Review of Sociology Vol. 11 (2005) 2, 87–104

GAME THEORETIC EXPLANATION FOR ABSENCE OF OCCURRENCE OF PUBLIC GOODS

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Abstract: We often face the fact nowadays in our environment that certain public institutions and services perform poorly. The daily press is full of complaints about the abysmal quality of public services; we all feel the decay of our environment. Numerous explanations of various scientific approaches were created to resolve these phenomena. In the following, we shall give a rather simple explanation of the above phenomena, an argument based on the principle of rational decisions, with the apparatus of game theory. The undermentioned explanation is very simple but the author considers that it gives an acceptable explanation for the problem. In the article, we shall first review the key concepts of the subject, we shall become conversant with the problems of public goods; then by means of a very simple game theory apparatus we shall realize that if the members of the community are supposed to follow their own interests, the occurrence of public goods by necessity fails and the existing goods start to deteriorate.

Keywords: public goods, repetitive games, social dilemmas

INTRODUCTION TO GAME THEORY

When individuals or groups of individuals decide on their behavior towards other individuals or groups, they have to face that their behavior affects the decisions and behavior of others. We designate an interaction as strategic game if the actors are aware of this effect; moreover, they take it into account in their behavior. (The player comprehends that the other comprehends that the former comprehends, etc.) Therefore we may imagine the strategic game pro tem as an interaction among the actors where the actors, during the formation of their behavior, take into consideration the other side's behavior that is known to them or regarded by them as possible. Let us think about the chess player, the good chess player ponders in thought over the possible several moves of the opponent in advance, and having all considered he or she decides on the actual move. Thus we call a game strategic if the opponent sides have conflicts of interest, the sides may have information and assumptions as to the other's goals, about the possible decision alternatives, but they are not necessarily informed symmetrically. Each player attempts to optimize his or her own position according to his or her own individual goals. Let us try to approach it more formally.

We define game theory as analysis of strategic interaction of rational actors or groups of actors. The notes used in the aforesaid definition have to be explained further.

Player: We identify players as decision-makers in a game if there are more than one in that particular game. If there is only one player, we talk about decision problem instead of a game. The number of the players is optional but countable.

Interaction: the decisions of at least one player directly affect the behavior of another player within the group. Otherwise, the game is a series of independent decision problems.

Strategy: We define strategy simply as the players' decision alternatives and their possible combination. Strategies are actions where each actor takes this interdependency into consideration. The strategies evidently depend on the structure of the game since if it is a single simultaneous game, the strategies are the available decision alternatives. If it is a sequential game (that is to say, the players take moves one after another), the series of consecutive moves makes up a certain strategy. In this case, the game can be characterized with a tree graph, namely we describe strategy as a decision alternative or a series of decision alternatives. If the game is repetitive, the strategic set is the possible combination of strategies of the basic game.

Rationality: Game theory uses rationality concept of the rational choice theory taken in the narrow sense, that is to say, the actor is supposed to behave consistently and maximizing utilities according the information available to him or her.

Payoffs: In case of a given game, victory is the goal of a player, but it is often difficult to determine what it really means. We often aim at putting a certain product on the market sooner or in better quality than the rivals, namely we can only rarely think in categories of winners and losers. We define a payoff as a result using a given strategic combination (that is to say, a given choice of strategy of the player and that of the opponents) that may be a numerical value but not necessarily. In an economic game, payoff may be our profit but it may even be the bankruptcy of the competing company.

Rules of the game: When detailing game theory, the actors are supposed to be aware of the nature of the game they participate in, moreover, they are supposed to know it about the others and the other players are supposed to know it, that is to say, the rules of the game are part of common knowledge.

In our definition we exclude games where it may not be known who participates in the game and who does not, where particular strategies and their consequences are not clearly defined. This definition is rather narrow but it is suitable for the present analysis.

Classification of Games

Strategic games may occur in various situations. In the following, we make an attempt to classify games according to some respects.

1. The moves of the players are concurrent or consecutive.

In chess, players move one after the other, first the white then the black; participants in an auction make their first bids at the same time, independently of one another. Distinction between sequential games and games of simultaneous moves are essential because they require different ways of thinking. In case of a sequential game, the players think in the following way: How will the opponent(s) react if I move this? The present move is based on the calculation of the effects of the future moves of the others. In case of games of simultaneous moves, decisions on the moves are based on the assumptions about the present moves of the rivals and the same applies to the rivals, too. In case of sequential games, the decision whether it is worth moving first or second is an important question what is often not easy to make.

2. Nature of the conflict of interests of the players.

In case of a very simple game – such as chess – there is a winner and a loser. In case of the card game, the reward of one side is the loss of the other. We call these games zero-sum games. Examining more generally, these games are about distributing a predetermined reward among the players; therefore, the sum of the possible rewards is not necessarily zero. In such cases we talk about constant sum games. In everyday life, in the course of economic activities the situation is usually not about dividing a previously set total. The behavior of the participants in the game often determines the size of the total and even all players may be winners. Similarly, a situation may be pictured where all players turn out to be losers, such as a nuclear war. Such games are called negative-sum games. In case of numerous games, the players may choose between co-operation and conflict; the conditions of opting for a certain alternative are often subjects of analysis. This case may occur independently from the total of the game.

3. Knowledge of players.

In case of chess, the players know completely their situation (location of their pieces), their possible moves and those of their opponents. We call them games of perfect information. Such conditions are usually exceptional; at the most some of the players have pieces of information that the others do not. In most of card games, the players know their own cards and try to infer the cards of the others, and also, to deceive the others as to their own cards. All players are aware of this, and therefore each attempts to take into consideration the deceptive intentions of the others as well. The pieces of information that are available to all players are called common knowledge. This common knowledge is much more than a mere sum of individual knowledge.

4. Rules of game are set or can be manipulated?

Rules of chess and sports games are set, and the referee is often to enforce the observance of rules. Economic, political games are not so simple; the players try over and over again to change and manipulate the rules according to their interest. It is often important to analyze to what extent the rules of the games can be manipulated and how much they are interested in observing the rules, especially in case of political games.

5. Whether co-operation is possible among players and if so, to what extent?

Strategic interactions of players are made up of a mixture of common interest and conflict. It is often useful to players to make a compromise over co-operation. In numerous cases, it is profitable to individual players to break such compromises unilaterally, trusting that the others will not do it. We may have various assumptions as to whether the others will keep the compromise and we can form our strategy according to them. If the compromises cannot be enforced, usually no co-operation comes into existence. Games where compromises may be enforced are called co-operative, where they may not, are called non-co-operative.

6. Single or multiple repetition of the game.

In case of several games, players meet only once and they play the game, each gets the reward (loss) and takes leave. However, often this is not the case, players play the same game many times. It may occur in economic life, in organizations, in a family. If so, we talk about repeated games. In case of repeated games, it is important to distinguish finitely and infinitely repeated games. If the game is repeated finitely, we distinguish games where the number of repetitions is previously set and fixed and games where this number is not known, only the fact that the game will at one time finish but it is not known when.

7. Finite or infinite games.

We talk about finite games if the number of players is finite and each of the finite players has finite strategies. Either the number of players or the strategic set of individual players is infinite, we talk about infinite games. In spite of all appearances, infinite games often occur. Let us consider, for example, that we model the optimal output of an oil refinery, in this case we have an infinite number of strategies.

8. Evolutionary (learning) games.

Often, even in the case of relatively simple games, the result of the games depends largely on the preparedness of players and on the ability of each player to modify his or her behavior according to the previous turns of the games.

Equilibrium

Game theory operates within the conceptual frames of equilibrium. What does it mean? Among the strategic combinations those come into existence which are the best answers to all possible moves of the others, therefore to their best moves as well. As we know from economics, it does not necessarily imply that everybody comes off well; moreover, often nobody comes off well. We regard equilibrium as a state where no player can gain by deviation from the given strategic combination.

Nash equilibrium: We call a strategy vector a strict Nash equilibrium if the gain decreases when deviating from the given strategy choice (that is to say, the strategy vector is in equilibrium if each player plays mutually the best answer).

Mixed strategy: The players often choose from their strategies not deterministically but they assign probabilities to the available strategies such way that the sum of assigned probabilities is one. In this case, we talk about mixed strategies and we get the payoffs and consequences after having probability considerations.

Prisoner's Dilemma

Prisoner's dilemma is the most cited example in game theory. It is usually mentioned with reference to the absence of occurrence of public goods. Let us take a simple example: Two offenders are accused of having committed some crime together. They are held apart, they both have two possible choices. Either they confess, in this case they testify against the other, or they do not confess, in this latter case they risk that the other testifies against them. Let us summaries the above example in a simple table.

Table 1. Prisoner's dilemma

	Confesses	Does not confess
Confesses	(10, 10)	(1, 20)
Does not confess	(20, 5)	(2, 2)

The numbers in the table represent the rate of punishment of each given strategy, that is to say, if none of the offenders confesses, they both get two years' imprisonment, if they both confess, they get ten years, and if one testifies and the other does not, the former gets one year and the latter gets twenty years. Glancing at the data of the table, the best solution for both sides would be the two–two years' imprisonment. Further analyzing the data, supposing that the individuals try to minimize their own punishment and they may not expect co-operative behavior of the other side, the strategy where both testifies will be dominant, that strategy, namely which is better at each point than that where both refuse to testify (since ten is lower than twenty, one is lower than two). Hence, our table shows that following personal selfishness a situation disadvantageous for both sides takes place (that is to say, Pareto efficient state and the Nash equilibrium do no coincide).

Prisoner's dilemma and the game theory in general are often characterized with utility and payoff functions, in this case the above table alters as follows:

Table 2. Payoff matrix of two person prisoner's dilemma

	Co-operates	Defects
Co-operates	(r, r)	(s, t)
Defects	(t, s)	(p, p)

$s<p<r<t$ $2r>s+t$[1]

We talk about multiple person prisoners' dilemma when the players have two strategies – co-operation and defection – and defecting pays better off for each player than co-operating, and collective co-operation pays better off for each player than collective defection.[2]

An analysis of Dawes (1980) showed that the two-player prisoner's game may not be generalized directly to multiple-player situation; firstly, the moves of each

1 The letters are traditional abbreviations: t – temptation, r – reward, p – punishment, s – sucker.

2 The last condition is usually abated and instead of all players the number of players is supposed to be higher than K.

individual do not unavoidably conflict with those of others, someone may be a free rider when the others may not necessarily identify them. Namely, the situation cannot be described as when each player knows perfectly the acts of the other players. Secondly, in the two-person game, the other player will clearly face the costs of defection whereas the costs will be split among the members of the community in multiple-player games. Thirdly, each player can affect directly the gain or loss of the other player in a two-person game while there is only a small chance to do so in a multiple-player game. Hence, multiple-player games cannot be dealt with so simply as two-player games. In the literature, real social dilemmas are characterized by these three features.

REPEATED GAMES[3]

Infinitely Repeated Games

In economics usual methods are the various evaluations of various moments of time, the so-called calculation of present value assessment. It is based on the different assessment by the decision-makers of the profits expected in different periods, according to the anticipated run of the market that is habitually called discounting. In case of repeated games it is of basic importance whether the game is finitely or infinitely repeated. Depending on that, the game leads to entirely different results. Selten's theorem applies to finitely repeated games. It states that in case of finitely repeated games if the basic game has equilibrium and it is definite, this equilibrium is the solution in each turn. In case of infinitely repeated games, the situation changes fundamentally, the so-called folklore theorems[4] declare that co-operation is rational for players if the conditions are appropriate (the payoff functions and the dependent discount rates are chosen adequately).

The aforesaid premises show that the time horizon of the participants is of basic importance in repeated games. If they presume that it is useful to them to discount in short or medium term, namely, they play a finitely repeated game, they will opt for defection, for free rider's strategy. If they discount in longer term, namely they regard the given situation as infinitely repeated game, co-operation may occur. To translate the aforesaid into everyday language: if the members of the society think in short terms the occurrence of imperative authorities is of essential importance. If the members of the society think in longer terms and they may think of the others that they are driven by similar values, the establishment of expensively maintained institutions is not a necessity. The aforesaid also illustrates the well-known fact that the maintenance of norm systems is economically beneficial to a society; while the establishment and maintenance of laws and related institutions, although very expensive, is crucial for the sake of preserving social processes if the norm systems do not work.

3 Here I recommend the books of Fudenberg.

4 These theorems have been known for long and the name folklore has spread since their first demonstrator is not known.

Repeated Prisoner's Dilemma

If the players have the possibility to repeat the game, we talk about repeated prisoner's dilemma. Let us take again a simple example: Usage of water in a tenement block is a repeated prisoner's dilemma given that the dwellers do not have individual water meters. It is a question whether individual inhabitants waste or spare water. (It is not accidental that people escape from the repeated prisoner's dilemma by opting for the individual strategy, installing a water meter). In case of finitely repeated prisoner's dilemma it is clearly shown that the dominant strategy will not be the co-operating one if the dilemma is solved backwards, starting from the last repetition; and that applies to the entire course of the game. If the players may repeat the game infinitely, their mode of calculation alters and there is a chance that their behavior will change as well.

Folklore Theorems to Repeated Games

One of the most important fields of the literature of non-co-operative games is the analysis of repeated games. The so-called folklore theorems have been declared since the beginning of the 1960s. There is a great deal of such theorems; here we shall confine ourselves to the analysis of finitely repeated games.

In our opinion, the usage of infinitely repeated games is often deceptive, since transition from finite to infinite is not trivial and may often lead to paradoxes. In situations in everyday life, people's horizon is finite and they take finite time span into consideration when forming their actions. In most cases, this finite time span is not very long, because an event that is repeated more than a hundred times is rare even in case of a frequently repeated activity.

Finitely Repeated Prisoner's Dilemma

In the previous example, the logic of backwards induction is built on numerous basic assumptions. Firstly, the players know which the last game of the series is. (If the end of the game is uncertain, because we do not know when the game ends or it is infinite, the mechanism of induction does not work, since there is no first move.) Second assumption behind the induction is the usual supposition in game theory that rationality is part of common knowledge. In a single game of prisoner's dilemma, it is a simple assumption that is easy to defend, but in case of repeated prisoner's dilemmas, it is less obvious an assumption (Selten 1975, 1990).

Prisoner's Dilemma with an Uncertain Number of Repetitions

We may assume that only an exterior imperative force may generate co-operation in games of prisoner's dilemma. It is so in single or finitely repeated prisoner's dilemma situations. On the other hand, in case of repeated games the players may be able to produce strategy combinations that deter the others from defecting and thus they enforce co-operation. (Among others, Axelrod's classic *tit for tat* strategy is of this sort [Axelrod 1984]). In practice, if certain conditions exist, *tit for tat* strategy is widespread, even in cases where exterior imperative forces are missing; there is only a chance of subsequent encounter and turn of the situation.

In case of games of infinite length, several combinations lead to the Nash equilibrium. The so-called folklore theorems show that a great deal of possible strategy combination may lead to Nash equilibrium.[5]

GAME THEORY AND PUBLIC GOODS

Rational Choice Theory and Social Institutions

In order to understand the importance of non-co-operative game theory, we have to examine the significance of rational choice theory in social sciences. Rationality, in its narrow sense, is apparently an inadequate description of human behavior in real situations. It is especially true if we aim not only at forecasting human behavior but even at analyzing the occurrence and operation of institutions created by humans. Our assumption is not too restrained regarding the train of thought of this article, since in every other case we may suppose to change the behavior of humans, because if humans are not maximizing utilities or they do not know their environment (namely, they do not have full information to their decisions), we may easily be making observations not about individual institutions but about inadequate knowledge or behavior of decision-makers. The Nash equilibrium is in fact the framing of this concept, to be exact, Nash equilibrium is the determination of what each human being would do if they were rational in the above sense and they might assume similar behavior about the others. If people do not act this way, the concept of Nash equilibrium may lead to false results.

Social Dilemmas

Social dilemmas are situations where individually rational acts of people lead to irrational results on communal level; that is to say, individually reasonable behavior produces situations where each gets to a worse situation than otherwise. There are such dilemma problems behind most of the public decision situations: We, as individuals, are better off using communal resources without contributing to their production. On the contrary, if everybody did so, such public resources would not be generated. For example, if fishermen catch as many fish as possible without taking the activity of the other fishermen into account, this behavior will in the long run lead to the extinction of fish; namely, individual selfishness may result in collapse of the community.

5 Many introductory books on game theory are available to the reader such as Forgó and Szép (1977), Szidarovszky and Molnár (1977), Mészáros (2003).

Public dilemmas can also be characterized as games with deformed equilibrium. (To use the previous frame: Nash equilibrium and Pareto optimum do not coincide.) A simple variation of social dilemmas is the previously drafted prisoner's dilemma where defection will be the Nash equilibrium for the players.

Multi-Person Dilemmas

Previously, we have described only the two-person situations in a simplistic way. However, real situations are much complex. The most important aspect in analyzing multi-person dilemmas is how costs and gains are distributed among individuals. In case of 'dilemma of contribution', individuals face immediately the cost, by means of which a stock is generated that is shared by all. In this case, individuals feel a strong urge to avoid the expenses; nevertheless, if all do so, all get in a worse position than by contributing. Another type is the 'dilemma of participation' where each individual gets immediate gain the costs of which are covered by the entire community. If no one can resist the temptation, the result is the destruction of the given stock. The two metaphors are often called differently as well: 'dilemma of contribution' as the production of public goods and 'dilemma of participation' as the commons dilemma.

In economics, these situations are called externalities, quoting the definition of Buchanan (1992): externalities are situations where individual behavior affects other individuals' situations without any agreement between the individuals. Namely and simply, externalities are non-compensated interdependencies. It results from the above reasoning that the solution of the multi-person prisoner's dilemma situations is not trivial and simple. Simple proposals that may be realized in two-person or small groups may not be implemented successfully in larger groups.

Definition: we talk about collective action problems in *wide sense* if interactions resulting from interconnected decisions of individuals culminate in mutual consequences.

Definition: we talk about collective action problems in a *narrow sense* if the behavior of individuals endanger mutually beneficial co-operation.

Free Rider Behavior

We often experience that some members of a community try to evade the communal efforts for a goal; if the community, however, attains the goal in the end, these members want to get a share of the rewards. As the saying goes: 'Let's grip it and you take it'. There are numerous examples of such instances in the literature from Aristotle to Hardin's article, published in Science in 1968, on commons dilemma. Hardin's instance is as follows: there is a group of shepherds that have flocks independently from one another and the shepherds as a community have a commons. Individual shepherds are interested in herding as many animals as possible to the commons since grazing does not generate costs to them. The long-term result of this process is evidently the decay of the commons as more animals graze there than possible.

Let us define free rider behavior as follows.

Definition: We regard member *A* of group *K* as a free rider regarding the production of the given stock exactly if:

1. Individual *A* intends to evade the production of the stock.
2. Individual *A* thinks that efforts of *k* members $(k<|K|)$ of the community suffice to produce the given stock.
3. Individual *A* thinks he or she need participate in producing the stock only if adequately informed members of the community participate in the common effort that results in real production of the stock.
4. Individual *A* thinks that his or her individual profit is higher by defecting from production of the stock than by participating in its production.
5. Individual *A* thinks that the utility of participating of all members of the community in production of the stock is to all members higher than the utility of defection of all.
6. Individual *A* thinks that his or her individual absence from the production of the stock brings about cost (that may be zero) to the members participating in the production of the stock.

(Note: The last three criteria in the definition formulate the intention of being a free rider, the second and third attempt at interpreting defection, and the first aims at the entire decision situation.)

The above definition does not suppose that the given individuals are in a game theory situation, it only supposes that they are able to weigh up the rationality of participating in the production of public goods for themselves. The above definition is well useable also in situations defined by game theory apparatus.

Free rider behavior is usually approached through prisoner's dilemma (as we have done), but it is not necessarily so since the most important element of the situation is the conflicting nature between individual interest and common good and the absence of any co-operation or co-ordination among individuals (Andreoni 1988) – Olson (1964) does not analyze the free rider behavior through prisoner's dilemma either.

Public Goods and Common Goods

The literature on public goods has a history of hundreds of years. From the classics of philosophy – Aristotle and Hume – to the founding fathers of economics – Adam Smith to John Stuart Mill – many have been concerned with problems of production and lack of institutions and goods, important to the community. In economic literature, Samuelson's essay[6] plays the part of the stove. Economic literature has not been so far unanimous in defining the concept;[7] in the following we shall use the definition of the

6 Aristotle *Politics*; Hume *A Treatise on Human Nature;* John Stuart Mill *Principles of Political Economy;* Samuelson *The pure theory of public expenditure.*

7 An excellent summary on various definitions: Blümel et al. 1986.

book of John Cullis–Philip Jones (2003): *Public Finances and Public Choice.* They define public goods as having two criteria:

– Non-competitive consumption: consumption of an individual does not decrease the profit of all the others.
– Lack of excludability: consumers may not be excluded from the gains – or only by very expensive means. If the stock is available, an individual cannot exclude the other from consumption. (In case of private goods, consumption of a stock is only possible by paying its 'price' on the market.)

The above two criteria are usually summarized in a small table:

Table 3. Definition of public goods

		Competitive consumption	
		Yes	No
Excludability	Yes	Collective goods (Club goods)	Market goods
	No	Public goods	Common goods

In case of public goods, the goods are distributed among the members of the community after their production. None of the members of the given community can be excluded from consumption. Common goods are goods where distribution of the goods causes problems due to the limits of the resources (such as fish stock, fresh air, biodiversity, etc.). The consumption of common goods is competitive and they can be characterized with the dilemma of participation, since their supply is limited. Public goods are characterized with non-competitive consumption, thus their supply is theoretically infinite and therefore they are characterized with the dilemma of contribution.

The classic work of Mancur Olson (1965) defines the public goods by lack of excludability, hence he regards the lower two cells of the above table together as public goods. In his book, Olson formulates his famous theorem:

Theorem (Olson): *Supply of public goods is always less than desired.*

In his book, Olson studies the relationship between group size and interest and states that the larger the size of the group the less interest the members have in participating in the production of the goods.

Public Goods and Prisoner's Dilemmas

In reference to the dilemma of public or common goods, let us suppose the following:

1. Utilities are part of common knowledge.
2. Scale of participation has two values: {yes, no}.
3. No one can be excluded from the gains; gains are shared equally by members of the group.
4. Costs are shared equally by members of the group.

5. Individual members of the group cannot make long-term agreements with one another.
6. Game is played once by the members of the group.

According to the above suppositions, gain depends apparently on participation of the members of the group; the participants, on the other hand, make up a real subset of those who have a share in the gains of the stock. Having the above criteria as supposed, the production of public goods leads to prisoner's dilemma game.

Let indicate:

u_i the payoff/profit of person *i*.

b/n the profit of individual *i* from a unit contribution of any individual to the production of the stock.

k_i scale of the participation of *i*, if yes = 1, if no = 0.

c cost of each individual if participating.

Hardin (1971) introduced the following utility function: $u_i = b/n \; ?_j \; k_j - ck_i$

If $b/n<c<b$ inequality is true to parameters *b* and *c*, production of public goods leads to prisoner's dilemma situation.

To illustrate the above reasoning, we get the well-known table to *n*=2, namely to a group of two members:

Table 4. Public goods game as prisoner's dilemma

	Co-operates	Defects
Co-operates	*(b-c, b-c)*	*(b/2-c, b/2)*
Defects	*(b/2-c, b/2)*	*(b/2-c, b/2)*

Slightly generalizing, the above utility function may be characterized as the production of common goods:

$u_i(k_1, \ldots k_n) = b + q_i f(k_1, \ldots k_n) - ck_i$

where q_i is the share of individual *i* in the stock, and

b_i is the basic utility (that may be negative).

In this case, for instance, by choosing $q=1/n$, $f(k_1, \ldots k_n) = a?_j \; k_j$, parameters $0<c<a<nc$ lead to prisoner's dilemma.

In case of public goods, mutual defection results in zero payoff and mutual co-operation results in positive payoff, such as the production of public goods in case of tax paying. In case of common goods, lack of co-operation leads to negative result, such as the classic commons dilemma.

Obviously, the mathematical representation of the two games is in some sense invariant, Pareto optimum and Nash equilibrium do not coincide, but in fact behavioral patterns basing the considerations of individuals differ significantly. In case of dilemma of contribution, we decide if we give up some resource already in our possession; whereas in case of dilemma of participation the thing we give up or we share is not in our possession.

In accordance with the differences of the game, different institutions to enforce co-operation have to be established in different ways. It is apparent in multi-person dilemma. Let us examine first the game of contribution. In this case, let us suppose that we have *N* similar players, thus defection is the dominant strategy, namely the Nash equilibrium, independently from the number of players. Nevertheless, the Pareto optimum is when all co-operate; it results in the highest payoffs. By increasing *N*, the difference between payoff in Pareto optimum and in Nash equilibrium is evidently growing; that is to say, Olson's reasoning is true, increasing the size of the group results in relatively worse dominant state.

Examining the game of participation we observe that the dominant strategy of each player is participation, while the Pareto optimal state is clearly different. Similarly to the aforesaid, by increasing the size of the group, the difference in payoffs between the two equilibriums is growing. In public goods dilemma in real life, however, co-operation is to be created easier by introducing contingent selective stimuli than in case of communal goods where the introduction of such stimuli is least possible (this situation was called second-order free rider problem by Heckathorn 1988).

Thus Olson's theorem can be divided into two according to the above dilemma,[8] and can be declared suiting the above train of thought.

Olson's theorem (1): Without co-ordination or an institution inspecting and sanctioning individual participation, public goods of positive (negative) value will be under- (or over-) supplied.

Olson's theorem (2): Without co-ordination or inspection, communal resources will be overused.

Repeated dilemmas

Examining the temporal run of the above dilemmas, they have to be separated according to the time horizon, whether the dilemmas are examined on finite or infinite time horizon. The two games differ here notably; since in case of the public goods problem, the equilibrium in finite repetition is that the stock is not produced; whereas in case of the common goods problem, an important distinction is whether the given stock is renewable or not. If the common stock is not renewable, the equilibrium will be its destruction; while many types of equilibriums may arise in case of the renewable common goods.

SOLUTION TO SOCIAL DILEMMAS

If members of the community perform some communal action, we believe that at least some of the members do something for the sake of the production of the given stock. The question is, who they are and what ration of the public goods they produce. In case of formal groups, such as organizations, some types of rules clarify who from the group is to act. But in informal groups or in inadequately defined communities, it is less simple.

8 Although by different train of thought, Ostrom (1990) did it first.

In his classic work, Olson makes a suggestion to solve the dilemma. He proposes the usage of individual (selective) stimuli in producing public goods. The task of selective stimuli is to bridge in some way the gap between the incidental high costs and the relatively low related profit. (Olson's solution can be applied to the dual task, namely to the common goods problem; nonetheless, here the stimuli are the expenses imposed on consumers of common goods.)

In the time since Olson's book, several proposals have been made to solve the social dilemmas;[9] in the following, the typical solutions to social dilemmas will be systematically reviewed.

Motivation Solutions

In the models, we take into account very often only the extent of gain of individual players, independently from the payoffs of the others. (Meanwhile we often listen to payoff of the others, as well.)

1a) Solutions considering communal values. In such experiments, it is supposed that each individual considers the common gain of the community besides his or her individual gain. The underlying observation is that individuals generally cannot be characterized by unambiguous behavioral schemes; that is to say, they may not be classified as co-operative and competitive.

1b) Communication. This approach can be described as co-operation related to the level of communication among the members of the group. Elinor Ostrom (1990) indicates the fact that communication among members of the group in repeated situations improves radically the chances of the group.

1c) Group identity. If members of the group have some communal consciousness, it will influence significantly the level of co-operation. The related literature states that group consciousness generates co-operation in small groups.

Strategic Solutions

Strategic solutions suppose that individuals are selfish and there is no change in the structure of the game; consequently, we want to have effects on the payoffs. As we mentioned above, payoffs can only be traced back well in the case of few players; therefore, the related literature deals mostly with the dilemma situation of two players or some more.

2a) Reciprocity. In *The Evolution of the Co-operation*, Axelrod scrutinizes the possibilities of breaking the prisoner's dilemma situation. Axelrod determines three important requisites for the emergence of co-operation.

– The players have to be constantly and mutually connected (otherwise, if players meet only once or a few times, defection will become the dominant strategy).

9 I recommend the writings of Bicchieri (1993), Crawford and Haller(1990), Dawes (1980), Kollock (1998), Kuran (1995), Lichbach (1996), Ostrom (1990) and Ullman-Margalit (1997) among others.

– Players should be able to identify one another.
– Players have to be informed about the past behavior of the others (in absence of this, defection will become an attractive alternative to some individuals).

According to Axelrod's analysis, the simplest strategy, the so-called *tit for tat* is the most effective. This strategy co-operates first, next it merely repeats the moves of the rival player. In most cases, such as prisoner's dilemma or insurance game, this strategy has proved to be very effective.

By studying the possible strategies, Axelrod made the following proposals:

– We should not be defeatist and skeptical about the co-operative intentions of the others.
– We should not defect first.
– We should behave on the basis of mutuality.
– We should not be too clever, we should listen instead.

The fourth advice means that it is important to understand what strategy our partner follows in reality. The first advice is very important in zero-sum games. In this case, victory over the partner is the short-term gain, but it obviously results in conflicts, therefore the triumph over the partner will lead to a bad process.

The second important lesson is that good strategies do not aim at how we shall beat our partner but at persuading our partner into co-operation, if possible.

2b) Partners in dilemma. An important aspect in Axelrod's analysis was the structure of the network of relations; relations and connections to one another affect notably the result, namely the emergence or lack of co-operation.

2c) Strategies. The above analyses applied to the two-person dilemma. In case of multi-person dilemmas, as we noted, the situation is much more complex. In these cases, *tit for tat* strategy is usually exercised; namely, co-operating as long as all other players co-operate, defecting otherwise. According to the note of later literature (Ostrom 1994), this strategy is almost never used in practice.

2d) Learning. Solutions to multi-person dilemmas presume that each member of the group does not follow entirely his or her individual utilities but they try to create conditions where some of the members of the group can be won for co-operation.

2e) Group solidarity. If the group as a group has an identity and some solidarity among the members of the group can be found, co-operation may evolve.

Structural Solutions

If rules of the game may change; that is to say, the consideration that the rules of the game are stable can be lifted, new possible solutions are available.

3a) Interactions. According to Axelrod's proposition:

– Let us have frequent and long interactions.
– Let us increase the level of identification.
– Let us improve our knowledge about actions of each individual.

If we follow these three basic rules, the level of co-operation will get better after each turn. (We note here that Axelrod's reasoning concerned two-person games, and as we have already brought it up, the generalization of such games to many persons is not self-evident at all. Moreover, examples to multi-person dilemmas may be constructed where co-operation would decrease instead of increasing if we followed these basic rules.)

3b) Structure of payoffs. Numerous analyses have specified that the level of co-operation will increase if gain from co-operation increases and gain from defection decreases (Komorita 1996). The nature and divisibility of the public goods count as well. Analyses also showed that if the given stock cannot be divided, the level of co-operation is higher than otherwise. When each individual gets real gain after each turn, inclination is high to gather the given minimal gain and to defect. Others argue that non-divisibility of the stock may lead to the emergence of group identity.

3c) Efficiency. Several actors argue (for example Olson, among others) that lack of co-operation in multi-person dilemma relates to the small effect of each individual on the whole situation. Among others, if we as individuals pay a minimal or small sum of health insurance contribution, in consequence no hospital would be closed and the grade of medical service would not decline dramatically either. It follows from the above statements that we have to attempt to structure the dilemma, if possible, so that individual efforts may generate perceptible and traceable changes. Division of the large group into small, well observable groups can be such a solution. In this case, the free rider behavior may endanger the emergence of the public good, produced by the group.

3d) Size of the group. As we have mentioned previously, the size of the group is a very important factor. The literature agrees on co-operation declining with the growth of the group. Olson also showed that additional costs – cost of organization of the group – arise with the growth of the size. In this case, inspecting and sanctioning institutions have to be created as well, in order to enforce co-operation.

If the stock produced by the group is not competitive, public stock may emerge in case of a large group, too, since the per capita cost of the production of the stock may be very low. In this case, many authors point to the importance of heterogeneity of the group.

3e) Inspection. One of the major problems of production of public goods is the impossibility of excluding anybody from consumption. One direction of solution can obviously be the putting up of limits. In this case, institutions have to be founded to check who contributes to the production of the public goods and to what extent. Hardin proposes this solution in his already cited article (we would like to note that Hobbes does the same in *Leviathan*). Apparently, the foundation of such institutions raises a great deal of questions; as Plato already noted, who inspects the inspectors.

3f) Penalties. As Dawes mentioned, there is often no chance of checking efforts, behavior and gain of others in multi-person dilemmas. However, co-operation may arise if co-operative behavior is rewarded and defection is chastened. A major statement of Olson's book is that selective stimuli have to be introduced to improve co-operation. Among others, Olson proposes the association of public goods with private goods. It is usually called beet and stick strategy; namely, co-operation arises more often if the others have the possibility to punish the defectors and stable co-operators get rewards. This solution results also in the establishment of institutions that have expenses. Such institutions have to inspect the behavior of individuals on the one hand, and they are to organize the punishment of defectors on the other. The costs of such institutions are often higher than the value of produced public goods.

SUMMARY

In her book, Elinor Ostrom identified three important factors of occurrence of public goods by analyzing public goods and public investments of various cultures.
1. The community has to be composed of well defined, stable members.
2. The profit of stock to be produced has to be very high in order to cover the costs of mutual control of the members of the community.
3. The members of the community not only know and check one another but they also communicate with one another.

It is clearly visible that the above three considerations can hardly be applied to public goods dilemmas in modern societies; hence the traditional solutions that have been elaborated by the communities so far almost cannot be applied nowadays to solving such problems.

Therefore we have to transform our institutions; if we consider the concept of solidarity in the given institution, we have to make it penetrable where individuals know and check each other; or we have to give way to individual self-interest, acknowledging the aspiration of individuals and the lower degree of solidarity.

REFERENCES

Andreoni, J. (1988): Why Free Ride? *Journal of Public Economics*, 291–304.
Axelrod, R. (1984): *The Evolution of Cooperation*. New York: Basic Books.
Axelrod R. and Dion, D. (1988): The Further Evolution of Cooperation. *Science*, 242: 1385–1390.
Bicchieri, C. (1993): *Rationality and Coordination*. Cambridge: Cambridge University Press.
Blümel, W., Pethig, R. and von dem Hagen, O. (1986): The Theory of Public Goods a Survay of Recent Issues. *Zeitschrift für gesammte Staatwissenschaft,* 142: 241–309.
Buchanan, J.M. (1992): *Piac, állam, alkotmányosság. Válogatott tanulmányok.* [Liberty, Market and State.] Budapest: Közgazdasági és Jogi Könyvkiadó.
Crawford, P. and Haller H. (1990): Learning How to Cooperate: Optimal Play in Repeated Coordination Games. *Econometrica,* 58: 571–595.
Cullis, J. and Jones, Ph. (2003): *Közpénzügyek és közösségi döntése.* [Public Finance and Public Choice.] Budapest: Aula.
Dawes, R.M. (1980): Social Dilemmas. *Ann, Rev. of Psychology*, 169–193.
Dawes, R.M. and Messick, D.M. (2000): Social Dilemmas. *Int. J. of Psychology*, 111–116.
Dixit, A. and Skeath, S. (1999): *Games of Strategy*. New York: W.W. Norton.
Forgó F. and Szép J. (1977): *Bevezetés a játékelméletbe*. [Introduction to Game Theory.] Budapest: KJK.
Fudenberg, D. and Levine, D. (1998): *Theory of Learning in Games*. Cambridge, MA: MIT Press.
Fudenberg, D. and Tirole, J. (1991): *Game Theory*. Cambridge, MA: MIT Press.

Hardin, G. (1968): The Tragedy of the Commons. *Science*, 162: 1243–1248.
Hardin, G. (1971): The Survival of Nations and Civilizations. *Science*, 172: 1297.
Heckathorn, D.D. (1988): Collective Sanctions and the Creation of Prisoner's Dilemma Norms. *American Journal of Sociology*, 94(3): 535–562.
Kollock, P. (1998): Social Dilemmas, *Ann. Rev. of Sociology*, 183–214.
Komorita, S.S. and Parks, C.D. (1996): *Social Dilemmas*. Westview.
Kuran, T. (1995): *Private Truths, Public Lies: The Social Consequences of Preference Falsification.* Harvard University Press.
Lichbach, M.I. (1996): *The Cooperator's Dilemma*. The Univ. of Michigan Press.
Mészáros J. (2003): *Játékelmélet*. [Game Theory.] Budapest: Gondolat.
Nash, J. (1951): Non Cooperative Games. *Annals of Mathematics*, 54: 286–95.
Olson, M. (1965): *The Logic of Collective Action*. Cambridge, Mass: Harvard University Press. [magyarul: *A kollektív cselekvés logikája*, Budapest: Osiris, 1997.]
Ostrom, E. (1990): *Governing the Commons: The Evolution of Institutions for Collective Action.* New York: Cambridge University Press.
Ostrom, E. (1994): *Rules, Games, and Common-Pool Resources.* Ann Arbor: University of Michigan Press.
Ostrom, E. (2000): Collective Action and the Evolution of Social Norms. *Journal of Economic Perspectives*, 13(4): 137–158.
Ostrom, E. Ahn, T.K. and Walker, J. (2001): Cooperation in PD Games: Fear, Greed, and History of Play. *Public Choice,* 106(1/2): 137–155.
Selten, R. (1975): Reexamination of the Perfectness Concept for Equilibria Points in Extensive Games. *International Journal of Game Theory*, 4: 25–55.
Selten, R. (1990): Bounded Rationality. *Journal of Institutional and Theoretical Economics*, 146(1): 649–658.
Szidarovszky F. and Molnár S. (1977): *Bevezetés a játékelméletbe műszaki alkalmazásokkal.* [Introduction to Game Theory with Technical Applications.] Budapest: Műszaki Kiadó.
Ullman-Margalit, E. (1977): *The Emergence of Norms.* Oxford: Oxford Univ. Press.