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A game model of people's participation in forest management in Northern India

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ABSTRACT. People have a marginal role in managing forests located in the vicinity of their villages in Northern India. This situation is scrutinized 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 finds such incentives in varying degrees for games at the State level and for games in 23 of the 32 considered villages.

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. Moreover, it is well-known that a higher level of people's participation may lead to a better quality of the forest, which is both beneficial for people living nearby and the State (see for instance Poteete and Ostrom, 2002). While most forests in India are under the control of the State, there also exist forests which are managed by people living nearby.

The forest councils considered in this paper, where the user-group and user-rights are well-defined, are a common property regime. The effectiveness of these forest councils depends, among other factors, on the amount of people's involvement. This paper addresses two research questions: (1) Are there incentives at the institutional level to participate in forest management? (2) Are there incentives at the village level to participate in forest management?

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To analyse the incentives for participation in forest management, it is useful to distinguish between a *situation* of forest management and a forest management *dilemma*. In a situation of forest management there are multiple individuals, using a communal forest. This becomes a forest management *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 (Ostrom *et al.*, 1994).

The case where forest management is a dilemma can be captured by the prisoner's dilemma (e.g. Hardin and Baden, 1977; Hardin, 1982; Bendor and Mookherjee, 1987). In the prisoner's dilemma, private interests conflict with public interests, preventing participation to emerge as an outcome. Hardin (1968), for instance, adopts the parable of the prisoner's dilemma to sketch the 'tragedy of the commons'.

Forest management is also problematic when it is represented by a chicken's game (Taylor, 1987). In the chicken's game, private interests again conflict with public interests, leading to an outcome of partial participation. Both the prisoner's dilemma and chicken's game constitute *collective dilemmas* (Bardhan, 1993a, 1993b; Bates, 1988), as they satisfy the previously mentioned conditions (1 and 2).

A situation of forest management does not have to be a dilemma. Runge (1981, 1984, 1986), for instance, pleads that forest management is 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. Runge uses this metaphor to explain why 'the tragedy of the commons' has not yet emerged on a larger scale. Forest management in Runge's case exhibit effective organizations, which check-and-balance the use of forests; there is no conflict between individual and collective optimal strategies.

Basu and Mishra (1993) argue that there does not need to be a dilemma in a single period in the sense of Wade (1987, 1988), but the dilemma shows up in the long run. This can be modelled as a repeated hawk/dove game, where people choose between the *dove* and the *hawk* strategy. Playing *dove* means sustainable forest management, while *hawk* results in forest exploitation. Playing *hawk* too often brings forests on the brink of disaster. Hence, forest degradation is not immediately apparent, but it is observed gradually over time.

Moreover, in many practical situations, people face the same choice situation over and again. Those situations can be modelled as repeated dilemmas (Axelrod, 1984; Kreps *et al.*, 1982; Kreps and Wilson, 1982; Milgrom and Roberts, 1982). A simple way to rationalize cooperation in repeated games is by considering *infinite repetitions*, which route is followed in section 3.

While it is customary in applied game theory to identify the game being played beforehand and then continue to discuss the implications, we follow the opposite route here. The kind of strategic play in the field is verified afterwards through an econometric technique (Lise, 1997b, 2001;

Lise *et al.*, 2001). Thereto, a field survey was conducted in rural India to collect primary data on people's willingness to participate in forest management and their benefits from such behaviour. The outcome of this econometric technique indicates the game people have been playing at the village and State levels. This result is compared with the observed situation in the field, and the implications are discussed.

This paper is organized as follows. Rather than choosing one particular game, people's participation in forest management is modelled as a non-cooperative game, having various games as open options (section 2). Section 3 derives for all these options the so-called critical discount factors, which describe whether incentives exist to sustain voluntary mutual participation in forest management. Sections 4–6 apply the model to three States in India, namely Haryana, Jharkhand, and Uttaranchal.[1] The three cases are presented and the nature of the data is discussed (section 4). Section 5 discusses how games at the State level are quantified and the outcomes are presented and discussed. The quantification of games at the village level along with the outcomes are explained and presented in section 6. Section 7 provides conclusions and recommendations.

2. The model

For studying the opportunities of local people to voluntarily participate in the management of forests adjacent to their villages, we set up a non-cooperative game model. The strategy is to choose the level of participation in forest management. Here participation means the amount of involvement of a villager in a local organization in the village to manage an adjacent forest.[2] A participating villager adheres to rules as formulated during village meetings. This participation is awarded with the right to (partially) access the forest from which they can collect resources like fuelwood and fodder (=their net benefits or payoff), but it may also give them rights to irrigation water from erected dams in the forest or a stipend paid for protecting and maintaining the forest. 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. When one peasant participates, while the other does not, the single participant keeps the rules as formulated during the village meetings (following Copeland and Taylor, 2002), while the other cheats on these rules, reducing the protection of the forest. This 'cheating' can be detected through 'social fencing', where the rule-abiding villager spots cheating. This can be reported to the forest guard. During a meeting of the village committee a decision can be taken on how to punish the cheat. In case of a small offence, only a warning may be issued. Finally, when both deviate, rules are not adhered to by both villagers.

[1] Before the year 2000 Jharkhand belonged to Bihar and Uttaranchal belonged to Uttar Pradesh (see also: http: //mha.nic.in/newstat.htm).

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

Table 1. *The participation game*

	Contender	
Challenger	*Participate (=P)*	*Defect (=D)*
Participate (=P)	x, x	b, a
Defect (=D)	a, b	y, y

Let us assume that the players of the game have the same preferences. While villagers are generally not identical, there are many situations where they are comparable; where they have equal opportunities.

Considering the motivation above, the two-person participation game can be formalized as follows.

1. The set of players consists of two imaginary entities: $\{1, 2\}$. Let us label the two imaginary entities as challenger i and contender–i, where the challenger is an average villager, which we consider in the analysis, while the contender represents an average of other villagers, which is evaluated in the mind of the challenger. More specifically, this paper deals with a 1 versus n_j–1 game, where n_j is the number of observations in village j.
2. Player i chooses the level of participation θ_i. While θ_i can be measured as a continuous variable in the presentation of the results, we only use two choices. We abbreviate the set of actions as {Participate, Defect}, or in short as $\{P, D\}$.
3. 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 where two identical players have two choices, consists of four different numerical values: $\{a, b, x, y\}$.

Table 1 shows the payoff matrix of the symmetric two-person bi-matrix game satisfying conditions (1–3). This game can easily be extended to n persons, namely by identifying one challenger and $(n - 1)$ contenders. It is now more instructive to write the payoffs as the choice of the challenger $\{P, D\}$ and the number of participating contenders. For instance, in a three-person game, the third person would choose between two matrices as shown in table 1, where the payoffs consist of six numerical values: $\{P2, P1, P0, D2, D1, D0\}$. The same principle can be applied to obtain a game with more players.

For interpreting the estimated games in sections 5–6 below, it is useful to classify them here. For that, we divide all 24 possibilities for strictly ordering the payoffs a, b, x, y into 12 distinct cases.[3] In 12 cases the game has a unique Nash equilibrium. In ten of these 12 cases the individual best response matches with the collective preferred outcome. We call such a game the *Pareto game*. In the remaining two cases, the individual best response conflicts with the collective preferred outcome; the well-known prisoner's dilemma.

[3] We call games, where some of the payoffs a, b, x, y are equal, *transition games*.

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Table 2. *Classification of games based on the payoff ordering and their critical discount factors*

	Payoff ordering		*The critical discount factors* ϕ	
Name of the game[a]	*Standard*	*Reverse*	*Standard*	*Reverse*
Prisoner's dilemma (1[b])	$a > x > y > b$	$b > y > x > a$	$\frac{a-x}{a-y}$	0
Pareto game[c] (5)	$x > \max\{a, y\}; b > y$	$y > \max\{b, x\}; a > x$	0	1
Assurance game (1)	$x > a > y > b$	$y > b > x > a$	0	0
Coordination game (2)	$x > y > \max\{a, b\}$	$y > x > \max\{a, b\}$	0	0
Chicken's game (1)	$a > x > b > y$	$b > y > a > x$	$\frac{a-x}{a-b}$	1
Battle-of-sexes game[d] (2)	$\min\{a, b\} > x > y$	$\min\{a, b\} > y > x$	1	1

Notes:
[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] The number of possibilities is denoted in the brackets.
[c] In the Pareto game the players have a dominating strategy which coincides with the collective preferred outcome.
[d] The battle-of-sexes game is opposite to the coordination game: the Nash equilibria consist of a participating and a deviating player.

The other 12 cases have two pure-strategy Nash equilibria. In six of these 12 cases, mutual participation (P, P) is a Nash equilibrium of the game. These games are known as coordination and assurance games. In the other six cases, the Nash equilibria consists of one player participating and one defecting. These games are well-known as the battle-of-sexes and chicken's games. In the coordination and battle-of-sexes games the Nash equilibrium payoffs are strictly greater than the remaining payoffs, which is not true for the assurance and chicken's games.

In this paper we are mainly interested in games where mutual participation is more beneficial than mutual defection ($x > y$). In general, this does not have to be the case. We refer to games where $x < y$ as *reverse* games. Table 2 shows the taxonomy of two-person two-action symmetric games.

3. Critical discount factors of the repeated participation game

For judging the quality and stability of the organization for forest management in the village, the participation game is repeated infinitely over time. Such a game can be analysed by considering trigger strategies, which are a code of behaviour, where the players agree to participate until a certain condition is violated, after that they defect forever to punish the deviant.[4]

[4] 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 coincide with subgame perfect equilibria. Infinitely repeated games with trigger

For each mentioned game in table 2, we derive the necessary conditions under which mutual participation can be sustained forever. The main question studied is the following: Assuming that both players participate, do they have an incentive to deviate? To answer that question, we assign to each game a so-called *critical discount factor*, denote this as ϕ. It is well-known from the Folk theorem (Fudenberg and Maskin, 1986) that such critical discount factors can be found. If the players 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.

As discussed in the introduction, a forest management dilemma can be represented by either a prisoner's dilemma or a chicken's game. While mutual participation cannot be sustained in the finitely repeated prisoner's dilemma, it is possible with infinite repetitions, if the players follow trigger strategy $\sigma_{it}^{\mathrm{pd}}$, assuming that they started with mutual participation

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

This trigger strategy prescribes to participate until a player deviates. After that both players defect forever. This leads to the following critical discount factor:[5] $\phi^{\mathrm{pd}} = \frac{a-x}{a-y}$.

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

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

Trigger strategy $\sigma_{it}^{\mathrm{chg}}$ prescribes to *keep on participating as long as the other did not deviate first*. Trigger strategy $\sigma_{it}^{\mathrm{chg}}$ differs from $\sigma_{it}^{\mathrm{pd}}$, because the deviant returns to participation, when the other person implements the infinite sequence of deviations. In this manner, the deviant can ascertain a higher payoff b instead of y. When both players follow this behaviour, then the critical discount factor can be derived similarly as in the case of the prisoner's dilemma, yielding the following critical discount factor: $\phi^{\mathrm{chg}} = \frac{a-x}{a-b}$.

The following trivial strategy sustains mutual participation, since it is a Nash equilibrium as $x > a$.

$$\sigma_{it}^{x>a} = \{\mathrm{P} \quad \text{irrespective of the choice of the other player} \tag{3}$$

strategies can be analysed as supergames, which are equivalent to normal form games.

[5] This trigger strategy can be found by rewriting the equation where the payoff of always participating ($x \sum_{i=0}^{\infty} \delta^i$) is equal to the payoff of defecting ($a + y \sum_{i=1}^{\infty} \delta^i$) (see for instance Stahl, 1991).

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Strategy $\sigma_{it}^{x>a}$ is not a trigger strategy, because mutual participation can be sustained through participating. Then, there is no incentive to defect ($\phi^{x>a} = 0$).

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

$$\sigma_{it}^{\text{rpg}} = \{D \quad \text{irrespective of the choice of the other player} \tag{4}$$

This is the opposite of the previous strategy, and it recommends to never participate ($\phi^{rpg} = 1$).

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

$$\sigma_{it}^{\text{og}} = \begin{cases} P & \text{as long as} \quad \theta_{-i,t-1} = D \\ D & \text{if} \quad \theta_{-i,t-1} = P \end{cases} \tag{5}$$

In this case, mutual participation cannot be sustained too ($\phi^{\text{og}} = 1$).

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

Lemma 1 *If σ_{it}^{ag} in Equation (6) combined with Equations (1)–(5), 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 2.*

$$\sigma_{it}^{\text{ag}} = \begin{cases} \sigma_{it}^{\text{pd}} & \text{for the prisoner's dilemma} \\ \sigma_{it}^{\text{chg}} & \text{for the chicken's game} \\ \sigma_{it}^{x>a} & \text{for games with } (P, P) \text{ a Nash equilibrium} \\ \sigma_{it}^{\text{rpg}} & \text{for the reverse Pareto game} \\ \sigma_{it}^{\text{og}} & \text{for all other games in table 2} \end{cases} \tag{6}$$

4. Forest management in three Indian States

In order to quantify the participation game, data are collected from three States of India: Haryana, Jharkhand, and Uttaranchal. These cases were selected because of their differences with respect to forest quality, kind of forest resources and the way the village council is organized. 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, as land-holding is quite unequal in villages with HRMSs,

Table 3. *Diversity among the three regional studies*

State	*Haryana*	*Jharkhand*	*Uttaranchal*
Name of local organization	Hill Resource Management Society	village society	forest council
Number of organizations in 1996	48	44	4645
Started in	1977	1984	1931
Initiated by	State	non-governmental organization	people

water rights were allotted to their members. However, a number of dams failed to provide any irrigation water. In addition to the net income derived from damwater, resources like fodder, fuelwood, bamboo, and fiber grasses could be collected as well from the forest.

In Jharkhand, a non-governmental organization encourages villagers to pool private land for planting trees since 1984. They adopted the Haryana model to the local circumstances in Jharkhand, which implies a negligible role for the State in these villages. The output from the pool is shared equally among its members of the well-organized 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 people who work on the pool receive, besides a part of the output from the pool, a stipend as well.

In Uttaranchal, the State allowed for the creation of forest councils by villagers since 1931. The role of the State in Uttaranchal is somewhere between Haryana and Jharkhand. A well-organized forest council decides on how to manage a communal forest. Resources like fuelwood, fodder, and timber can be collected from the forest on a rotation basis in order to preserve the quality of the forest. Land and cattle holding is fairly equal in the hills of Uttaranchal and women are involved in forest management to a larger extent than in Haryana and Jharkhand. Table 3 points out the diversity between the three situations of forest management.

Representatives of the households were selected randomly, by visiting villages in these three States in 1995 and 1996. In total, 385 households from 32 villages have been interviewed. The variation in the data sample is presented in table 4. Table 4 shows that the field survey covered 9, 12, and 11 villages and 127, 123, and 135 households in Haryana, Jharkhand, and Uttaranchal. Furthermore, table 4 splits the number of respondents up by age, education, and position in the village council. The table shows that the average age, the level of education, and the number of common members is higher in Uttaranchal than in Haryana and Jharkhand.

The field survey yielded a broad range of quantitative information around the following groups of variables:

Table 4. *Inter-State variation in gender, age, education, and position in forest council*

	State					
	Haryana		*Jharkhand*		*Uttaranchal*	
Interviewed persons	*Frequency*	%	*Frequency*	%	*Frequency*	%
Gender						
Male	118	92.9	113	91.9	123	91.1
Female	9	7.1	10	8.1	12	8.9
Age groups						
11–20	13	10.2	10	8.1	7	5.2
21–30	41	32.3	36	29.3	17	12.6
31–40	34	26.8	36	29.3	30	22.2
41–50	22	17.3	22	17.9	36	26.7
51–60	10	7.9	10	8.1	22	16.3
61–100	7	5.5	9	7.3	23	17.0
Education groups						
0 Illiterate	48	37.8	34	27.6	20	14.8
1–4 Literate	6	4.7	24	19.5	9	6.7
5–6 Primary pass	16	12.6	7	5.7	25	18.5
7–9 Middle pass	26	20.5	32	26.0	30	22.2
10–11 Metric pass	24	18.9	16	13.0	17	12.6
12–14 Inter-college pass	4	3.1	7	5.7	17	12.6
15–20 Graduated	3	2.4	3	2.4	17	12.6
Position in the village council for forest management						
No member	3	2.4	1	0.8	3	2.2
Common member	68	53.5	50	40.7	89	65.9
Managing member	36	28.3	41	33.3	16	11.9
Guard	0	0.0	0	0.0	3	2.2
Casher	7	5.5	8	6.5	1	0.7
Secretary	4	3.1	8	6.5	2	1.5
President	9	7.1	15	12.2	21	15.6

- their perception of the quality of the forest;[6]
- their level of participation in forest management;[7]
- family ownership of capital goods, like land, cattle, and private assets;
- family members' income from different sources;
- family expenditures for food items and clothes;

[6] Poteete and Ostrom (2002), for instance, argue that asking for the perception of the quality of the forest may be more useful than physically measuring the quality of the forest, as 'local action depends on perceived benefits from the forest and threats to them' (Ibid., page 22).

[7] An important issue is whether people had an incentive to lie during the surveys. This incentive was there during the test phase of the interviews, as they thought the interviewer to represent the government. But by starting the interviews with psychological response questions concerning their level of participation (See table 5), this suspicion was eliminated.

- various other indicators, like caste, religion, gender, education, family size, etc.[8]

Lise (2000) shows, via a combined factor and econometric analysis, under which conditions a villager is most likely to opt for a high level of participation; what drives people's participation in forest management. It follows that participation goes up when the forest quality is good and/or when people have a high level of forest dependence. Furthermore, a low average level of education in the family, a high level of education of the respondent and a greater involvement of women in the community tends to increase participation.

5. Games at the state level

The participation game of section 2 is quantified as follows. The payoff (π_i) is taken as the total sum of the amount of resources which are collected by the members of a village council for forest management, multiplied by the average local market value (also derived via the field survey) of these resources.[9] The cost of collecting resources is assumed as zero here. This is most probably reasonable for rural India, where alternative labour opportunities – competing with resource collection in the communal forests – are rare. Hence, payoffs are net benefits. More specifically, the payoff in Haryana includes besides fuelwood, fodder, fibre grass, and bamboo also the additional net incomes due to irrigation by damwater. The payoff in Jharkhand consists of the stipend paid to villagers working in the pool and the yield from the common pool. In Uttaranchal the payoff is composed of the market value of collected fuelwood, fodder, and timber. There are great differences in the average payoffs, as the average payoff in Jharkhand is about two times the average payoff in Haryana, while the average payoff in Uttaranchal is about one-third of the average payoff in Haryana.

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 involvement in forest management. Their psychological responses are recorded on an integer scale varying from 1 to 5, where a higher number represents a higher willingness to participate. Table 5 shows the average responses to each question. Inspection of this table shows that the indicators of participation obtained the highest response in Jharkhand, in-between in Haryana and the lowest in Uttaranchal.

[8] The detailed questionnaires, which have been adapted to the State-specific situation, can be obtained from the author upon request.

[9] Prices differ across States. While they are almost the same in Haryana and Uttaranchal, they are the half in Jharkhand. However, the salaries in Jharkhand are also half of those in Haryana. In that sense the 'stakes' of free-riding and participating are comparable across States. And the argument of Hotte et al. (2000), that prices affect the incentive to monitor and enforce property rights, cannot be used to explain the different outcomes across States.

Table 5. *First principal component per State, derived from indicators of participation*

	Principal components			*Average values*		
Indicators of participation	*Haryana*	*Jharkhand*	*Uttaranchal*	*Haryana*	*Jharkhand*	*Uttaranchal*
Planting in the forest	0.383		0.048	2.19		2.24
Contribution to the forest/pool	0.226	0.172	0.177	3.06	3.22	2.76
Benefiting from the forest/pool	0.094	0.098	0.233	3.98	3.51	3.19
Ability to use the pool		0.082			3.67	
Benefits from using the pool		0.156			3.42	
Importance of meetings		**0.535**	0.095		4.63	3.98
Agreement with decisions	0.049	**0.832**	**0.771**	3.79	4.73	4.04
Attendance of meetings	**0.797**	**0.787**	**0.594**	4.11	4.50	3.78
Ability to influence decisions	**0.682**	**0.868**	**0.810**	4.15	4.55	3.61
Frequency of meetings	**0.792**	–0.020	0.275	3.80	4.30	2.73
Interest in the meetings	**0.640**	0.292	**0.842**	3.98	4.50	3.56
Gain from meetings	**0.611**	0.271	**0.815**	4.02	4.52	3.67
Suggesting in meetings	**0.584**	0.280	0.488	3.06	3.52	3.26
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). An empty cell means that the information on that indicator of participation was not collected.

One way to aggregate such indicators of participation into a level of participation is by performing a factor analysis on these indicators. This is 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 variables: the principal components. Table 5 presents the first factor for the three cases considered in this study.[10] It turns out that the dominating variables in these factors are all related to the quality and usefulness of the meetings as a platform for monitoring and managing the forest/pool. In the case of Haryana, Jharkhand, and Uttaranchal, the first factor respectively explains 45 per cent, 36 per cent, and 35 per cent of the variation.

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. For aggregating the level of participation of other villagers, consider the following formalization. Define the set of villages as $V := \{1, 2, \ldots, v\}$ in which a forest council exists. Let N_j, for $j \in V$, be the set of $|N_j|$ (surveyed) members in village j, where $|N_j|$ is the cardinality of set N_j. Let $N := \cup_{j \in V} N_j$ be the collection of all observations and let $|N|$ be the total number of people surveyed within a State.

The first way of aggregating the level of participation of the other villagers is by taking the mean, where a player can be considered as being insensitive towards the strategy of other players (mean situation).

$$\bar{\vartheta}_i = \frac{1}{|N_j| - 1} \sum_{\{k \in N_j | i \neq k\}} \theta_k \quad \text{for all } i \in N_j \text{ and } j \in V \tag{7}$$

When the aggregation of the level of participation of other villagers, $\bar{\vartheta}_i$, is based on the mean, we call it model I.

The second way of aggregating the level of participation of the other villagers is by taking the 'variance', where a player can be considered as being *sensitive* towards the strategy of other players, as opposing decisions lead to higher values in this case (variance situation).

$$\sigma_{\vartheta i} = \frac{1}{|N_j| - 1} \sum_{k \in N_j} (\theta_k - \theta_i)^2 \quad \text{for all } i \in N_j \text{ and } j \in V \tag{8}$$

When the aggregation of the level of participation of other villagers, σ_{ϑ_i}, is based on the variance we call it model II.

By interpreting formulas 7 and 8, an important distinction emerges between the mean and the variance situation.[11] In the mean situation, a large value for the level of participation always means 'participate', while a small value means 'defect'. In the variance situation, when the variance among the actions is small, the actions of the challenger and the contender are nearly the same. However, when the variance is large, the action of the contender must be the *opposite* to the action of the challenger.

It is also possible to extend the mean and variance situation to more than two persons. An n-person game can be derived from the same data, as long

[10] Actually, 2, 3, 4 principal components were found in respectively Haryana, Jharkhand, and Uttaranchal (Lise, 2000).

[11] Equation (12) shows the difference in a formal way.

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as $n < |N_j|$ for all $j \in V$. Let use divide the game into one challenger and $n-1$ contenders. The contenders can be subdivided into $n-2$ contenders, which choose ϑ_i directly from the observed θs and a composite contender. The action of the composite contender is derived from the remaining observations, which set can be denoted as $M_j (\subset N_j)$. Formulas 7 and 8 change as follows for the multi-person game

$$\bar{\vartheta}_i = \frac{1}{|M_j|} \sum_{k \in M_j} \theta_k \text{ for all } i \in N_j \backslash M_j \text{ and } j \in V \tag{9}$$

$$\sigma_{\vartheta i} = \frac{1}{|M_j|} \sum_{k \in M_j} \left(\theta_k - \frac{1}{|N_j| - |M_j|} \sum_{l \in N_j \backslash M_j} \theta_l \right)^2 \quad \text{for all } i \in N_j \backslash M_j \text{ and } j \in V \tag{10}$$

Here the action of the composite contender is the average or 'variance' of the level of participation of $|M_j|$ the other villagers.

Hence, we have the triplet $(\pi_i, \theta_i, \vartheta_i)$ for all 385 interviewed households across 32 villages in three Indian States. A game can be estimated by normalizing 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* $\{A, B, X, Y\}$ based on these normalized levels of participation. One way to do so is by the QUICK CLUSTER procedure of SPSS, which calculates the cluster centers. Then 'large' cluster centers correspond to '*P*' and 'small' cluster centers to '*D*'. The QUICK CLUSTER procedure has the characteristic that the within-group distances are minimized and the between-group distances are maximized. 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 an almost equal size, with the help of an EXCEL spreadsheet. This can be done in two steps. The first step separates participators and non-participators, using the level of participation θ_i. We take the *median* of the level of participation θ_i as the separating threshold value θ^*. The separation between participators and non-participators can be denoted formally as follows

$$\begin{aligned} P &= \{i \in N \mid \theta_i \geq \theta^* (\text{person } i \text{ is participating})\} \\ D &= \{i \in N \mid \theta_i < \theta^* (\text{person } i \text{ is not participating})\} \end{aligned} \tag{11}$$

The second step splits these two sets into two more subsets by taking the *median* of the subset *P* or *D* as the threshold value. Denote these as ϑ_P^* and ϑ_D^* respectively. In this manner, it is possible to realize four subsets of observations combining large and small levels of participation. Equation 12 specifies the required division.

$$\begin{array}{lll} & \text{Mean} & \text{Variance} \\ \theta_i \geq \theta^*, \vartheta_i \geq \vartheta_P^* \text{ (large, large)} & \Rightarrow i \in PP & i \in PD \\ \theta_i \geq \theta^*, \vartheta_i < \vartheta_P^* \text{ (large, small)} & \Rightarrow i \in PD & i \in PP \\ \theta_i < \theta^*, \vartheta_i \geq \vartheta_P^* \text{ (small, large)} & \Rightarrow i \in DP & i \in DP \\ \theta_i < \theta^*, \vartheta_i < \vartheta_P^* \text{ (small, small)} & \Rightarrow i \in DD & i \in DD \end{array} \tag{12}$$

Table 6. *The estimated games at the institutional level in three States*

	a	b	x	y	*Payoff order*	*Name of the game*	ϕ
The Euclidean cluster method							
I.har	1969	7361	5080	5207	$b > y > x > a$	Reverse prisoner's	
	(0)	(8491)	(2584)	(4914)		dilemma	0
I.jha	7772	7001	13225	1129	$x > a > b > y$	Pareto game	0
	(17405)	(7104)	(21035)	(71)			
I.utt	1849	0	2394	0	$x > a > b = y$	Pareto/assurance	
	(2012)	(0)	(2336)	(0)		game	0
II.har	7514	0	7139	4530	$a > x > y > b$	Prisoner's dilemma	0.125
	(6083)	(0)	(7973)	(3341)			
II.jha	1078	0	11240	1797	$x > y > a > b$	Coordination game	0
	(0)	(0)	(18718)	(2173)			
II.utt	144	0	2410	1019	$x > y > a > b$	Coordination game	0
	(169)	(0)	(2326)	(1491)			
The homogeneous grouping method							
har	5185	9112	5217	6837	$b > y > x > a$	Reverse prisoner's	
	(3452)	(12614)	(2463)	(5258)		dilemma	0
jha	11973	11963	13688	5923	$x > a > b > y$	Pareto game	0
	(22591)	(19558)	(20776)	(5645)			
utt	1896	2728	2037	2253	$b > y > x > a$	Reverse prisoner's	
	(2226)	(2754)	(2166)	(1952)		dilemma	0

Notes: I = the mean situation; II = the variance situation; har = Haryana, jha = Jharkhand, utt=Uttaranchal; ϕ = the critical discount factor; The number in the brackets denotes the variance in the payoff within the payoff group.

This way of creating payoff groups is called the *homogeneous grouping method*.

Finally, the payoffs can be calculated by applying the following formula, where $|DP|$ denotes the number of observations in payoff-group DP:

$$a = \frac{1}{|DP|}\sum_{i \in DP}\pi_i ; b = \frac{1}{|PD|}\sum_{i \in PD}\pi_i ; x = \frac{1}{|PP|}\sum_{i \in PP}\pi_i ; y = \frac{1}{|DD|}\sum_{i \in DD}\pi_i \tag{13}$$

It is also possible to assign the observations to payoff groups in the n-person game. The challenger and n–2 contenders can be assigned to P and D via equation (11). The final composite contender can be assigned to PP, PD, DP, DD by comparing the average level of participation of the challenger and n–2 contenders with the level of participation of the final contender via equation (12). Similarly to equation (13), the average payoffs can be calculated for the n-person game, by taking the averages within each 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 sensitivity of the challenger towards the strategy of the contender (mean and variance situation). Hence, there are four possible outcomes per State. It is remarkable

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to observe that the results are exactly the same in the mean and the variance situation for the homogeneous grouping method. The Euclidean cluster method leads to the most reliable result from a game theoretic point of view, as the method clusters together villagers with similar levels of participation. Hence, the first six 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 mean 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 seem to be *insensitive* towards differences with the levels of participation of other villagers.

In the case of the Euclidean cluster method and the variance situation, which is quite different from the mean situation, no participation is found in Haryana in the short term (prisoner's dilemma), while conditional participation is found in Jharkhand and Uttaranchal (coordination game). Table 6 indicates that the estimation result is quite robust, as the relative difference $100 \times \frac{x-a}{x}$ is over 90 per cent in Jharkhand and Uttaranchal. In Haryana a value of –5 per cent is found, which indicates that the prisoner's dilemma may not be a very severe conflict. Moreover, the critical discount factor $\phi = 0.125$ is rather low and mutual participation is still a likely outcome in the long run.

In the case of the Euclidean cluster method and the mean situation, mutual participation can be sustained in all three cases. In Haryana a higher payoff is possible by mutually defecting (reverse prisoner's dilemma), while unconditional participation is found in Jharkhand (Pareto game) and a somewhat more conditional participation is found in Uttaranchal (Pareto/assurance game). This typically represents the actual situation. Participation is difficult to achieve in Haryana, because of unequal landholding and a great difference between rich and poor. In Jharkhand the villagers are willing to work in the pool, as there are hardly any good labor alternatives. In Uttaranchal the people in the village are quite equitable and are willing to participate when others are willing too.

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 insensitive towards the level of participation of other villagers, mutual participation is more likely to emerge. Table 6 shows that the difference between x and a is smaller. The likelihood of a deviation from mutual participation can be calculated as: $100 \times \frac{x-a}{x}$. This is 61 per cent for Haryana, 41 per cent for Jharkhand, and 23 per cent for Uttaranchal, which means that the organization for forest management is less stable once villagers are indifferent to the level of participation of other villagers.

Table 7 shows the average level of participation (final cluster centers) in each payoff group.[12] High levels of participation are underlined to distinguish between high and low levels of participation, which we labelled

[12] It was necessary to consider 5 instead of the usual 4 clusters in the mean situation in Haryana, otherwise the difference between some final cluster centers would not be statistically significant.

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

Cluster	θ	$\bar{\vartheta}$	π	*Cases*	*Cluster*	θ	σ_ϑ	π	*Cases*
Model I.har: reverse prisoner's dilemma					*Model II.har: prisoner's dilemma*				
1	0.21	0.32	y	9	1	0.40	0.08	y	29
2	$\underline{0.67}$	$\underline{0.54}$	x	34	2	0.05	$\underline{0.60}$	a	4
3	$\underline{0.55}$	0.10	b	48	3	$\underline{0.64}$	0.03	x	56
4	0.04	$\underline{1.00}$	a	1	4	$\underline{0.85}$	0.09	x	38
5	$\underline{0.84}$	0.39	b	35					
Model I.jha: Pareto game					*Model II.jha: Coordination game*				
1	0.11	0.30	y	2	1	0.00	$\underline{1.00}$	a	1
2	$\underline{0.87}$	$\underline{0.63}$	x	77	2	$\underline{0.67}$	0.07	x	25
3	0.63	$\underline{0.69}$	a	20	3	$\underline{0.88}$	0.04	x	94
4	$\underline{0.84}$	0.13	b	24	4	0.31	0.44	y	3
Model I.utt: Pareto/assurance game					*Model II.utt: Coordination game*				
1	$\underline{0.74}$	$\underline{0.84}$	x	111	1	0.29	0.21	y	11
2	$\underline{0.88}$	0.00	b	1	2	$\underline{0.88}$	$\underline{0.80}$	b	1
3	0.38	$\underline{0.85}$	a	19	3	0.06	$\underline{0.81}$	a	3
4	0.17	0.29	y	4	4	$\underline{0.73}$	0.06	x	120

Notes: θ is the level of participation of the challenger; $\bar{\vartheta}$ is the level of participation of the contender based on the mean; σ_ϑ is the level of participation of the contender based on the variance; har = Haryana, jha = Jharkhand, utt = Uttaranchal; $\{a, b, x, y\} \in \pi$ is the payoff or net benefit from participation.

as 'Participate' and 'Defect' in table 1. From table 7, we can see that the number of observations is quite unevenly distributed. While the amount of mutual participation in the mean situation in Haryana is around 27 per cent (payoff group '*PP*'), the amount of mutual participation in the mean situation in Jharkhand and Uttaranchal varies from 63 per cent to 82 per cent respectively. In the variance situation, mutual participation is much more common and varies from 74 per cent in Haryana to 97 per cent in Jharkhand. This clustering of observations into payoff group *PP* indicates a high number of participating villagers. In addition, table 7 has no observation in payoff group *PD* in Jharkhand and Uttaranchal, which demonstrates a limitation of the Euclidean cluster method. In this case we take the payoff equal to zero, as the action-pair (P, D) is not observed.

6. Games at the village level

The previous section addressed the first research question, namely whether there are incentives at the institutional level for villagers to participate voluntarily in forest management. We now turn to the second research question, to verify whether there are incentives at the village level.

The homogeneous grouping method is used here to estimate games at the village level. Such an approach is viable as the estimated games at the State level are quite similar to the ones found with the Euclidean cluster method in the mean situation. For instance, table 6 shows that the games in Haryana and Jharkhand are the same, while only the game in Uttaranchal

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Table 8. *The estimated payoffs in villages in Haryana*

Village name	*a*	*b*	*x*	*y*	*Payoff order*	*Name of the game*	ϕ
Panchkula district							
Sukhomajri (19)	2712 (1917)	7003 (2217)	11448 (8325)	6636 (5763)	$x > b > y > a$	Pareto game	0
Dhamala (16)	3079 (2384)	6606 (4730)	12497 (8220)	5661 (4594)	$x > b > y > a$	Pareto game	0
Main Nada (11)	5029 (4282)	10457 (2610)	7505 (2429)	7776 (294)	$b > y > x > a$	Reverse prisoner's dilemma	0
Harijan Nada (4)	1969 (0)	4605 (0)	5183 (0)	4193 (0)	$x > b > y > a$	Pareto game	0
Godam (30)	3963 (1136)	4717 (1254)	4012 (348)	4004 (1739)	$b > x > y > a$	Pareto game	0
Ambala district							
Mandpa (11)	9518 (6342)	14207 (4251)	32543 (35561)	3860 (1003)	$x > b > a > y$	Pareto game	0
Masoompur (12)	3266 (2207)	3865 (371)	3208 (1144)	6260 (2517)	$y > b > a > x$	Reverse Pareto game	1
Thathar (14)	6181 (3326)	5168 (2950)	4708 (2048)	5913 (3869)	$a > y > b > x$	Reverse Pareto game	1
Yamuna Nagar district							
Salehpur (10)	6541 (4991)	4593 (555)	8589 (2813)	9648 (1135)	$y > x > a > b$	Reverse coordination game	0

Note: The values in brackets denote the standard errors. The choice of the challenger (= level of participation) is based on the first principal component of the indicators of participation. The choice of the contender is based on the mean of the levels of participation of other villagers. The number in the brackets in the first column denotes the number of observations per village, while the number in the brackets of the payoffs denotes the variance in the payoff within the payoff group.

changes from a Pareto/assurance game to a somewhat different reverse prisoner's dilemma.

To explore the games at the village level, we divide the data into four equally sized payoff groups via the homogeneous grouping method at the village level. The average payoffs, standard deviations and the resulting games at the village level are presented in tables 8 to 10.

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. While we find one prisoner's dilemma and one chicken's game, the results show that mutual participation can be sustained in most of the cases. Here we use the data as a guide in deciding upon the likelihood of mutual participation to be sustainable.

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Table 9. *The estimated payoffs in villages in Jharkhand*

Village name	*a*	*b*	*x*	*y*	*Payoff order*	*Name of the game*	ϕ
Barwadih subdivision							
Hendehas (7)	6596	21338	6719	46388	$y > b > x > a$	Reverse assurance game	0
	(3239)	(0)	(9251)	(0)			
Chapri (16)	713	5068	4551	5111	$y > b > x > a$	Reverse assurance game	0
	(539)	(5578)	(5257)	(5639)			
Barhania (16)	6608	8889	9511	9762	$y > x > b > a$	Reverse coordination game	0
	(4454)	(6239)	(1423)	(579)			
Sindhorwa (9)	39154	82415	52206	78309	$b > y > x > a$	Reverse prisoner's dilemma	0
	(55373)	(5807)	(45211)	(0)			
Muru(6)	840	12361	12663	24291	$y > x > b > a$	Reverse coordination game	0
	(1188)	(0)	(12462)	(0)			
Daltonganj subdivision							
Bhusaria (9)	3906	0	18226	7811	$x > y > a > b$	Coordination game	0
	(5523)	(0)	(16152)	(0)			
Bakhari (9)	108	0	5220	1991	$x > y > a > b$	Coordination game	0
	(153)	(0)	(6429)	(2816)			
Kumbhawa (7)	4818	4390	4663	4470	$a > x > y > b$	Prisoner's dilemma	0.446
	(433)	(91)	(391)	(0)			
Sakanpirhi and Tandwa (16)	8194	3219	15442	7989	$x > a > y > b$	Assurance game	0
	(9971)	(5021)	(11940)	(8678)			
Mundaria (10)	4044	13412	3284	5084	$b > y > a > x$	Reverse chicken's game	1
	(5996)	(1489)	(5688)	(6744)			
Kashia (9)	4345	1159	6443	4141	$x > a > y > b$	Assurance game	0
	(6144)	(1639)	(3183)	(5856)			
Khamdih (9)	4489	5087	8714	4559	$x > b > y > a$	Pareto game	0
	(5697)	(5498)	(182)	(5862)			

Table 10. *The estimated payoffs in villages in Uttaranchal*

Village name	*a*	*b*	*x*	*y*	*Payoff order*	*Name of the game*	ϕ
Pauri Garhwal district							
Ulli (14)	896 (1122)	1013 (887)	711 (1388)	1211 (708)	$x > a > b > y$	Reverse Pareto game	1
Than (8)	428 (80)	252 (37)	335 (473)	335 (473)	$a > x = y > b$	Prisoner's dilemma/ Reverse Pareto game	1
Thamana (5)	0 (0)	0 (0)	0 (0)	0 (0)	$a = b = x = y$	Game without gain	1
Nishni (23)	3724 (2215)	4675 (1840)	3252 (2186)	3150 (3711)	$b > a > x > y$	Battle-of-sexes game	1
Chamoli Garhwal district							
Bachher (13)	127 (177)	1640 (922)	936 (1070)	927 (758)	$b > x > y > a$	Pareto game	0
Makkumath (15)	787 (493)	1277 (1127)	1326 (777)	1290 (1725)	$x > y > b > a$	Coordination game	0
Ushara (6)	2080 (610)	4219 (0)	3373 (3917)	2781 (0)	$b > x > y > a$	Pareto game	0
Sagar (5)	1936 (0)	2906 (0)	4349 (983)	50 (0)	$x > b > a > y$	Pareto game	0
Almora district in the Kumaun region							
Shama (22)	3012 (2096)	3777 (6061)	3358 (1728)	4056 (1904)	$y > b > x > a$	Reverse assurance game	0
Panyali (8)	5625 (1325)	3515 (79)	5287 (1647)	3238 (1409)	$a > x > b > y$	Chicken's game	0.160
Reema (16)	1216 (858)	1714 (2568)	1390 (1041)	2150 (1652)	$y > b > x > a$	Reverse assurance game	0

The outcome in tables 8 to 10 can also be compared with laboratory experiments with common-pool resource games. A common outcome of such experiments is that, at the aggregate level, subgame perfect equilibria organize the data quite well, while, at the individual level, subjects rarely follow Nash behaviour. Moreover, experiments shows that repetition, communication, and threats increase the likelihood of mutual participation (see for instance Keser and Gardner, 1999; Kagel and Roth, 1995; Ostrom *et al.*, 1992; Walker *et al.*, 1990). The household data we are using here, comes from villages where the level of participation is set in the context of repeated interaction, where communication is possible and punishments can be expected via the village meetings. These circumstances may explain why we only find two common-pool resource *dilemmas* out of 32 cases.

Table 8 shows high net benefits from mutual participation in Sukhomajri, Dhamala and Mandpa. These villages all have functional irrigation dams. The failure of access to damwater shows up in Masoompur and Thathar, where mutual participation is associated with the lowest possible payoff. Main Nada could compensate its loss of damwater by a collective purchase of a diesel pump. The single caste village Harijan Nada also has incentives for participation. In Godam, where villagers weave baskets from bamboo collected from the communal forest, mutual participation is fragile, as $100 \times \frac{x-a}{x} = 1$ per cent only.

It is reassuring to find a critical discount factor of zero in Sukhomajri (Mishra, 1996) and Salehpur (Lise, 1997a), as these villages are known as the most successful cases in Haryana. In Sukhomajri the participatory process once started, 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 in Salehpur was not positive, which may explain why mutual participation is less beneficial than the Nash equilibrium of mutual defection.

Table 9 shows that the estimated games have a regional linkage in Jharkhand. In the Barwadih subdivision, we only find reverse games, where mutual participation always can be sustained ($\phi = 0$). In the Daltonganj subdivision, we find in most villages that $x > y$, while the result is more mixed. In the most remote village Kumbhawa, which is about 40 kms away from the headquarters in Daltonganj city, we find a prisoner's dilemma with $\phi = 0.45$, while $100 \times \frac{x-a}{x} = 3$ per cent only. In Mundaria we observe only partial participation. Hendehas, Barhania, Bakhari, Kashia, and Khamdih are the other 'new' villages (planting effort since 1994). There mutual participation is unlikely to break down, as planting in the pool is still going on and funding of labour in the pool is still taking place.

Among the 'old' villages (planting effort before 1994), Muru is the only village where mutual participation has already broken down, mainly due to destruction of the pool by wildlife. Table 9 shows indeed a reverse coordination game, while mutual participation is still a Nash equilibrium. In the other 'old' villages, mutual participation is still sustainable, but it is not sure whether this will be the case in the future. Mutual participation is under pressure in Bhusaria, because of difficulties in protecting the pool. In Tandwa and Sakanpirhi, the people are losing faith in the pooling process, as the common pool did not yet substantially benefit them. Finally, the pooling process is benefiting only a part of the people in Chapri.

Table 10 presents the games in villages of Uttaranchal. The location of the villages can be divided into three geographical regions, namely the Pauri Garhwal, Chamoli Garhwal, and Almora districts. As expected there are no incentives for participation in Thamana, where the communal forest is virtually gone. In Ulli, only a part of the villagers is actually interested in preserving the forest.

It is intuitive to find the highest incentive for participation in the most remote Chamoli Garhwal district. This district is also famous from the chipko movement.[13] In Sagar, where the president of the forest council is suspended, mutual participation is expected to break down, but this does not show up in the data. The meetings are proceeding well in Sagar, but conflicts emerge in the field, when they try to carry out the agreed-upon rules.

In Panyali, the people are paying a yearly fee for collecting resources from the communal forest, 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 non-trivial critical discount factor of 0.16. Nevertheless, the absolute net benefits are the highest in Panyali, which also indicates a high quality of the communal forest. In Shama and Reema, theft of forest products is common, participation is conditional, and the Nash equilibrium of mutual defection is more beneficial ($y > x$) than the Nash equilibrium of mutual participation.

7. Conclusions and recommendations

The main objective of this paper has been to use data on indicators of participation in forest management and net benefits from the forest to derive what kind of game is being played among users of communal forests. Three distinct institutional settings were chosen, because of their successes in involving people in forest management on the one hand, and the diversity in achieving this, on the other hand. While the literature suggests that the game played by forest users may be usefully modelled as either a prisoner's dilemma, a chicken's game, or an assurance game, we extend the possibility to a number of other games too. Moreover, rather than choosing a game beforehand, the data have been used to verify whether villagers act in harmony with each other or not. In addition, this choice situation is also modelled as a repeated game, where villagers voluntarily choose their level of participation in forest management. Trigger strategies are formulated to calculate critical discount factors above which mutual participation can be sustained in equilibrium.

By estimating games, we have also derived a quantitative measure for the effectiveness and stability of an organization for forest management. Moreover, we can conclude from the estimation results that the studied organizations for forest management in India vary in their effectiveness. Participation is difficult to achieve in Haryana, because of unequal

[13] In a protest women embraced trees and successfully avoided large-scale tree-cutting.

landholding and a great difference between rich and poor. In Jharkhand the villagers are willing to work in the pool, as there are hardly any good labour alternatives. In Uttaranchal the people in the village are quite equitable and are willing to participate when others are willing too. This most likely outcome is based on the assumption that villagers are insensitive to variation in the level of participation of other villagers. The studied organizations for forest management in India turn out to be more stable when villages are sensitive to variation in the level of participation of other villagers in Jharkhand and Uttaranchal. In Haryana, organizational stability can only be guaranteed in the long run, when villagers discount the future above 0.125.

We do find non-trivial critical discount factors (with a value between zero and one). Moreover, we find that mutual participation can be sustained in most of the cases, namely in 23 out of the 32 studied villages the critical discount factor is zero, while in two more villages we find a critical discount factor of 0.45 and 0.16. In the remaining seven villages the critical discount factor is one. This outcome is also comparable to laboratory experiments with common-pool resource games, which have shown that repetition, communication, and threats increase the likelihood of mutual participation. As this compares well to the household data we are using here, it may explain why we only find two common-pool resource dilemmas in the studied villages.

The results of the estimation method, as explained in this paper, have been presented as a two-person binary choice game. However, in each step, we also explain how the method can be extended to a multi-person game. The main conclusion from a computational point of view is that the estimated games at the village and the State level do match well with the actual situation in the field. Hence, the estimation method can be recommended for application to any situation where actors have to solve collective action problems in managing a common resources.

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