emitters can not shift it fully, or that a shift to more energy-efficient technology is achieved at cheaper cost than paying the tax. In this respect, the CO_2 tax can not be recommended as the means to emission abatement, if tradable-market regimes are sure to set at least an obligatory level of reduction in emission. According to Svendsen (1998), $50 should be taxed on a ton of CO_2 in order to achieve the goal of the tax regime. Such a level of tax is not realistic.

The total cost of all innovative technologies for energy saving, expected to be feasible from the year 2000 to 2010 in Japan, is estimated at about ¥54.7 trillions, and so annual average is about ¥5.5 trillions, according to CASA (1997). Of course, only a part of them such as solar energy and hybrid engines may be of innovative type in a true sense. However, reduction in the cost of energy expenditure is estimated at about ¥19 trillions per annum after the year 2010 onward. It means the repeated expenditure of 5.5 trillions per year for 10 years can bring about a drastic decline in the cost of 19 trillions ten year's later onward. The R&D expenditure of this type is not given proper incentive under the tradable-permits regime under consideration.

(4-3) Incentive to the participation of developing countries

According to the supposition of this paper, the myopic type of country-player has no incentive to join in the social contract for emission abatement owing to myopia measured approximately by high parameter value, E_M, of perceptibility level. For this type of player, the marginal benefit of any additional effort for abatement is negative, and so the optimal effort level should be zero. However, even the myopic type of player

has irresistible incentive to accept monetary reward, if it is a due compensation for his or her effort. So, we have to discuss on other incentives to the participation of the myopic players than direct benefit obtained from preservation of the global commons, In this sub-section we propose an incentive design by which effort to absorb or sequester emitted greenhouse gasses should be encouraged. Such an incentive design should allow the effort of the absorption or sequestration of emitted gasses to be traded among all types of players, because it can stimulate even non-signatory (myopic) player to make that effort.

Suppose that the marginal cost of afforestation or reforestation by the myopic players themselves is given by c_M which is constant. Denote by z_M and θ_M the absorption effort of the myopic player and its absorption coefficient, respectively. Then, the effort of absorption can be traded between the long run and the myopic players, if such a trade is allowed in a market. As a necessary condition for the trade, Inequality (23) must be met.

$$(24)\quad c_M z_M < p_M z_M < c_j z_j, \quad \text{for } z_j = z_M, \quad j \in \text{long run type},$$

where p_M is the market price of the afforestation or reforestation effort (See Figure-7).

The first part of Inequality (24) assures the myopic player that the market price of their absorption service exceeds their opportunity cost. The second inequality means that some long run players should be found out, whose marginal cost for abatement effort is high enough. Under this market regime the myopic players are given incentive to contribute to the absorption of emitted gasses through their own works of growing and preserving forests, which is technically feasible by their own technologies.

In order to give such an incentive to the myopic players, they do not have to be obliged to join in any social contract on targeted reduction in emission. It is enough for the long run players to admit that they allow one another to trade the absorption effort of the myopic players. It is enough for the social contract concluded by the long run players to include a provision stipulating they shall allow themselves to count the absorption effort bought from any non-signatory in their own right.

The above regime may seem to be similar to the Clean Development Mechanism discussed in COP3 in 1997, but is quite different in the point that the latter regime does not allow the non-signatories to trade their own effort of sequestration or absorption with the signatories, and that only the signatories have incentive to

afforestation or reforestation in the territory of the non-signatories. The effect on sequestration may be the same in technical sense, but the incentive to the participation of the developing countries is given only under the market regime proposed in this sub-section.

The developing countries have been criticizing the developed ones for the latter's not compensating the former for accumulated deterioration of the global commons' quality. And they have been insisting that they have their own right to put their first priority on the development of their economy. This argument implicitly implies that they have also their own right to deteriorate the quality of the global commons now. According to the idea of the property right, their logic appears to be absolutely right. They have an excuse to reject any social contract that stipulates all countries should share the burden to stop the deteriorating process of the commons' quality on equal footing. On the other hand, the developed countries can not accept the argument that they should compensate all countries for any deterioration without separating "accumulated" from "being accumulated," because that argument allows the developing countries to freely access to the global commons from now on. It seems that the interests of both sides, are in conflict too much to be reconciled.

As a compromise, the, idea of awarding emission right to each country in proportion to the size of population was suggested by Bertram (1992). It is an interesting idea, but that logic, which purported to be based on the property right, lacks an important aspect, as will be discussed in the next sub-section. What is worse, it does not give the developing countries any incentive for more energy-efficient technologies. As long as they can keep a big population, they can receive automatically a big volume of permits.

The market system suggested in this sub-section has an advantage of stimulating the developing countries to contribute to sequestration of the greenhouse gasses, even if they do not have to join in any international social contract to bind them to lower-rate of economic growth.

(4-4) Reexamination of the concept of the property right to the global commons

The global commons, taken as resources for common use on global scale, is a common pool resource for all world citizens of all generations, in the meaning that it is a necessary condition for the survival of the human species. The property right to the global commons, therefore, should be defined as the right of the survival of the human

species as a whole. Accordingly, we take into consideration the siuvival right of not only the present but also future generations when we have to define the property right to the global commons. It may be conceded that tradable-peimits regimes under experiment or planning take into allowance the right of the future generations by setting the target level of reduction in the total emission of greenhouse gasses. As long as the targeted level of total emission is determined on the basis of scientific finding on the survival condition, it may be admitted that the property right of the future generations is taken into allowance in spite of there being some room for maneuvering for evaluation of the scientific finding in present generations' favor. Regarding this maneuver, the present generation has common interests. With respect to how to assign the property right among the present generation, however, we have been facing with more severe conflict among all appropriators of the present generation. What should be the principle for the assignment of the right to the present generation?

When the global commons is recognized as a necessary condition for the survival of the human species, the so-called emission right is conceded only when the total of amassed emissions is below the level set by the future survival condition. Nobody of the present generation has the right of destroying survival conditions for the future generations. The targeted level of reduction in emission should meet this condition, on the condition that the scientific finding can provide proper information on that level. This is the first principle for any tradable-permits regime to meet.

Secondly, the present generation has to assign the initial property right to each member. Here, we have to take into consideration two principles related with the survival of the present generation. First, each member has his or her innate right for survival. Secondly, each member has the right to calculate his or her survival conditions on the basis of the present living standard. The first principle justifies the idea of "one-perrnit-per-head" proposed by Barrett(1994). The second principle may give a justification to the so-called grandfathering rule, but the right to improve the present living standard is not the same as that rule. Therefore, the initial assignment of the emission right to each country should be defined on the basis of two criteria, that is, population size and national income per head. This way of assignment leads each country to holding the initial assignment in proportion to the national income of that country. The permits are traded among all countries in accordance with market rules agreed by all signatories, after the initial assignment.

Finally, but not the least, emission accumulated in the past should be treated by

emitters responsible for it. Or the deteriorated quality of the commons caused by the past emission should be restored to the pre-deterioration level of quality by the burden of the emitters themselves. That restoration can be brought about through afforestation, reforestation and/or development of innovative technologies. The accumulated emission means a kind of "crime" committed by the past emitters, even if they did not anticipate harmful effects of then emission at the time of their emission. So, they have to atone for the crime. However, discussions on how to atone should be separated from those on how to aid less developed countries in developing their economy, even if those two problems can be solved by a measure at the same time.

Regarding the first and second principle of defining the property right, all countries have to take responsibility for joining in negotiation on equal footing. Even the developing countries can not escape from negotiation for binding themselves to concerted energy consumption. However, the developed countries are responsible for the great portion of the past emission. Unless they concede the past crime and try to take actions for atonement for it, the developing countries can resist against any idea that all countries have to share the burden for preservation of the commons on equal footing. The developed countries must not give the developing countries any excuse for rejecting negotiation on the burden sharing for the future generations. In this respect, the grandfathering rule, whose predecessor is traced back to the tradable-permits regime of EPA, has the serious problem of giving a good excuse for rejection to the negotiation, in addition to moral hazard problem suffered by that rule.

As a way to reconcile the first and second with the third principle for the definition of the property right, some incentive regimes can be suggested in accordance with the logic of this section. For example, markets for sequestration effect of forests can be designed in a way more favorable to the developing countries than to the developed ones. Or ecologically benign technologies can be sold to the developing countries at prices more favorable to them than to the developed countries. Without determination to take responsibility for the past emission anyhow, it is difficult to let non-signatories join in the social contract on equal footing.

5. Summary and Conclusions

One of the characteristics of the global commons is that it takes time and energy to perceive the seriousness of its deteriorating quality. It takes time, because only after a volume of emission has been accumulated, harmful effects can be perceived. It takes energy and cost, because we have to sacrifice a part of our present enjoyment for restoration of the quality of the global commons. We have to take into consideration these aspects of the time and energy, when we have to build models to describe benefit of the global commons. I approximately denoted those two aspects by a parameter value called the allowable limit of deterioration.

I classified all appropriators of the global commons into two types; the long run type and the myopic one. The former can obtain a positive benefit from preserving the global commons much earlier than the latter, because of lower value of the parameter. They can comprise the signatories that have intention to join in negotiation for preservation of the global commons. Such a negotiation can become possible, because the political entrepreneurs can enter organizers' market, provided that the long run type of player can grow to the majority. The pessimistic conclusion of Olsonian group theory was refuted by appeal to the existence of the political entrepreneurs.

International social contracts aimed at restoring the commons' quality are made possible, when each country player can represent the majority will of the long run individual players, regarding how to restore the quality of the global commons, tradable-permits regime is one of the focal points. In this paper, two problems with this regime were pointed out, and I proposed some refinements on the tradable-permits regimes under planning o

First of all, it should be emphasized that only a part of players in the world community are of the long run type yet. The myopic players have no intention to share the burden for restoration of the deteriorated quality of the global commons. Accordingly, the long run players have to devise special designs to give the myopic players incentives to making effort of the restoration. I proposed a tradable-permit regime to allow less developed countries to sell their effort of afforestation and reforestation in that market. This refined regime seems similar to the Clean Development Mechanism agreed in COP3, but is different in nature.

Secondly, a design for incentive to the development of innovative green technologies was proposed. The market regimes of emission permits under planing can attain a scale of reduction in emission, but in so far as the target level of the reduction is determined on the basis of the maximization of group interests subject to

the existing technologies, innovative technologies with long gestation period and huge cost are not given proper incentives for development. I proposed that some super-advance market for the development effort should be introduced into the existing tradable-permits regime.

Thirdly, it was insisted that the concept of the property right to the global commons should be reexamined. Any country has no right of disregarding the survival conditions for the future generations of the human species. In this respect, all countries have obligation to join in the burden sharing for preserving the global commons. And the initial assignment to the right should be in proportion to the national income of each country. However, developed countries are responsible for most of the emission accumulated in the past, and have to take responsibility of the" past crime." Without devising some measures for atonement for it, less developed countries can continue to resist against any idea of self-constraint on equal footing.

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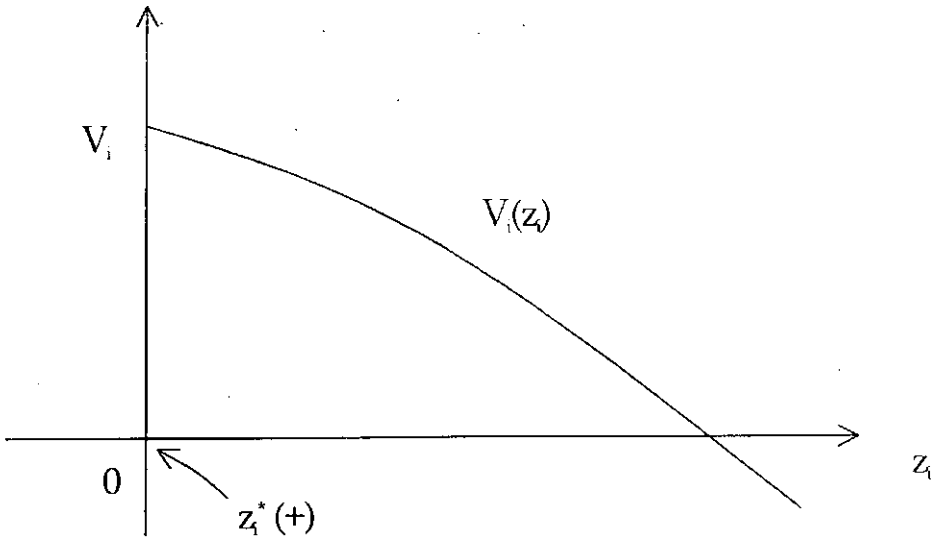

Fig. 2

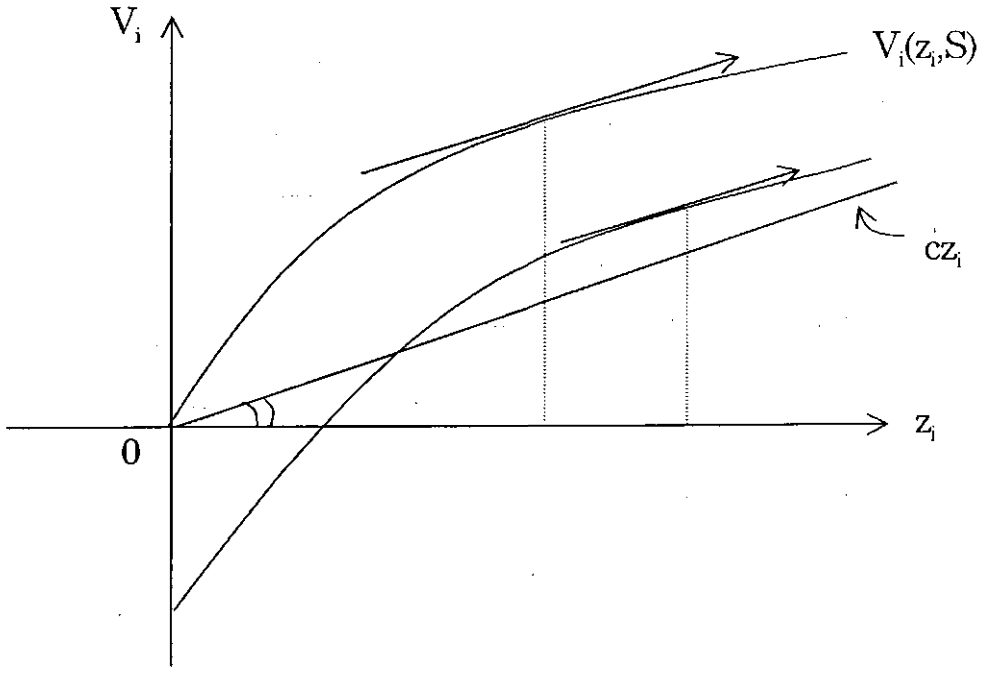

Fig. 3

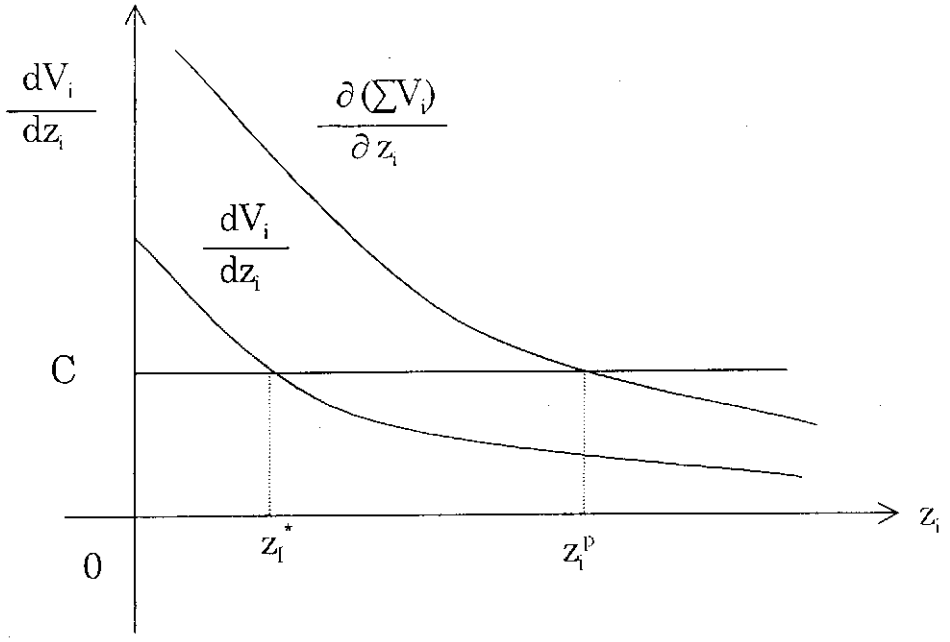
$\frac{dV_i}{dz_i}$
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Fig. 4

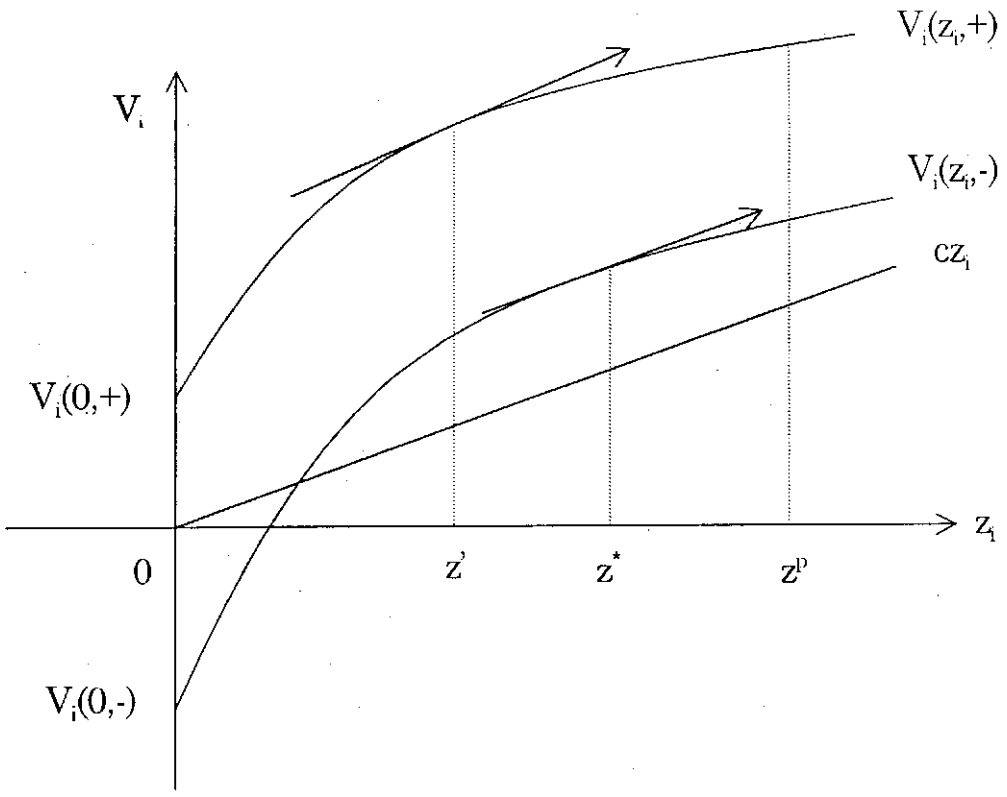
$V_i(z_i,+)$
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Fig. 5: Marginal Benefit and Marginal Cost

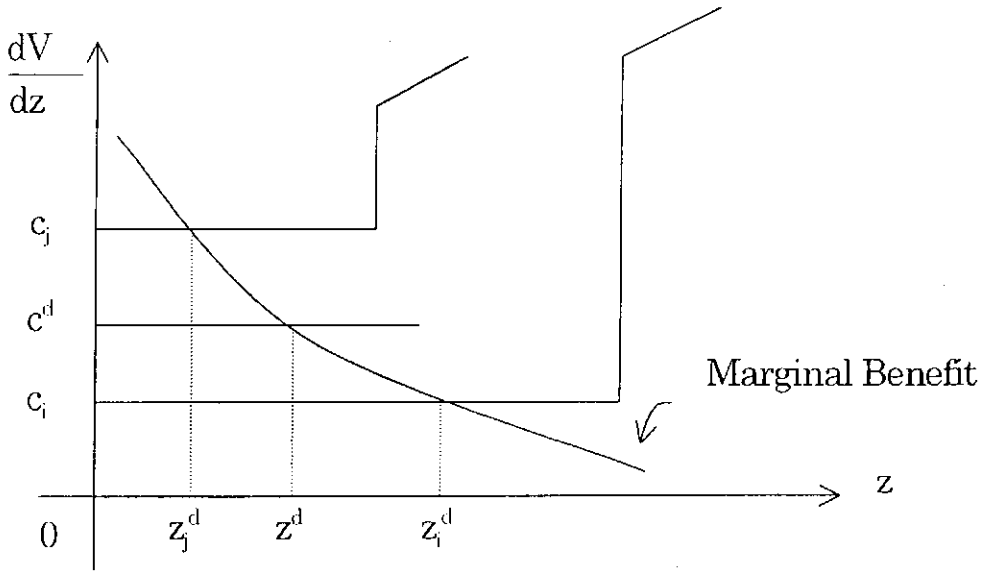


Fig. 6: Sift-Down of Marginal Cost

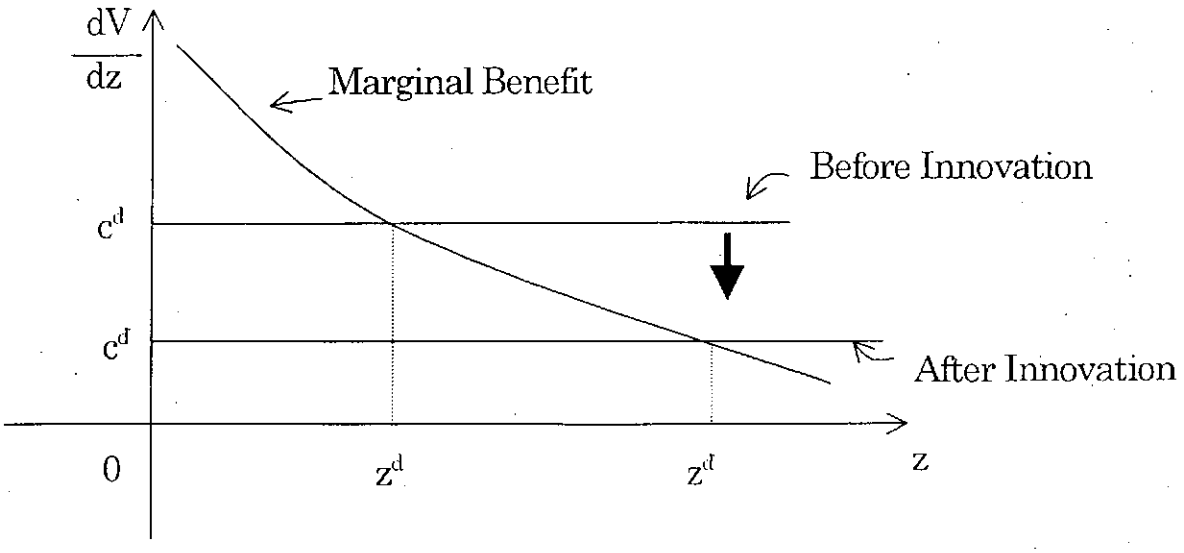
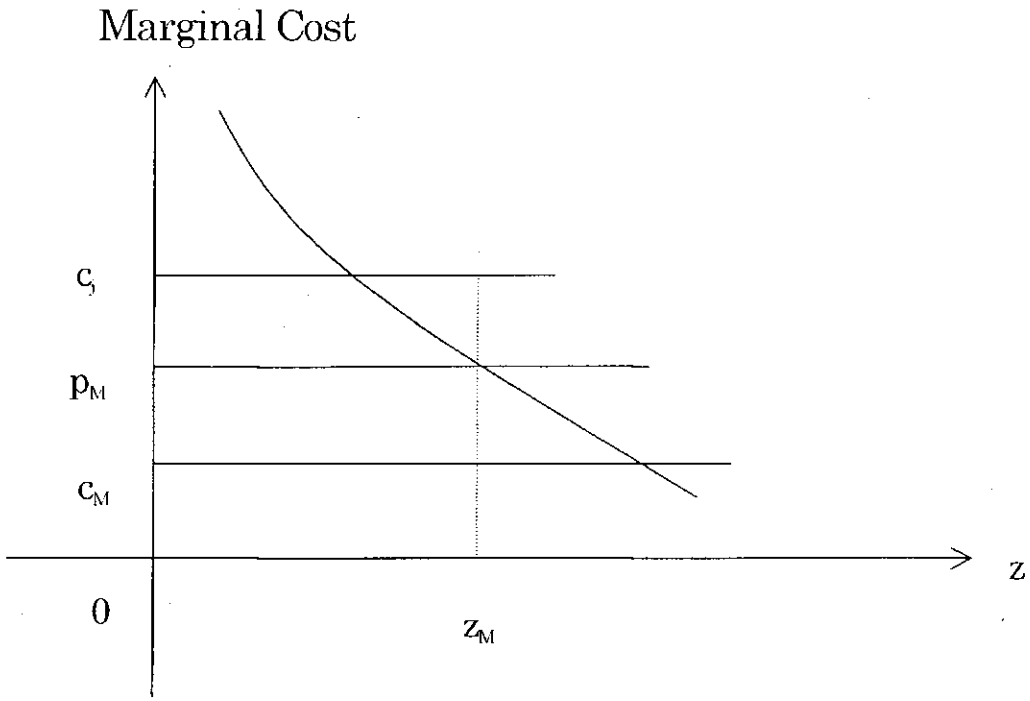


Fig.7



Management of the Global Commons: Problems with Property Right Approach

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Motivation

1. Ecologically conscientious voters (individual players of cooperative type) are organizing themselves into concerted action in the meaning that their favorite policies are being adopted by the government, in spite of the fact that each national community consists of a large group. Could the Olsonian logic be refuted? What is the missing link of the Olson's group theory?

2. In international negotiation games, the developed countries consist of a privileged group. They are playing an infinitely repeated game, and so they can pursue maximizing group interests (Parato optimum). When, however, less developed countries continue to pursue enjoying open access to the global commons, sooner or later, external effects caused by them may surpass recovery effects attained by the cooperative effort of the privileged group.

3. In this respect, market regimes under planning such as tradable emission-permits, have serious flaws. Proper incentives should be designed in order to stimulate the less developed countries to participate in cooperative actions and to encourage the developed countries to develop innovative green technologies.

4. The concept of the property right to the global commons should be re-examined in order not to give any excuse for rejecting negotiation on cooperative preservation of the global commons on equal footing.

Objectives

In order to achieve common interests, or to provide new collective goods, two processes must be gotten through and two kinds of cost barrier must be overcome:

(i) organizing process —> organizer's cost
(ii) providing process —> direct cost of provision.

Then, how can the appropriators of the global commons get through these two processes?

To answer that question,

1. I derive the logical possibility of the group actions of large group on the basis of the same behavioral assumptions of the Olson's group theory, by appeal to (i) the coexistence of various types of selfish-individualists, classified in terms of time-horizon, and (ii) the entrance of political entrepreneurs.

2. I propose (i) that super-advance market for the development of innovative technologies should be designed, (ii) that the market regime of afforestation effort made by any country should take over the Clean Development Mechanism, and (iii) that the concept of the property right to the global commons should meet three principles.

The Main Logic of Group actions

1. To get through the organizing process, political entrepreneurs, rationally selfish type of social organizer, must come into play at some stage. It is because any selfish individualist does not take on organizing work without compensation for the cost of the work owing to free-rider's incentive.

2. The political entrepreneurs weigh benefit against cost of their organizing work. The benefit depends on the possibility of full-time official works. The cost depends on the present cost to organize group members into agreement on group actions. Both benefit and cost depends on the number share of long-run type of player. The higher the share is, the higher expectation of benefit and the lower cost.

3. Though all players are assumed to be always selfish, they are classified in terms of the difference of time-horizon into two types;

   (i) long-run type —• maximization of long ranged payoff
   (ii) myopic type —* maximization of present payoff

4. In this paper the time-horizon is reflected in allowable ceiling to accumulated pollutants. It approximately expresses the perceptibility of seriousness of the commons' quality.

The allowable ceiling of the long run type, EL, is much lower than EM of the myopic type. When the total of accumulated emission increases up to the ceiling value, the quality of the global commons becomes a benefactor to utility of the long run type. However, the ceiling value of the myopic one is too high to put a positive evaluation on the commons' quality (Fig-1, Fig-2).

(1) $U_i (y_i, z_i, S) = y_i + Vi (z_i, S)$, $\quad i = 1,2,\ldots, l$.

(8) $U_i = (I_i - cz_i) + V_i (z_i)$, $\quad i = l+1, \ldots, n$.

Note: when accumulated emission reaches to E_L, $dV/dz > 0$.

(4) $S(t) = E - \sum_i \int^t (e_i + e_{-i}) dt$, $\quad E = E_L$.

(2) $e_i(t) = \theta_y y_i - \theta_z z_i \quad i = 1,2,\ldots, l$

(3) $I_i = y_i \square + c z_i \quad i = 1,2,\ldots\ldots n.$

(5) $S(t) = E (t) + \sum_i \int^t (c\theta_y + \theta_z) z_i dt$

(6) $E (t) = E - \sum_i \int^t \theta_y I_i dt$, $\quad E = E_L$ or E_M.

(1)' $U_i = (I_i - cz_i) + V_i (z_i, E (t) + \sum_i \int_t (c\theta_y + \theta_z) z_i dt)$,
$i = 1,2,\ldots, l$.

5. Optimization Under Non-Cooperative System of Decision Making

The optimization of the long run type (Fig-2):

(9) $dV_i / dz_i = \partial V_i / \partial z_i + (c\theta_y + \theta_z) \partial V_i / \partial S = c$, $\quad i = 1, 2,\ldots, l$

→ $z_i^* > 0$: the long run type is ready for accepting the direct cost.

The optimization of the myopic type (Fig-1):

(9)' Max $U_i = (I_i - cz_i) + V_i (z_i)$, $\quad i = l+1, \ldots, n$.

→ $z_i^* = 0$: the myopic type is not ready for accepting the direct cost of provision

6. Optimization Under Cooperative System of Decision Making and Static Externality

The Group optimization of the long run type (Fig-3):

(10) Max $\sum_i U_i(z_i, S)$, s.t. income constraint.

$$= \sum_i(I_i - cz_i) + \sum_i V_i (z_i,\ E(t) + \sum_i \int^t (c\theta_y + \theta_z)\, z_i\, dt)$$

$$\downarrow$$

(11) $\partial V_i / \partial z_i + (c\theta_y + \theta_z) \sum_i \partial V_i / \partial S = c$

$\rightarrow z_i^p > z_i^*$; Static Externality

7. Dynamic Externality

(12) $\sum_i z_i^d(t) > \sum_i z_i^p(t)$

$\sum_i \theta_y I_i = \sum_i (c\theta_y + \theta_z)\, z_i^d(t)$

(Note: the summation of (12) is over all i).

If it is assumed $\sum_i z_i^d(t) < \sum_i z_i^p(t)$, the worsening process of the commons' quality can be stopped by one country effort. In the case of the global commons, in general, this inequality relation does not hold, if the cooperative use is confined to one country.

8. The possibility of the group actions of the long-run type

If the players of long run type are arranged in order of the scale of E, the number share of the long run type continues to increase positively with increase in accumulated emission. At some stage, political entrepreneurs come into play to take on organizer's role. As long as the long run type can grow to the majority, the common will of the majority members can be pursued by the government.

Assumption:

$l \square 1/2 \cdot n$ for developed country
$l < 1/2 \cdot n$ for less-developed country

Isn't it possible that when survival conditions continue to deteriorate, the long run type can grow to the majority in developed country?

(13) $S(t) = E - \int^t \sum_j I\theta_y \, dt = E - (nI\theta_y)t, \square\square$ for $t < t_L$
$- \int^t \sum_j I\theta_y \, dt + \int^t (c\theta_y + \theta_z) z^*(t) dt$, for $t \geq t_L$

(14) $dS / dt = \gamma(Z^*(t) - \mathbf{I}) < 0$, for $t \geq t_L$
$-\mathbf{I}$, for $t < t_L$

(15) $Z^*(t) = \sum_j \int^t (c\theta_y + \theta_z) z^*(t) \, dt$, for $t \geq t_L$, $j \square$ long run type

(16) $\mathbf{I} = \sum_i \theta_y I = n\theta_y I$

(17) $S(t) = - \int^t \sum_i I_i \ell_y + \int^t \sum_j (c\ell_y + \ell_z) z^*(t) \, dt < 0$, $t \square t_L$

(18) $\sum_i I_i \ell_y > \sum_j (c\ell_y + \ell_z) z^*(t)$, for any t.

(19) $\sum_i I_i \ell_y > \sum_j (c\ell_y + \ell_z) z^P(t)$, for any t.

9. The developed countries consist of a privileged group of international game, and play an infinitely repeated game. The cooperative strategy of z_i^P is a subgame perfect equilibrium.

Assumption: the cooperative effort of the privileged group can stop the deteriorating process of the global commons' quality.

Super-game of the Long run Players : Symmetric Case (Fig-4)

Non-Cooperative Optimization:

(20) $dV_i / dz_i = \partial V_i / \partial z_i + (c\ell_y + \ell_z) \partial V_i / \partial S = c$, $z_1 = z_2 = \ldots = z_i$.

$\rightarrow z^*$

Group (Parato) Optimization:

(21) $d\sum_j dV_j / dz_i = \partial V_i / \partial z_i + (d_y + l_z) \sum_j \partial V_i / \partial S = c,\ z_1 = \ldots = z_l$

$\rightarrow z^p$

Free-Rider's Optimization:

(22) $dV_i / dz_i = \partial V_i / \partial z_i + (d_y + l_z) \partial V_i / \partial S = c,$
subject to $z_j = z^p(t)$ for $j \neq i$.

10. The dynamic externality on the world scale comes true some day,
if the income level of the developed countries continues to increase,
and if they are allowed to appropriate the global commons under open access system.

Tradable Permits Regime

1. Assumptions (Fig-5)

(i) Non-symmetric players,
(ii) A privileged group consisting of long run players, and
(iii) Cooperative effort is determined on the basis of the average player.

2. Incentive to the development of innovative technologies (Fig-6)

Maximization of group interests
subject to the existing technology —> no incentive for the innovation

The value of R&D in terms of abatement of emissions:
(gestation period = T, expenditure on R&D per period = C)

(23) $Z^d(T) = c \int_T^{\infty} (z^{d*}(t) - z^d(t))\, l\, dt.$

→ Super-advance market for Z^d

3. Incentive to the participation of developing countries

Tradable-permits regimes under planning do not give proper incentive for the afforestation effort of developing countries.

Necessary condition for trade of afforestation effort (Fig-7):

(23) $c_M z_M < p_M z_M < c_j z_j$, for $z_j = z_M$,

$j \in$ a set of long run players

Difference from the Clean Development Mechanism:

Incentive for afforestation effort by less developed countries

4. Reexamination of the Concept of Property Right to the Global Commons

The property right to the global commons should be explicitly defined from the point of view of survival right of the human species as a whole.

Three Principles:

(i) All appropriators of the present generation have take into due consideration of the survival right of the future generations.

(ii) The initial assignment of the right among the present generation should be in proportion to the national income level of each country.

(iii) The accumulated emissions in the past should be taken responsibility of by the past emitters.

5. New Criteria to Evaluate Aid Projects for Economic Development

Aid projects should be planned to compensate for past pollutions.

Aid projects should support the effort of emission abatement by beneficiary-country itself.

Aid projects should support NGOs in order to enlighten ecologically-unconscious players. This encourages political entrepreneurs to enter immature organizers' market in less-developed countries.

Fig-1

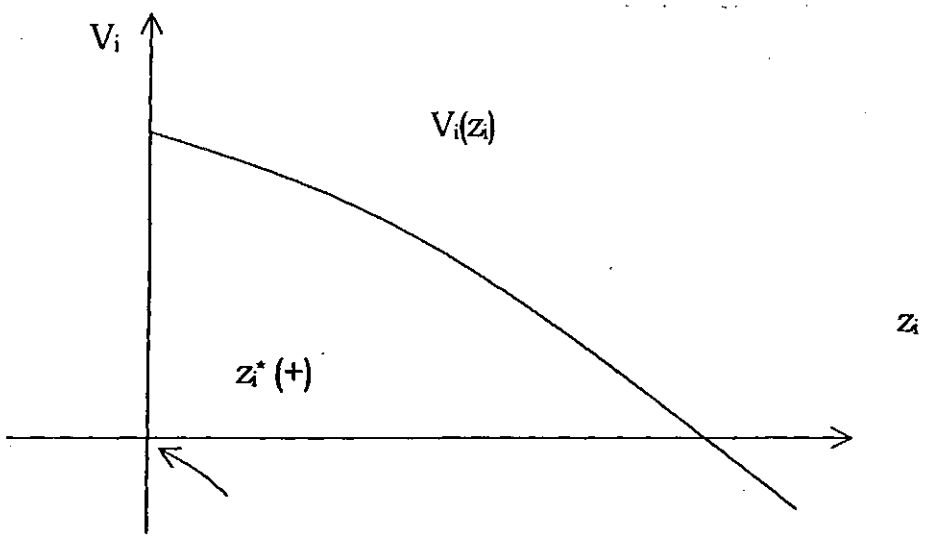

Fig. 2

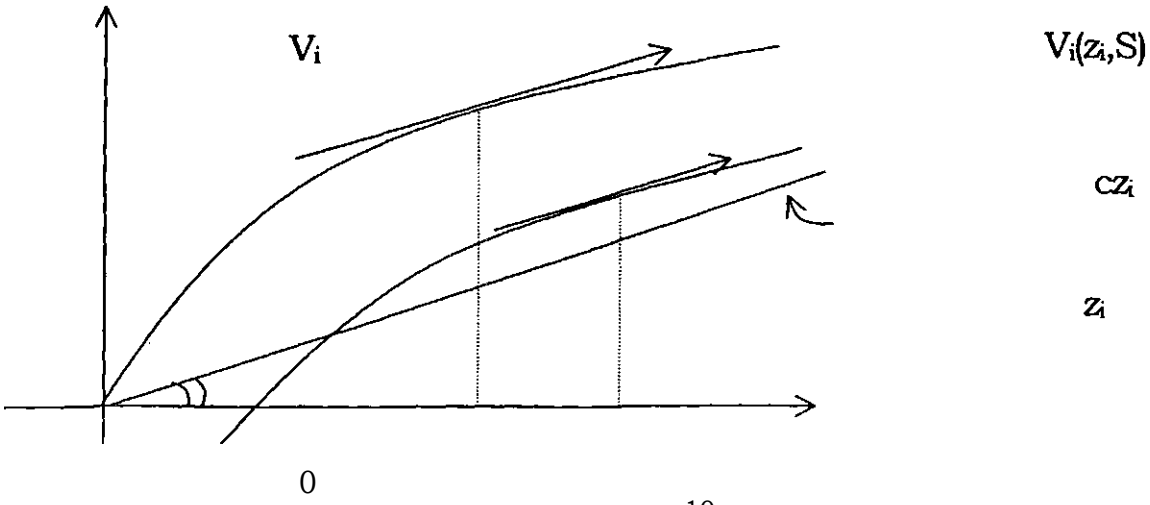

Fig. 3

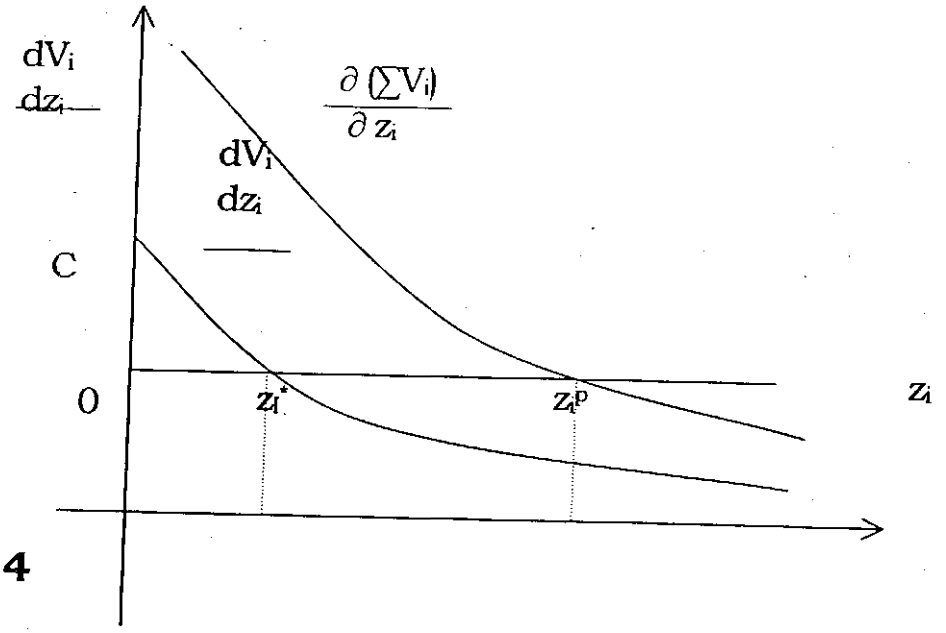

Fig. 4