Common Pool Resources and Social Norms: Internal cost & Less than Full Compliance – Fishery example

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Heechan Kang and Timothy Haab

1. Introduction

In the recent years, the social norms[1] have been gained much attention from the economists as an important driving force of individual behavior. In particular, a number of studies (Ostrom, 1990) on the management of common-pool-resource (CPR) [2]by decentralized (endogenous) institutions constituted by local communities of individual have continuously reported the significance of social norm in accounting for the efficient sustainability of CPR. As Hardin (1968) described, this type of resources would be destined to be extinct eventually without specifying property right or intervention of a third party. However, it has been claimed by a number of recent field studies that this tragedy-of-commons metaphor has been overcome in local commons such as forests, pastures and inshore fisheries (Ostrom, 1990; Somanathan, 1991; Bromley, 1992; McKean, 1992, and Acheson, 1993). In common, they argue that the social norm have always had a primary influence on an individual choice on CPR. A number of field studies also have documented that social norms usually are backed up by a variety of sanctions: frowning faces, verbal

[1] Social norm is a rule of behavior.

[2] N. McCarthy et al(2001) define that these resources are characterized by joint access by a finite set of users and by rivalry in appropriation and Ostrom et al (1994) define the CPR are natural or humanly created systems that generate a finite flow of benefits where it is costly to exclude beneficiaries and one person's consumption subtracts from the amount of benefits available to others

assaults, scorn and anger, destruction of equipment, formal punishments (fines) and so forth, which is deemed ‘external cost’ by non-compliers. Furthermore, a collective sanction becomes more imperative as the extent of its impact on CPR increase and mutual trust by itself may not be sufficient to control people’s behavior. In contrast, some scholars have acknowledged another type of cost, called ‘internal cost’ which emerges internally for breaking social norms thus have a negative effect on one’s utility. Coleman (1987) makes the distinction between ‘externalized norms’ and ‘internalized norms’. Crawford and Ostrom (1995) argue that even though the internal cost is not easily observed, the forbidden behavior by a norm can bring it about for one engaging in that action.

Despite the empirical documentation of potentially sustainable outcomes, however, theoretical explanations remain in their infancy. Since Hardin’s (1968) seminal work on the ‘tragedy of the commons’, a number of models based on neo-classical economics have tried to explain the existence of common pool resource equilibria consisting of partial compliance or defection (Sethi and Somanathan, 1996; Haab and McConnell, 2002). Of particular interest, evolutionary models of compliance, which incorporate the behavioral outcomes of others into individual decision making, have proven popular in explaining collective behavior problems associated with sustainable CPR outcomes. However, these evolutionary models fail to incorporate two commonly observed characteristics of common pool resource decision environments: partial compliance equilibria and costly sanctioning behavior.

Haab and McConnell (2002) develop a rudimentary evolutionary model of compliance behavior and show that heterogeneous distributions of compliance costs across a population can result in a less than full compliance equilibrium. The model of Haab and McConnell ignores the possibility of endogenous sanctioning of deviant behavior. Other evolutionary models of common pool behavior assume altruistic motives for sanctioning or costless sanctioning.

The purpose of this paper is to provide a theoretical explanation for partial compliance equilibria in a common pool resource allocation problem in the presence of costly sanction. First, the relationship between the external cost and the internal cost is provided. Second, with very stylized example such as fishery case where each player is assumed to play two stages evolutionary game, we will show that partial compliance exist and are stable, and furthermore, sanctioning behavior can be sustained by voluntary monitors among compliers.

2. Social norm, Sanction, communication and Internal cost

Of the particular features of common-pool-resource is the possibility of stock reduction rather than permanent abundance. One reflecting this feature is known as 'marginal user cost' or 'shadow price' of resource stock. Marginal user cost is an opportunity cost that appropriator pays for the reduction of a unit of future resource stock. Thus, if the future resource stock is not reducible, marginal user cost would be negligible. Beside non-renewable resource, stock of renewable resource can be reducible with harvesting activity when the harvesting rate is higher than the reproducing rate of that resource. According to neo-classical theory, with assumption of one harvester and one property right, this harvester is expected to maximize the present value of flow of profit over time. However, in a competitive harvesting situation (more than one harvester and no specifying property right), a rational harvester is expected not to consider this marginal user cost and maximize current flow of profit over time.

A process to make people to recognize this marginal user cost is known as 'internalization'. At first, we can imagine the conventional centralized enforcement such as legal penalty (fine) or subsidy for noncompliance to make people internalize the marginal user cost. Here, in the absence of central enforcement, we approach this problem in a different way. Once the social norm is constructed by people who regularly are involved in using CPR, people recognize the social code of behavior (what is something ought or ought not). This rule of behavior already personalized in one's mind can berate himself emotionally who does not obey a social norm and can be shared or transmitted through a channel of a persuasion. Here, this emotional self-rebuke is classified as an internal cost while the external persuasion employs carrot-and-stick expressed as communication (or moral suasion) and social (or personal) sanction. In other words, some individuals have an initial propensity to follow a norm because their embodied social norm can entail sufficient internal cost. Further, they are willing to keep persuading other people to recognize socially accepted norm by means of sanction and communication until almost everyone reciprocates and suffers sufficient level of internal cost.

The general pattern of individual's internal cost revealed in usage of common-pool circumstance is that it can be influenced by others' strategies (Haab and McConnell, 2002). For example, they find that the recreation boaters are less likely to throw trash overboard when never seeing others discharging trash while they are more likely to throw trash overboard when observing others discharging trash. In other words, individuals may account for the actions of others when choosing their own behavior. This finding implies that as the number of defectors increases, individual would feel less guilty (less internal cost) when he chooses defection because it is not easy to separate his defecting behavior from many other defectors'.

As for sanctions, we only focus on the totally decentralized social enforcement. In particular, we assume that each member of CPR is not allowed to be directly involved in personal sanctions. Instead, an endogenous institution takes charge of sanctioning any members of CPR engaging in defecting behaviors that are detected and reported by other members. As for social communication, like Ostrom (1990), who argues that commoners often establish an institution in order to 'enforce' and 'share' the established norms, we assume that the endogenous institution not only sanctions defectors but also arranges regular meetings to establish communication processes to convince members to adhere to social norm.

While the idea of the external persuasion process such as social sanction and communication is intuitively appealing, its real effect on individual's internal cost is activated only when these two processes comes together. The single-handed use of social sanction may be deemed a physical cost dispossessing a benefit acquired from a defecting attempt so that it may not be effectively transmitted into ones' internal cost. On the other hand, the external persuasion with only communication may be regarded as an ineffective and untrustworthy method. As a result, with aid of social sanction, communication process can have an impact on each individual's own internal cost. On the other hand, with existence of a given level of communication process, social sanction can increase individual's internal cost.

The central insight of external persuasion is that it necessarily aggrandizes the extent of its level until everyone reciprocates and reaches a sufficient level of internal cost. In design principles of CPR in ‘Governing the Commons’ by Ostrom (1990), she argues that successful management CPR has been achieved by ‘graduated punishments’. Here, by extending her argument, we propose an external graduated persuasion process which can be intensified in accordance with the number of the defectors among the total number of appropriators. Equation (1) shows the external graduated persuasion process is a function of social sanction (S) and communication (C) both of which is intensified with the share of defectors (d). Here, As a proxy of number of defectors, we choose a share of defectors (d) which is a ratio of the number of defectors (D) over total number of appropriators (N) ($d = D / N$).

$$EP = f(S(d), C(d)) \geq 0 \text{ where } \partial S / \partial d > 0 \text{ and } \partial C / \partial d > 0 \quad (1)$$

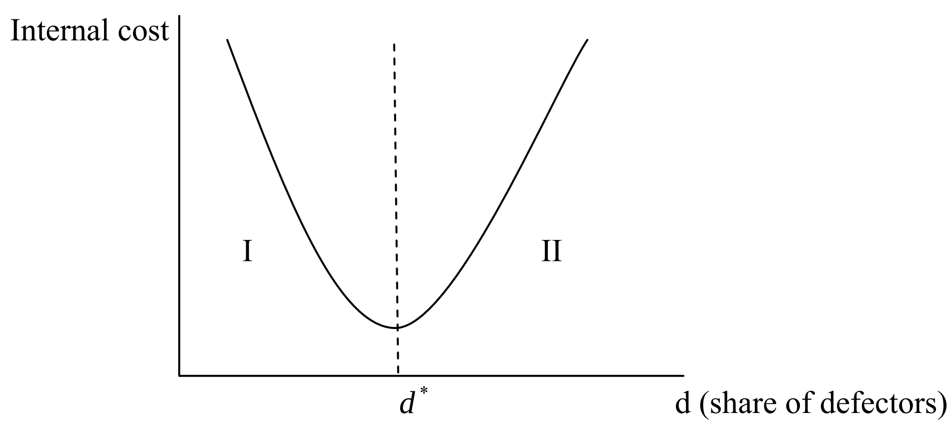
To describe the mechanism of evolutionary behavior of defectors versus compliers, we need to examine the functional relationship of the internal cost with the number of defectors and the external persuasion. Here each individual is assumed to have a different internal cost affected by the share of defectors (d) and external persuasion (EP).

$$IC_i = IC_i(d, EP(d)) \geq 0 \quad (2)$$

All individuals find that internal costs are non-increasing in the share of defectors $\partial IC_i / \partial d \leq 0$, and non-decreasing in the level of external persuasion $\partial IC_i / \partial EP(d) \geq 0$. Since previously we assume that the external persuasion is strengthened in accordance with the share of defectors ($\partial EP(d) / \partial d \geq 0$), the function of internal cost can be simplified as $IC_i = IC_i(d) \geq 0$ and thus as can be seen, the total impact of the share of defectors on individual’s internal cost is ambiguous ($\partial IC / \partial d \geq, = or \leq 0$).

According to this argument, the internal cost can either increase or decrease with the share of defectors, depending on prevalence of two oppositely directed effects. Internal cost is influenced not only reciprocally on one others' strategies, but also by sanctions and communications. In one sense, as the number of defectors increases, individual would sense less guilty when he chooses defection (called 'negative effect'). In another sense, as the number of defector increases, the external persuasion is intensified and thus individual would feel more guilty (called 'positive effect'). As assumed before, the impact on internal cost by negative effect and positive effect is idiosyncratic. Heuristically, with initially fewer defectors, the negative effect is assumed to override the positive effect, while with larger defectors, the positive effect is assumed to dominate the negative effect.

<Figure 1> individual's internal cost and share of defectors[3]



<Figure 1> shows a general prototype of relationship between individual's internal cost and the share of defector, in which the internal cost is U-shaped decreasing (an area I) and then increasing (an area II) with d . The switching point (d^*) is not necessarily the same for all people. Some people who have stronger negative effect are more likely to have d^* on

[3] Mathematically, in order to show quadratic function like U-shape, it is necessary to be assumed that the positive effect should increase faster with the share of defectors than the negative effect decrease. In other words, $\left|\frac{\partial IC}{\partial EP}\frac{\partial EP(d)}{\partial d}\right| > \left|\frac{\partial IC}{\partial d}\right|$. However, here, the decreasing and then increasing internal cost with the share of defectors like V-shape is sufficient.

the right side and some people who have stronger positive effect are more likely to have d^* on the left side. On average, d^* is assumed to be located in the middle.

To explain evolutionary system, let us assume that there is a hypothetical endogenous club of fisherman called the fisherman's club, composed of all fishermen (N) in a given community. All new entrée into the fishery of this area should affiliate with this club[4]. We assume that in this small and closed group, people know each other well, can communicate easily and actions taken by others are easily observed. This club has an institution in charge of three main executive roles; first, it constitutes a council establishing the internal rule (norm) binding each fisherman's harvesting level. Second, it arrange meeting. Third, it has authority to allow any member of the club to monitor the defecting behavior in fishing levels, and when reported, sanction certainly those defectors instead of monitor.

In this club, there are three kinds of members: compliers (C) who follow the social norm instituted by the council, defectors (D) who refuse to follow this norm, and monitors (M) who not only follow the social norm but also voluntarily monitor and report the defecting behavior at his own cost.

Although these three different kinds of people (defector, complier and monitor) appear to coexist in the club at a particular time, we assume, there is hierarchical decision process where each individual first chooses between becoming 'a complier' and 'a defector', and then second takes position as either 'a simple norm follower' or 'a monitor'. In the first decision stage, we assume that each fisherman can choose harvesting level either at h^N (defector's harvest level) or at h^C (complier's harvest level). Harvesting levels in the middle are unavailable. However, the average level of harvesting in this club can be any level

[4] We assume that new agent (entrée) can reduce the wealth of the former agent, and thus the cost of collective good depends on the size of the user group. See Aggrawal and Goyal (1999) for analysis of the case of scale economics in monitoring costs.

between h^N and h^C because the average harvesting level ($\overline{h}$) of this community is determined by the following formulas $\overline{h} = d * h^N + (1-d) * h^C$, and $h^N \leq \overline{h} \leq h^C$

In general, people always compare benefit and cost of their strategies. If the defecting benefit exceeds the defecting cost, then people choose to be defectors and vice versa.

The defector's payoff changes as follows:

$$\Pi^N(h^N, x) = \pi_i^N(h^N, x) - IC_i(d, EP(d)) - S(d) \quad (3)$$

where the defector may incur internal costs (IC_i), or external cost like sanction ($S(d)$) or both.

The complier's payoff is likewise:

$$\Pi^C(h^C, x) = \pi_i^C(h^C, x) \quad (4)$$

[5]

Here we define that an individual's defecting benefit (DB_i) is

$$DB_i = \pi_i^N(h^N, x) - S(d) - \pi_i^C(h^C, x)$$

where $\pi_i^N(h^N, x)$ and $\pi_i^C(h^C, x)$ defector's and complier's revenue function, respectively increasing with harvesting level (h^N, h^C) and other composite goods (x), and $S(d)$ is the graduated social sanction by the endogenous institution. We assume that this graduated social sanction is a stochastic variable because some defecting behavior may not be perfectly detected by monitors, all defecting behaviors may not be reported by monitors, and some monitors can be involved in private sanction although not permitted. On the other hand, an individual's defecting cost (DC_i) is equivalent to internal cost

$$DC_i = IC_i(d, EP(d))$$

[5] It is possible that the compliance behavior can incur costs, especially opportunity cost such as specific time cost to follow social norms. Here we assume that this cost may be constant so that it is not affected by the share of defectors.

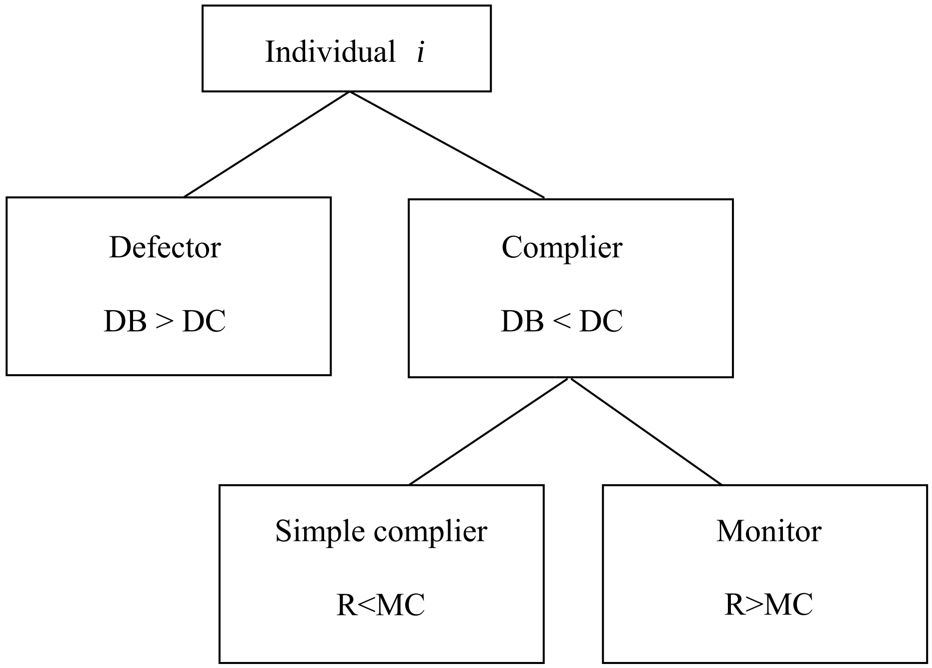
In the second decision stage, compliers choose either to be simple compliers or monitors. It may be essential that monitoring behavior entails the costs, for example, monitoring times. If this kind of cost is not sufficiently remunerated, it is irrational for monitor to incur a private cost. We propose that monitoring behaviors are supported by all compliers who observe them, who send positive image scorings ('reputation') to monitors.

3. Evolutionary Game with internal cost

The main differences of the evolutionary game from conventional game theory are that it assumes that each individual participates in the infinitely repeated game and exhibits limited rationality instead of full rationality. Thus, with his/her trial and error experience from an infinitely repeated game, he/she must choose the most profitable strategy at each stage instead of accurately calculating all future payoffs based on his/her own best strategy and other's expected strategies. This approach is based on the principle that what works well for one player is more likely to be used again while what works poorly is more likely to be discarded (Axelord, 1984). The evolutionary principle works as though the more effective species are more likely to survive and reproduce in the biological systems. In particular, players observe each other and one who produces lower payoffs tends to imitate those who produce higher payoffs.

With all above assumptions, we investigate the dynamics of a population through an evolutionary model. The norm game is described in <Figure 2>.

<Figure 2> Two stages norm game



DB the defecting benefit
DC defecting (internal) cost
R reputation (positive image scoring)
MC monitoring cost

3.1 Only one stage game

In this section, we investigate the simplest case in which the external persuasion are not involved so that each individual only chooses either to be a complier or a defector according to his/her defecting benefit ($\pi_i^N - \pi_i^C$) and internal cost (IC_i). The endogenous institution only engages in specifying social norms. Thus, here we can expect that each member is involved in only a norm-guided restraint behavior. Based on this assumption, we will show that full compliance equilibrium is rarely possible and that full defection equilibrium is more feasible.

First, a defector's payoff is

$$\Pi^N(h^N, x) = \pi_i^N(h^N, x) - IC_i(d)$$

A complier's payoff is

$$\Pi^C(h^C, x) = \pi_i^C(h^C, x)$$

The change of the proportion of defector follows;

$$\dot{d} = d(\Pi^N - \overline{\Pi}) \qquad \text{Where } \overline{\Pi} = d\Pi^N + (1-d)\Pi^C \tag{5}$$

This equation indicates that the proportion of defector increases over time if the defector's payoff is larger than average payoffs. In other words, people keep comparing defector's payoff to average payoff, and if the defector's payoff is greater than average payoff, then compliers will adopt the defectors' strategy and incumbent defectors will continue their strategy. Equation (15) can be written as

$$\dot{d} = d(\Pi^N - d\Pi^N - (1-d)\Pi^C) \tag{6}$$

$$= d(1-d)(\pi_i^N(h^N, x) - IC_i(d) - \pi_i^N(h^C, x))$$

In this one stage game, we note that a defecting benefit is $DB_i = \pi^N - \pi^C$ while a defecting cost is $DC_i = IC(d)$. A net defecting benefit (NDB_i) is

$$NDB_i = \pi_i^N(h^N, x) - \pi_i^C(h^C, x) - IC_i(d) \tag{7}$$

Based on equation (7), we can infer that current defectors can increase their net defecting benefit, as more people become defectors because IC_i decrease with d . Thus, once they have become defectors, they have no incentive to return to compliers because otherwise, they realize that the comparing net defecting benefit diminishes. On the reasonable inference, we assume that the defecting benefit is always non-negative ($\pi_i^N - \pi_i^C \geq 0$), otherwise, the society is always full of compliers. In addition, we assume that each individual has a minimum defecting (internal) cost level in his mind below which his internal cost cannot plummet even when all other people become defectors.

To find the stable equilibrium of this equation, it is required that the derivative $\dot{d}$ with respect to d is negative at each equilibrium point.

$$\frac{\partial \dot{d}}{\partial d} = (1-2d)\left[\pi_i^N - \pi_i^C - IC_i(d)\right] - d(1-d)(\frac{\partial IC_i}{\partial d}) \quad (8)$$

At $d = 1$, $\frac{\partial \dot{d}}{\partial d} = \Pi^C - \Pi^N$ and is negative when $\Pi^N > \Pi^C$. (9)

At $d = 0$, $\frac{\partial \dot{d}}{\partial d} = \Pi^N - \Pi^C$ and is negative when $\Pi^C > \Pi^N$. (10)

At $d = d^*$ where $0 < d^* < 1$ and $\Pi^C = \Pi^N$,

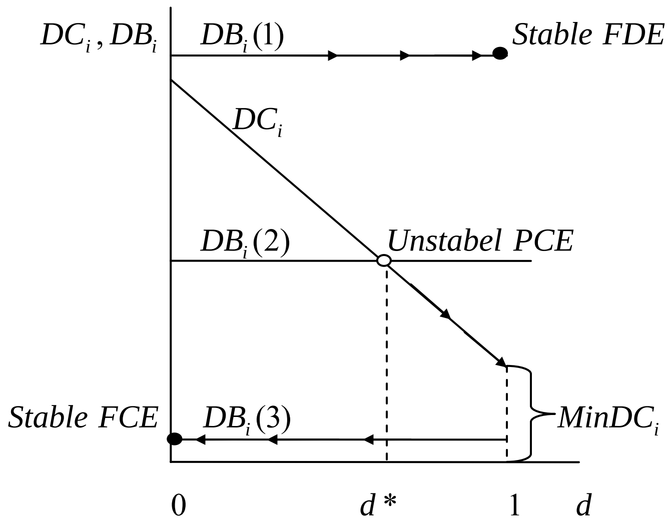
$$\frac{\partial \dot{d}}{\partial d} = -d^*(1-d^*)(\frac{\partial IC_i}{\partial d}) \quad (11)$$

And can not be negative since $(\frac{\partial IC_i}{\partial d}) < 0$

Based on derivative (9), it is evident that if 'defecting benefit' ($DB_i = \pi^N - \pi^C$) is greater than 'defecting cost' ($DC_i = IC_i$) at $d = 1$, then a full defection equilibrium is stable. A derivative (10) suggests that if defecting benefit is less than defecting cost at $d = 0$, then full compliance equilibrium can be stable. Based on (11), if the share of defector lies in $0 < d^* < 1$, then the path does not stay in this equilibrium but converges to the full defection equilibrium.

<Figure 3> shows stable Full Defecting Equilibrium (FDE) and stable Full Compliance Equilibrium (FCE) and unstable Partial Equilibrium.

<Figure 3> The stable FDE and FCE and the unstable PCE



In <Figure 3>, we assume arbitrarily that there exist three different levels of defecting benefits ($\pi_i^N - \pi_i^C$) such as $DB_i(1)$, $DB_i(2)$ and $DB_i(3)$ depending on the relative magnitude between π^N and π^C. We note that defecting cost (DC_i) is decreasing with the share of defectors due to the reciprocal influence of the others' behaviors. Apparently, when the defecting benefit is extremely higher than the defecting cost ($DB_i(1) > DC_i$), full defecting equilibrium (hereafter FDE) is stable while full compliance equilibrium (hereafter FCE) is stable when the defecting benefit is extremely lower than minimum defecting cost ($DB_i(3) < MinDC_i$). However, in this case, we should note that this stable FCE exists only if we assume the minimum defecting cost ($MinDC_i$); otherwise, this path would converge inevitably to the full defecting equilibrium since we assume strictly positive defecting benefit ($\pi^N - \pi^C > 0$) and irreversible conversion from compliers to defectors governed by decreasing individual's internal cost. The partial compliance equilibrium is unstable over

$0 < d < 1$ because a conversion of one more person to a defector can make each individual's defecting benefit exceeds defecting cost ($DB_i > DC_i$), leading to the conversion of everyone else into defectors while inverse movement is unattainable since the internal cost is assumed always decreasing.

These results suggest that the management of CPR with social norm backed only by internal cost may be unsuccessful. In fact, if 'all' members of a community have a high internal cost where even the minimum internal cost is higher than defecting benefit ($MinIC_i > DB_i$), then a CPR can be managed efficiently. However, if individual's internal cost is heterogeneous (some people have low internal costs while others have high internal costs), then this CPR would be doomed to extinction, which is another example of 'tragedy of commons'. Since heterogeneous internal cost among people is the most predictable case and we are unsure of whether a minimum internal cost exists for all people, a more reasonable case is a stable FDE. Therefore, in the next section, we will seek for the possibility of breakout from 'tragedy of commons' by including the external persuasion.

3.2 Two stages game.

3.2.1 The first stage

In this chapter, we add the second stage and consider the stage 1 and the stage 2 at the same time. The main difference from the previous model is that the endogenous institution can use the external persuasion process. As described before, the external persuasion process is only effective when the social sanction and communication are operated together. Here, we will show that the external persuasion process with only the social sanction can achieve the stable FCE only for a limited circumstance. On the other hand, the external persuasion process with both the graduated punishment rule and communication process can achieve not only stable FCE but also stable partial compliance equilibrium (hereafter PCE).

(1) A game with the internal cost and the external graduated persuasion

Here we investigate the most general case in which the endogenous institution chooses the social graduated sanction and the communication process.

The defector's payoff function changes as follows:

$$\Pi^N(h^N, x) = \pi^N(h^N, x) - IC_i(d, EP(d)) - S(d) \qquad (12)$$

Now, the main difference between this and the previous defector's payoff is that the graduated sanction can affect the defector's payoff directly and indirectly as an argument of internal cost. The main reason the graduated sanction is included in the internal cost is that we assume that a communication process exists among members to persuade people to recognize the possibility of sanctions and to adhere to the social norm. As we investigated in the section 3, the changes in the internal cost along with the share of defectors rely mainly on the relative predominance between the positive effects and the negative effects. Here, as before, we assume the U shape of internal cost.

The complier's payoff function is the same as before.

$$\Pi^C(h^C, x) = \pi^C(h^C, x)$$

The change of the proportion of defector follows;

$$\dot{d} = d(\Pi^N - \overline{\Pi}) \text{ Here } \overline{\Pi} = d\Pi^N + (1-d)\Pi^C \qquad (13)$$

$$= d(1-d)(\pi^N(h^N, x) - IC_i(d, EP(d)) - S(d) - \pi^C(h^C, x))$$

Again, we define defecting benefit as $DB_i = \pi^N - \pi^C - S(d)$ while defecting cost is equivalent to $DC_i = IC_i(d, EP(d))$. Now, we note that the defecting benefit is no longer constant but decreasing with the share of defector because sanction is assumed to intensified with the share of defectors ($\partial S(d) / \partial d > 0$). A net defecting benefit (NDB_i) is

$$NDB_i = \pi^N(h^N, x) - \pi^C(h^C, x) - IC_i(d, EP(d)) - S(d)$$

Compared to the previous no external persuasion case, this defector may not always increase his net defecting benefit with more defectors because thereby they may suffer more social sanctions and more internal cost. Possibly, they may have incentive to return to compliers as internal cost and the external persuasion increase.

Here as assumed before, individual's defection benefit can not be negative ($\pi^N - \pi^C - S(d) > 0$)[6]. In other words, even if possible, endogenous institution may set the maximum level of social sanction until defecting benefit is zero.

The stable equilibrium condition requires that the derivative $\dot{d}$ with respect to d is negative at each equilibrium point.

$$\frac{\partial \dot{d}}{\partial d} = (1-d)(\Pi^N - \Pi^C) - d(\Pi^N - \Pi^C) - d(1-d)\left(\frac{\partial IC_i(\cdot)}{\partial d} + \frac{\partial IC_i(\cdot)}{\partial EP}\frac{\partial EP}{\partial d} + \frac{\partial S}{\partial d}\right) \qquad (14)$$

$$\text{At } d = 1,\ \frac{\partial \dot{d}}{\partial d} = \Pi^C - \Pi^N \text{ and is negative if } \Pi^N > \Pi^C. \qquad (15)$$

$$\text{At } d = 0,\ \frac{\partial \dot{d}}{\partial d} = \Pi^N - \Pi^C \text{ and is negative if } \Pi^C > \Pi^N. \qquad (16)$$

[6] This assumption is only for a convenience. The endogenous institution can increase the level of the graduated sanction as much as to make the defecting benefit zero or negative. In either case, there would be no room for internal cost. We assume that one of the main goals of the sanction is to increase or foster each individual's internal cost. Thus, the endogenous institution may not choose the policy, which expels all possibilities to increase internal cost.

At $d = d$ ($0 < d < 1$) and $\Pi^C = \Pi^N$,

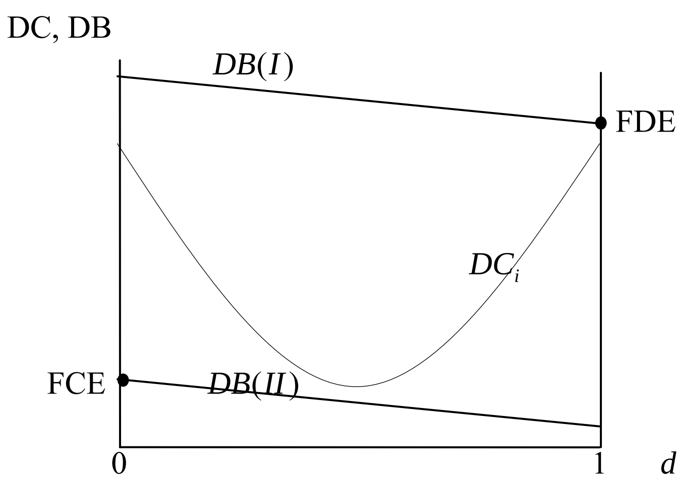
$$\frac{\partial \dot{d}}{\partial d} = -d(1-d)\left(\frac{\partial IC_i(\cdot)}{\partial d} + \frac{\partial IC_i(\cdot)}{\partial EP}\frac{\partial EP(d)}{\partial d} + \frac{\partial S}{\partial d}\right) \qquad (17)$$

And this is negative only if $\left(\frac{\partial IC_i(\cdot)}{\partial d} + \frac{\partial IC_i(\cdot)}{\partial EP}\frac{\partial EP(d)}{\partial d}\right) + \frac{\partial S}{\partial d} > 0$

FDE is stable (equation (29)) if $\Pi^N > \Pi^C$ is true at $d = 1$. FCE is also stable (equation (30)) if $\Pi^C > \Pi^N$ is true at $d = 0$.

<Figure 4> shows the potential cases of FCE and FDE. In contrast to the previous only one stage game, internal cost is more likely to show U shape because there is interaction between the negative effect ($\frac{\partial IC_i(\cdot)}{\partial d}$) and the positive effect ($\frac{\partial IC_i(\cdot)}{\partial EP}\frac{\partial EP(d)}{\partial d}$). We also note that the defecting benefit ($\pi^N - \pi^C - S(d)$) is decreasing with the share of defectors

<Figure 4> the stable FCE and FDE

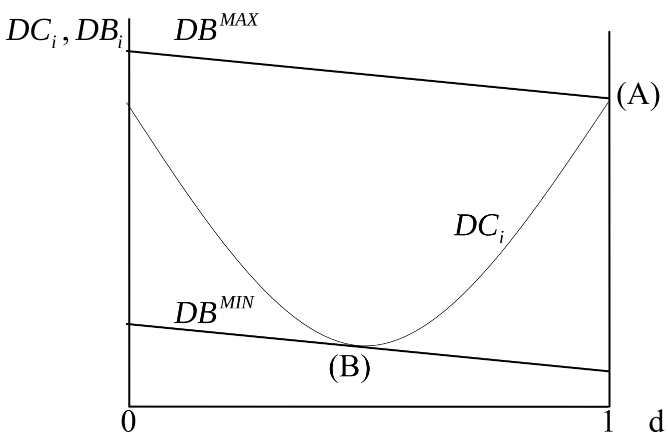


In <Figure 4>, we assume arbitrarily two levels of defecting benefits ($DB(I)$ and $DB(II)$). Comparing $DB(I)$ and DC_i, we can notice that if the defecting benefit is always greater than the defecting cost over all level of d, then full defection equilibrium

(FDE) is stable. In addition, comparison between $DB(II)$ and DC_i implies that full compliance equilibrium (FCE) is stable if defecting benefit is always less than the internal cost over all level of d .

Here we analyze the partial compliance (defection) equilibrium case. Prior to the main explanation, we need to pose some assumptions with regard to the defecting benefit and the social sanction.

<Figure 5> Max and Min DB



Suppose that the endogenous institution impose the social sanction to the defectors according to its predetermined rule. They follow this rule: $S(d) = \alpha * d + \beta$

For a convenience, we assume that α is constant but β is adjustable. Applying this to individual defecting benefit, we have a defecting benefit function such as

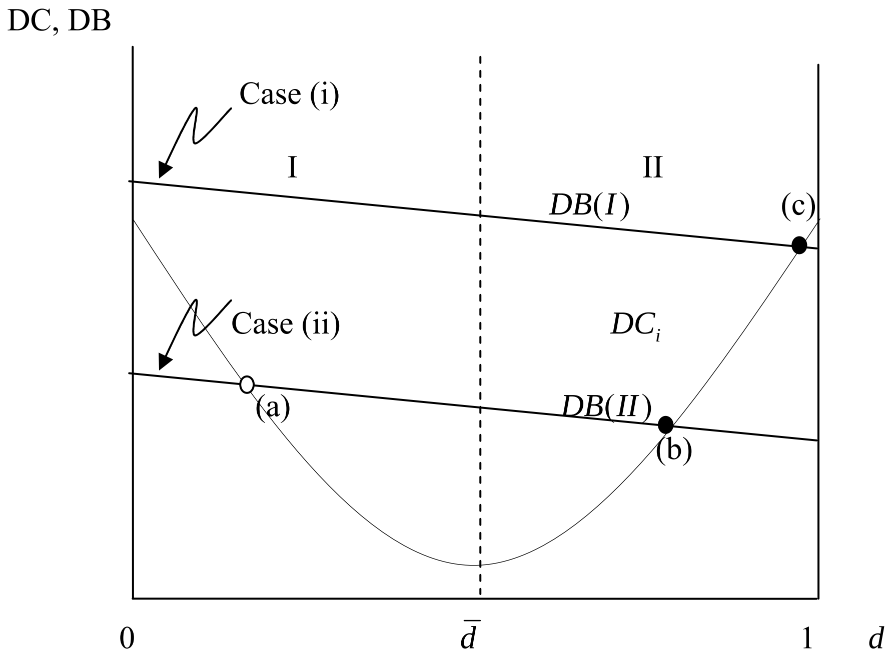
$$DB = \pi^N - \pi^C - \alpha * d - \beta$$

As we move the defecting benefit vertically by adjusting β , the defecting benefit lines meet the internal cost curve at two points (A) and (B) in <Figure 5>. We note that at point (A), the defecting benefit line meets the internal cost curve where $d = 1$, and at point (B), the defecting benefit line is tangent to the internal cost curve. Let us define 'the maximum level of defecting benefit (DB^{MAX}) where DB line meets DC curve at point (A) and 'the minimum level of defecting benefit (DB^{MIN}) where DB line meets DC curve at point (B).

Proposition

If the sanctioning level is set such that the defecting benefit lies between the minimum DB and the maximum DB ($DB^{MIN} < DB < DB^{MAX}$ *), then the DB line meets the internal cost curve at one point(i) or two points(ii). In case (i), this point is always a stable partial compliance equilibrium where* $\left|\frac{\partial S}{\partial d} + \frac{\partial IC_i}{\partial EP}\frac{\partial EP}{\partial d}\right| > \left|\frac{\partial IC_i(\cdot)}{\partial d}\right|$*. In case (ii), the point located in the area where* $\left|\frac{\partial S}{\partial d} + \frac{\partial IC_i}{\partial EP}\frac{\partial EP}{\partial d}\right| < \left|\frac{\partial IC_i(\cdot)}{\partial d}\right|$*, is unstable partial compliance equilibrium while the other point located in the area where* $\left|\frac{\partial S}{\partial d} + \frac{\partial IC_i}{\partial EP}\frac{\partial EP}{\partial d}\right| > \left|\frac{\partial IC_i(\cdot)}{\partial d}\right|$*, is a stable partial compliance equilibrium.*

<Figure 6> the potential (un)stable partial compliance equilibriums.



In <Figure 6>, we draw the picture to plot the defecting benefit, which lies between minimum DB and the maximum DB ($DB^{MIN} < DB < DB^{MAX}$), case (i) shows that the defecting benefit line meets the internal cost at one point while the case (ii) shows that the defecting benefit line meets the internal cost at two points. An empty point (a) designates the unstable equilibrium while the dotted points (b) and (c) designate the stable equilibriums.

Point (a) is an unstable equilibrium because it is nested in the area I where the internal cost is decreasing, that is, $\left|\frac{\partial IC_i}{\partial EP}\frac{\partial EP}{\partial d}\right| < \left|\frac{\partial IC_i}{\partial d}\right|$. Thus, a deviation from this point can make the path converges to the stable partial compliance equilibrium (b). For example, a conversion of one more person to be a defector makes each individual's defecting benefit exceed the defecting cost ($DB_i > DC_i$), which leads to more defectors until the path converges to the point (b). On the other hand, equilibrium point (b) and (c) are stable because they are nested in the area II where the internal cost is increasing, that is, $\left|\frac{\partial IC_i}{\partial EP}\frac{\partial EP}{\partial d}\right| > \left|\frac{\partial IC_i}{\partial d}\right|$. Thus, any attempt to deviate from this point has a propensity to return to this point again. For example, from point (b) or (c), a conversion of one more person to be a complier makes each individual's defecting benefit exceed defecting cost, leading to more defectors while a conversion of one more person to be a defector makes each individual's defecting benefit less than his defecting cost, leading to more compliers.

The results from this analysis indicate that if the endogenous institution sets the level of graduated punishment at the point in which the defecting benefit lies between the minimum DB and the maximum DB ($DB^{MIN} < DB < DB^{MAX}$), the path of evolution always converges to the stable partial compliance equilibrium regardless of the initial share of defectors.

These results suggest an important implication for policy. This community of CPR can achieve the full compliance equilibrium only if the graduated punishment level is set so that the internal cost is always greater than the defecting benefit. On the other hand, if the graduated punishment level is set so that defecting benefit is always greater than internal cost, then this community becomes a full defection. In the middle case, only partial compliance equilibrium is stable.

(2) A game only with the graduated sanction but no communication

Here, we suppose that the endogenous institution only chooses the social graduated sanction while not allowing the communication process. The defector's payoff function changes as follows:

$$\Pi^N(h^N, x) = \pi^N(h^N, x) - IC_i(d) - S(d)$$

$IC(d)$ decreases over the share of defectors because $S(d)$ cannot go into internal cost due to absence of the communication process.

The complier's payoff function is the same as before.

$$\Pi^C(h^C, x) = \pi^C(h^C, x)$$

The change of the proportion of defector follows;

$$\dot{d} = d(\Pi^N - \overline{\Pi}) \text{ Here } \overline{\Pi} = d\Pi^N + (1-d)\Pi^C$$

$$= d(1-d)(\pi^N(h^N, x) - IC_i(d) - F(d) - \pi^C(h^C, x))$$

Te derivative $\dot{d}$ with respect to d is;

$$\frac{\partial \dot{d}}{\partial d} = (1-d)(\Pi^N - \Pi^C) - d(\Pi^N - \Pi^C) - d(1-d)(\frac{\partial IC_i(\cdot)}{\partial d})$$

From this derivative, we note that the full compliance equilibrium is stable when always $\Pi^N > \Pi^C$ regardless of the share of defectors and the full defection equilibrium is stable when always $\Pi^C > \Pi^N$ regardless of the share of defectors. Since $\frac{\partial IC_i(\cdot)}{\partial d} < 0$, partial compliance equilibrium is not stable. We can note that this evolutionary model is almost the same as the one stage game in section 4.1 except for a decreasing defecting benefit. Like the previous results, the stable full compliance equilibrium is possible only if we assume the minimum internal cost. These results suggest that the management of CPR with only graduated sanction may be unsuccessful.

3.2.2 The second stage game

Among the stable equilibriums in the first stage, it may not be possible to rank that one is better than the others. However, partial compliance equilibrium may coincide with a casual real world observation where some portions of the population are defector and others are compliers. Thus, the following paper proceeds with this partial compliance equilibrium that would be considered the most general case. In addition, prior to the second stage game, the most crucial finding (or assumption) is that the partial compliance equilibrium in the first stage is steady state, which means the ratio of compliers (or defectors) would be unchanged over long periods of time.

Once the first stage is complete, the compliers are ready to play in the second stage. In this next stage, compliers choose either to become simple compliers or monitors. This second stage game is called a ‘reputation game’ because all compliers have incentive to increase their reputation from this second stage game. Each complier sends and receives positive image scoring to all other compliers at the same time. In particular, people who decide to monitor defecting behaviors additionally receive more reputation (positive image-scorings) due to the additional cost (monitoring cost) which they pay. Receiving positive image scorings is based on the findings of Horne and Cultip (2002) and Horne (2000), which reveal that people willingly support sanctioning behavior. In their model, sanctioning subject is assumed to participate in an actual punishment behavior by hypothetically paying a sanctioning cost. Meanwhile, our model assumes that the endogenous institution participates in an actual sanction instead according to report (notice) from monitors within community. We expect that in our model the monitors who also pay the monitoring cost can earn the same amount of positive image scoring as their models without much modification. For a convenience, we make three assumptions. First, the defectors in the first stage cannot be monitors simultaneously. Second, the positive image scoring sent for compliance behavior itself is negligible. Third, one monitor's positive image scoring sent to other monitors is perfectly offset by his received ones from other monitors. Thus, it seems that compliers are the image sending parts while monitors serve as the image receiving parts. The first and the second assumptions exclude the case in which the defectors in the first stage disguise themselves as compliers in order to get into the second stage game. They may have no incentive to send positive image scoring in favor of monitoring behavior because, once then, more and more true complier have incentive to become monitors, leading to increasing the possibility for defecting behavior to be detected. On the other hand, in return, they gain negligible positive image scoring for covering them up as compliers.

One monitor's reputation is an average of total positive image scoring sent by all compliers. To increase reputation for monitoring behavior, we assume, the endogenous institution discloses the list of all monitors periodically; thus, all compliers can recognize monitors' behaviors and send positive image scoring. Explicitly,

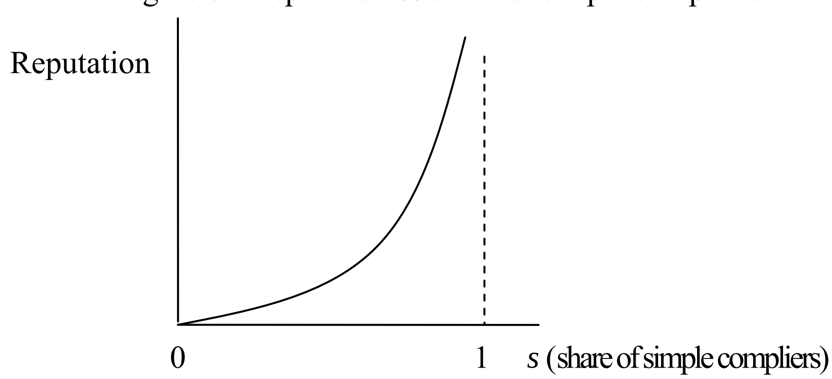
$$R = \frac{1}{M}\sum_{S}\omega_i = \frac{S}{M}\omega = \frac{S}{C-S}\omega = \frac{s}{1-s}\omega \tag{18}$$

Here, R represents the average reputation given to each monitor. M is the total number of monitors, S is the total number of simple complies, C $(=M+S)$ is the total number of compliers as a result of the first stage game, and ω_i is the sending image scoring from all compliers, and small s is the share of simple compliers over total compliers ($s=\frac{S}{C}$).

For a simplicity, we assume that the total positive image scorings ($\sum_S \omega_i$) earned from all compliers are divided and distributed to each monitor evenly ($\frac{1}{M}\sum_S \omega_i$). In addition, we assume that each complier sends the same amount of sending image scoring ($\sum_S \omega_i = S \times \omega$).

From (30), we can figure out that R always increases with the share of the simple compliers, that is, $\frac{\partial R(s)}{\partial s} \geq 0$. R is infinite when $s=1$ and is zero[7] when $s=0$.

<Figure 7> Reputation & share of simple compliers



In <Figure 7>, we note that the benefit to choose a monitor is always positive as long as a society has at least one simple complier, and this benefit becomes greater if this society has more simple compliers. At the rudimental monitor-sanction process, the anchored

[7] In fact, the reputation, when the community is consist of the full monitors, may not be zero because it is possible that the sending positive image to other monitors scoring is not always perfectly offset by receiving ones from other monitors. However, for a convenience, we follow the simplest assumptions.

monitoring behavior would be rewarded with high reputation, but as the number of monitors increases, the benefit in average reputation decreases because the sending part (simple compliers) shrinks and the receiving part (monitors) increases.

On the other hand, the monitoring behavior entails the cost including a private time cost for monitoring activity. For simplicity, monitoring cost is assumed constant.

In fact, all compliers who are ready to play the second stage game compare the benefit (reputation) to the cost (monitoring cost) and make decision on strategy. If reputation (R) is greater than monitoring cost (MC), then compliers have incentive to become monitors. If not, it would be better to remain as simple compliers.

We have to note that reputation works as follow: it affects utility positively in such a way that reputation either endows happiness to monitors directly or helps other economic transactions with other people. On the other hand, the total reputation heavily relies on the size of the community, the degree of intimacy among people, the degree of frequency meeting same people again and the proportion of total compliers in the given community. With the relatively large size of members, we can expect that the intimacy and the degree of frequency meeting same people again declines. Thus, the reputation from a given compliance behavior can be small. Here we assume that the size of group is relatively small as before, and there are frequent relationships among members.

Now, we define that the monitor's payoff is

$$\Pi^{M} = \pi^{C} + R(s) - MC \qquad (19)$$

Here, $R(s)$ is an average reputation dependent on the share of simple compliers (s), and MC is a constant monitoring cost.

The simple complier's payoff is the same as before

$$\Pi^S = \pi^C \qquad (20)$$

Keeping in mind that people are still limitedly rational, and at steady state from the first stage, the share of compliers (or share of defectors) was stable in a partial compliance equilibrium, we will find the conditions for stable equilibrium.

The change of the share of simple compliers is

$$\dot{s} = s(\Pi^S - \overline{\Pi}^C) \text{ where } \overline{\Pi}^C = s\Pi^S + (1-s)\Pi^M \qquad (21)$$

This equation indicates that the share of simple compliers increases over time if their payoff is larger than the average payoffs of compliers. In other words, according to the comparison between monitoring cost and reputation, they choose between simple compliance and monitoring. If the monitoring cost is higher than potential reputation gain, they would choose simple compliance. Otherwise, they would choose monitoring.

Equation (33) can be written as

$$\dot{s} = s(1-s)(\Pi^S - \Pi^M) \qquad (22)$$

$$= s(1-s)(MC - R(s))$$

To find stable equilibrium of this equation, it is required to take a derivative $\dot{s}$ with respect to s then check whether the sign is negative at each equilibrium point.

$$\frac{\partial \dot{s}}{\partial s} = (1-2s)(MC - R(s)) - s(1-s)(\frac{\partial R(s)}{\partial s}) \qquad (23)$$

At $s = 1$, $\frac{\partial \dot{s}}{\partial s} = R(s) - MC$ and it is negative if $MC > R(s)$. (24)

At $s = 0$, $\frac{\partial \dot{s}}{\partial s} = MC - R(s)$ and it is negative if $R(s) > MC$. (25)

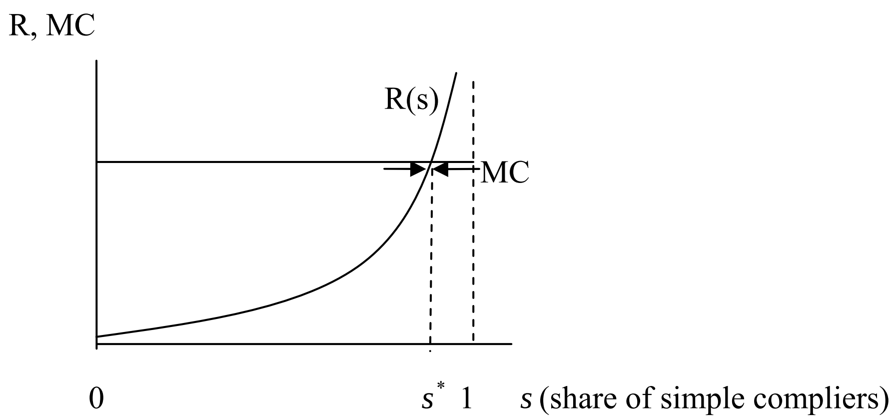
At $s = s^*$ where $0 < s^* < 1$, and $R(s) = MC$,

$$\frac{\partial \dot{s}}{\partial s} = -s(1-s)(\frac{\partial R(s)}{\partial s}) \tag{26}$$

And it is always negative because we assume that $\frac{\partial R(s)}{\partial s} > 0$.

In (36), we note that at $s = 1$, the reputation $R(s) = \infty$. Therefore, this equilibrium cannot be stable because MC can not be greater than infinity. In (34), we also note that at $s = 0$, the reputation $R(s) = 0$. This means that this equilibrium cannot be stable unless monitoring cost is negative, which is unimaginable. Therefore, the unique stable equilibrium is a partial equilibrium consisting of some simple compliers and monitors in which $0 < s^* < 1$.

<Figure 8> Stable Partial equilibrium



As can be seen in <Figure 8>, the partial compliance at s^* is stable because deviation from this point tends to return to this point. For example, one more person becoming a monitor makes $MC > R(s)$. This forces that person to return as a simple complier. One more person becoming a simple complier makes $R(s) > MC$. This forces that person to return as a monitor.

4. Implication

Consequence of this two stage game is that in this community, there co-exist the defectors ($D^* = d^* \times N$), the simple compliers ($S^* = s^* * C^*$) and the monitors ($M^* = C^* - S^*$). Continued with the first stage game stage game, the main drawback of this two stage game is that the social sanction in the first stage governed by total monitoring activity in the second stage is not necessary to be sufficient enough to guarantee the partial compliance equilibrium. For example, it is possible that sometimes the total monitoring activity determined in the second stage game falls short to support a certain level of the social sanction assuring the partial compliance equilibrium.

To avoid this problem, the endogenous institution can target two main methods: first, they can attempt to change the shape of internal cost so that the switching point is more likely to be close to the origin. This goal is possible if the positive effect of the share of defectors dominates the negative effect of it. Only possible way to achieve it is to increase the communication process for a given level of the social sanction. Second, they can change the social setting affecting reputation for the monitoring behavior. The reputation for a given community depends on individual specific way to appreciate monitoring behaviors and social foundation. Although we ignore the difference of individual specific appreciation in our analysis, this part may be devoted for future studies. On the other hand, how much people appreciate the reputation relies on many factors such as social mechanism of endowment of reputation for given compliance behavior, education and the cultural constraint. Therefore, if the endogenous institution changes social foundation in order to foster the means to increase the reputation for a given monitoring behavior, as we investigated in the second stage game, more compliers have incentive to become monitors.

5. Conclusion

In our paper, we attempt to develop the theoretical model describing the empirical evidences of the common pool resources. The real world observation shows that some common pool resources are managed more efficiently than the ‘tragedy of common’ by less than all compliers (the partial compliance equilibrium). With *U* shape of internal cost function and the graduated punishment mechanism, we show that the partial compliance equilibrium is stable and observable frequently. In addition, we show that some compliers have incentive to be monitors if we assume that the monitoring behavior yields a benefit in reputation.

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