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Working Paper Series

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Tsimane' Amazonian Panel Study Working Paper #

Income inequality and deforestation:

Evidence from a small-scale, pre-industrial society in the Bolivian Amazon

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Abstract

Income inequality erodes social capital, harms health, and undermines economic development, so it is natural to ask whether income inequality might also hurt the conservation of common-pool natural resources. Income inequality could undermine conservation by eroding cooperation, but it could enhance conservation by inducing the better-off to impose their preferences about conservation. We contribute to the literature on the link between income inequality and conservation by presenting evidence from communities of Tsimane' Amerindians, a foraging-farming society in the Bolivian Amazon. We estimate the correlation between village income inequality and household deforestation in a common-pool natural resource regime. The sample includes a panel of 37 villages and 387 households surveyed in 2001 and 2002. We find a negative correlation between village income inequality and household deforestation, which supports the idea of unilateral conservation that occurs when the benefits of conservation for the better-off overshadow its costs. Results hold up when using different measures of inequality and deforestation. We test and compare several explanations for why income inequality correlates with less deforestation.

JEL Classification: Q23, Q57

Key words: Income inequality, deforestation, Gini coefficient, anthropometrics, Tsimane', Bolivia

I. Introduction

Recent years have seen growing interest in exploring how income inequality affects quality of life. Preliminary evidence suggests that income inequality erodes social capital (Alesina & La Ferrara, 2000; Costa & Kahn, 2001; Knack & Keefer, 1997), harms health (Kawachi & Berkman, 2000; Kawachi, Kennedy, Lochner & Prothrow-Stith, 1997), and might undermine economic growth (Forbes, 2000), so it is natural to ask whether the income inequality of communities might affect the conservation of their common-pool natural resources.

People shape the conservation of common-pool natural resources they use through their individual behavior and through their collection action (Baland et al., 2005). Income inequality tends to erode collective action, thereby harming conservation (Bardhan, Ghatak & Karaivanov, 2000; Dayton-Johnson, 2000; Baland et al., 2005; Ruttan & Borgerhoff, 1999), but it tends to increase the benefits of conservation for the better-off, who might impose their preferences about conservation on the rest of the community (Abraham & Platteau, 2004; Bardhan, Ghatak & Karaivanov, 2000; Baland & Platteau, 1997a). As a result, the net effect of income inequality on the conservation of common-pool natural resources is ambiguous because it reflects the strength of the two opposing forces (Baland et al., 2005; Baland & Platteau, 1997b).

Income inequality raises the costs of cooperating to solve common problems (Bowles & Gintis, 2002; Deaton & Lubotsky, 2003; Knack & Keefer, 1997; Platteau, 1994; Putnam, Leonardi & Nanetti, 1993). Better-off people are more likely to bear the higher costs of cooperation and conservation because they benefit more from common-pool resources in absolute terms than the poor, even though the poor depend more on common-pool natural resources in relative terms (Adhikari, 2002; Baland & Platteau, 1997a; Takasaki et al., 2001; Cárdenas et al., 2002). By influencing the individual behavior of the better-off, income inequality produces unilateral conservation (Ruttan & Borgerhoff, 1999).

At the same time as it promotes greater conservation through the individual behavior of the better-off, income inequality could also erode collective action or social capital – trust, safety nets, and other expressions of pro-social behavior that enable people to act collectively when using common-pool natural resources (Coleman, 1990; Ostrom, 2000). Expressions of collective action in the use of common-pool resources include regulations (Dayton-Johnson, 2000), transfers, taxes, or quotas (Baland & Platteau, 1997a), coercion (Ruttan & Borgerhoff, 1999), and patron-client relations (Abraham & Platteau, 2004; Baland & Platteau, 1997a; Ruttan & Borgerhoff, 1999). Collective action correlates with greater effectiveness monitoring and sanctioning the use of common-pool natural resources (Abraham & Platteau, 2004; Molinas, 1998).

Theory suggests that income inequality should produce ambiguous effects on the conservation of common-pool natural resources, but the empirical literature that explicitly tests the effects of income inequality on conservation is scant. Most empirical researchers have found that income inequality enhances conservation of natural resources (Cárdenas et al., 2002; Ruttan & Borgerhoff, 1999; Abraham & Platteau, 2004; Bardhan, Ghatak & Karaivanov, 2000; Baland & Platteau, 1997a) but Dayton-Johnson (2000) finds that the effects of inequality in land holdings on the maintenance of water canals in Mexico resembles a U and Baland et al. (2005) working in Nepal find that income inequality produces weak effects on firewood collection.

Here we present estimates of the effect of village income inequality on household clearance of old-growth forest. We contribute to the nascent empirical literature on income inequality and conservation in several ways. First, we draw on unusual information from Tsimane' Amerindians, a highly autarkic society of foragers and farmers in the Bolivian Amazon. The use of information from a highly autarkic society allows us to obtain reliable estimate of the effect of income inequality on deforestation because such societies lack the racial and ethnic heterogeneity and modern institutions to reduce income inequality (e.g., government transfers) that have made it hard to estimate the direct effect of income inequality on indicators of well-being in industrial economies. Further, expressions of social capital, such as gift-giving and communal labor, permeate highly autarkic settings. Second, we take a novel approach to the measure of income. Instead of using monetary income, which is difficult to measure and contains random measurement errors in a highly autarkic setting, we use physical stature, an anthropometric indicator of long-run nutritional status that is less prone to random measurement error than monetary income (Komlos & Baten, 2003; Komlos, 2003). Research by economic historians and others suggests that physical stature correlates reliably with income across a wide range of societies and time periods (Komlos & Baten, 2003; Alderman, Hoddinott & Kinsey, 2003; Fogel, 1994; Komlos, 1989, 1994, 2003; McLean & Moon, 1980; Steckel, 1995, 2003; Strauss & Thomas, 1998). To ensure robustness in results we also use other definitions of income besides physical stature.

II. Sample

Information comes from a long-term bio-cultural study of Tsimane' Amerindians designed to estimate the effect of market penetration on their welfare and use of natural resources (Byron, 2003; Foster et al., 2005; Godoy, 2001; Reyes-García et al., 2003a; Reyes-García, 2001; Vadez et al., 2004). We draw on two waves of surveys collected from the same subjects during February-April of 2001 and 2002. The baseline survey of 2001 contained 37 villages and 387 households. Villages differed in openness to markets and in distance to the closest market town. On average, 39% of the income in a village came from market transactions in cash with the outside world (std dev = 0.17). In each village we selected at random an average of eight households for the survey (std dev=3.25). In each household, we selected at random one of the two household heads to answer survey questions and to take anthropometric measures. For questions that applied to the entire household, we allowed other household members present to correct or to contribute to the answer provided by the household head. Data on the clearance of old-growth forest was collected from the male household head because men do much of the forest clearance.

Between 2001 and 2002 the sample of households shrunk by 18%, from 378 to 311. Households and people left the sample because they moved to another village to visit relatives or to hunt, or because they moved to logging camps, cattle ranches, or to towns in search of employment. One village refused to participate, so we replaced it with another village of similar socioeconomic characteristics. Nine subjects died during the study. We tried to find attriters when they returned to the village or when they moved to another village, but we did not try to find attriters who left the Tsimane' territory. A quarter of the attrition came from people in a single village with a Catholic mission. They initially allowed us to interview them, but later, as a group, refused to participate in the study or to be interviewed a second time for reasons that remain unclear. Besides the households from the village with the Catholic mission that refused to take part in the second survey, only one other household refused to take part in the follow-up survey of 2002. Elsewhere we show that attriters do not differ from those who stay in observed socioeconomic or demographic variables (Godoy et al., 2005) so we do not think attrition will bias estimates.

The latest Bolivian census (2002) puts the Tsimane' population at about 8,000 people. If we use the 2001 survey to estimate the average household size (mean=6.02; std dev=2.60), the Tsimane' population would contain 1,329 households. Since we surveyed 378 households in 2001, the study covered 28.44% of all Tsimane' households.

III. The people: Farming, social capital, and encroachment

A. General background and farming. The Tsimane' live in the eastern foothills of the Andes in the department of Beni. They have been in contact with outsiders since colonial times, but they started to come into more frequent and prolonged contact with outsiders in the 1970s, when loggers, ranchers, colonist farmers, and traders entered the area and the government built roads crossing the Tsimane' territory (Chicchón, 1992; Ellis, 1996; Reyes-García, 2001). The Tsimane' are linked with the regional and with the national economy through the sale of forest goods and rice, the principal agricultural crop (Vadez et al., 2004). Tsimane' sell thatch palm and farm crops to itinerant traders who ply the rivers of the area, but they also take the goods to sell to the town of San Borja (population ~18,000). They sell timber to logging firms and work as unskilled laborers for cattle ranchers, logging firms, and for colonist farmers who have moved into or next to the Tsimane' territory.

Despite contact with outsiders, Tsimane' have low income and are highly autarkic. Mean annual personal income from cash earnings and from the imputed value of farm and forest consumption is US$332, a third of the average income in Bolivia ($US980/person) or of all low and medium-income nations ($US 1,140/person). Goods bought in the market accounted for only 2.68% of the total value of household consumption.

Tsimane' depend on the forest, but they have started to depend more and more on farming, with farm products accounting for more than 50% of their income (Reyes-García, 2001). Tsimane' practice traditional slash-and-burn agriculture. Households clear every year an average of 0.40 hectares of old-growth foreset (std dev = 0.50) and 0.53 hectares of fallow forest (std dev 4.77). About half of the households (45.51%) did not clear old-growth forest but relied instead on fallow forests. We focus on the clearance of old-growth forest because it contains more biological diversity than fallow forest (Godoy, 2001), but we also report the results of analyses using the clearance of fallow forest as a dependent variable.

In cleared plots Tsimane' sow their mains staples: rice (*Oryza sativa*), maize (*Zea maiz*), manioc (*Manihot esculenta*), and plantains (*Musa balbisiana*). They also plant a smaller surface of a variety of other crops, such as sugar cane (*Saccharum officinarum*), peanuts (*Arachis hypogeae*), sweet potatoes (*Ipomoea* *batata*), ahipa (*Pacchyrhizus tuberosus*), pata de anta (*Passiflora triloba*), and citrus (*Citrullus lanatus*) (Huanca, 1999; Piland, 1991; Vadez et al., 2004).

Tsimane' farming is extensive among communities far from market towns; those communities have abundant forest available to fulfill subsistence requirements. Communities closer to market towns face more land pressure. Tsimane' usually abandon their plots after one or two cultivation cycles to clear another plot. The market economy influences the way Tsimane' farm. Although participation in the market has not yet reduced the diversity of crops sown, it has put rice cultivation at the center stage of their commercial farming system (Vadez et al., 2004).

B. Social capital. At first inspection the Tsimane' appear as an egalitarian society. Like other indigenous Amazonian groups, the Tsimane' have a preferential system of cross-cousin marriage (men marry mother's brother's daughter), which creates a thick and wide web of relatives linked by descent and by marriage (Daillant, 1994).

Households visit each other often within and across villages to see relatives or to exchange goods and information (Ellis, 1996). An earlier study done in 2000 with 508 households in 58 villages suggests that only 10% of adults lived in their village of birth. Constant visiting and migration between villages homogenizes many outcomes, such as ethnobotanical knowledge (Reyes-García et al., 2003b).

Like other indigenous Amazonian populations, the Tsimane' routinely share home-brewed beer (chicha). Any Tsimane' can walk into a Tsimane' household serving chicha and expect to be served. Cooking is often done in open courtyards and eating is communal in the smaller villages. Successful hunters share game with close kin and neighbors. In an earlier panel study lasting six quarters (1999-2000), we found that 11% of all goods entering households from morning until dusk on days selected at random came as gifts or as transfers from friends or from relatives; those goods accounted for 6.70% of the total value of household consumption. Fishing with plant poisons is often done communally (Pérez, 2001). About a quarter of all fishing events with nets or with fish poison were done communally. Communal work prevails in the construction and in the maintenance of schools, in the clearing of soccer fields and public places, and in village festivities.

Descriptive statistics from the data used in this article highlight the prevalence of gift giving, communal labor, and labor help. The share of households that made gifts during the week before the day of the interview were as follow: 71% of household gave home-brewed beverages (chicha), 58% cooked food, 45% plantains, 42% meat, 37% rice, 32% fish, 31% manioc, 28% maize, and 12% gave medicines and seeds. During the week before the day of the interview, 22-26% of households helped others or engaged in communal hunting, fishing, miscellaneous work, and farming, 13% of households did errands for others, and

8% offered medical help. Only 7.5% of households did not make any gifts, 39.0% of households did not do any communal work or offered any labor help during the week before the day of the interview, and only 4.45% of households did not make either any gifts or offer any help. The figures suggest that Tsimane' share a wide range of goods and display a wide range of pro-social behavior (Gurven, 2004).

C. Encroachment. The main encroachers into the Tsimane' territory include loggers, ranchers, colonist farmers, and traveling traders. Encroachers offer employment, buy goods, and provided credit to Tsimane'. The data suggests that loggers accounted for 41.87% of formal employment, traders accounted for 13.55%, colonist farmers for 8.43%, and cattle ranchers accounted for 5.72%. Together, encroachers accounted for 69.57% of all formal employment for Tsimane' households. 53.38% of households that interacted with traders, 32.56% of households that interacted with cattle ranchers, and 17.65% of households that interacted with colonist farmers bought goods from them or sold goods to them. Over half (53.38%) of households that interacted with encroachers received credit from them. For all these reasons, encroachers correlated with higher cash earnings of villagers. Later we discuss the significance and implications of the finding to explain our main results of the link between village income inequality and forest clearance.

Among encroachers, traveling traders ranked highest in importance. Traveling traders were the most frequent encroachers; 55.32% of households had been in contact with a traveling trader during the previous month. Of the households that interacted with traveling traders, more than half (55.38%) sold or bought goods from them. Traveling traders accounted for most of the credit supplied in the area; 34.21% of households that encountered traders received credit from them. Unlike loggers, cattle ranchers, or colonist farmers, traveling traders were well perceived by villagers. Only 0.32% of subjects who interacted with traders expressed a negative attitude toward them (e.g., told them to leave the village), compared with 6.17% for loggers, 10.47% for cattle ranchers, and 17.65% for colonist farmers.

IV. Econometric model and estimation strategy

We use the following linear approximation to estimate the effect of income inequality on household-level deforestation:

$$[1] \qquad D_{hvt} = \alpha + \beta I_{vt} + \gamma R_{vt} + \lambda A_{ivt} + \rho S_{hvt} + \tau P_{vt} + \varphi B_{hvt} + \psi V_{vt} + \varepsilon_{ivt}$$

where D_{hvt} is the amount of old-growth forest cleared by household h of village v at time t. Since the dependent variable was censored at zero (45.51% of households did not clear old-growth forest) we use lowered-censored Tobit regressions for the core analysis. I_{vt} corresponds to the Gini coefficient of adult physical stature in village v at time t. We use the physical stature of the household head as a proxy for income and use the age and sex norms of Frisancho (1990) to standardize physical stature and to calculate the Gini coefficient for height in each village. Hence, the Gini coefficients of physical stature we use refer only to the physical stature of household heads. The Gini coefficient has become the gold-standard in studies of income inequality (Fields, 2001; Ray, 1998) in part because of the ease of interpretation. The Gini coefficient ranges from 0 to 100, with higher numbers signifying more inequality. The interpretation of Gini coefficients is straightforward; a community with a Gini coefficient of income of 0.40 has twice as much income inequality as a community with a Gini coefficient of income of only 0.20.

As control variables we include the following: road access, age of household head, household size, village population size, and body-mass index of the household head (BMI; kilograms/meters^2). R_{vt} refers to whether or not the village had access to a road. A_{ivt} is the age of the household head, i, measured in years. S_{hvt} is a measure of household size and corresponds to the number of people living in the household at the time of the survey. P_{vt} is a measure of the village population size at the time of the survey. B_{ihvt} is the body-mass index of the household head and proxies for short-run nutritional status. To take into account the effect of unobserved fixed attributes of the villages, we include a full set of village dummy variables, V_v. ε_{ivt} is the error term or the part of the information that remains unexplained by the model. Table 1 contains definition and summary statistics of the variables used in the regressions.

INSERT TABLE 1 ABOUT HERE

Our estimation strategy consists of running four regressions that build in complexity; most of the regressions contains a full set of village dummy variables with clustering of households by village-year because households are nested in villages. First, we run a regression with only village dummy variables to assess the share of the variance in household deforestation explained by village attributes. Second, we include only the variable for village income inequality without any controls to isolate the specific effect of village income inequality on household deforestation. In the third regression we add other explanatory variables besides a full vector of village dummy variables and the Gini coefficient of inequality to the second regression. In the first three regressions we use the actual measures of deforestation. In the fourth and last regression we change the definition of deforestation and include the logarithm of area deforested instead of using raw levels to facilitate the interpretation of results. We use the logarithm of area deforested to obtain the percentage change in household deforestation from a one-point change in the Gini coefficient of adult physical stature. We also report the results of sensitivity analyses to ensure robustness of empirical results.

V. Results

Table 2 contains the regression results. Column [1] contains the results of a regression with the amount of old-growth forest cleared by a household as a dependent variable against a full set of village dummies and clustering of households by village-year. The R-squared value, 0.053, is low. All village attributes together explain a small share of the variation in household deforestation, suggesting that deforestation stems from household and personal variables more than from village-level variables.

INSERT TABLE 2 ABOUT HERE

Column [2] includes the Gini coefficient of physical stature in the village as the only explanatory variable. The coefficient for the variable is negative and significant (coefficient=-18.39, p=0.009). A one-point increase in the Gini coefficient of physical stature of household heads in the village correlates with a reduction of 18.39 _tareas_ of deforestation by a household (1 _tarea_ = 0.10 hectares).

In column [3] we include a full set of village dummies and other control variables besides the Gini coefficient of physical stature. The correlation between the Gini coefficient of height and deforestation remains negative and statistically significant. The Gini coefficient of village height is negative (coefficient=-44.609, p=0.002), implying that a one-point increase in the Gini coefficient of adult physical stature in a village correlates with 44 fewer tareas of old-growth forest cleared by a household.

In column [4] we change the dependent variable. Instead of expressing the area of old-growth forest cleared by a household in raw levels, we take the logarithm of the amount of old-growth forest cleared. In column [4] we use the same explanatory variables as in column [3]. The effect of height inequality on the logarithm of deforestation remains negative and statistically significant (coefficient= -9.87, p= 0.001). An increase of one point in the village Gini coefficient of adult physical stature correlates with a decrease of about 9.87% in the area of old-growth forest cleared by a household.

VI. Sensitivity analyses

To assess whether the negative correlations between the Gini coefficient of adult physical stature and deforestation reported in Table 2 holds with other econometric specifications or with changes in the way we defined income or income inequality, we did sensitivity analyses by introducing seven changes. First, in panel A of Table 3 we changed the measure of inequality and replace the Gini coefficient of adult physical stature with: (a) the standard deviation of the logarithm of adult physical stature and (b) the coefficient of variation of adult physical stature. We changed the measure of inequality because results could be sensitivity to the measure of inequality used (Ray, 1998). Second, in panel B we used the Gini coefficient of raw stature without standardizing it by the age and sex norms of Frisancho (1990). Third, in panels C-D, we vary how we express deforestation. In the core models of Table 2 we used the area of forest cleared by the household, but in the sensitivity analysis we divide the area of forest cleared by the number of people in the household (panel C) or by the number of male-adult-equivalents (panel D) since the total number of male-adult-equivalents might be a more appropriate proxy of household needs and household labor supply (Deaton, 1997). In panel E we assess whether the results apply when using fallow forest instead of using old-growth forest as the dependent variable. Last, in panel F we show the results of sensitivity analysis in which we use other definitions of income besides adult physical stature. Instead of using the Gini coefficient of adult physical stature, we use the Gini coefficient of monetary income earned during the two weeks before the days of the interview (including the value of goods received in barter) and the Gini coefficient of body-mass index, a canonical indicator of short-run nutritional status.

Table 3 shows the results of the sensitivity analyses: column [1] contains the dependent variable of each regression, column [2] contains a summary of the change introduced in the explanatory variable, and columns [3-4] contain the coefficients and standard errors of the explanatory variables. The regressions of Table 3 are identical to the regression of column 3 in Table 2 except for the changes noted in the previous paragraph.

INSERT TABLE 3 ABOUT HERE

In panel A we replace the Gini coefficient of adult physical stature, first with the standard deviation of the logarithm of adult physical stature and, second, with the coefficient of variation of the age and sex-standardized z score of stature. We find that the negative correlation between inequality in stature and deforestation persists. When we use the standard deviation of the logarithm of stature, we find that an increase of one standard deviation in the logarithm of villagers' stature correlates with a decrease of 14.24 tareas of old-growth forest cleared by a household, whereas a one-point increase in the coefficient of variation of adult physical stature in a village correlates with a reduction of 21.53 tareas of area deforested.

In the core regressions we use the age and sex-standardized z score of height for age to estimate the Gini coefficient of stature in the village. In panel B we re-estimated the regressions using a measure of stature inequality in the village drawing on raw stature (not on height standardized by age and sex). The results shown in panel B suggest that the relation between inequality in stature and deforestation remains negative and significant for each measure of inequality: Gini of raw stature (coefficient=-199.49, p=0.081), standard deviation of the logarithm of raw stature (coefficient=-105.45, p=0.081), and coefficient of variation of raw stature (coefficient=-104.12, p=0.084).

Since household size measured with the number of people might be a poor proxy for household needs because it does not take into account the age and sex composition of the household, we replaced the dependent variable with the level of deforestation of old-growth forest per person (panel C) and per male-adult equivalent (panel D). In panel C we include deforestation of old-growth forest/person as the dependent variable. The coefficients for each measure of inequality of age and sex-standardized height remain negative and significant. The results of panel D suggest that the relation between deforestation expressed per male-adult equivalent and height inequality in the village also remains negative and significant.

The regressions in panel D suggest that an increase of one percentage point in the Gini coefficient of physical stature correlates with a reduction of 13.81 tareas (p=0.012) in the area deforested/male-adult equivalent. When we use the standard deviation of the logarithm of adult physical stature, the reduction in deforestation/male-adult equivalent is 4.48 tareas (p=0.058), and 6.35 tareas/male-adult equivalent (p=0.014) when we measure inequality with the coefficient of variation of age and sex-standardized adult height.

In panel E we use the area of fallow forest cleared by a household as a dependent variable. The results suggest that stature inequality does not correlate with area of fallow forest cleared by households. In panel F we assess the effect of income inequality on deforestation using earnings over the two weeks before the day of the interview and current body-mass index to proxy for income. The results shown in panel F suggest that Gini measures of monetary income inequality did not correlate with forest clearance. Last, recall that the dependent variable was censored at zero. To assess whether results were robust to the econometric specification, in panel G we report the result of a median regression. Those results suggest that the negative relation between stature inequality and deforestation of old-growth forest persist. An increase of one percentage point in the Gini coefficient of adult physical stature correlates with a reduction of 26.51 tareas ($p=0.001$) in the area of old-growth forest cleared.

We tried to test for selectivity bias by including instruments that would predict whether households cleared any old-growth forest, but that would not correlate with the intensity of deforestation. To test for selectivity bias we included household demographic variables (e.g., number of adults; dependency ratios) as instruments, but found that they did not work well, so we conclude that the results presented might contain biases from self-selection.

In sum, the results of the robustness analyses confirm many of the results of the core regressions. Income inequality in the village using adult physical stature as a proxy for income correlates negatively with the amount of old-growth forest cleared by a household. We find that results do not hold when using area of fallow forest as a dependent variable, or when using BMI and monetary income to measure village income inequality.

VII. Discussion

To explain why households in communities with greater income inequality clear less old-growth forest, we explore two hypotheses: 1) the role of social capital and 2) the effect of the opportunity cost of clearing old-growth forest among better-off people.

The first hypothesis implies that better-off people in a community transfer resources to poorer people to equalize outcomes and to maintain social equilibrium. If the better-off transfer resources to the less well-off, the less well-off might not need to deforest as much. To explore the idea we test whether better-off households make more transfers than worse-off households. If we find that they do, then social capital might be a possible mechanism for why greater income inequality correlates with less clearance of old-growth forest.

The variable for social capital has two dimensions. One dimension consists of the amount of gifts given to other Tsimane' during the week before the day of the interview. Gifts include medicine, seeds, cooked foods, and staples such as fish, meat, plantains, maize, and rice. The second dimension consists of labor help and cooperation among individual through unpaid work during the week before the day of the interview.

We used ordinary least squares to regress expressions of generosity against cash earnings (including the value of goods received in barter) during the two weeks before the day of the interview while controlling for fixed effects of villages, wealth, age, and village inequality in adult physical stature. We found that the coefficients for the social-capital variables were positive and significant. Every additional boliviano of earnings correlated with 0.075 (p=0.006) more episodes of gift giving and with 0.021 more (p=0.061) episodes of labor help or communal help/week (1 USD = 7.90 bolivianos). The finding suggests that better-off households (at least measured through monetary income) make grater transfers than less well-off households and that social capital might explain why households in villages with greater income inequality might clear less old-growth forest.

In communities with greater levels of income inequality, poor households have no urgency to turn to the forest to look for resources since the mechanism of communal generosity, through transfers from rich to poor households, guarantees them an alternative source of consumption. The fact that greater income inequality correlates with less clearance of old-growth forest also implies that better-off households do not increase their level of deforestation to compensate for the larger transfers they may make, otherwise the reduction in deforestation by less well-off households would be offset by an increase in deforestation by better-off households.

The second hypothesis we explore is that better-off villagers deforest more, and that they are also more likely to benefit from the presence of outsiders in the village. This hypothesis builds on the work of Ruttan and Borgerhoff (1999) and views the differential use of natural resources as the outcome of differential benefits/costs faced by people at different points in the scale of income distribution. If outside encroachers bring new economic opportunities for better-off villagers, the opportunity cost of exploiting the forest increases for the better-off so deforestation should decrease for the better off (Cárdenas et al., 2002; Baland & Platteau, 1997b). This assumes that the better-off have the human capital skills to interact with outside encroachers.

To test the second hypothesis we correlated the number of outside encroachers a household came into contact during the month before the interview with cash earnings and found that household cash earnings correlated positively with the number of encroachers; each additional encroacher correlates with 67.35 more bolivianos earned (p=0.001). The presence of encroachers in communities also correlated with lower deforestation by Tsimane'; each additional encroacher that a household interacted with correlated with 6.134 fewer tareas of old-growth forest cleared (p=0.027) by the household. The presence of encroachers in communities might constitute another source of income for villagers and increase the opportunity cost of forest clearance.

In sum, both social capital and the presence of encroachers in communities might help explain why village income inequality correlates with less deforestation. Social capital eases the pressure on old-growth forest that poorer households might have exerted, and the presence of encroachers raises the opportunity costs of deforestation for better-off households. One problem with the hypotheses is that, if true, we should have also found a negative correlation between village income inequality and the clearance of fallow forest.

VIII. Conclusions

The evidence presented here suggests a negative correlation between adult stature inequality in a village and household deforestation. Our results mesh with empirical studies reviewed earlier that found a positive correlation between income inequality and conservation. The finding that greater income inequality enhances conservation lends support to the idea of unilateral conservation.

We also present evidence to explain why village income inequality might enhance conservation. We argued that social capital and the higher opportunity cost of forest clearance for better-off villagers might explain the relation. Social capital in the form of transfers and cooperation might relieve the pressure of poorer households to clear old-growth forest. The fact that better-off households are more likely to benefit from the presence of encroachers might explain why they deforest less. When encroachers arrive, the opportunity cost of deforestation increases for better-off households since encroachers bring new employment opportunities.

The results of the analysis suggest that future research on income inequality and household deforestation might benefit not only from estimating the relation between income inequality and deforestation in other sites to assess the applicability of our findings, but also in exploring the mechanisms by which income inequality shapes the use of common-pool natural resources. Recent research suggests that income inequality might not always erode health or economic prosperity (Forbes, 2000; Osler et al., 2002), and the same may be true with conservation. Further empirical research will allow us to gain a better understanding of the conditions under which income inequality harms or helps conservation.

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Table 1. Definition and summary statistics of variables used in the regressions.

Name	Definition	N	Mean	Std Dev
A. Dependent variable, deforestation of old-growth forest				
Deforestation	Area of old-growth forest cut by household the year before. Area in tareas of old-growth forest, 1 tarea = 0.10 ha	561	4.048	5.108
B. Explanatory variables				
Inequality	Gini of household zht at the village level. zht, height-for-age z-score for household heads	72	0.187	0.054
C. Controls				
Road access	Village has access by car/motorcycle	37		
	yes	13	35.14%	
	no	24	64.86%	
Age	Age of household head in years	564	34.293	12.594
Household size	Number of people in the household	564	6.023	2.606
Population in village	Number of people in each village	37	123.743	87.715
BMI	Body-mass index (kg/m^2) of the household head	558	23.168	2.464

Table 2. The effect of income inequality on deforestation: results of tobit regressions

	Dependent variable: deforestation of old-growth forest			
Explanatory variables	**raw levels**			**log deforestation**
	1	**2**	**3**	**4**
Height inequality		-18.394**	-44.609**	-9.879**
		(7.030)	*(14.096)*	*(2.951)*
Road access			1.628	0.417
			(1.360)	*(0.284)*
Age			-0.003**	-0.001*
			(0.001)	*(0.001)*
Household size			0.629*	0.121*
			(0.286)	*(0.059)*
Population in village			-0.036**	-0.007**
			(0.012)	*(0.003)*
BMI			0.309*	0.058*
			(0.156)	*(0.033)*
Year			-0.514	-0.186
			(0.744)	*(0.155)*
Village dummies	yes	no	yes	yes
N	561	561	542	542
Pseudo R^2	0.053	0.003	0.069	0.116

Notes: Regressions are lowered-censored tobits with clustering of households by village-year.
Standard errors shown in parentheses.
* and ** significant at 95% and 99% confidence levels.
Dependent variable = area of old-growth forest cleared/person; area in tareas. 10 tareas=1 hectare.

Table 3. Results of the sensitivity analysis.

Dependent variable	Explanatory variable	Coefficient	Std. Error
A. Changes in definition of inequality			
Deforestation	Standard deviation of logarithm of age and sex-standardized height	-14.425**	6,099
Deforestation	Coefficient of variation of age and sex-standardized height	-20.535**	6,652
B. Height in raw levels			
Deforestation	Gini of height	-199.494*	114,268
Deforestation	Standard deviation of logarithm height	-105.454*	60,317
Deforestation	Coefficient of variation height	-104.125*	60,172
C. Deforestation expressed per person			
Deforestation/person	Gini of age and sex-standardized height	-11.727**	4,664
Deforestation/person	Standard deviation of logarithm of age and sex-standardized height	-3.522*	2,018
Deforestation/person	Coefficient of variation of age and sex-standardized height	-5.389**	2,198
D. Deforestation expressed per adult equivalent			
Deforestation/adult equivalent	Gini of age and sex-standardized height	-13.812**	5,456
Deforestation/adult equivalent	Standard deviation of logarithm of age and sex-standardized height	-4.486*	2,364
Deforestation/adult equivalent	Coefficient of variation of age and sex-standardized height	-6.350**	2,572
E. Deforestation of fallow forest			
Fallow forest	Gini of age and sex-standardized height	5,317	9,177
Fallow forest	Standard deviation of logarithm of age and sex-standardized height	1,904	3,840
Fallow forest	Coefficient of variation of age and sex-standardized height	2,070	4,347
F. Other types of income			
Monetary income	Gini of monetary income earned in last two weeks, including value of goods obtained in barter	-1,542	4,515
Body-mass index (BMI)	Gini of adult BMI in village	12,155	36,519
G. Median regression			
Old-growth forest cleared by household	Same as in model 3 of Table 2, except we use median rather than tobit regression	-26,151**	3,376

Notes: Regressions are Tobits with clustering by village-year
N = 542 observations
* and ** significant at 95% and 99% confidence levels

Acknowledgements

Earlier versions of this paper were presented in seminars at the Heller School for Social Policy and Management, Brandeis University, and at the Yale School of Forestry in April 2004. Thanks go to both institutions. Two grants from the National Science Foundation (SBR-9731240 and SBR-9904318) and a grant from the World Bank as part of the World Bank-Netherlands Partnership Program on Learning and Research Program on Culture and Poverty funded this research. Lobo, R., Manami, E., Conde, P., Pache, E., Tayo, S., Cari, J., Cari, M., Roca, D., Pache, J., Pache, and V. Cuata helped collect information and provided logistical support. Special thanks to Monique Borgherhoff Mulder for commenting on an earlier version of the paper.