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Summary

People have a marginal role in managing forests located in the vicinity of their villages in Northern India. This situation is scrutinised in this paper by studying strategic play of forest users. Thereto, a 1 versus *n* - 1 game of people's participation in forest management is estimated for three institutional and historical distinct cases at the state and village level. Critical discount factors are derived to verify whether incentives exist for villagers to mutually participate in managing commonly used forests. This paper find such incentives in varying degrees for games at the state level and for games in 28 of the considered 32 villages.

Keywords: Game estimation, repeated games, people's participation, forest management, rural India

JEL: C72, Q20

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1 Introduction

The role of people in forest management in India has been low. This paper argues that such a marginal role is not justified, given the potential of people to participate voluntarily. A higher level of people's participation may well result in a better quality of the forest, which is both beneficial for the nearby living people and the state.

While most forests in India are under the control of the state, there exist some forests which are managed by nearby living people. Forests are a commonly owned by a number of people, in that sense it can be considered as a common-pool resource. The problem of managing a common-pool resource, or simply the common-pool resource problem, has become a topic of debate after the appearance of Hardin's (1968) 'tragedy of the commons.' The 'tragedy of the commons' is rephrased by Stevenson (1991) as the 'tragedy of open access', because the tragedy does not occur in a common property regime, where the rights are well-defined. A well-defined group of users in combination with well-defined rights make a common property regime. The well-functioning of a common property regime depends on the amount of people's involvement.

To analyse the common-pool resource problem, let us distinguish between common-pool resource *situation* and common-pool resource *dilemma* (Ostrom *et al.*, 1994). In a common-pool resource situation there are multiple individuals who are using a common-pool resource. This becomes a common-pool resource *dilemma* when the following conditions hold simultaneously.

1. Individual optimal strategies lead to suboptimal outcomes for the group, due to uncoordinated behaviour.

2. There are institutional feasible alternatives, where collective optimal outcomes can be achieved (ibid.).

The common-pool resource situation does not have to be a dilemma, as Hardin presumes, but in case of a conflict it is useful to know how it can be resolved. The prisoner's dilemma and the chicken's game are typical examples, which satisfies these two conditions.

There is an interesting debate in the literature on how to model a common-pool resource situation using game theoretic modeling. While such an approach has many similarities to the situation of forest management, it has not been applied to such a situation before. On the one hand, both Ostrom (1990) and Wade (1987, 1988) argue that classical approaches of the 'tragedy of the commons' (Hardin, 1968; Hardin and Baden, 1977) and 'the logic of collective action' (Olson, 1965) lead to metaphorical policy devices, which cannot be used directly in decision making. On the other hand, Ostrom and Wade are in favor of using game theory for modeling common-pool resource situations. The advantage of simple game theoretic models is that they are easy to understand, while such models can point out conflicts which can emerge when a common-pool resource situation becomes a common-pool resource dilemma.

To solve a common-pool resource dilemma, Wade (1988) pleads for the formation of local organisations for coordinating people's actions for managing a common-pool resource. Basu and Mishra (1993) argue that there does not need to be a common-pool resource dilemma in a single period in the sense of Wade, but the common-pool resource dilemma shows up in the long run. This can be modeled as a hawk/dove game, where people choose between the *dove* and the *hawk* strategy. Playing *dove* means preserving the common-pool resource, while *hawk* results in exploitation of the common-pool resource. Playing *hawk* too often brings the common-pool resource on the brink of disaster. Hence, degradation of the common-pool resource is not immediately apparent, but it is observed gradually over time.

Runge (1981, 1984, 1986) pleads, as contrary to the common belief that the common-pool resource situation is rather akin to the assurance game, where one prefers to do what the other does, while mutual participation has the highest preference. This is, typically, not a dilemma and it leads to a self-enforceable solution. It explains why 'the tragedy of the commons' has not yet emerged on a larger scale.

Hence, strong arguments to model the common-pool resource situation as a prisoner's dilemma (R. Hardin, 1982; G. Hardin and Baden, 1977; Taylor, 1987; Bendor and Mookherjee, 1987), an assurance game (Runge, 1981, 1984, 1986) and a hawk-dove game (Basu and Mishra, 1993) or, what is the same, a chicken's game (Taylor, 1987) can be found in the literature. The prisoner's dilemma and chicken's game constitute *collective dilemmas* (Bardhan, 1993a; Bates, 1988). This debate has not yet brought an answer of the same tenor.

Bardhan (1993a, 1993b) goes even further to argue that the common-pool resource dilemma can change from one dilemma to the other or can even be resolved as time goes on. He gives an informal discussion on this transition process. In many practical situations, people face the same choice-situation over and again. Those situations can be modeled as repeated dilemmas (Axelrod, 1984; Kreps *et al.*, 1982; Kreps and Wilson, 1982; Milgrom and Roberts, 1982). A simple way to rationalise cooperation in repeated games is by considering *infinite repetitions*, which is the route of this paper.

It is customary in applied game theory to start with identifying the game in a situation and then continue to discuss the implications. This paper follows the opposite route. The kind of strategic play in the field is not identified beforehand. Instead, the game being played is verified through an econometric technique using primary data from a field survey in rural India, which was an enquiry into people's willingness to participate in forest management (Lise, 1997b, 2001; Lise *et al*, 2001). The estimation result shows which game the people have been playing at the village and state level. This result is compared with the situation in the field and the implications are discussed.

This paper is set up as follows. Forest management is as a special case of common-pool resource management, about which a number game theoretic models exist. These models form a starting point for setting up a game model of people's participation in forest management (Section 2). Section 3 derives for all generic bi-matrix symmetric games the discount factors, which are used to verify whether incentives exist for people to voluntarily participate in forest management. Section 4 applies the model to three Indian states, namely Haryana, Bihar and Uttar Pradesh. The nature of the data is discussed and the game estimation procedure is explained and performed at the state and village level. The last section provides conclusions and recommendations.

2 The model

In order to study the opportunities of local people to voluntarily participate in the management of forest adjacent to their villages, let us model this as a non-cooperative game. The strategy of a peasant in rural India is to choose the extent of participation in forest management. Here participation means the amount of involvement of a villager in a local organisation in the village to manage an adjacent forest. Participation also means for a peasant to adhere to rules as formulated during village meetings. Their participation is awarded with the right to (partially) access the forest from which they can collect resources like fuelwood and fodder (=their payoff). Let us refer to this situation as the *participation game*.

The simplest form of such a game consists of only two persons, who have a choice between two alternatives: to participate or not. Let us assume that the players of the game have the same preferences. While villagers generally do not all have the same preferences, there are many situations where they are comparable or where they have equal opportunities.

Considering the motivation above, the participation game can be formalised as follows.

a. The set of players consists of two persons: $\{1, 2\}$. Let us label the two persons as challenger i and contender $-i$, where the challenger is the person which we consider in the analyses, while the contender represents other persons in the village, which are evaluated in the mind of the challenger.

b. Player i chooses the level of participation θ_i. For the time being, we only focus on two choices. Then we can abbreviate the set of actions as {Participate, Do not participate}, or in short as {P, D}.

c. The payoff to the challenger i is $\pi_i(\theta_i, \theta_{-i})$, where θ_i is the action taken by player i. The total payoff set in the situation with two choice alternatives and two players, consists of four different numerical values: $\{x, y, a, b\}$.

Table 1 shows the payoff matrix of the symmetric two-person repeated game described above. While the game, introduced above, is a two person game, the estimated game in Section 4 is more general, as it is a 1 versus $n-1$-person game.

To interpret the estimated games in Section 4, it is useful to classify all generic games. For that, we divide all 24 possibilities for ordering the payoffs a, b, x, y into twelve distinct cases, based on strict inequalities. Games with equal payoffs are called *transition games.* In 12 cases the game has a unique Nash equilibrium. In 10 of these 12 cases the individual best response matches with the collective preferred outcome. Such a game is called the *Pareto game*. In the remaining two cases, the individual best response conflicts with the collective preferred outcome; the well-known prisoner's dilemma.

The other 12 cases have two pure-strategy Nash equilibria. In 6 of these 12 cases, mutual participation a Nash equilibrium of the game. These games are known as coordination and assurance games. In the other 6 cases, the Nash equilibria have one player participating and the other does not. These games are well-known as the battle-of-sexes and chicken's games.

The coordination and battle-of-sexes games are very similar to, respectively, the assurance and chicken's game. There is, however, a difference. For the coordination and battle-of-sexes games the Nash equilibria payoffs are strictly greater than the remaining payoffs, which is not true for the assurance and chicken's games. Table 2 shows the taxonomy of two-person two-action symmetric games.

3 Critical discount factors of the repeated participation game

The participation game can also be repeated infinitely over time. Such a game can be analysed by considering trigger strategies. Trigger strategies are a code of behaviour, where the players agree to participate until a certain condition is violated, after that they do not participate forever to punish the deviant. Formally, challenger i follows a *trigger strategy* to proceed in the game: $\sigma_{it} = \{$"Participate at time t as long as a certain condition is satisfied"$\}$.

For analysing repeated games, subgame perfect equilibria generally need to be found. However, in our specific case, it suffices to look at Nash equilibria, as they coincides with subgame perfect equilibria in our case of infinite repetitions and trigger strategies, as such games can be analysed as supergames which are equivalent to normal form games.

The taxonomy of Table 2 will be used to derive necessary conditions under which mutual participation can be sustained in the infinitely repeated participation game. The main question studied is the following: Assuming that both players participate, do they have an incentive to deviate? It is possible to assign to each game a so-called *critical discount factor*, denote this as ϕ. If the people discount their future –with factor δ which is equal for both players– above the critical discount factor, mutual participation can be sustained in equilibrium. The smaller the value of a critical discount factor, the greater is the likelihood to preserve mutual participation. It is a well-known from the Folk theorem (Fudenberg and Maskin, 1986) that such critical discount factors can be found. Let us consider two special cases first: the prisoner's dilemma and the chicken's game.

There exists a conflict between individual and group rationality in the standard repeated prisoner's dilemma. Mutual participation becomes a possible outcome in the infinitely repeated prisoner's dilemma if the players follow the following trigger strategy σ_{it}^{pd}, assuming that they started with mutual participation.

$$\sigma_{it}^{\text{pd}} = \begin{cases} \text{P} & \text{as long as } \theta_{t-1} = (\text{P,P}) \\ \text{D} & \text{if } \exists i \in N, \exists \tau < t : \theta_{i\tau} = \text{D}. \end{cases}$$

This trigger strategy prescribes to participate until a player deviates. After that both players do not participate forever. It is well-known how to calculate the critical discount factor ($\phi^{\text{pd}} = \frac{a-x}{a-y}$) from this trigger strategy (see for instance Stahl (1991)).

The chicken's game has two pure Nash equilibria: (P,D) and (D,P). Consider the following *complex* trigger strategy:

$$\sigma_{it}^{\text{ch}} = \begin{cases} \text{P} & \text{as long as (1) } \theta_{t-1} = (\text{P,P}) \text{ or } (\text{D,D})\text{; or:} \\ & \text{(2) } \exists \tau < t : (\forall s < \tau : \theta_s = (\text{P,P}) \text{ or } (\text{D,D})) \wedge (\theta_{i\tau} = \text{D} \wedge \theta_{-i\tau} = \text{P}) \\ \text{D} & \text{if } \exists \tau < t : (\forall s < \tau : \theta_s = (\text{P,P}) \text{ or } (\text{D,D})) \wedge (\theta_{i\tau} = \text{P} \wedge \theta_{-i\tau} = \text{D}) \end{cases}$$

Trigger strategy σ_{it}^{ch} prescribes to *keep on participating as long as the other did not deviate first*. Trigger strategy σ_{it}^{ch} differs from σ_{it}^{pd}, because the deviant returns to participation, when the other person implements the infinite queue of deviations. In this manner, the deviant can ascertain a higher payoff b instead of y. Payoff b is the highest payoff the challenger can get, when the contender deviates, which is the least desirable action. Hence, b is the minimax payoff. When both players follow this behaviour, then the critical discount factor can be derived similarly as in the last case of the prisoner's dilemma. This yields the following critical discount factor: $\phi^{\text{ch}} = \frac{a-x}{a-b}$.

Consider the following trivial strategy which sustains mutual participation, since it is a Nash equilibrium; 'mp' stands for *mutual participation.*

$$\sigma_{it}^{\text{mp}} = \begin{cases} \text{P} & \text{irrespective of the choice of the other player} \end{cases}$$

Behavioral strategy σ_{it}^{mp} is not a trigger strategy, because sustainability of mutual participation can be achieved by participating. In that case, the potential deviator has to participate as well in order to maximise his/her payoff ($\phi^{\text{mp}} = 0$).

It is also possible to consider the trivial strategy which sustains mutual non-participation, which is again a Nash equilibrium. Superscript 'rp' stands for *reverse Pareto game*:

$$\sigma_{it}^{\text{rp}} = \begin{cases} \text{D} & \text{irrespective of the choice of the other player} \end{cases}$$

This is the opposite of the previous strategy, and it recommends to never participate ($\phi^{\text{rp}} = 0$).

Finally, it is also possible that a mix of participation and non-participation is the Nash equilibrium. In that case each player wants to take the opposite action from the other player. Let us refer to these cases as 'other games'. The strategy σ_{it}^{og} can be described as follows:

$$\sigma_{it}^{\text{og}} = \begin{cases} \text{P} & \text{as long as } \theta_{-i,t-1} = \text{D} \\ \text{D} & \text{if } \theta_{-i,t-1} = \text{P} \end{cases}$$

In this case, mutual participation cannot take place as well ($\phi^{\text{og}} = 1$).

The question, whether it is profitable to deviate from mutual participation in the past, can be answered by summarising the critical discount factor for every possible game. The result of this section is summarised in the following lemma.

Lemma 1 *If σ_{it}^{ag} in Equation 1 is the code of behavior then mutual participation can be sustained if and only if $\delta \geq \phi$, where ϕ is as given in Table 3.*

$$\sigma_{it}^{\text{ag}} = \begin{cases} \sigma_{it}^{\text{pd}} & \text{for the prisoner's dilemma } (a > x > y > b) \\ \sigma_{it}^{\text{ch}} & \text{for the chicken's game } (a > x > b > y) \\ \sigma_{it}^{\text{mp}} & \text{for games with (P,P) a Nash equilibrium } (x > a) \\ \sigma_{it}^{\text{rp}} & \text{for the reverse Pareto game } (y > \max\{b, x\}; a > x) \\ \sigma_{it}^{\text{og}} & \text{for all other games in Table 2} \end{cases} \quad (1)$$

4 Estimation of games

4.1 Forest management in three Indian states

In order to apply the game model of people's participation, data is used from a comparative study in three states of India: Haryana, Uttar Pradesh and Bihar. These cases were selected because of their differences with respect to forest quality, kind of forest resources and the way the village council is organised. At the same time these three cases all have in common that they are driven by voluntary people's participation.

In Haryana, the state leases the forest to a number of villages, since 1977. In each village, villagers have formed a council to manage their forest, namely a Hill Resource Management Society (HRMS). All residents of the village became members of that HRMS. In most villages the state has built dams to serve a double purpose: to check soil erosion of the hilly area of the forests and to provide irrigation water to the villagers. In order to share damwater equally, HRMSs allotted water rights to their members, but this did not work in every village. Moreover, a number of dams failed to provide any irrigation water, and land is distributed quite unequally. Besides income derived from damwater, resources like fodder, fuelwood, bamboo and fiber grasses could be collected as well from the forest.

In Bihar, a non-governmental organisation encourages villagers to pool private land for planting trees since 1984. They adopted the Haryana model to the local circumstances in Bihar. The output from the pool is shared equally among its members of the well-organised village committee. One third of the profit goes to the people who pool land, one third to people who plant and maintain the saplings, and one third to the village development fund. The role of the state is negligible in these villages. The people who work on the pool receive a stipend, besides a part of the output from the pool.

In the hilly region of Uttar Pradesh, the state allowed for the creation of forest councils by villagers since 1931. A well-organised forest council decides on how to manage a communal forest. The role of the state in Uttar Pradesh is somewhere between Haryana and Bihar. Resources like fuelwood, fodder and timber can be collected from the forest at a rotation basis in order to preserve the quality of the forest. Land and cattle holding is fairly equal in the hills of Uttar Pradesh and women are involved in forest management to a larger extent than in Haryana and Bihar.

Table 4 points out the diversity between the three situations of forest management. In total 385 households from 32 villages have been interviewed. I selected representatives of the households randomly, by visiting these villages in 1995 and 1996. The variation in the data sample can be found in Lise (2000). In the field survey, I covered 9, 12 and 11 villages and 127, 123 and 135 households in Haryana, Bihar and Uttar Pradesh. My field survey also yielded a broad range of information about the following groups of socio-economic variables:

- Their attitude to the environment;
- Their attitude to the village council for forest management;
- Ownership of land, cattle and private assets;
- Income from different sources;
- Caste, religion, gender, education, family size, etc.

Table 9 shows a selection of the socio-economic variables which have been constructed from this data.[1]

4.2 Games at the state level

The participation game of Section 2 can be quantified as follows (Lise, 2001). The payoff (π_i) is generally derived from the total sum of the amount of resources which are collected by the members of a village council for forest management times the average market value of these products. The payoff in Haryana includes besides fuelwood, fodder, fibre grass, and bamboo also the added value of damwater. The payoff in Bihar consists of the stipend paid to villagers working in the pool and the yield from the common pool. In Uttar Pradesh the payoff solely consists of the market value of collected fuelwood, fodder and timber.

The level of participation (θ_i) of the challenger is constructed in two steps. First, indicators of participation are derived by interviews with members of a village council for forest management. Each member responded to a number of questions about their contribution to, benefit from and

[1] The questionnaires can be found in Lise (1997).

involvement in forest management. People can choose their level of participation in many aspects of forest management. These can be broadly divided in three different components.[2]

i. Contribution by plantation in and protection of the forest.

ii. Sharing in the benefits from using the forest.

iii. Involvement in decision-making and evaluation of forest management.

Their psychological responses are recorded on an integer scale varying from 1 to 5, where a high number represents a high willingness to participate. One way to aggregate such indicators of participation into a level of participation is by performing a factor analysis on these indicators. This is, for example, possible by running the `FACTOR` procedure of SPSS. A factor analysis is a method for translating a large set of variables into the main choice-variable: the principal component. Table 5 shows the first principal component for the three cases considered in this study.

Hence, we have the pair (π_i, θ_i) for all 385 interviewed households across 32 villages in three Indian states. Within a particular village, the level of participation of the contender (ϑ_i) can be calculated by aggregating the level of participation of the *other* villagers. This paper aggregates the level of participation of other villagers in two ways. First by taking the mean, which can be considered as being risk neutral towards the strategy of other players (mean situation). Second by taking variance, where a player is risk averse toward the strategy of other players, as one opposing player gets a high weight in this case (variance situation). This leads to triplet $(\pi_i, \theta_i, \vartheta_i)$.

There is an important distinction between the mean and the variance situation. In the mean situation, a large value of a level of participation always means 'participate', while a small value means 'do not participate'. This is not the case in the variance situation, where the action of the contender is conditional on the action of the challenger. When the variance is small, the actions of the challenger and the contender naturally have to be the same, but when the variance is large, the action of the contender must be *opposite* to the action of the challenger.

A game can be estimated by normalising the levels of participation (θ_i, ϑ_i) of all interviews between 0 and 1. The interviews can then be divided into four *payoff* groups based on these normalised levels

[2]Refer to Pongquan (1992) for a comparative discussion on the definition of people's participation.

of participation. One way to do so is by the `QUICK CLUSTER` procedure of SPSS. The `QUICK CLUSTER` procedure has the characteristic that the wihin-group distances are minimised and the between-group distances are maximised. This way of creating four payoff groups is called the *Euclidean cluster method*. Alternatively, the sample could also be split into four payoff groups of equal size, with the help of an EXCEL spreadsheet . The latter way of creating payoff groups is called the *homogeneous grouping method*. Finally, the payoffs can be derived by taking the averages within the payoff group.

Table 6 shows the games at the state level which are estimated using the Euclidean cluster method and the homogeneous grouping method. Furthermore, a distinction has been made concerning the risk perception of the challenger towards the strategy of the contender (mean or variance situation)). Hence, there are four possible outcomes per state. The Euclidean cluster method leads to most reliable result from a game theoretic point of view as the method clusters together villagers with similar levels of participation. Hence, the first 6 games of Table 6 are most likely to represent the actual game being played. There are, however, still two options. Out of these two options, the variance situation seems to provide the best representation of the reality, as the estimation results for the Euclidean cluster method and the homogeneous grouping method are the closest. This implies that the consulted villagers would not mind if all villagers have a the same attitude to the forest, but they seem to be sensitive towards radical different levels of participation of other villagers.

In the case of the Euclidean cluster method and the variance situation, partial participation is observed in Haryana (reverse battle-of-sexes game), conditional participation in Bihar (coordination game) and unconditional participation in Uttar Pradesh (Pareto game). This typically represents the actual situation. Partial participation takes place in Haryana, because of unequal landholding and a great difference between rich and poor. In Bihar the villagers are quite hesitant in pooling their privately owned land, but they are willing to, if others are. In Uttar Pradesh the people in the village are quite equitable and seem to have great stake in participating in forest management. Table 6 shows for the case of the Euclidean cluster method and the mean situation, a higher incentive to participate than in the variance situation. This indicates that, if a villager is risk neutral towards the distribution of the level of participation of other villagers, mutual participation is more likely to emerge.

Table 7 shows the average level of participation (final cluster centers) in each payoff group. It was necessary to consider 5 instead of the usual 4 clusters in the case of Haryana, otherwise the difference between some final cluster center would not be statistically significant. High levels of participation are underlined to distinguish between high and low levels of participation, which we labeled as 'Participate' and 'Do not participate' in Table 1. From Table 7, we can also see that the number of observations is quite unevenly distributed. While the amount of mutual participation in Haryana is around 28% (payoff group 'x'), the amount of mutual participation in Bihar and Uttar Pradesh is varying between 62% and 82%.

4.3 Games at the village level

The Eclidean cluster method is used here to derive the games at the state level. This method is not useful for deriving games at the village level as there is not enough information available in one village for estimating a game. In a single village we can observe either equilibrium behaviour or off-equilibrium behaviour. We, crucially, need the variation over a number of villages for spanning the full payoff matrix meaningfully.

I assume here that the homogeneous grouping method can be used to explore games at the village level, in case the estimated games are sufficiently similar to the ones found with the Euclidean cluster method. We can see from Table 6 that the games in Haryana and Bihar are the same and that the game in Uttar Pradesh changes from a Pareto game to a quite similar coordination game.

Let us divide the data into four equally sized payoff groups via the homogeneous grouping method, to explore the games at the village level. Then, we take the payoff as a dependent variable and try to find which socio-economic variables can be included as descriptive variables. This is equal to estimating the following equation, for each payoff group, in each state.

$$
\begin{aligned}
\pi &= \beta_1 \text{ ANIMUN } + \beta_2 \text{ AVAGE } + \beta_3 \text{ CAPIT } + \beta_4 \text{ CAPPC } + \beta_5 \text{ CASGR} \\
&+ \beta_6 \text{ CONPC } + \beta_7 \text{ EDU15 } + \beta_8 \text{ EDU7 } + \beta_9 \text{ EDUS } + \beta_{10} \text{ FODTOT} \\
&+ \beta_{11} \text{ FORDEP } + \beta_{12} \text{ FWTOT } + \beta_{13} \text{ LANDO } + \beta_{14} \text{ NRCH } + \beta_{15} \text{ NRSGE} \\
&+ \beta_{16} \text{ RELNR } + \beta_{17} \text{ RES } + \beta_{18} \text{ SEXS } + \beta_{19} \text{ WFMOV } + \text{constant} + \text{error}
\end{aligned} \tag{2}
$$

The estimated coefficients are shown in Table 8 for each payoff equation. These coefficient are estimated with the STEPWISE procedure of SPSS, such that only significant variables are included into the regression equation. By substituting the village level average values into statistical significant socio-economic variables which describe the payoffs (Table 8), it is possible to derive village level games. The average payoffs and related games at the village level are shown in Tables 10 to 12.

In order to interpret the games at the village level, let us consider whether mutual participation can be sustained or not when the game is played repeatedly. As argued in Section 3, when the critical discount factor is zero, mutual participation can always be sustained. Mutual participation cannot be sustained when the critical discount factor is one. A fraction between zero and unity denotes the non-trivial discount factor. Then participation can be sustained only if the people are sufficiently patient.

In three villages of Haryana, Godam, Thathar and Salehpur, it is expected that mutual participation can be sustained. These are recently formed Hill Resource Management Societies. Since I did not observe a participatory breakdown in the other villages, they may be able to sustain mutual participation. It is quite surprising to find a critical discount factor of 1 in Sukhomajri (Mishra, 1996) and Salehpur (Lise, 1997a) in Table 10, as these villages are known as the most successful cases in Haryana. In Sukhomajri the participatory process once started, where the villagers and the state representatives came to an agreement over sharing the benefits. Salehpur is known as the more recent successful revival of Sukhomajri. However, at the time of the interviews, the perception of the villagers was not as positive as during the earlier successful years. This might explain why mutual participation was found not to be sustainable.

In Bihar, Muru is the only village where mutual participation is already breaking down, mainly due to destruction of the pool by wildlife. Table 11 shows indeed a critical discount factor of 1. Mutual participation is weakening in Bhusaria, because of difficulties in protecting the pool. In Tandwa & Sakanpirhi, the people are losing faith in the pooling process, as the common pool did not yet substantially benefit them. The pooling process is benefiting only a part of the people in Chapri. However, mutual participation is likely to be preserved in Sindhorwa. Mutual participation is unlikely to break down in the other villages, where planting in the pool is still going on and funding of labor in the pool is still taking place.

Based upon the insights from the field in Uttar Pradesh, incentives for participation are not expected to be found in Thamana and Sagar. In Thamana the communal forest is almost gone. In that respect it is surprising to find a Pareto game for that village (Table 12). In Sagar, where the president of the forest council is suspended, mutual participation is expected to break down. The meetings are proceeding well in Sagar, but conflicts emerge in the field, when they try to carry out the agreed-upon rules. In Than, Nishni, Bachher, Makkumath, and Reema, mutual participation can be sustained as expected. In Ulli, only a part of the villagers is actually interested in preserving the forest. In both Panyali and Ushara, the people are paying a yearly fee for collecting resources from the communal forest, this is also true for Shama (by fining). This may be the reason that the people are not interested in contributing to planting in the communal forest. This may also be the reason why we find a critical discount factor of 1 for Panyali.

5 Conclusions and recommendations

The main objective of this paper was to estimate a game model, where it is not a priori known which game people play; whether they act in harmony with each other or not. This choice-situation is modeled as a repeated game where villagers choose their level of participation in forest management in Northern India. Trigger strategies are calculated to find critical discount factors above which mutual participation could be sustained.

Formal game theory was applied to a practical situation. The model is driven by and applied to the voluntary choice of villagers to participate in forest management to make it more cost effective. The estimated game in this paper is by no means restricted to this particular application alone. Moreover, it can be applied to any situation where actors have to solve collective action problems in managing a common resources.

From an empirical point of view, this paper finds that the willingness of people to participate in forest management differs across the three cases. I find partial participation in Haryana, conditional participation in Bihar and unconditional participation in Uttar Pradesh. The willingness to sustain mutual participation at the village level gives a more favorable picture: in 28 out of the 32 studied villages, mutual participation can be sustained.

The main conclusion from a theoretical point of view is that the homogeneous grouping method, the game estimator at the village level, works well for most villages, but not all of them. This could have been caused by the quality of the data which have been collected. Nevertheless, this paper has shown that the Euclidean cluster method, the game estimator at the state level, leads to reliable results and can be recommended for further application in other situations.

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Collection of Tables

Table 1: The participation game.

	Contender:	
Challenger:	Participate (=P)	Do not participate (=D)
Participate (=P)	x, x	b, a
Do not participate (=D)	a, b	y, y

Table 2: Classification of games based on the payoff ordering.

Number of possibilities	Name of the game[a]	Payoff ordering	
		standard	reverse
1	prisoner's dilemma	$a > x > y > b$	$b > y > x > a$
5	Pareto game[b]	$x > \max\{a, y\}; b > y$	$y > \max\{b, x\}; a > x$
1	assurance game	$x > a > y > b$	$y > b > x > a$
2	coordination game	$x > y > \max\{a, b\}$	$y > x > \max\{a, b\}$
1	chicken's game	$a > x > b > y$	$b > y > a > x$
2	battle-of-sexes game [c]	$\min\{a, b\} > x > y$	$\min\{a, b\} > y > x$

[a] The prisoner's dilemma, assurance game, coordination game and the chicken's game are well-known. Two other games, Pareto game and the battle-of-sexes game are added to complete the classification.

[b] In the Pareto game the players have a dominating strategy which coincides with the collective preferred outcome.

[c] The battle-of-sexes game is opposite to the coordination game: the Nash equilibria consist of a participating and a deviating player.

Table 3: The critical discount factors ϕ.

Name of the game:	standard	reverse
prisoner's dilemma	$\frac{a-x}{a-y}$	0
Pareto game	0	1
assurance game	0	0
coordination game	0	0
chicken's game	$\frac{a-x}{a-b}$	1
battle-of-sexes game	1	1

Table 4: Diversity among the three regional studies.

State	Haryana	Uttar Pradesh	Bihar
Name of local organisation	Hill Resource Management Society	forest council	village society
Number of organisations in 1996	48	4645	44
started in	1977	1931	1984
initiated by	state	people	non-governmental organisation
property regime	state	common	private (group)

Table 5: First principal component per state, derived from indicators of participation.

State:	Haryana	Bihar	Uttar Pradesh
Planting in the forest	0.383		0.048
Contribution to the forest/pool	0.226	0.172	0.177
Benefiting from the forest/pool	0.094	0.098	0.233
Ability to use the pool		0.082	
Benefits from using the pool		0.156	
Importance of meetings		**0.535**	0.095
Agreement with decisions	0.049	**0.832**	**0.771**
Attendance of meetings	**0.797**	**0.787**	**0.594**
Ability to influence decisions	**0.682**	**0.868**	**0.810**
Frequency of meetings	**0.792**	-0.020	0.275
Interest in the meetings	**0.640**	0.292	**0.842**
Gain from meetings	**0.611**	0.271	**0.815**
Suggesting in meetings	**0.584**	0.280	0.488
Percentage of variance explained	45.1%	36.0%	35.4%
Number of observations	127	123	135

Note: Numbers in bold face denote a dominating indicator (factor loading >= 0.5 or <= −0.5). An empty cell means that the observations on that indicator are missing.

Source: See text.

Table 6: The estimated games at the institutional level in three states.

The Euclidean cluster method:

Model	x	y	a	b	Payoff order	Name of the game	ϕ
I.har	4468	6771	4352	7413	$b > y > x > a$	reverse prisoner's dilemma	0
I.bih	13225	1129	7772	7001	$x > a > b > y$	Pareto game	0
I.upr	2394	0	1849	0	$x > a > b = y$	Pareto/assurance game	0
II.har	4960	6134	10431	9397	$a > b > y > x$	reverse battle-of-sexes game	1
II.bih	12982	8109	752	6483	$x > y > b > a$	coordination game	0
II.upr	2806	1164	0	1367	$x > b > y > a$	Pareto game	0

The homogeneous grouping method:

Model	x	y	a	b	Payoff order	Name of the game	ϕ
I.har	4884	6493	5513	9145	$b > y > a > x$	reverse chicken's game	1
I.bih	13688	5923	11973	11963	$x > a > b > y$	Pareto game	0
I.upr	2037	2253	1896	2728	$b > y > x > a$	reverse prisoner's dilemma	0
II.har	5368	5725	6321	8781	$b > a > y > x$	reverse battle-of-sexes game	1
II.bih	18106	11832	6254	7545	$x > y > b > a$	coordination game	0
II.upr	2723	2550	1608	2042	$x > y > b > a$	coordination game	0

Notes:
I = the mean situation;
II = the variance situation;
har = Haryana, bih = Bihar, upr=Uttar Pradesh;
ϕ = the critical discount factor.

Table 7: Final cluster centres and the number of households within the clusters.

Model I.har:
reverse assurance game

Cluster	θ	ϑ	π	cases
1	0.21	0.32	y	9
2	0.67	0.54	x	34
3	0.55	0.10	b	48
4	0.04	1.00	a	1
5	0.84	0.39	b	35

Model II.har:
reverse battle-of-sexes game

Cluster	θ	ϑ	π	cases
1	0.29	0.11	y	21
2	0.94	0.97	b	3
3	0.59	0.06	y	47
4	0.82	0.08	x	36
5	0.72	0.28	a	20

Model I.bih: Pareto game

Cluster	θ	ϑ	π	cases
1	0.11	0.30	y	2
2	0.87	0.63	x	77
3	0.63	0.69	a	20
4	0.84	0.13	b	24

Model II.bih: coordination game

Cluster	θ	ϑ	π	cases
1	0.19	0.52	a	3
2	0.66	0.09	y	19
3	0.87	0.14	x	82
4	0.82	0.96	b	19

Model I.upr:
Pareto/assurance game

Cluster	θ	ϑ	π	cases
1	0.74	0.84	x	111
2	0.88	0.00	b	1
3	0.38	0.85	a	19
4	0.17	0.29	y	4

Model II.upr:
Pareto game

Cluster	θ	ϑ	π	cases
1	0.74	0.41	b	35
2	0.17	0.91	a	4
3	0.26	0.19	y	10
4	0.72	0.09	x	86

Notes:
θ is the level of participation of the challenger;
ϑ is the level of participation of the contender;
har = Haryana, bih = Bihar, upr=Uttar Pradesh;
$\{a, b, x, y\} \in \pi$ is the payoff or gain from participation.

Table 8: The payoff equations in Haryana, Bihar and Uttar Pradesh.

State	Haryana				Bihar				Uttar Pradesh			
Variable	*x*	*y*	*a*	*b*	*x*	*y*	*a*	*b*	*x*	*y*	*a*	*b*
Const	-3649	13761	12062	-7867	-87484	7184	-17293	3819	1141	1849	1293	-2478
	(2753)	(2432)	(2480)	(4288)	(18387)	(12236)	(8367)	(1464)	(429)	(898)	(584)	(1027)
ANIMUN	966								437			
	(270)								(62)			
AVAGE					2229							
					(420)							
CAPIT				-0.0009							-0.0042	
				(0.0003)							(0.0019)	
CAPPC	0.012											
	(0.003)											
CASGR		-1976	-2064	2621			4446					
		(753)	(837)	(1060)			(1747)					
CONPC						-15.3						
						(7.3)						
EDU15										-1198		
										(423)		
EDU7										1116		
										(478)		
EDUS												177
												(68)
FODTOT	-34.8			171								36.9
	(13.4)			(14)								(10.9)
FORDEP	4886											
	(2300)											
FWTOT										50.8	61.6	
										(14.5)	(12.8)	
LANDO								480	-14.7			
								(123)	(6.0)			
NRCH				-1355								
				(615)								
NRSGE							1564					
							(755)					
RELNR	3355	-2096				23312						
	(1483)	(720)				(5668)						
RES					60028							
					(17570)							
SEXS					53781							
					(16419)							
WFMOV												292
												(113)
R^2	0.868	0.306	0.169	0.856	0.677	0.402	0.295	0.344	0.619	0.469	0.490	0.411

Note: The values in brackets denote the standard errors. The last row shows the number of observations in the payoff group.

Table 9: The meaning of the used socio-economic variables.

$\pi \in \{a, b, x, y\}$ = Payoff [Rs/year], where Rs are expressed in 1996 prices.

ANIMUN = Animal units expressed in 'cow'-units ([OX] + [COW] + 1.2 × [BUFFALO] + 0.25 × [GOAT] + 0.10 × [PIG] + 2.67 × [MULE] + 2.67 × [CAMEL] + 2.67 × [HORSE]).

AVAGE = Average age of all family members.

CAPIT = Capital owned by the whole family. (Rs/year)

CAPPC = Per capita capital. (Rs/year)

CASGR = Caste-group (number between 1 and 5, higher number is lower caste).

CONPC = Total value of per capita consumption. (Rs)

EDU7 = Average years of schooling of people above 7 years.

EDU15 = Average years of schooling of people above 15 years.

EDUS = Education of the interviewed person.

FODTOT = Total use of fodder. (quintal/year)

FORDEP = Forest dependence (the amount of goods collected from the forest divided by the total need).

FWTOT = Total use of fuelwood. (quintal/year)

LANDO = Amount of private land owned. (acres)

NRCH = Number of children.

NRSGE = Number of children expected to be send to school.

RELNR = Religion number. (1. Hindu, 2. Muslim, 3. Christian, 4. other)

RES = Level of resources based on the first principal component of three environmental indicators: DEGRA (To which extent do you consider the current state of the forest degraded?), STA10 (What was the state of the forest about 10 years ago?), FODQU (What is the quality of the resources, like fodder and fuelwood extracted from the forest?), which is finally normalised between zero and unity.

SEXS = Gender of interviewed person.

WFMOV = Number of family members working outside the village.

Table 10: The estimated payoffs in villages in Haryana.

Village name:	x	y	a	b	payoff order	Name of the game	ϕ
Godam	4280	3762	3806	-1251	$x > a > y > b$	assurance game	0
	(2857)	(2432)	(2480)	(302)			
Mandpa	15121	7714	7934	16965	$b > x > a > y$	Pareto game	0
	(4792)	(2432)	(2480)	(4093)			
Sukhomajri	5194	7398	7603	9320	$b > a > y > x$	reverse battle-of-sexes game	1
	(3389)	(2553)	(2614)	(1757)			
Dhamala	9740	4218	7149	20290	$b > x > a > y$	Pareto game	0
	(4344)	(2808)	(2706)	(5693)			
Main Nada	10503	7337	7934	7703	$x > a > b > y$	Pareto game	0
	(3904)	(2562)	(2480)	(67)			
Masoompur	7513	6884	7067	10171	$b > x > a > y$	Pareto game	0
	(3532)	(2651)	(2722)	(3482)			
Thathar	6890	5876	6014	3996	$x > a > y > b$	assurance game	0
	(3184)	(2658)	(2731)	(1363)			
Salehpur	5130	6726	6902	15389	$b > a > y > x$	reverse battle-of-sexes game	1
	(3443)	(2688)	(2764)	(2060)			
Harijan Nada	5189	3702	4838	7779	$b > x > a > y$	Pareto game	0
	(3993)	(3169)	(2898)	(1329)			
All villages	5368	5725	6321	8781	$b > a > y > x$	reverse battle-of-sexes game	1
# observations	(32)	(31)	(32)	(32)			

Note: The values in brackets denote the standard errors. Choice of the challenger is based on the first principal component. Choice of the contender is based on the variance, among the challengers within a village.

Table 11: The estimated payoffs in villages in Bihar.

Village name:	x	y	a	b	payoff order	Name of the game	ϕ
Hendehas	23070	8891	4639	7235	$x > y > b > a$	coordination game	0
	(19740)	(14564)	(9170)	(745)			
Chapri	5669	13577	4639	7302	$y > b > x > a$	reverse assurance game	0
	(19458)	(14987)	(8997)	(870)			
Barhania	33293	48476	7768	9267	$y > x > b > a$	reverse coordination game	0
	(21448)	(14065)	(8555)	(884)			
Sindhorwa	38519	17424	6329	4607	$x > y > a > b$	coordination game	0
	(22054)	(15770)	(8661)	(259)			
Muru	1740	23302	6011	9863	$y > b > a > x$	reverse Pareto game	1
	(20758)	(18410)	(8966)	(1417)			
Bhusaria	9135	3150	8409	6087	$x > a > b > y$	Pareto game	0
	(20334)	(13837)	(8797)	(2119)			
Bakhari	27723	7503	4011	5112	$x > y > b > a$	coordination game	0
	(22707)	(13731)	(8991)	(269)			
Kumbhawa	19095	14540	5750	6332	$x > y > b > a$	coordination game	0
	(22479)	(13724)	(9380)	(639)			
Sakanpirhi	13223	7991	-8639	7283	$x > y > b > a$	coordination game	0
and Tandwa	(19434)	(13366)	(9110)	(673)			
Mundaria	23684	805	3208	6346	$x > b > a > y$	Pareto game	0
	(21048)	(14599)	(9231)	(687)			
Kashia	13302	7499	-1730	5347	$x > y > b > a$	coordination game	0
	(22033)	(13359)	(9627)	(509)			
Khamdih	8609	11433	5593	4963	$y > x > a > b$	reverse coordination game	0
	(21549)	(13732)	(9081)	(240)			
All villages	18106	11832	6254	7545	$x > y > b > a$	coordination game	0
# observations	(31)	(30)	(31)	(31)			

Note: The values in brackets denote the standard errors. Choice of the challenger is based on the first principal component. Choice of the contender is based on the variance, among the challengers within a village.

Table 12: The estimated payoffs in villages in Uttar Pradesh.

Village name:	x	y	a	b	payoff order	Name of the game	ϕ
Ulli	1966	1860	1480	1148	$x > y > a > b$	coordination game	0
	(488)	(1553)	(678)	(219)			
Than	2336	1745	1294	2135	$x > b > y > a$	Pareto game	0
	(506)	(1544)	(743)	(317)			
Thamana	1217	664	31	1906	$b > x > y > a$	Pareto game	0
	(721)	(2912)	(771)	(350)			
Nishni	2310	1846	1321	1730	$x > y > b > a$	coordination game	0
	(479)	(1509)	(645)	(153)			
Bachher	2229	1665	1276	1076	$x > y > a > b$	coordination game	0
	(491)	(1626)	(661)	(226)			
Makkumath	2723	2043	1731	2695	$x > b > y > a$	Pareto game	0
	(485)	(1620)	(695)	(245)			
Ushara	3335	4422	3158	3294	$y > x > b > a$	reverse coordination game	0
	(531)	(1507)	(759)	(452)			
Sagar	3168	2109	1431	3229	$b > x > y > a$	Pareto game	0
	(501)	(1649)	(700)	(220)			
Shama	3274	3191	2558	3020	$x > y > b > a$	coordination game	0
	(541)	(1469)	(735)	(261)			
Panyali	2975	4018	3143	3109	$y > a > b > x$	reverse Pareto game	1
	(678)	(2242)	(919)	(629)			
Reema	2122	2397	1708	1742	$y > x > b > a$	reverse coordination game	0
	(482)	(1389)	(667)	(165)			
All villages	2723	2550	1608	2042	$x > y > b > a$	coordination game	0
# observations	(34)	(33)	(34)	(34)			

Note: The values in brackets denote the standard errors. Choice of the challenger is based on the first principal component. Choice of the contender is based on the variance, among the challengers within a village.

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