Participatory policies and intrinsic motivation to conserve forest commons

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Participatory policies for natural resource management and poverty reduction have been implemented worldwide. Inclusive participation and empowerment potentially enhances intrinsic motivation to conserve resources. However, whether participation in activities for poverty reduction enhances intrinsic motivation for resource conservation is unknown. We evaluate the impact of participation, in activities to develop sustainable livelihoods, on the intrinsic motivation of forest-dwelling community members to conserve forest commons. As a component of Brazil's *Bolsa Floresta* programme, these activities involve decision-making, skills training and knowledge exchange related to sustainable livelihoods. Using a framed common-pool resource game with 160 community members in Amazonas State, we measure intrinsic motivation via members' extent of cooperation to conserve trees. We obtain an estimate of impact by exploiting a natural experiment, whereby the treatment

group was offered the choice to participate in activities to develop sustainable livelihoods. We find that participation crowds in cooperative behaviour and hence, intrinsic motivation to conserve forest commons. This result suggests that enabling participation and empowering community members in the development of sustainable livelihoods has a positive effect on conservation behaviour. Our results have critical implications for participatory policies with dual environment-development goals in settings where policy recipients are marginalised.

Participatory policies to conserve common-pool resources, such as forests, engage and transfer powers to local stakeholders in natural resource management [1, 2]. Participation can be characterised by the extent and timing of stakeholder involvement [2-4]. A shift to more inclusive participation, i.e. extending it to the full decision-making process, potentially empowers stakeholders who were previously restricted in their access to and use of resources. By giving stakeholders the knowledge, confidence, means, or ability to make decisions in natural resource management, greater empowerment has been shown to be empirically associated with more collective action in the commons, e.g. monitoring of resource use [5]. In turn, more collective action is often a key determinant of improved resource conservation outcomes [e.g. 5, 6].

Empowerment can change stakeholder behaviour when stakeholders become intrinsically motivated, i.e. gaining personal fulfilment or satisfaction [7, 8]. Thus, a change in behaviour, such as an increased willingness to engage in collective action and cooperate in the commons, could be driven by an enhanced intrinsic motivation to conserve resources. This behavioural change is critical in the context of conservation policy's role in either strengthening ('crowding in') or weakening ('crowding out') stakeholders' intrinsic motivations to conserve resources [9, 10]. So-called 'motivation crowding' effects are often estimated via the use of economic games that measure cooperation levels in resource settings, including the behavioural responses of players to hypothetical treatments in conservation policy [11].

However, the evidence as to whether such treatments, involving incentives or disincentives, have generated motivation crowding effects remains inconclusive [e.g. 12-15].

Participatory conservation policies in poorer countries often have a strong focus on reducing poverty too. It is unclear whether inclusive participation in poverty-reduction activities have a positive effect on the intrinsic motivation to conserve resources. Becoming empowered implies more opportunities for decision-making, learning new skills or gaining knowledge related to the development of new livelihoods thus giving stakeholders more control over their labour - a key asset of the rural poor. This surely motivates stakeholders but if the new livelihoods are not directly tied to resource use, it is unclear whether they would influence intrinsic motivation to conserve resources. A positive impact is perhaps more likely when livelihoods are tied to resource use, even indirectly, e.g. eco-tourism, and where a culture of environmental sustainability is encouraged [16].

We explore this idea in Brazil's forest conservation and poverty reduction programme *Bolsa Floresta* (PBF), implemented by *Fundação Amazonas Sustentável* (FAS, Amazon Sustainable Foundation) [17]. In 2018, almost 40,000 people in 581 communities, claiming 11 million hectares of forest in Amazonas State, were enrolled in PBF. Amazonas remains heavily forested and has historically low rates of deforestation. Yet, FAS is concerned about future deforestation risk, particularly close to the state capital, Manaus, and has no monitoring or enforcement capacity at the commons scale. The onus is thus on community members enrolled in PBF to monitor resource use and enforce rules at this scale.

Enacted by the State of Amazonas in 2007, PBF comprises four components. The first is *Family*, a monthly household-level cash payment (Supplementary Information, Section A). Next, *Association* supports community leaders in forest co-management, followed by *Income*, in which FAS offers community members a platform for creating sustainable livelihoods. Finally, *Social* involves investments in public services, including healthcare and education.

To integrate these components, FAS implements a ‘social contract’ to empower community members who, prior to PBF, were often marginalised through the implementation of top-down conservation policies that prohibited resource-intensive activities, and the non-provision of public services such as healthcare. The social contract is implemented through the intensive engagement of FAS personnel, funds and outreach in enrolled communities. Community members enrolled in PBF are offered greater control over resource use as well as tools and opportunities that facilitate sustainability in resource management and livelihoods. Tools and opportunities are made available by FAS via a participatory approach concentrated in the *Income* component. This approach is applied to workshops held at the community scale.

Workshops are the main vehicle for developing livelihoods, such as ecotourism and handicrafts, in the expectation of these replacing more resource-intensive livelihoods and hence, potentially contributing to sustainability [18, 19]. Open to all community members, including leaders, the role of FAS in workshops is to help members develop business plans, learn new skills and obtain knowledge related to livelihoods. As well as training, workshops provide a forum for knowledge exchange among community members; outside the workshops, there is an emphasis on the ‘multiplication of knowledge’, in which trained community members pass on their skills and knowledge to other members of their communities (Supplementary Information, Section A).

Participation in workshops is voluntary and community members decide which livelihoods to implement. To varying degrees, participation in workshops (and the corresponding livelihoods chosen) tends to be collaborative. Individual participation incurs private costs, such as an opportunity cost of time spent in workshops and the provision of in-kind inputs, e.g. labour. Livelihoods proposed by community members are funded by FAS, e.g. for equipment and training. Expected financial benefits are uncertain, depending on whether community members succeed in creating livelihoods.

Participants also benefit from new decision-making opportunities (e.g., deciding which handicrafts to produce), learning new skills (e.g. to produce new handicraft lines) and gaining new knowledge (e.g. about the market for handicrafts). These non-pecuniary benefits could motivate conservation behaviour, yet as they are not contingent on such behaviour, i.e. are generated irrespective of conservation behaviour, motivational crowding occurs when participants are intrinsically motivated in their use of forest resources [20, 21].

To test whether the participatory approach implemented by FAS crowds in participants' intrinsic motivation in their use of forests, we measure the extent to which they cooperate in a common-pool resource (CPR) game (*Methods*). We adopt 'extent of cooperation' as our outcome measure based on previous work (e.g., exposure to war [22] and property rights reform [23]). Framed in terms of timber extraction, the greater the extent of cooperation, the lower the rate of tree extraction and the more trees conserved.

A precondition for implementing PBF is that communities' territorial claims and resource use rights must first be formalised via the establishment of a mixed-use reserve, such as a *Reserva de Desenvolvimento Sustentável* (RDS, Sustainable Development Reserve). Reserves comprise multiple communities, each claiming a forest commons in exchange for agreeing to restrictions on resource-intensive activities, e.g. logging. We exploit exogenous variation in the timing of reserve formation to generate treatment and control groups (*Methods*). Opportunities to participate in the *Income* component were only available in the treatment group. To account for the possibility that some community members in the treatment group might choose not to participate, we analyse our data within an intention-to-treat (ITT) framework that includes both participants and non-participants in the treatment group.

Results

We conducted a CPR game and household survey in a sample of community members from two reserves (Fig. 1, *Methods*). Located on opposite sides of the *Rio Negro* (Black River), 10-20 km apart, the reserves are broadly similar (Supplementary Table I, Supplementary

Fig. 1, Supplementary Information, Section A). Our treatment group, RDS Rio Negro, was established in 2008 and has been enrolled in all four components of PBF since 2009. Created in 2014, our control group, RDS Puranga Conquista, was only enrolled in the *Family* component. As opportunities to participate in the *Income* component were made simultaneously across communities in the treatment group, our first ITT effect is estimated from our natural experiment at the reserve scale.

Our second ITT effect is estimated at the community scale, the scale at which sustainable livelihoods in the *Income* component were developed. Four communities in the treatment group were matched with three communities in the control group (*Methods*, Supplementary Table 2). A range of livelihoods has been implemented in the treated communities, from tourist accommodation to sport fishing (Table 1). A majority were either in the early or intermediate stage of development. Many community members reportedly had yet to receive tangible, private benefits from these livelihoods.

As community members initiated and attended workshops to develop sustainable livelihoods, we also estimate a treatment effect at the individual scale, based on the rate of participation in workshops. Workshops take place at all stages in the development of most if not all livelihoods, and play an instrumental role in activities and processes that take place outside the workshops (Supplementary Information, Section A). As such activities and processes are a function of workshop participation, the participation rate could proxy for 'intensity' of participation in the *Income* component.

The average participation rate in the treatment group, containing 100 community members, is almost two workshops per person. In the control group, with 60 members, it is one workshop per person despite there being no such workshops organised in these communities (Supplementary Table 3, Supplementary Fig. 2), an anomaly we address in *Methods*. Regarding attrition, 45 community members in the treatment group stated that they did not participate in any *Income* workshops. Community members who were already enrolled in the *Family* component, including non-participants in the treatment group, were recruited to play six rounds of our CPR game.

In every round, average tree extraction rates per player are higher in the control group than in the treatment group. Fig. 2 shows the average extraction rates per player in each round, treatment group vs control group (Supplementary Fig. 3 shows rates per player by community). Players often chose similar extraction rates across rounds (Supplementary Table 4). Average rates are relatively low, because, in every round, most players opted to extract no trees at all (Supplementary Fig. 4). To handle large numbers of observed zeros, we apply a hurdle model [24], which combines a selection model with an outcome model, to our data (*Methods*).

Reserve- and community-level ITT effects are associated with a higher likelihood of zero tree extraction. The reserve ITT effect is estimated with a dichotomous dummy variable ('Reserve') using round one data only. In column 1 of Table 2, it has a negative and positive coefficient in the 'Select' and 'Outcome' panels, respectively. Estimating a reserve ITT effect using all rounds of data generates a similar result (Supplementary Table 5). As Select denotes the decision of whether to extract zero or a positive number of trees, this result implies that the reserve ITT effect is significantly associated with a higher likelihood of choosing zero extraction ($p=0.031$). By contrast, it has an insignificant effect in the Outcome panel, for the decision of how many trees to extract for players extracting a positive number of trees.

A community-level ITT effect is estimated using all rounds of data and dichotomous dummy variables for each of the four treated communities. Column 1 of Table 3 shows that the coefficient on these variables is negative for three communities (4, 5 and 7) in both the Select and Outcome panels, and statistically significant for two (4 and 7) in the Select panel ($p<0.001$). Thus, the treatment is significantly correlated with a higher likelihood of choosing a zero extraction rate in two of the four treated communities. Note that as *Income* workshops were initiated according to the demands of community members, unobserved confounders potentially influence the community ITT effects.

Participation in *Income* workshops is associated with a higher likelihood of a player choosing zero tree extraction. An individual treatment effect is first estimated using a dichotomous dummy variable, ‘Individual (0,1)’, which is coded ‘1’ if one or more workshops were attended. In column 2 of Table 2, this variable has a negative yet insignificant association with extraction rates in both panels. A second individual effect is estimated using workshop participation rate, ‘Individual (#)’. In column 3 of Table 2, a higher rate is significantly correlated with a higher likelihood of zero extraction (p=0.049). From columns 3-5 in Table 2, the marginal effect of participation ranges from -0.38 to -0.56. Thus, attendance at one additional workshop is associated with half-a-tree less extracted in the game.

We include the reserve ITT variable alongside the individual treatment variables in columns 2-4 of Table 2. The inclusion of either individual variable reduces the size of the coefficient on the reserve variable and its statistical significance in the Select panel (compare column 1 to columns 2 and 3, in Table 2). This implies that part of the reserve effect comes from the individual effect. As the reserve variable may be picking up effects from the other components of PBF (*Methods*), it also acts as a control when estimating the individual effect.

If participation is correlated with unobserved factors that are also correlated with extraction rates, e.g. kinship ties, then our individual treatment effect could be biased. We add further pre-treatment controls in column 4 of Table 2. The coefficient on Individual (#) remains stable, although its statistical significance is reduced (from p=0.049 in column 3 to p=0.060 in column 4, Table 2). We next add post-treatment controls (column 5, Table 2), which are likely to be endogenous: as expected, the coefficient on Individual (#) is larger and gains statistical significance (compare columns 4 and 5 in Table 2). The effect of Individual (#) on extraction rates is robust to the addition of all controls (Supplementary Table 6 and 7).

A significant individual treatment effect first emerges when participants attend three or more workshops. Column 2 of Table 3 includes a pair of participation rate dummy variables. First, ‘Individual (1-2)’ is for participants who attended a total of one or two workshops; in the Select panel, it is positively correlated with extraction rates. Second, ‘Individual (3-15)’ is for participants who attended three or more workshops; it is negatively correlated with extraction rates and indicates the threshold over which a significant negative effect first emerges in the Select panel (p=0.060). Supplementary Table 8 shows results from testing alternative pairs of dummies.

If a higher participation rate motivates higher levels of cooperation which, in turn, motivates further participation in workshops then there is potential for reverse causality (*Methods*). We use the number of adults in the household as an instrument for Individual (#). Results (Supplementary Table 9) are consistent with those in Table 2. However, our instrument is relatively weak, which increases the likelihood of finite sample bias when conducting instrumental variable analysis in a small sample [25]. Other empirical issues, and our strategies to address these, are discussed in *Methods*. Results (Supplementary Table 10-14, Supplementary Information, Section B) are in line with Table 2.

Discussion

Our results contribute to knowledge and understanding of how conservation policies influence intrinsic motivations of local stakeholders in their use of natural resources. In particular, the behavioural response of marginalised stakeholders to conservation policies when there is an additional focus on poverty reduction and when policy implementation involves the application of a participatory approach with a goal of stakeholder empowerment. This type of policy can be characterised as a hybrid, which in the case of PBF combines aspects of participatory governance, payments for ecosystem services and the development of alternative livelihoods.

Among the beneficiaries of PBF, we observed relatively low tree extraction rates in both the treatment and control groups, certainly lower than comparable studies, e.g. [26]. Mean extraction rates in round one were 22% and 16% of the Nash equilibrium extraction rate (20 trees) in our control and treatment groups, respectively. These rates indicate high levels of cooperation and thus high levels of intrinsic motivation to conserve forest commons. The fact that these rates are high in both groups possibly reflects the intensive engagement of the policy manager, FAS, in our study area and the influence of two bottom-up conservation policies – the mixed-use reserves and PBF – over a number of years. While we observed relatively strong conservation behaviours and attitudes among the beneficiaries of PBF, including those only enrolled in the *Family* component, we note that other, unobserved factors may also play a role in generating these high cooperation levels, e.g. high levels of pre-existing trust among community members.

Different types of benefit are generated by the components of PBF. In the *Income* component, with its focus on developing sustainable livelihoods, participant empowerment is characterised as a non-pecuniary benefit of participation. The participatory development of livelihoods (costing 35% of PBF funds) has the potential to be a cost-effective and sustainable way of increasing conservation behaviour relative to the *Family* cash transfer, which absorbs half of all funds invested in PBF [14, 18, 19].

At different treatment scales, the participatory approach is associated with higher levels of cooperation and hence, crowding in of intrinsic motivation to conserve forest commons. The approach thus had a positive effect despite mixed success in creating livelihoods. This has important implications for other, similar policies implemented in settings where local people are marginalised.

Conceived as a social contract, PBF seems to have generated a normative sign of a desirable societal action among policy beneficiaries [27]. In particular, the process of creating sustainable livelihoods improved participants' knowledge and understanding of the potential conservation benefits generated by these livelihoods. This process connected participants not only to the wider economy but also to society, often for the first time. Thus, the managers of other, similar policies could attempt to communicate – indeed sell – the broader environmental implications, and not just the private benefits of participation in activities to develop sustainable livelihoods.

Per similar policies in other settings, PBF has dual environment-development objectives that need the inclusive participation of community members for meeting both objectives in the long-run. Given an attrition rate of almost 50%, future research could examine why non-participants in our treatment group chose not to participate. There may be barriers to participation, including those related to intra-community inequalities. Wealth or asset inequality could be exacerbated if participation mostly benefits those who are already relatively wealthy [28, 29].

Our measure of forest conservation behaviour is derived from game outcomes. Although game outcomes generate a useful signal about members' conservation behaviour and hence, possible sources of deforestation risk, there remains a question of whether players would behave similarly in a real forest setting. If participation is effective in changing social norms regarding cooperation in the commons over the longer-term then game outcomes could proxy for forest outcomes. To test this idea, we would need to re-run the game with the same sample of community members and collect forest commons data in our study setting.

Further research could also examine the mechanism by which empowerment and inclusive participation influences intrinsic motivation to conserve the commons. Despite lacking precise data on the collaborative processes inherent in the development of livelihoods, we observed that the extent of collaboration varied depending on the livelihood chosen by community members. Where collaboration is critical for livelihood development, there is likely to be a building of trust, which may help motivate cooperation [30, 31].

Collaboration typically involves communication. Participants in the *Income* component played the CPR game without communicating, indeed without knowing who else was in their groups, which often included non-participants too. A communication treatment combined with data on collaborative processes could explore whether and how exposure to these processes translates into solving the commons dilemma. By not allowing communication, our CPR game might have prevented those free-riders who may have simply misunderstood the dilemma from learning how it could be solved. Communication would allow for learning, giving cooperative players an opportunity to persuade players extracting trees to cooperate thus potentially increasing collective benefits [14, 32, 33]. Other reasons for non-cooperation and players' strategies to address these could also be explored in a communication treatment.

Another possible mechanism concerns how empowerment relates to the psychological mechanisms underlying motivation crowding [10, 20, 21]. Giving people more control over their labour via opportunities for decision-making, learning skills and gaining knowledge potentially enhances participants' feelings of autonomy. The central role of sustainability in many of the livelihoods suggests that the relevant psychological triggers were present for motivating conservation behaviour. Additional research is needed, however, to determine whether autonomy, or other psychological moderators, played a role in our setting.

In our setting, profitable, alternative uses of forest land are limited by the nutrient-poor soils and waters of the Rio Negro. Yet, the influence of policies like PBF on cooperative behaviour should be similar in other settings, in Brazil and elsewhere, where alternative uses of forest land are more profitable. In such settings, there is likely to be a higher risk of external threats to forest commons due to, e.g. illegal logging. Where governments struggle to enforce forest laws and counter external threats, e.g. due a lack of capacity, greater intrinsic motivation to conserve forests could motivate communities to organize in a manner that enables them to resist external threats. Programmes similar to PBF could, if they foster greater cooperation within communities, directly or indirectly support actions such as building solidarity with other marginalized groups and forming cooperatives to negotiate better prices for products that have been sustainably produced.

Methods

Natural experiment and common-pool resource game. The *Bolsa Floresta* programme (PBF) is only implemented in communities located in Amazonas State after a mixed-use reserve (e.g. RDS) has been established, and communities' territorial claims and forest use rights have been formalised. We exploit exogenous variation in the timing of reserve formation to generate treatment and control groups. Our treatment is the opportunity extended to community members to participate in the *Income* component, where the participatory approach developed by FAS is concentrated. Community members were sampled from communities in two reserves (Fig. 1).

Our treatment group was RDS Rio Negro. Created in 2008, it has since 2009 been enrolled in all four components of PBF. Our control group, RDS Puranga Conquista was created later, in 2014, due to being previously designated a strict protected area by the government of Amazonas State, in 1995. Territorial conflicts involving communities, State and Federal agencies slowed the process of establishing RDS Puranga Conquista [34]. This provides a plausibly exogenous means by which our treatment and control groups were assigned. Only the *Family* component had been implemented in the control group. Thus, all sampled community members, in both our treatment and control groups, were receiving the *Family* cash transfer but only members in the former were offered opportunities to initiate and attend *Income* workshops, from 2009 onwards.

In principle, RDS Puranga Conquista acts as a kind of counterfactual, i.e. allowing us to measure cooperation levels in the absence of opportunities to initiate and attend *Income* workshops in RDS Rio Negro. This rests on the assumption that our treatment and control groups are similar. On the basis of a limited set of observable characteristics, such as size, deforestation rates, number of communities and distance to market, they can be considered broadly similar (Supplementary Fig. 1, Supplementary Information, Section A). Also, on the basis of the earliest household data collected (in 2015) sufficient to allow for a comparison (Supplementary Table 1), average incomes aside, there seems to be few substantial differences between the groups.

We matched communities across the treatment and control groups to ensure that our post-matching treatment and control groups were as similar to one another as possible. Matching was undertaken using a community-level dataset for a limited set of variables: ethnicity, main livelihood activities, access to a public boat service, presence of a primary school, presence of a Conservation Centre and population. These data were gathered by FAS for all communities located in the treatment and control groups (Supplementary Table 2). To mitigate post-treatment bias, we use data gathered in 2009, i.e. the year when the *Income* component was made available to communities in the treatment group.

Pre-matching, we made a number of observations. First, all 17 communities in the treatment group were defined as non-indigenous (*cabocla*). Additional to concerns about differences between indigenous and non-indigenous groups (Supplementary Information, Section B), the fact that none of the treated communities were defined as indigenous implied excluding those that were – five in total – from the control group. Second, all treated communities extracted timber as a main economic activity. This was important for the framing of the CPR game (see below). We thus excluded communities in the control group that did not extract timber. Third, as all treated communities had access to a public boat service (*recreio*), which proxied for market access, we excluded communities in the control group that did not have access to a boat service. This left three communities in the post-matching control group, each of which had its own primary school. A single Conservation Centre, built and run by FAS, is present in one community in each of the control and treatment groups. In the post-matching sample, both of these communities were excluded.

Turning to the treatment group, we first excluded communities that did not have their own school, which reduced the group to 10 communities. We then used the population data to finalise the post-matching treatment group. The three communities in the post-matching control group (Pagodão, VL Nova do Chita and Santa Maria) had populations that ranged from 83 to 120 people. By contrast, the 10 remaining treated communities had a wider range: 31-224. We individually matched each of the three communities in the control group to treated communities. This was undertaken by calculating the differences in populations between communities across the two groups before selecting the treated community that minimised the difference for each community in the control group, thus generating three communities in the post-matching treatment group (Camará, Saracá and 15 de Setembro).

At the start of the fieldwork, one more community was added to the treatment group, N. S. Perpétuo Socorro (Supplementary Information, Section B), on the basis of minimising the difference between the population of this community and the average population of the three communities in the post-matching control group.

Insufficient data existed for precise *ex ante* matching of individuals across the treatment and control groups, although registers of community members enrolled in the *Family* component enabled us to sample these members only. That all players were receiving the monthly *Family* cash transfer allowed us first, to establish a baseline level of conservation behaviour in the sample and second, made it easier for players to understand the idea of collective benefits being generated in a common-pool resource (CPR) game.

Effective commons-level monitoring and enforcement requires collective action to share monitoring costs and prevent free-riding on the benefits of conservation [30, 31]. The extent to which community members already cooperate in the commons, and the extent to which this is crowded-in due to participation in the *Income* component, is evaluated by application of a CPR game. Framed in terms of tree extraction, players individually decided how many trees to extract and how many to leave standing. Trees extracted generated a private payoff; trees left standing generated collective benefits shared equally among the players assigned to a particular group (see below). The structure of game payoffs was such that rational, selfish players had an incentive to extract as many trees as possible. Higher individual payoffs accrued when there were sufficient collective benefits of a standing forest to share, i.e. when more players left more trees standing. This can occur if, over the course of multiple rounds, strategic behaviour emerges among players, e.g., conditional cooperation [35-37].

Experimental and household survey data were collected from all seven communities, in July 2018. In each community, we organised one CPR game played over six rounds. Players were anonymously and randomly assigned to a group of four players. At no point before, during or after the game did players know the identity of the other players in their groups. No communication was allowed during or between rounds. In every round, 80 trees were available in each group. Players extracted 0, 5, 10, 15 or 20 trees, with the remainder shared among the group equally: if a player extracted 20 trees, she received BRL 4.00 plus a quarter share of the value of trees remaining; if she extracted no trees, she received BRL 1.60 plus a quarter share of the value of trees remaining (Supplementary Information, Section B).

After the game, players were individually surveyed, including demographic data, livelihoods and social networks. Questions on participation were conveyed to all players in both the control and treatment groups. These questions elicited responses about meetings, different types of workshop and community organisations, both those related and unrelated to PBF. Workshops are common practice in PBF, which may have led to misunderstandings over the participation questions in the household survey, e.g. when community members join PBF, they attend two workshops where details of the *Income* component are presented. This could explain why some survey respondents in the control group stated positive rates of participation in *Income* workshops. We also conducted 26 in-depth elite interviews (Supplementary Information, Section D). In all aspects of our research, we complied with the relevant regulations (e.g. prior authorisation from the environmental agency responsible for the reserves), obtained informed consent from all research participants and confirm that the study complied with the Research Ethics Policy and Procedure, as laid down by the Research Ethics Committee of the London School of Economics and Political Science (LSE).

Analytical methods. Our empirical analysis evaluates the impact of the participatory approach developed by FAS, the treatment, on cooperation in the commons. As participation in the *Income* component is voluntary, our treatment may suffer from attrition if some community members in the treatment group opted not to participate. If this attrition is non-random then it could bias estimates of our treatment on cooperation because it would capture the effect of a self-selected group. This bias occurs if non-participants are systematically different from participants in dimensions that determine participation, and then cooperation.

An intention-to-treat (ITT) framework is adopted to test for evidence of a treatment effect, i.e. of the participatory approach, by including in the empirical analysis all participants and non-participants in the treatment group [38]. The reserve-level ITT effect is broad in that it could, in theory, be picking up the effects of *Association*, *Income* and *Social* on cooperation. The *Association* component involves the participation of community leaders in institution building at reserve level while the *Social* component involves engagement with, rather than the participation of, community members. Public services via the *Social* component are provided unconditionally to all community members. The community-level ITT effect may pick up on variation in the initiation and implementation of workshops across treated communities. How workshops are initiated and implemented depends on the needs and demands of community members. Thus, unobserved confounders could potentially bias our community ITT effects. The individual treatment effect also suffers from potential endogeneity problems, which we discuss below.

Our outcome variable is the number of trees extracted in round *r* by individual *i* in the CPR game. This is a bounded dependent variable (0, 20) and because we observed many zeros, we adopted a hurdle model [24], a general form of a selection model. Specifically, the hurdle model combines a selection model that determines boundary points of the dependent variable with an outcome model that determines its non-bounded values. It simultaneously allows for a decision of whether to extract zero or a greater than zero number of trees and if greater than zero, the number of trees to extract. The model is estimated using maximum likelihood. Formally, for individual i the tree extraction decision in round *r* is specified as:

$y_{ir1} = \gamma_1 Treat_{i(c,R)} + \epsilon_i$, <u>decision</u>: whether or not to extract trees

$y_{ir2} = \beta_1 Treat_{i(c,R)} + v_i$, <u>decision</u>: how many trees to extract

$$y_{ir} = \begin{cases} \beta_1 Treat_{i(c,R)} + v_i & \text{if } y_{ir1} > 0 \text{ and } 0 < y_{ir2} \leq 20 \\ 0 & otherwise \end{cases}$$

where: $Treat_{i(c,R)}$ is the treatment variable (individual *i*, community *c*, reserve *R*), which, depending on the model estimated, is either a dichotomous dummy variable ('Reserve', 'Individual (0,1)'), a pair of dichotomous dummy variables ('Individual (0-*x*)', 'Individual ((*x*+1)-15)'), a set of four dichotomous dummy variables ('Community 4', 'Community 5', 'Community 6', 'Community 7') or a continuous variable ('Individual (#)'); ϵ_i is a standard normal error term; and, $v_i$is an error term, which has a truncated normal distribution with lower truncation point $-x_i\beta$. Standard errors are clustered at group level (40 clusters in total). This allows for intragroup correlation when using all rounds of data, i.e. due to the potential for strategic behaviour, such as reciprocity, which could influence rates in subsequent rounds.

The coefficients on $Treat_{i(c,R)}$ are given by γ_1 and β_1**.** To support our hypothesis that participation crowds in intrinsic motivation to conserve forest commons, these coefficients would need to be negative. A negative γ_1 (β_1) is thus associated with a higher likelihood of zero extraction (a lower extraction rate).

All of our treatment effects are separately estimated using round one extraction data (Table 2) and all rounds of data (Supplementary Table 5), except for the community-level treatment effects and the pairs of participation rate dummy variables. These two treatment effects are only estimated using all rounds of data (Table 3) due to multicollinearity when using round one data only.

Sources of bias and robustness checks. The following checks are applied to our individual treatment effect, specifically the participation rate variable. All results are shown in the Supplementary Information (Section B and Supplementary Table 9-14).

Omitted variables. There are likely to be factors that are correlated with individual participation and extent of cooperation, which if not included in the analysis could lead to omitted variable bias. We add two sets of controls, pre-treatment and post-treatment. The former is unlikely to be affected by the treatment while the latter could be affected by the treatment and hence, potentially endogenous. There are two pre-treatment controls, age and gender, and six post-treatment controls, beginning with another demographic variable, level of education. This acts as a proxy for the player's opportunity cost of time in *Income* workshops, with a higher education level raising this cost.

Next, we add three variables to control for cooperative behaviour. First, a kinship index that indicates the strength of kinship ties based on social network questions in the household survey. Players named the three people they were closest to in their community, indicated who they were (e.g. family), and how often they interacted. Second, a variable that indicates whether the player belonged to a community organisation prior to the formation of the reserve. Third, a variable that controls for whether the player is in the 'Leadership Directory', i.e. was a community leader in the past or is one in the present, and hence, may have participated in the *Association* component.

Finally, we add two policy variables that might also be associated with higher levels of cooperative behaviour. First, whether players (they or members of their household) had received any tangible benefits from *Income* activities. Second, the number of months a household was enrolled in the *Family* component, which controls for the duration of exposure to cash payments, and the conservation approach and ethos of FAS (social desirability bias). It also controls for community residency thus minimising the potential for bias due to movements between the control and treatment groups ('leakage').

In models using all rounds of data, we add the control 'Round', a dummy for the game round that acts as a time fixed effect, controlling for common learning trends across players.

Reverse causality. We instrument for the participation rate variable using the number of adults in the household in an IV probit model (Supplementary Table 9): the more adults in a household, the larger the household labour supply and the lower the opportunity cost of time spent in the *Income* workshops (i.e. the lower the marginal product of labour) and hence, the higher the likelihood of participation. If, however, households with more (fewer) adults are more cooperative than households with fewer (more) adults then this variable will be correlated with the error term and the exclusion restriction will not be satisfied. On the basis of local knowledge, however, the pattern is unclear. Given labour-intensive livelihoods, smaller households might depend more on community support than larger ones, e.g. for help with childcare, but an individual's level of cooperation could plausibly be the same in both cases.

In the absence of a formal test, the inclusion of 'Kinship index', one of the post-treatment controls, in the first stage of the IV probit could help fulfil the exclusion restriction as a higher value indicates close and regular interaction with adult family members. From column 4 in Supplementary Table 6, stronger kinship ties are associated with a higher likelihood of zero extraction (p=0.044), and reduce the size of the coefficient on Individual (#) as well as its statistical significance (compare columns 3 and 4 in Supplementary Table 6).

Self-selection into the CPR game. Not everyone we invited to play in the CPR game in the treatment group volunteered to play (Supplementary Table 10). Community members participating in the *Income* component might be more likely to attend the CPR games than those in the control group. Using the *Family* registers and socio-economic data collected in a FAS survey undertaken in 2015, we test for differences in observable characteristics between volunteers and non-volunteers in the treatment group (Supplementary Table 11).

Robustness checks. Five are undertaken (Supplementary Table 12 and 13). First, non-participants from the treatment group are grouped as observations in the control group. Also, some community members from the control group stated non-zero rates of participation in *Income* workshops and are grouped as observations in the treatment group. All of these observations are dropped. Second, we test whether results for the participation rate individual treatment effect are driven by outliers by log transforming this variable and adding a Battese correction on zeros [39]. Third, a placebo test is undertaken by replacing the participation rate variable with the participation rate in Conservation Centre workshops (also run by FAS and supposedly mandatory). Fourth, we restrict our sample to the six communities in the original post-matching treatment and control groups. Fifth, possible social desirability bias is addressed by including the duration that a household has been receiving the fishing allowance (*Seguro Pesca*), which, apart from PBF, is the only other government- or NGO-enacted environment-related programme that has a relatively high rate of penetration in the study area.

Alternative specifications. We apply four (Supplementary Table 14): two count data models that can handle large numbers of zeros (zero-inflated negative binomial (ZINB) model, zero-inflated Poisson (ZIP) model); a standard OLS model that uses the average individual extraction rate across all six rounds of data as a dependent variable; and, after converting all of our non-zero observations to ones, a panel probit with individual-level random effects.

Data Availability

The data that support the findings of this study are available from the corresponding author upon request.

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Acknowledgements

For helpful discussions and comments we thank: J. Bouma, B. Groom, E. Gsottbauer, A. Kontoleon, A-K Koessler, L. Lima, R. Lubowski, M. Malen, S. Roth, V. Salviatti, G. Shreedhar, V. Solidade; participants at the Sustainability and Development Conference (Michigan), BIOECON (Wageningen), plus research seminars at Cambridge University, Hamburg University and the LSE. We also thank our research assistants (A. Ferreira, C. França, T. Farias, A. de Carvalho, E. Mota, L. Barros, L. M. Ferreira, M. Leitão, R. J. da Costa) in the Institutional Links project 'Participatory Approaches to Natural Resource Conservation in the Brazilian Amazon', funded by the British Council (Newton Fund, grant reference: 261873660 (SSP-C577)). The Fundação Amazonas Sustentável (FAS) provided further funding and logistical assistance. This article is dedicated to the memory of Tony Hall, who sadly passed away in May 2019.

Author contributions

A.H., V.V., and C.P. conceived the project, C.P and G.S. designed the experiment, household survey and interview questions, G.S., E. L., and C.P. conducted the experiments, G.S. and E.L. conducted the interviews, C.P. developed the analytical approach, analysed the data and wrote the paper.

Figure legends

Fig. 1. Map showing location of communities sampled in RDS Rio Negro (treatment group) and RDS Puranga Conquista (control group), Amazonas State, Brazil

Note: The background is satellite imagery, which shows the extent of forest cover in the study area. The map was constructed using QGIS 2.18 [40].

Fig. 2. Average extraction rates per person: treatment vs control groups

Note: Unit of analysis is individual-round. Bars denote 95% confidence intervals ±1.96 standard errors. Using a Wilcoxon rank-sum test on whether the two groups have the same median extraction rate, we reject the null hypothesis of equal medians for rounds two ($p=0.029$) and three ($p=0.028$). Combining extraction rates from all rounds, the null hypothesis of equal medians is rejected ($p<0.001$).

Tables

Table 1. ***Income*** **livelihoods by stage of development & % community members (players) receiving benefits**

Treated community (# CPR game players)	*Income* projects in treated communities & stage of development (% of players in community receiving private benefits)		
	Early	Intermediate	Advanced
Camará (16)	Animal husbandry (6)	Fruit & veg production (6) Fishing & agriculture (6) Handicrafts (0)	Restaurant (6) Tourist accommodation (0)
Saracá (20)		Handicrafts (35) Fishing & agriculture (20) Tourist accommodation (15) Sport fishing (10) Fruit & veg production (5) Animal husbandry (5) Carpentry (0) Bakery (0)	Restaurant (65) Beekeeping (5)
15 de Setembro (28)	Fruit & veg production (0)	Animal husbandry (8) Handicrafts (4) Sport fishing (4)	Bakery (4) Restaurant (0) Tourist accommodation (0)
N. S. P. Socorro (36)	Fishing & agriculture (11) Sport fishing (6)	Restaurant (8) Fruit & veg production (6) Animal husbandry (3)	Handicrafts (14) Tourist accommodation (6) Beekeeping (6) Carpentry (0) Rubber tapping (0)

Table 2. Reserve ITT and individual treatment effects on individual tree extraction decisions (round one only)

Dep. Var.: R1 extract		**1**	**2**	**3**	**4**	**5**
Select	Reserve	-0.445	-0.439	-0.400	-0.391	
		P=0.031	P=0.040	P=0.069	P=0.084	
	Individual (0,1)		-0.039			
			P=0.858			
	Individual (#)			-0.086	-0.085	-0.112
				P=0.049	P=0.060	P=0.025
	Constant	-0.168	-0.134	-0.065	-0.203	0.072
		P=0.191	P=0.443	P=0.658	P=0.577	P=0.899
Outcome	Reserve	2.218	2.174	2.219	2.161	
		P=0.138	P=0.133	P=0.129	P=0.120	
	Individual (0,1)		-0.416			
			P=0.787			
	Individual (#)			0.005	-0.133	1.259
				P=0.991	P=0.809	P=0.085
	Constant	6.026	6.291	6.020	7.141	0.903
		P<0.001	P<0.001	P<0.001	P=0.008	P=0.840
Pre-treatment controls		N	N	N	Y	Y
Post-treatment controls		N	N	N	N	Y
Pseudo R2		0.015	0.020	0.022	0.038	0.086
N		160	157	157	156	142

Note:
Coefficients from hurdle model. Unit of analysis is individual-round. The ‘Select’ panel shows results for the decision of whether to extract zero or a positive number of trees while the ‘Outcome’ panel shows results for the decision of how many trees to extract for players extracting a non-zero number of trees. Pre-treatment controls are age and gender. Post-treatment controls are education level, strength of kinship ties, pre-reserve membership of a community organisation, membership of a leadership directory, financial benefits received from *Income* activities and number of months enrolled in the *Family* component. All models include clustered standard errors.

Table 3. Community ITT and individual treatment effects on individual tree extraction decisions (all rounds)

Dep. Var.: ALL extract		1		2	
Select	Round	-0.011	P=0.614	-0.011	P=0.593
	Community 4	-0.997	P<0.001		
	Community 5	-0.058	P=0.759		
	Community 6	0.107	P=0.599		
	Community 7	-0.854	P<0.001		
	Individual *(*1-2)			0.085	P=0.629
	Individual (3-15)			-0.371	P=0.060
	Constant	-0.115	P=0.208	-0.308	P=0.025
Outcome	Round	0.332	P=0.141	0.307	P=0.167
	Community 4	-1.424	P=0.279		
	Community 5	-0.048	P=0.969		
	Community 6	0.290	P=0.667		
	Community 7	-1.251	P=0.354		
	Individual *(*1-2)			0.276	P=0.774
	Individual (3-15)			-0.395	P=0.668
	Constant	7.158	P<0.001	7.038	P<0.001
Pseudo R2		0.038		0.009	
N		960		954	

Note: Coefficients from hurdle model. Unit of analysis is individual-round. The ‘Select’ panel shows results for the decision of whether to extract zero or a positive number of trees while the ‘Outcome’ panel shows results for the decision of how many trees to extract for players extracting a non-zero number of trees. ‘Round’ denotes a dummy for round in the CPR game. Average participation rates in *Income* workshops per treated community: (4) 0.7; (5) 2.9; (6) 1.4; (7) 1.9. Models include clustered standard errors.