5

Co-ordination and Leadership in the Unregulated Common Property: Some Lessons from Game Theory

In the previous chapter, describing the various advantages of small-group settings, we have drawn attention to the fact that the prisoner's dilemma is not necessarily an appropriate representation of the payoff structure obtaining in situations of unregulated common property. We now want to delve into this issue by discussing different game forms that may be more relevant in this respect, particularly the so-called chicken game, the co-ordination game, and heterogeneous games that combine the payoff structures of the PD and these two games. Note that so far, the analysis has been essentially focused on *appropriation* problems understood as collective action problems concerned with excluding potential beneficiaries and allocating the subtractable flow of an existing common property resource. Another category of collective action problems may arise: these are the *provision* problems which are to do with the process of creating a resource, maintaining or improving its production capabilities, or avoiding its destruction. The latter type of problems are obviously akin to the well-known *public goods* problems (Ostrom, 1990: 30–3; Ostrom *et al.*, 1993).

5.1 Unilateral Contribution

Let us first consider a kind of situation in which everybody agrees that something is to be done but the problem is who will actually do it. In the real world, indeed, one encounters many situations in which a collective problem is solved through unilateral action. Olson has clearly such situations in mind when he discusses the possibility of groups being *privileged*. A *privileged* group is defined as a group so small 'that each of its members, or at least some one of them, has an incentive to see that the collective good is provided, even if he has to bear the full burden of providing it himself' (Olson, 1965: 50). This happens when the collective good (or some quantity of it) can be obtained at a cost sufficiently low in relation to its benefit that it pays any individual in the relevant group to provide it all by himself. In other words, the total gain resulting from the production of a collective good or from the avoidance of a collective bad is so large in relation to the total cost that an individual's share of the aggregate gain would exceed the total cost. Such a situation may also obtain when the group is composed of individuals of unequal size or extent of interest in the collective good. According to Olson, in *heterogeneous* groups, the greater the interest in the collective good of any

		Player B	
		C	D
Player A	C	8, 8	6, 10
	D	10, 6	2, 2

FIG. 5.1. A 2 × 2 symmetrical chicken game

single member, the greater the likelihood that this 'large' member will get such a significant proportion of the total benefit from the collective good that he will gain from seeing that the good is provided, even if he has to pay all of the cost himself [ibid. 33–4]. As we shall see below, however, the case of heterogeneity may cover a wide variety of different situations which need to be carefully specified. Indeed, the meaning behind the notion of interest has to be clarified in order to be able to predict which type of resource user (the rich or the poor) is more likely to contribute.

Collective action in privileged groups

Let us begin by examining the situation obtaining in small homogeneous groups. This situation can be portrayed as a two-person chicken game, that is, as a game in which there are two (Nash) equilibria in pure strategy and in each of these one player co-operates while the other defects. Consider the game with the payoff structure described in Figure 5.1.

The following provision problem can serve as a first illustration. Assume that players A and B are two small-scale marine fishermen who stand threatened by the invasion of a fleet of foreign trawlers in their traditional fishing-zone. The incomes of A and B are presently 10 units. However, to maintain the level of their present catches, they need to have their inshore waters legally protected against the encroachments of the foreign boats. It is assumed that they can succeed in securing that protection from their government provided that they make lobbying efforts (which is the 'public good' to be produced) the total cost of which amounts to 4 units. If both players defect in the sense that they refuse to exercise pressure on their government until it agrees to act in their interests, the competition from the highly efficient foreign trawlers will soon bring their individual incomes down to a mere 2 units (D,D). The total benefit of the lobbying action—that is, the joint payoff (C,C) minus the joint payoff (D,D), or 16–4 = 12—is therefore much larger than its total cost (4). If A and B co-operate in the sense that they agree to share that cost equally between them (C,C), they will both be assured of receiving a payoff of 8 units. Moreover, the lobbying action is so rewarding that it can pay a single player to bear the entire cost of it (D,C, or C,D): the politically active player (the 'sucker') will then get 6 units while the passive player (the free-rider) will of course get more, 10 units in this instance.

From Figure 5.1, it is then easy to see that players have no dominant strategies in this game. What each will decide to do depends on what he expects the other to do. As in a PD game, each player prefers that the other undertakes the lobbying action while he refrains from moving since he will thereby get the maximum possible income (10 units). However, and contrary to the situation obtaining in a PD game, each is willing to take full responsibility for that action if the other refuses to do anything about it. In other words, the consequences of nobody doing the lobby are so disastrous that either of the players would undertake it if the other did not (it is better to be a 'sucker' and to get 6 units of net income than not to be a 'sucker' and get only 2 units).[1]

The problem in the above game is of course that the best symmetric payoff (8,8) cannot be achieved because (C,C) is not an equilibrium outcome: player A would choose to defect if he expected player B to choose to co-operate. However, *with communication*, the players can make a *self-enforcing* plan of action (in the sense that neither player could gain by unilaterally deviating from this plan) that gives them both higher expected utility than what they can get in the absence of communication. In other words, they can benefit, from co-ordinating their actions. Thus, they could agree to toss a coin and then choose (C,D) if it is heads and (D,C) if it is tails. As pointed out by Myerson, this plan of action is self-enforcing, even though the coin toss has no binding impact on the players: player A could not gain by choosing D after heads, since player B is then expected to choose D (Myerson, 1985: 254; 1991: 249–50). In game theory, this plan is known as a *correlated equilibrium*. In our example, it gives each player an expected utility of 8 ($0.5 \times 6 + 0.5 \times 10$). This is a better result than that achieved under the randomized or mixed-strategy equilibrium (7.33) where, in one-ninth of the cases, the worst outcome (D,D) will materialize.

Under a correlated equilibrium, agents endogenously and *non-co-operatively* generate a *co-ordinated* solution which gives them the assurance that collective action will take place: one of them will have to undertake it, but under a scenario agreed on by everybody.

There are many other applications of the chicken game to provision problems, such as maintenance and surveillance of common properties (irrigation systems, pastures, collective fields, hunting-grounds), in particular protection tasks aimed at enforcing exclusive rights against possible intrusion by outsiders, activities of lobbying and political representation, and initiation of collective action. The latter example actually refers to the problem of leadership and is noticeably present in all situations where the production of a public good is envisaged. It should nevertheless be borne in mind that not all the aforementioned activities can be described as chicken games. As we shall see below, this depends on the particular configuration of costs and benefits obtaining in each situation.

[1] There are actually three Nash equilibria of this game: not only (C,D) and (D,C), but also a randomized Nash equilibrium, called a 'mixed strategy' equilibrium in which each player plays his different strategies with a certain, predetermined probability. In the mixed equilibrium of the game considered here, each player co-operates with probability 2/3 and defects with probability 1/3. The expected utility for each is therefore equal to $2/3(2/3 \times 8 + 1/3 \times 6) + 1/3(2/3 \times 10 + 1/3 \times 2) = 7.33$.

		Fisherman B	
		enters	does not enter
Fisherman A	enters	−1, −1	10, 0
	does not enter	0, 10	0, 0

FIG. 5.2. Assignment problem as a 2×2 chicken game

Contrary to a widely held view, chicken games may also be suitable for depicting appropriation problems. Consider the case of fishing of lobsters or some other bottom-dwelling species. It is easy to find situations in which the number of (potential) fishermen exceeds the number of locations where enough lobsters can be caught to justify the effort involved. There then arises the problem as to how those fishing locations will be assigned so as to avoid the eruption of harsh conflicts (since two fishermen fishing on the same spot would be doing so at loss). In some fishing communities, such a problem is solved by recognizing the claim of the 'first entrant' into the fishing-ground (see Chapter 10, sect. 2). This solution clearly corresponds to a chicken game as illustrated in Figure 5.2.

Assigning exclusive rights to the first entrant is not the only possible solution to the problem concerned. Assignments by lottery are not infrequently practised which really amount to a correlated equilibrium as defined above (see also Chapter 10).

Extending the chicken game to N-player situations is quite straightforward: there are as many Nash equilibria in pure strategies as there are players and, in each of them, a single player contributes while the others freeride. In an infinitely repeated framework, the folk theorem also holds, implying the existence of a plethora of equilibria. Paradoxically perhaps, some of these equilibrium outcomes may be characterized by a large number of 'non-co-operative' rounds: indeed, a player may have an interest in building a reputation of being 'tough' so as induce another player to contribute.

It is noteworthy that, in the above two numerical examples, the equilibrium outcomes in pure strategies are Pareto-optimal. This is not necessarily so, at least in the one-shot game. For the sake of illustration, let us consider the case of two fishermen who must decide how many boats to put out at sea. If they put out one boat each, their payoffs are (4,4). If they put out two boats each, the catch per boat becomes so low that the net profit (payoff) is negative so that the outcome is (−1,−1). On the other hand, if one of the fishermen puts out two boats while the other puts only one boat, the former's payoff jumps to 6 while the latter's payoff is 1. The corresponding payoff matrix is given in Figure 5.3.

In the one-shot version of the above chicken game, there are two Nash equilibria in pure strategies {(1,6), (6,1)} and one in mixed strategy, where putting out one boat is played with a probability of 1/2, and putting out two boats, with a probability of 1/2, yielding an expected payoff of 2.5 to each fisherman. It is therefore evident that the

no. of boats		Fisherman B: 1	Fisherman B: 2
Fisherman A	1	4, 4	1, 6
	2	6, 1	–1, –1

FIG. 5.3. A chicken game with a non-(Pareto) optimal equilibrium

Pareto-optimum (4,4) cannot be achieved. In the long finitely repeated version of that game (and *a fortiori* in an infinitely repeated version), however, the Pareto-efficient allocation can be approximately reached if each player obeys the following equilibrium strategy as described in Myerson (1991: 338). Each fisherman puts out only one boat as long as both of them have done so, until the last two rounds. If the two fishermen have always abided by this plan of action, then, in the last two rounds, they both play the mixed equilibrium that yields expected payoffs (2.5, 2.5) at each round. On the other hand, if, in a round before the last two rounds, either fisherman ever deviates from the strategy of putting only one boat at sea, then the two fishermen thereafter play the equilibrium that, at each round, gives payoff 1 to the fisherman who deviated first and payoff 6 to the other one. (If both deviate first at the same round, then let us say that the fishermen act as if fisherman A deviated first). It is a subgame-perfect equilibrium for both fishermen to behave according to this scenario in the T-round finitely repeated game (for any positive integer T). Furthermore, this equilibrium gives an expected average payoff per round of $((T-2) \times 4 + 2 \times 2.5)/T$, which gets close to 4 when T is large.

It is important to note that there are also equilibria of such finitely repeated games that are worse for both players than any equilibrium of the one-shot game, but of course are not worse than the minimax value (for more details, see Myerson, 1991: 339). One can therefore conclude that, contrary to a widely held view, repetition does not always improve the average performance of the group.

The above results actually illustrate an important theorem of game theory which has been proved by Benoit and Krishna (1985) following which, if a strategic-form game has multiple equilibria (when it is not repeated) that give two or more different payoffs to each player, then, under general conditions, the average payoffs in subgame-perfect equilibria of long finitely repeated versions of this game are very close to *any* average payoffs attainable in the *infinitely* repeated versions of the game (Myerson, 1991: 338). (Bear in mind that the folk theorem applies in the latter case.) This theorem points up the essential difference that exists between prisoner's dilemmas and other game forms and the consequent danger, frequently encountered in the so-called 'collective action' literature, of confining the analysis to the former as though the theoretical propositions applying to it could be easily generalized to other games. More specifically, while in PD games, the results obtained under infinitely repeated

		Player B (poor)	
		C	D
Player A (rich)	C	15, 3	13, 5
	D	17, 1	2, 0

FIG. 5.4. A 2 × 2 asymmetrical chicken game

versions radically differ from those obtained in finite versions, this is not true of other game forms.

Collective action in heterogeneous groups

Let us now turn to situations where asymmetric payoffs prevail, reflecting economic inequalities within the small group. As pointed out above, Olson then predicts that the richer party will necessarily contribute because he has a higher stake. To examine the validity of this prediction, let us start by considering the chicken game presented in Figure 5.4 in which it is evident that player A (the richer player) has a lot to lose if (D,D) occurs.

As is typical of any 2 × 2 chicken game, there are two equilibria in pure strategies leading to an asymmetric outcome (D,C) or (C,D), and an equilibrium in mixed strategy where all outcomes have a positive probability of occurrence. It cannot therefore be taken for granted, as Olson seems to do, that the richer party necessarily plays C in equilibrium. This is all the more so if we assume that the richer party is superior not only in economic terms but also in terms of power. As a matter of fact, in the kind of situation contemplated here, one obvious form which the power of the rich can take on is his ability to make a move prior to the poorer and weaker party. If this is so, the appropriate tool for analysing the decision problems of both parties is no more the strategic form game used above but a two-step chicken game best described in extensive form. In a two-player extensive game, decision-making is sequential so that one player (the follower) can observe what the other (the leader) has done before deciding his own action. In Figure 5.5, we have translated the payoff matrix described in Figure 5.4 into such an extensive form.

Player B will make his decision to play C or D only after having observed what player A has done. His best strategy is clearly 'play C if A has played D, and play D if A has played C'. The strength of player A lies in the fact that, owing to his privileged position as the first mover, he is able to take into consideration B's best reactions while making his own decision in the first stage of this sequential game. In this case, it is obvious that he will choose to play D in the expectation that player B will choose C. The outcome (D,C) is therefore the unique subgame-perfect Nash equilibrium. Note carefully however that, for the above result to obtain, it is necessary that the first move

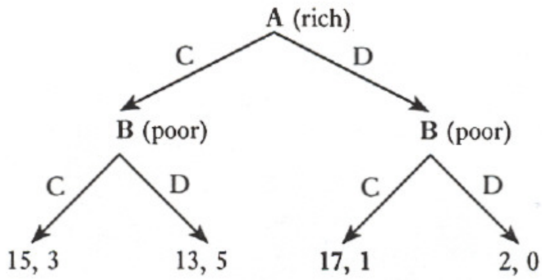

FIG. 5.5. A 2 × 2 asymmetrical chicken game with sequential moves

by the richer party is perceived by the poorer party as an unmistakable signal about the intention of the former. This is precisely the ability of the richer party to commit himself to a particular plan of action and to signal it in an unambiguous way to the weaker party that constitutes the source of his power. If such power imbalance did not exist, one could argue that the above representation is unsuitable to describe the decision problem under concern. This is because, if power is more or less evenly distributed, the position of the first mover cannot be clearly established: one player can give a signal to the other to which the latter may respond by a counter-signal, to which the former again responds, etc. The analysis of such games, which involve continuous time, lies beyond the scope of the present work.

Even in the absence of any explicit demonstration of power by the richer party, the sheer poverty of the poorer party may create a situation in which he is forced to contribute. This may most obviously happen when the latter's subsistence is threatened by, say, the neglect or the disappearance of a common property. Consider the following problem: a land area is being irrigated through a surface canal system and the proper maintenance of some water control infrastructure is crucial for the satisfactory performance of the system. The land in the command area is unequally distributed among two persons: the rich and the poor. Yet, contrary to the rich who possesses a large portfolio of assets including the irrigated parcels, the poor has no other wealth besides his tiny plots of irrigated land. In such circumstances, it is a serious possibility that the rich is less mindful of the proper maintenance of the irrigation system. We moreover assume that maintenance works can be effectively carried out by a single player alone. That this is not a completely unrealistic assumption is attested by the observation made by Yoder (1986) about the Thambesi irrigation system in Nepal. As a matter of fact, we are told that maintenance carried out prior to the monsoon rains requires 'only four to five hours of work with all the members participating', as a result of which it is possible for only a few farmers to keep the whole system going (Yoder (1986), quoted from Ostrom and Gardner, 1993: 97).

Fitting the above set of assumptions is the payoff matrix depicted in Figure 5.6.

Two Nash equilibria in pure strategies (and none in mixed strategy owing to the infinitely negative payoff accruing to the poor in case of universal neglect) characterize the above game. This being said, there is good ground to believe that, given the peculiar circumstances highlighted above, the two 'pure' Nash equilibria are not

		Poor	
		maintains	neglects
Rich	maintains	15, 3	13, 5
	neglects	17, 1	2, −∞

FIG. 5.6. A 2 × 2 asymmetrical chicken game with a subsistence constraint

equally plausible. Indeed, one of them (neglects, maintains), is likely to emerge as a 'focal' point because, the poor, being subsistence-minded, is not ready to incur the least risk that the system ends up remaining unmaintained. In fact, what this means is that, given the binding nature of the subsistence constraint, the poor tends to adopt a maximin strategy which is justifiable in rational terms. In particular, if there is the slightest chance of the rich being irrational, mindless, or prone to making 'mistakes', the poor is eager to ensure his livelihood by choosing the safe outcome, which is personally to carry out the maintenance work. (In game-theoretical terms, the (neglects, maintains) outcome is the only trembling-hand equilibrium.)

In actual fact, it is not difficult to find, in the real world, situations in which the poorer segments of the population have a vital interest in the preservation of common properties, while the rich do not have that concern because they have available to them significant *exit* options. Here lies another source of power in the hands of the rich.

The array of possibilities may be further enlarged if we allow for the fact that the situation of the poor may be so desperate that he cannot be forced to contribute. Consider the following appropriation problem. There are two players who can choose between a conservationist strategy, C, or a more destructive strategy, D, regarding the exploitation of a common property resource. One of them is very poor, so that he cannot afford to follow *alone* the conservationist strategy, C. (For instance, his concern about sheer survival in the short run may lead him to heavily discount the future benefits of such a strategy and to overweigh the present costs, an issue which has already been addressed in Chapter 3.) Such is not the case, however, with the other player who, being richer, can safely adopt a more conservative use of the resource. This situation is depicted in Figure 5.7.

Evidently, the above game is not a chicken game. The poor has a dominant strategy, which is to defect, while the rich has a payoff structure characteristic of a chicken game. The only equilibrium outcome is (13,5), in which the poor, despite his weaker economic position, cannot be coerced into being the single contributor. Such a result (which is Pareto-inferior) also holds in any finitely repeated version of the game, as was observed with the PD game, with which it shares the feature of yielding a unique equilibrium. (The theorem of Benoit and Krishna (1986) does not apply.)

An important lesson to be drawn from the latter example is that a player does not enjoy a decisive advantage over another player who is hard-pressed by a survival

		Poor: C	Poor: D
Rich	C	15, 4	13, 5
	D	17, −1	2, 2

FIG. 5.7. A 2 × 2 asymmetrical heterogeneous game with a subsistence constraint

		Poor: C	Poor: D
Rich	C	15, 4	16, 2
	D	14, 2	2, 2

FIG. 5.8. A 2 × 2 asymmetrical game with a norm of participation

constraint. This arises from the fact that, in some circumstances in which he has actually no choice, the poor may credibly precommit himself to non-co-operation. In this case, power, understood as the ability to precommit to non-co-operation, appears to be on the unexpected side.

A last form of power is worth mentioning, which is perhaps more subtle or disguised than those analysed above. Under this form, the stronger party assumes a leadership role in devising and putting into effect a system of sanctions (in the form of payoff transfers) that punishes all free-riders, including himself. This allows him to bring pressure to bear on the weak party so as to make him share the burden of collective action even though the latter has much less interest than the former in the success of this action. In other words, the strong party agrees to bind himself to co-operation in order to bring the weak party to co-operate. One can think of a norm of participation according to which everybody, rich or poor, must join the collective action irrespective of whether there is much or little to gain from participating. By referring to such a norm, the rich and powerful can thus drive the poor and weak to take actions that entail large benefits for the former and small (or even negative, as in the game below) ones for the latter (for example, all landowners, both large and small, participate to an equal extent to the construction of an irrigation canal). This situation is illustrated by the game portrayed in Figure 5.8, which is actually a modified version of the game depicted in Figure 5.7 in which a player pays a fine of 3 units to the other player whenever he free-rides on the other's effort. (We return in Chapter 8 to the role of sanctions as a co-operation-enforcing mechanism.)

It is easy to verify that the game in Figure 5.8 is virtuous in the sense that universal co-operation is the only equilibrium outcome. What needs to be stressed is that in this instance such an outcome has been achieved through a subtle manipulation. As a matter of fact, the stronger party has resorted to a genuine strategy of delusion. By threatening himself with sanctions for any act of free–riding on the weaker party's effort, he conceals the fact that he has no interest in defecting: clearly, the threat is empty as far as he is concerned.

That power is effectively exercised in the above instance is evident from the fact that, were the poor allowed to do it, he would vote against establishing the aforedescribed norm of participation and the payoff transfers associated with it. As a matter of fact, he earns a payoff of 4 units after this norm has been laid down whereas he could earn 5 units in the initial situation. The rich will of course vote in the opposite way since the change in the payoff matrix brings him a payoff gain of 2 units (he earns 15 instead of 13 units).

Note carefully that the problem of whether or not to establish the norm of participation with the attendant payoff transfers is quite distinct from the question as to whether, once established, the punishment system involved is self-enforcing. It is easy to see that, if the right to punish is vested with either the rich or the poor, punishment will not be meted out whenever the agent (whether rich or poor) has to punish himself. If, however, the punishment mechanism is actuated by a neutral external agent or any kind of automatic device set for that purpose, it will be unfailingly enforced (provided that, whenever he punishes, the punisher gets a reward, say ε, from the guilty player). The corresponding game is the three-stage game described in Figure 5.9 in which we have assumed that the rich makes the first move and there are three players including the punishing agent. The latter must choose between two strategies: punish (denoted by P) and abstain from punishing (denoted by N).

Knowing that the punishing agent always punishes (he always plays P rather than N), the poor has an interest in co-operating if the rich has done so in the first round of the game whereas he is indifferent between co-operating and defecting if the rich has previously defected. Being aware of this optimal reaction of the poor conditional

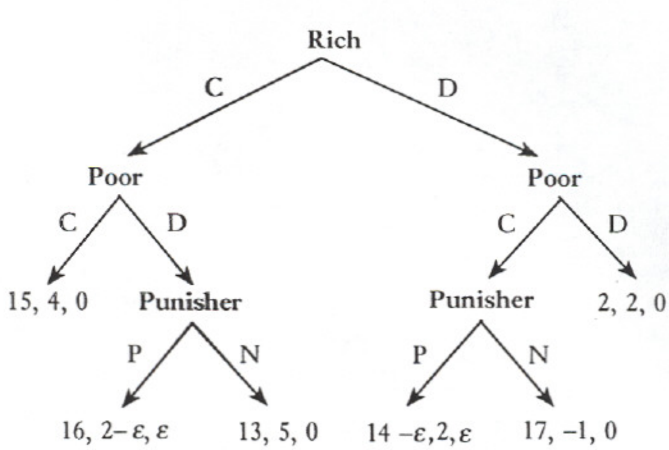

FIG. 5.9. A three-stage sequential asymmetrical game with a punishing player

on his own previous move, and knowing that he will be punished if the (D,C) outcome materializes, the rich will choose to co-operate, since he will thereby get 15 payoff units instead of either $(14 - \varepsilon)$ or 2 units. As a consequence, the co-operative outcome (C,C) is a subgame-perfect equilibrium.

Incentive dilution in a chicken game

As we have seen in the previous chapter, the size of the group may be an important determinant of the success of collective action. That the incentive for the members of a group to act in a collectively rational way tends to become thinner as the number of members increases is a proposition generally understood in the framework of the prisoner's dilemma. What we now want to argue is that, starting from a chicken game, the same dilution process may occur. As the size of the group increases, the structure of the game modifies itself from a chicken game into that of a prisoner's dilemma, and, as a result, the collectively rational outcome which was initially established degenerates into the Pareto-dominated non-co-operative outcome.

Let us illustrate this result with the help of a simple example. A group of n members can create a public good which yields a benefit of b to each of them at a collective cost of $c(n)$, where c is an increasing function of n, but $(c(n))/n$ is decreasing with n. Each member of the group is free to contribute or not. If he contributes, he shares the cost $c(n)$ with the m other willing contributors so that each of them incurs individually a cost of $(c(n))/(m + 1)$. If not, he simply free–rides on the public good produced by others, enjoying its benefits without incurring any cost. We assume that $b - (c(n))/n$ is always positive, so that creating the public good is collectively rational. However, we also assume that there exists n^*, with $n^* > 0$, such that, if $n < n^*$, $b - c(n) \geq 0$ and, if $n > n^*$, $b - c(n) \leq 0$. Figure 5.10 portrays the choice problem facing player i.

As can be readily seen from the figure, as long as n is relatively small ($n \leq n^*$ so that $b > c(n)$), the payoff structure given above defines an N-player version of a chicken game. However, when the size of the group increases, $c(n)$ rises up to a point where $b - c(n)$ becomes negative: the payoff structure of the above game turns into a PD and defecting becomes a dominant strategy. In other words, in the simple example described here, when the group is small, the cost of creating the public good is also small

Pay-off to player i if the number of other players contributing is

		$n-1$	$n-2$	$n-3$	. . .	0
Player i	contributes	$b-\dfrac{c(n)}{n}$	$b-\dfrac{c(n)}{n-1}$	$b-\dfrac{c(n)}{n-2}$		$b-c(n)$
	does not contribute	b	b	b		0

FIG. 5.10. Endogenous transformation of a chicken game into a PD game

so that everyone is ready to pay for it, even if he is alone to do so. However, as the size of the group increases, the cost involved also increases, while the individual benefits remain unchanged. Consequently, financing the public good on a voluntary basis becomes problematic when the group reaches a certain size. This is essentially the same argument as that put forward by Olson to underline the advantage of small ('privileged') over large groups, even though he presented it in the converse way (as the size of the group increases, the total cost of producing the public good is constant but the share of the benefits accruing to each individual declines).

5.2 Co-ordinated contributions

An important class of problems that arise in connection with the management of common property resources requires symmetric and co-ordinated actions to be overcome. Examples abound both in appropriation and in provision problems. For instance, in a fishery where the use of dynamite is an available technical option, it is obvious that self-restraint must be practised by everybody if the destruction of the fishing-ground is to be avoided. Protection of the breeding-grounds gives rise to the same problem. To quote examples from other sectors, restricted use of fire for the clearing of agricultural lands or management of water control infrastructures (including control of soil salinity and water-logging problems through sub-surface drainage) also require co-ordinated actions. Important issues of provision, such as steep-slope management and anti-erosion control in mountainous terrain, programmes of pest control, or certain surveillance actions requiring a critical amount of effort (e.g. guarding coastal fishing-grounds against the encroachments of mechanized boats) obviously belong to the above class of problems.

The one-shot assurance game

The game form suitable for representing this kind of situation is known as the assurance game (see Sen, 1967, 1973, 1985; Runge, 1981, 1984*b*, 1986; Dasgupta, 1988; Taylor, 1987; see also Ullmann-Margalit, 1977: 41; Collard, 1978: 12–13; 36–44, 80–9; Field, 1984: 699–700; Levi, 1988: ch. 3). In this game, a minimal effort must be contributed by all players if they are to receive any benefit from their own action.

To return to a familiar example, consider the case in which two fishermen must independently decide whether to put one or two boats at sea for the catching of fish. Let us assume that their payoffs for the various possible outcomes are as given in Figure 5.11.

The important point to note is that, contrary to what obtains in a PD game, the net payoff accruing to a player when he freerides on the public good provided by the other player (6 units) is smaller than the net payoff he would receive by co-operating (8 units). Nevertheless, if actors think it best to co-operate with each other, they still find it very unpleasant to be exploited by free–riders: contrary to what is observed in the chicken game, each player prefers mutual defection (where he gets a payoff of 2 units)