ELSEVIER

Ecological Economics 38 (2001) 105–118

ECOLOGICAL ECONOMICS

www.elsevier.com/locate/ecolecon

ANALYSIS

Tenure security, private time preference, and use of natural resources among lowland Bolivian Amerindians

R. Godoy [a,*,1], K. Kirby [b], D. Wilkie [c]

[a] *Sustainable International Development Program, Heller Graduate School and Department of Anthropology Brandeis University, Waltham, MA 02254-9110, USA*

[b] *Department of Psychology, Williams College, Williamstown, MA 01267, USA*

[c] *Wildlife Conservation Society, 2300 Southern Blvd, Bronx, New York, NY 10460-1090, USA*

Received 21 August 2000; received in revised form 14 December 2000; accepted 15 December 2000

Abstract

To estimate the effect of tenure security and private time preference on the use of different types of natural resources, such as old-growth and fallow forests, fish, and game, we did a survey and a psychological experiment with 443 households in 42 villages of Yuracaré, Mojeño, Tsimane', and Chiquitano Indians in the Bolivian lowlands. Results of multivariate tobit regressions suggest that: (1) among the Yuracaré, Tsimane', and Mojeño rates of private time preference had a small economic and statistical effect on the use of natural resources and (2) tenure security, proxied by residence duration in the village and by conflict with abutters, only affected the consumption of wildlife (principally of game). Results suggest that public policies to improve property rights over natural resources among indigenous people might have greater immediate impact on the conservation of wildlife than on the conservation of forest cover.

Keywords: Tenure; Private time preference; Deforestation; Wildlife; Bolivia

1. Introduction

Tenure insecurity and high rates of private time preference should increase the depletion of natural resources if rights of access to resources are open or uncertain (Deacon, 1999), but so far the idea has not been put to a direct empirical test with primary information (Southgate et al., 1991; López, 1992; Alston et al., 1996). In a recent article, Bohn and Deacon (2000) use proxies of political instability and compare the effects of political instability on deforestation and on investments in mineral exploration and production in a cross-section of countries. To our knowledge, researchers have yet to collect primary informa-

* Corresponding author. Tel.: +1-781-7362784; fax: +1-781-7298561.

E-mail address: leandra@sprintmail.com (R. Godoy).

[1] e-mail: rgodoy@brandeis.edu.

0921-8009/01/$ - see front matter
PII: S0921-8009(01)00144-6

tion on direct measures of tenure security and private time preference and to estimate how the two might affect the use of different types of natural resources.

In this article we take a first step in filling the gap. We do so by presenting the results of an ethnographic and quantitative study among the Chiquitano, Yuracaré, Tsimane', and Mojeño Indians in the Bolivian lowlands. We did a survey to collect information on the area of old-growth and secondary forest cleared, consumption of wildlife, experimental information on private time preference, attitudes toward risk, direct measures of tenure security, and other socioeconomic and demographic attributes of subjects, households, and villages. We designed the survey to estimate the effect of tenure security and private time preference on the use of different types of natural resources.

Answering the question, "what is the effect of private time preference and tenure security on the use of natural resources?", merits attention for reasons of scholarship and of public policy. On the academic side, it is unclear the extent that private time preference affects the use of natural resources. Theory suggests private time preference could either worsen or enhance conservation. Only with empirical analysis can one assess the direction and magnitude of the effect. Further, though researchers have made progress identifying the socioeconomic attributes of private time preference (Loewenstein, 1992; Pender, 1996; Becker and Mulligan, 1997), they have paid less attention to its socioeconomic consequences, particularly in the use of natural resources.

The question also deserves attention for reasons of public policy. In much of tropical Latin America encroachers continue to move into the territory of indigenous people and may be increasing feelings of tenure insecurity among indigenous people. Feelings of greater insecurity could increase the rate at which indigenous people deplete their own natural resources. They may be clearing more forest, selling more timber, and foraging more animals than they might otherwise do as they try to claim land and capture rents from natural resources before outsiders step in. If outsiders heighten feelings of tenure insecurity among indigenous people and unleash a race to increase the rate of extraction of natural resources, they may undermine indigenous mechanisms of conservation.

Thus, the natural resources of indigenous people may face threats from the outside and from the inside, and the policy prescriptions to improve conservation and to remedy the two threats will differ from those to mitigate a solely external threat. If insecurity by encroachers makes indigenous people more impatient and makes them deplete natural resources at a faster rate than they might otherwise do, then policy-makers will need to develop a two-pronged strategy — one for outsiders and another for insiders.

2. Background

2.1. Tenure security, private time preference, and the use of natural resources: a review.

In this section we review quantitative studies that contain discussions of the links between tenure security, private time preference, and the use of natural resources.

2.2. Tenure security

Drawing on the theoretical work of Farzin (1984) on quantitative information over time from a cross-section of nations, and on qualitative historical information from past civilizations, Bohn and Deacon (1994, 1999, 2000) present evidence to suggest that periods of political turbulence correlate with greater depletion of some types of natural resources but not of others. They find that high discount rates accelerate the depletion of natural resources when investment costs are low. If the extraction of a natural resource requires high initial investments, then political uncertainty tends to curb extraction.

Bohn and Deacon (2000) go on to show that political uncertainty curbs the extraction of oil, gas, and hard minerals because the resources require large outlays in exploration and in development before production begins. But they also show that political uncertainty hastens the clear-

ance of forests in most developing nations because agents in poor nations clear forest without making large investments. Much deforestation in developing nations reflects the actions of poor farmers working with simple technologies. In forestry, unlike mining or oil exploration, tenure insecurity increases depletion because investment costs are less important.

Several case studies support the conclusions of Bohn and Deacon (2000). Research by Southgate and his colleagues along the frontiers of eastern Ecuador (Southgate, 1990; Southgate et al., 1991) and research by Alston et al. (2000) along the Brazilian Amazon suggests that tenure insecurity correlates with higher rates of forest clearance. Though not related to deforestation, results of other case studies indicate that tenure security increases investments on land and increases the value of property (Alston et al., 1996). In many parts of the developing world, tenure insecurity increases deforestation because people clear forest as a first step in claiming rights to land (Alston et al., 2000; Myers, 1994).

But results from a growing number of studies suggest that tenure security in the form of land titling alone might bear a weak or an unclear link to conservation or to the use of natural resources. For instance, Place and Migot-Adholla (1998) show that land registration and titling had a small impact on crop yields among smallholders in Kenya. Farmers obtained titles to enhance security of rights rather than to increase agricultural production. Feder and Nishio (1999) echo the finding by noting that land titling produces economic effects only when it increases the tenure security of farmers. A recent case study by Wood and Walker (2000) in Brazil suggests that land titling has ambiguous effects on farm investments and on conservation, particularly when systems of legal recourse are not in place to deal with trespassers. Alston et al. (2000) imply that titling may undermine conservation if governments put more emphasis in titling agricultural lands than forests.

2.3. Private time preference

We use the terms private time preference, private discount rate, and patience interchangeably. We equate the concepts with a person's willingness to substitute consumption over time or to delay gratification. Private time preference could affect the use of natural resources in two opposite ways, depending on how one views a natural resource. For brevity we focus on forest clearance in the discussion below, but the argument could apply to other types of natural resources.

If one views forest clearance as a form of private investment through which people build inheritance for their heirs, accumulate wealth, or claim land, then a low rate of private time preference (i.e., concern for the future) should cause forest clearance to increase. Among the groups studied, forest clearance resembles private investment because some households clear forest to claim de facto title and to establish land as inheritance for their children.

But one could also view forest clearance as a form of immediate consumption rather than investment. As people clear forest they can sell logs and use the remaining branches as firewood. Some annual crops are ready for harvest in 3–4 months. Further, when people convert forests to pasture, herbivore carrying capacity will likely increase (Robinson and Bennett, 1999) as will revenues from selling livestock.

As forest clearance contains aspects of investment and consumption, theory would suggest that the effect of private time preference on deforestation ought to be ambiguous, and ought to depend on the relative strength of the investment and consumption effects.

Few researchers have estimated the effects of private time preference on conservation (Cuesta et al., 1997). In the highlands of Ethiopia researchers found that higher rates of private time preference induced farmers to lower investments in the control of soil erosion (Holden et al., 1998). Among the Tsimane' Amerindians of the Maniqui River in the Bolivian rain forest, researchers carried out an experiment using real (rather than hypothetical) rewards of food to elicit private time preference. They found that high rates of private time preference correlated with less clearance of forest (Godoy et al., 1998; Godoy and Jacobson, 1999).

3. Property rights over common-pool natural resources

Several anthropologists have provided ethnographic descriptions of the groups under study (Godoy, 2000; Beni and McDaniel, 2000; Huanca, 1999). Therefore, in this section we focus on the system of property rights over common-pool natural resources to provide a qualitative background for the statistical results discussed later.

Among the four groups each village manages natural resources within its traditional jurisdiction. People clear old-growth forest for agriculture in areas close to the village to lower transport costs, and do so without consulting other villagers. Villagers manage fallow forests by planting trees or by leaving standing trees alone to serve as markers of private property. Villagers can identify the owner of a fallow forest because villagers remember who cut the forest, and they can identify the forest by the trees planted or left standing on the plot. People in remote villages do not exclude other villagers from using fallow forest plots. But in villages closer to market towns people have started to fence fallow plots or to exclude others from using those plots.

Villagers manage common-pool natural resources in a communal way. In principle only villagers have rights to hunt, clear forest, or extract plants in village lands. Unlike highland indigenous communities of Bolivia, where villagers spell out and enforce rules of use and exclusion with clarity and vigor (Guillet, 1983; Godoy, 1991), lowland indigenous communities have fuzzier rules over how to use common-pool natural resources. Owing to ambiguity about local rules of use and to the absence of government protection, traders, loggers, oil firms, colonist farmers, and cattle ranchers extract resources or clear forest without asking villagers for approval. Some outsiders give indigenous people shotguns, rifles, ammunition, alcohol, and other commercial goods in exchange for the right to extract forest products or to use forests.

Outside groups find it easy to encroach on village territories because the Government of Bolivia does not recognize the rules and rights that villagers have over lands. For years the policies of the Bolivian Government have supported the rights of outsiders more than the rights of villagers. The government grants rights to logging or to oil firms to work in indigenous territories without compensating indigenous people. As outside encroachers receive the support of the government, community rules are undermined. When asked, villagers say communal lands are intended only for the use of villagers, but in practice outsiders have used village lands with impunity for many years.

Faced with rising encroachment, lowland indigenous people have begun to organize at the level of the village and at the level of the entire ethnic group, and have started to build alliances with other ethnic groups to defend their territorial rights (Yashar, 1998). Since the early 1990s, indigenous organizations have been successful in forcing the government to address tenure rights of indigenous people in some of the new laws related to forestry and to land reform. Though in principle the central government of Bolivia now recognizes the territorial rights of lowland indigenous people, it has yet to put in place the regulations and the institutions to implement the laws.

Starting with the Law of Popular Participation of 1994, the central government of Bolivia took steps to give more administrative and financial responsibilities to local governments. The steps have given municipal governments some responsibilities over the administration of land and of natural resources, but the laws have not legalized or devolved any authority over the management of natural resources to indigenous groups (Assies, 1999; Pacheco and Kaimowitz 1999).

Despite attempts by the central government to demarcate and to legitimize the title of some indigenous territories, progress has been slow and many villagers still do not know with certainty where their territory ends and where the territory of other villages or users begins. Ambiguity over who owns what has created many tensions around the use of natural resources in communities. For example, villagers often disregard bans on logging imposed by the central government or by the government of the indigenous group and sell logs on the side to the best bidder. Community mem-

bers have started to demand that many of the formal and informal fees that logging firms used to pay to the umbrella government of the entire ethnic group or to the municipal government now be paid, instead, directly to them. Tenure ambiguities have pitted outsiders against indigenous people, the old against the young, villagers against one-another and their leaders.

The ambiguity around indigenous rights, provoked by encroachment and by a central government unwilling to legalize rights to land, erodes indigenous institutions and local practices for managing natural resources. The government takes the weakening of indigenous institutions as evidence that indigenous groups cannot manage natural resources well, and legitimizes the government practice of continuing to transfer usufruct rights to outsiders.

Village institutions have been unable to resolve tenure conflicts for several reasons. First, among Amazonian indigenous populations villages act with much autonomy, a fact related to a mobile, horticultural and foraging mode of subsistence. Unlike the more sedentary farming indigenous villages of the highlands, in the Bolivian tropical lowlands there are generally no native political organizations whose authority cuts across many different villages. When indigenous groups face encroachment from outsiders they lack an umbrella organization and the historical tradition of cooperation across villages to defend their territory. Second, policy biases on the part of the central government have undermined the limited authority of community institutions.

4. Methods

4.1. The survey

The information for this study comes from an ethnographic study and survey done by two graduate students during 1997–1998. Huanca (1999) did research among the Tsimane', Yuracaré, and Mojeño of the river Sécure in the department of Beni and McDaniel (2000) did a similar study and used the same survey among the Chiquitano in the department of Santa Cruz. During June–July, 1997, we tested the survey among the Tsimane' near the town of San Borja in the department of Beni. Researchers did the survey at the end of their ethnographic study (in 1998) among 886 household heads (evenly split between female and male heads), in 443 households, and 42 villages (Table 1). They surveyed 2.79–11.80% of the households in each ethnic group, or 3.54% of all the households in the total population of the four groups (row "c", Table 1). Godoy and Contreras (2001) discuss the survey design and the measurement of variables. Here we focus on aspects of the survey not covered in previous publications.

We did the survey with the female and with the male household heads. Reliable information on time preference is limited to the Yuracaré, Tsi-

Table 1
Unique number of subjects, households, and Amerindian villages surveyed and population size[a]

	Ethnic groups:				
	Tsimane'	Mojeño	Yuracaré	Chiquitano	Total
(A) Surveyed:					
1. Subjects	58	264	124	440	886
2. Households	29	132	62	220	443
3. Villages	2	13	7	20	42
(B) Population:					
1. People	5124	19 759	3339	48 524	76 746
2. Households	1022	3068	525	7876	12 491
(C) Sample:					
Households surveyed as % of households in population [A.2/B.2]	2.83%	4.30%	11.80%	2.79%	3.54%

[a] Population figures come from Censo Indígena, 1994-1995.

mane', and Mojeño. This is why the regression to estimate the effect of private time preference on the use of natural resources (Table 6) excludes the Chiquitano. Later we explain why the information on time preference for the Chiquitano may be unreliable and discuss the measurement of tenure security.

The information we collected on the dependent variables refers to the entire household, but the information we collected for many of the explanatory variables (e.g., age) came from both the female and from the male household heads. Information on the rate of private time preference came from only one of the two household heads chosen at random. The regression with time preference as an explanatory variable (Table 6) contains as additional right-hand side variables only the socioeconomic and the demographic attributes of the household head who took part in the experiment. In the regression with various indexes of tenure security as explanatory variables (Table 5) we had to decide on whose personal attributes to include on the right-hand side of the equation. We could have included the attributes of the wife, of the husband, or of both. We tried all three permutations and found that the main conclusions reported here did not change, though the results became statistically stronger when we included both household heads because the sample size doubled. To be conservative and to reduce the risk of type II errors we use information from only one household head. For arbitrary reasons we decided to use the personal attributes of the male household head in the regressions reported in Table 5.

4.2. Econometric approach and variables

Tables 2 and 3 contain definition and summary statistics of the variables used in the regression analysis. Below we discuss how we defined and measured variables.

4.2.1. Dependent variables

The dependent variables included four types of natural resources: area of old-growth and fallow forest cleared in 1997 and consumption of fish and game during the week before the interview. A large share of households did not consume fish (59.08%), game (60.46%) or cut old-growth (37.86%) or fallow (21.71%) forest. We use a tobit model because dependent variables were censored at zero.

Table 2
Definition of variables

Dependent variables:	
ogf	Hectares of old-growth forest cut/household/person, 1997
fallow	Hectares of fallow forest cut/household/person, 1997
game	kg of game meat/household/person in week before interview
fish	kg of fish/household/person in week before interview
Explanatory variables:	
education	Maximum education of household head
height	Height of subject in centimeters
BMI	Body-mass index of subject (kg/mt^2)
age	Age of subject in years
impatience	Private time preference or discount rate of household heads in logarithms; see text and Table 3
consistent	Scored at or above 7/9 in test of consistency for measures of time perference; see text
twice	Households surveyed twice; 1 = twice; 0 = once
risk	Risk attitude measured through test of Eysench et al. (1985); see text
residence	Number of years in village of household heads
credit	Value in Bolivianos of credit received (1US$ = 5.23 bolivianos)
hhsize	Total household size
conflict	Conflict with loggers, ranchers, smallholders, oil firms during 1997; see text
distance	km from village to nearest town in straight line using Global Positioning System receiver
time	Minutes of walking from center of village to nearest old-growth forest; zero indicates that old-growth forest borders village
Yuracaré	Dummy variable; 1 = Yuracaré; 0 = non Yuracaré
Tsimane'	Dummy variable; 1 = Tsimane'; 0 = non Tsimane'
Mojeño	Dummy variable; 1 = Mojeño; 0 = non Mojeño
Chiquitano	Dummy variable; 1 = Chiquitano; 0 = non Chiquitano

4.2.2. Explanatory variable: time preference

To estimate a subject's private time preference we asked subjects whether they wanted a small, immediate monetary reward now or a larger reward at a specified delay. We chose at random the male or the female head of the household to answer the nine questions shown in Table 4. To provide an incentive to take each question seriously we told subjects that we would select at random one of the nine questions at the end of the interview, and that they would receive the reward that they chose on that question in the number of days specified. The value of the rewards was not trivial. The average immediate reward was $b5.64 and the average delayed reward was $b8.00 ($b5.23 = $US1.00; $b = bolivianos). The daily wage in logging camps, ranches, and nearby towns was about $b12.00, thus, the rewards amounted to more than half a day's work.

To mitigate concerns on the part of subjects about whether or not researchers would be around to deliver delayed rewards, we carried out the experiment on time preference about half-way through fieldwork, and left enough time to ensure that the date for delivering the delayed reward took place before the study ended. Researchers had been in the area doing fieldwork for about 6 months when the experiment took place (February–April, 1998) and remained in the field for another 5–6 months after the experiment ended.

We estimated a person's discount rate from the nine choices they made (Kirby and Marakovic, 1996; Kirby et al., 1999). Previous research with animals and humans using real rewards (Mazur, 1987; Kirby, 1997) has shown that a hyperbolic discount function fits better actual discounting data than does an exponential function. We express the hyperbolic discount function as $V = A/(1 + kD)$, where V is the present value of a reward A at the delay D, and k is a parameter measuring the rate of private time preference. Using this equation, for each question we can solve for the value of k that would make a person indifferent

Table 3
Summary statistics of variables

Variable	Obs	Mean	SD	Min.	Max.
Dependent variables:					
ogf	478	908	1.10	0	7.5
fallow	478	1.08	1.20	0	12.5
game	343	1.53	3.82	0	34.5
fish	478	2.40	5.02	0	42.5
Explanatory variables:					
education	478	3.32	3.05	0	16
height	478	162	6.22	133	182
BMI	478	23.7	2.50	18	41
age	478	40.7	13.0	18	79
impatience	278	−4.73	2.90	−8.75	−1.39
consistent	278	0.854	0.150	0.55	1.55
twice	478	0.096	0.295	0	1
risk	478	2.93	1.31	0	5
residence	478	23.1	16.2	0.1	77
credit	478	30.6	215	0	3000
hhsize	478	6.21	2.47	2	17
conflict	478	0.849	0.850	0	3
distance	478	98.4	43.2	48.4	186
time	478	45.2	49.1	0	180
Yuracaré	478	0.12	0.329	0	1
Tsimane'	478	0.102	0.303	0	1
Mojeño	478	0.271	0.445	0	1
Chiquitano	478	0.502	0.500	0	1

Table 4
Delayed-choice values and associated discount rates for questions to elicit private time preference[a]

Question number	Reward value:		Delay (days)	k at indifference	r at indifference
	Today	Later			
3	$b7.8	$b8.0	162	0.00016	0.00016
6	$b8.0	$b8.5	157	0.00040	0.00039
4	$b6.7	$b7.5	119	0.0010	0.00095
5	$b6.9	$b8.5	91	0.0025	0.0023
1	$b5.5	$b7.5	61	0.0060	0.0051
9	$b5.4	$b8.0	30	0.016	0.013
8	$b4.1	$b7.5	20	0.041	0.030
7	$b3.3	$b8.0	14	0.10	0.063
2	$b3.1	$b8.5	7	0.25	0.14

[a] "k at indifference" indicates the value of the hyperbolic discount rate at which the immediate and the delayed rewards are of equal value. "r at indifference" indicates the value of the continuously-compounded exponential discount rate at which the immediate and the delayed rewards are of equal value. $US1.00 = $b5.23.

between the immediate and the delayed rewards. For example, in question 7 we offered subjects a choice between $b3.3 today or $b8.0 in 14 days. A person with a discount rate of 0.10 would be indifferent between the two rewards. If a participant selected the immediate reward on the question, one could infer that this person had a rate of private time preference greater than 0.10. If a participant selected the delayed reward on the question, one could infer that this person had a rate of private time preference less than 0.10. In this way the nine questions correspond to nine values of k at indifference, and taken together they define ten ranges of private discount rates.

Eight of the ranges are bounded above and below. To illustrate, in the second question we offered participants a choice between $b3.1 today or $b8.5 in 7 days. A participant with a discount rate of 0.25 would be indifferent between the two rewards. Suppose that a participant chose the immediate reward on question 7 (implying $k > 0.10$) but chose the delayed reward on question 2 (implying $k < 0.25$). Taking the two trials together, one can infer that this person has a discount rate between 0.10 and 0.25, and the midpoint of the interval provides our best estimate of the person's discount rate. We used the geometric mean of the range to avoid assigning less weight to the smaller of the two rate parameters. In this example, the procedure would produce an estimated discount rate of 0.16. Choices of all nine immediate rewards or of all nine delayed rewards represent the endpoints of our measure, and for such choices we cannot place bounds on the estimate of k. Participants who chose in this way were assigned the value of k corresponding to those endpoints. Of the 185 subjects, 45 were at the lower bound (patient) and 30 at the upper bound (impatient).

The values of k generated using the hyperbolic discounting equation and the rate that would be generated using a continuously-compounded exponential function are nearly identical over most of the range, as shown in the comparison of values in Table 4. The results that follow do not depend on using one value or the other. We use the hyperbolic rate k to allow comparison with previously published results.

Because a subject's choices are not necessarily consistent with any single value of k, the parameter estimates cannot be made by identifying the switch from the immediate to the delayed rewards moving down the right column of Table 4. Instead, one needs to assign each participant a k value that yields the highest proportion of choices consistent with that assignment. For each participant one needs to compute the proportion of that person's choices that were consistent with assignment to each of the 10 values of k defined by the

questionnaire (bounded or unbounded). Participants were assigned the value that yielded the highest consistency among her or his choices. Consistency here is a relative rather than an absolute measure, with the discount rate that yields the highest relative consistency across trials providing the best estimate of the participant's k value. When two or more values yielded equal consistency, the participant was assigned a value corresponding to the geometric mean of those values. In the statistical analysis discussed below we only use information from subjects who scored at or above 7/9 in the test for consistency.

Because we sampled a small group of subjects twice, we were able to compare the results of the two tests to estimate the reliability of the tests given by each experimenter. For the experimenter who tested the subjects in the Sécure River we obtained significant correlations between the two tests. However, for the experimenter who tested the Chiquitano we obtained a correlation that was slightly negative and not significantly different from zero. This experimenter was not a Bolivian and did not speak an Indian language with fluency. It is possible that subjects either did not fully understand the choice task, did not fully trust that the rewards would be delivered as stated, or had self-presentation reasons for choosing as they did in front of a stranger. Because of the unreliability of this sample we excluded information from the Chiquitano in the analysis of time preference.

4.2.3. Explanatory variable: tenure security and its close covariates

Since there are no individual titles to land in the area we had to use proxies for tenure security. We used conflict with abutters as our chief explanatory variable for tenure security. Previous researchers (e.g., Alston et al., 2000) have used conflicts to proxy for tenure security. In this study, we used the number of conflicts over land the entire village had experienced with loggers, cattle ranchers, colonists farmers, and oil firms to develop a cardinal number or index of conflict for the village. The measure of conflict does not capture intensity or duration.

To ensure robustness in empirical results and to control for a close covariate of tenure security we added another, less direct proxy for tenure security: residence duration in the village. By using two measures of tenure security at the same time readers can form their own opinion about the relative weight of each.

We assume that people with a longer residence in a village would have firmer informal usufruct rights to fallow forest and to farmlands compared with newer arrivals in the village. If the intuition is correct, we would expect longer residence in the village to be associated with smaller areas of old-growth forest cut because they would feel more secure about right rights to land, and other villagers would also know and respect those rights. But one could also argue that in frontier regions people clear forest in a gradual way owing to labor scarcity, so people with a longer residence in a village ought to have cleared more forest than recent arrivals. In the next section we discuss the variables we used to control for the close covariates of residence duration.

4.2.4. Control variables

Since longer residence duration could be associated with depletion of animals and less old-growth forest proximal to the settlement, the variable for residence duration might also capture the availability of natural resources. Many studies have shown that the availability of animals and forest increases the farther away one moves from roads and towns (Smith, 1976; Mamingi et al., 1996; Ngnegueu and Fotso, 1996; Nelson and Hellerstein, 1997; Forman and Alexander, 1998; Wilkie and Carpenter, 1999; Robinson and Bennett, 1999). We include two proxies for the availability of natural resources: distance from the village to the nearest town and the amount of time it took to walk from the village to the nearest old-growth forest. We measured the distance from the village to the town in a straight line using a Global Positioning System receiver. Since residency duration could also correlate with a person's age we also included age as a control.

Besides distance and age, we included many other controls. We used formal education and height to proxy for permanent income. We measured body-mass index (BMI) (kg/m^2), a sensitive index of current income and nutritional status in simpler economies. To elicit attitudes toward risk — a possible covariate of private time preference

— we adapted questions from Venturesomeness subscale of the I-7 impulsiveness scale (Eysench et al., 1985). Other variables included credit and household size. Except for the variables for risk, conflict, and ethnic groups, all other variables are expressed in logarithms.

We tested for heterogeneity among the ethnic groups and accepted the assumption of homogeneity at the 95% confidence level. We carry out the analysis for the pooled sample with dummy variables for ethnic groups.

5. Results

We split the discussion into two sections: one corresponding to the effect of tenure security on the use of natural resources (Table 5) and the other corresponding to the effect of private time preference on the use of natural resources (Table 6).

5.1. Tenure security

We first discuss the effects of residence duration in the village, we then discuss the effects of conflict with abutters, and we end by discussing the joint effect of both variables on the use of natural resources. The analysis includes all four ethnic groups.

Results suggest that length of residence in the village was associated with a lower area of old-growth forest cleared, but with a greater area of fallow forest cleared (Table 5). A doubling in the length of residency in the village lowered the area of old-growth forest cut by about 23.5% ($t = 1.36$; $P > |t| = 0.175$), but increased the area of fallow forest cut by about 14.3% ($t = 1.216$; $P > |t| = 0.225$). Because they have been in the village longer and have built up more fallow forest for themselves, households that have lived longer in the village may not need to clear as much old-growth forest as newer arrivals and may be able to rely on fallow forest for their agricultural needs. This is why tenure security, measured by length of residence duration in the village, may have different effects on the use of different types of forests, though in neither case were results statistically significant at the 90% confidence level or above.

Residence duration affected the consumption of wildlife in different ways. A doubling of the length of residence in the village reduced the amount of game consumed by about 32.3% ($t = 1.01$; $P > |t| = 0.313$). Longer residence had a negligible economic and statistical effect on fish

Table 5
The effect of tenure security on the use of natural resources[a]

Variable	Dependent variables Item	OGF	Fallow	Fish	Game
Residence duration	Coefficient	−0.235	0.143	0.005	−0.323
	t	1.360	1.216	0.028	1.010
	$P>\|t\|$	0.175	0.225	0.978	0.313
Conflict	Coefficient	0.061	−0.215	−0.514	1.323
	t	0.241	1.334	2.159	2.926
	$P>\|t\|$	0.800	0.183	0.031	0.004
Joint	F	0.950	1.610	2.330	4.89
	Prob$>F$	0.3859	0.201	0.098	0.008
Obs Left		181	104	283	208
Uncensored		297	375	196	136
Total		478	479	479	344
Pseudo R^2		0.0304	0.025	0.295	0.108

[a] Regressions are left-censored tobits. Regression includes all the explanatory variables listed in Tables 2 and 3 except private time preference. Dummy variables for three of the four ethnic groups included; Chiquitano is excluded category. "Joint" is test for joint significance of residence duration and conflict. Under "Obs" or observations, left are left-censored observations.

Table 6
The effect of private time preference and tenure security on the use of natural resources[a]

Variable	Dependent variables Item	OGF	Fallow	Fish	Game
Time preference:	Coefficient	−0.028	0.040	−0.061	−0.007
	t	0.352	0.601	0.920	0.065
	$P>\|t\|$	0.725	0.548	0.359	0.949
Tenure:					
Residence duration	Coefficient	−0.051	0.007	−0.235	0.354
	t	0.220	0.041	1.225	0.925
	$P>\|t\|$	0.826	0.967	0.222	0.358
Conflict	Coefficient	0.196	−0.162	−0.297	1.757
	t	0.668	0.673	1.225	3.863
	$P>\|t\|$	0.505	0.502	0.222	0.001
Joint	F	0.260	0.230	1.57	7.580
	Prob $>F$	0.775	0.797	0.211	0.001
Obs Left		71	54	36	23
Uncensored		125	143	161	71
Total		196	197	197	94
Pseudo R^2		0.058	0.021	0.063	0.094

[a] Same notes as in Table 5, except only Yuracaré, Tsimane', and Mojeño included. Dummy variables for Mojeño and Yuracaré included; Tsimane' is excluded category.

consumption. The residence duration elasticity of fish consumption was 0.005 ($t=0.028$; $P>|t|=0.978$).

We next examine the effect that conflict with abutters had on the use of natural resources. Contrary to what one might have expected, conflict with abutters did not seem to affect the use of natural resources in the same way. Conflicts increased the use of some resources and decreased the use of other resources. Conflict was associated with a smaller area cut of fallow forest (coefficient $=-0.215$; $t=1.334$; $P>|t|=0.183$) and with less consumption of fish (coefficient $=-0.514$; $t=2.159$; $P>|t|=0.031$) but with a greater area cut of old-growth forest (coefficient $=0.061$; $t=0.241$; $P>|t|=0.800$) and with greater consumption of game (coefficient $=1.323$; $t=2.926$; $P>|t|=0.004$). Conflicts had strong economic and statistical effects on the consumption of fish and game but not on forest clearance.

The results of tests for the joint significance of residence duration and conflict suggest that tenure insecurity only had strong statistical effects on the consumption of game (prob $>F=0.022$).

5.2. Private time preference

The results shown on Table 6 for the Mojeño, Yuracaré, and for the Tsimane' of the Sécure River suggests that the time-preference elasticities of use of common-pool natural resources were generally negative and statistically insignificant at the 90% confidence level. Impatience seemed to curb the extraction of natural resources. A doubling of a person's rate of private time preference was associated with a reduction of about 2.8% in the area of old-growth forest cut ($t=0.352$; $P>|t|=0.725$), 6.1% in the amount of fish consumed ($t=0.920$; $P>|t|=0.359$), and of about 0.7% in the amount of game consumed ($t=0.065$; $P>|t|=0.949$).

A doubling of a person's private rate of time preference was associated with approximately a 4% increase ($t=0.601$; $P>|t|=0.548$) in the area of fallow forest cut. Although the latter result is statistically and physically insignificant, it makes ethnographic sense. Impatient people tend to use fallow forest because fallow forests are easier to cut than old-growth forest (Godoy and Jacobson, 1999).

The regressions of Table 6 also contain the two variables for tenure security discussed in the previous section: residence duration and conflict with abutters. The results for the groups in the Sécure River suggest that conflict with abutters increased the consumption of game (coefficient = 1.757; $t = 3.863$; $P > |t| = 0.001$) even after controlling for private time preference, game availability, and a broad range of other covariates.

6. Policy implications

We conclude by discussing the policy implications of the study. We noted at the beginning that throughout much of the tropical lowlands of Latin America encroachers continue to move into indigenous territories and we asked whether such threats would not cause indigenous people to accelerate the rate of extraction of natural resources from within before outsiders could claim the resources. If one could find evidence that encroachment increased rates of depletion from inside, then one would have to broaden the policy agenda to include policies aimed at making both outsiders and insiders reduce their rates of extraction.

The results of the study lend partial support to the spillover hypothesis for most common-pool natural resources. The threat of outsiders does not seem to make insiders eat all the geese that lay golden eggs. Conflict seems to reduce the consumption of fish, increase the consumption of game, and to have virtually no effect on the clearing of forest. Conflict seems to worsen and enhance conservation at the same time.

On the positive side, the results suggests that policy-makers should focus first and foremost on reducing pressure by encroachers if they wish to enhance the conservation of game. On the negative side, less conflict and greater tenure security may induce greater investments in fishing, turning conservation by conflict (Nietschmann, 1990; Vandemeer, 1996) on its head: depletion with peace. Greater feelings of tenure security from less conflict may make it easier for indigenous people to increase investments in fishing, a resource that until now may have been inadvertently preserved.

Acknowledgements

The study was financed by (1) Programs of Cultural Anthropology and Human Dimensions of Global Change of the National Science Foundation (SBR 9417570, DBS 9213788, SBR 9307588, SBR-9731240) and (2) the Conservation, Food & Health Foundation. We presented an earlier version of the paper at the conference on 'Patterns and Processes of Land Use and Forest Change', hosted by the Center for Latin American Studies, University of Florida, Gainesville, FL, March 23–26, 1999. We would like to thank Charles Wood and the people who took part in the conference, CICOL, and Bob Deacon, Ed Balsdon, Tomás Huanca, Marco Boscolo, Cristian Vallejos, Josh McDaniel, and two anonymous referees for commenting on earlier drafts of the article.

References

Alston, L.J., Libecap, G.D., Schneider, R., 1996. The determinants and impact of property rights: land titles on the Brazilian frontier. Journal of Law, Economics and Organization 12, 21–65.

Alston, L.J., Libecap, G.D., Mueller, B., 2000. Land reform policies, the sources of violent conflict, and implications for deforestation in the Brazilian Amazon. Journal of Environmental Economics and Management 39, 162–188.

Assies, W., 1999. Lands, Territories and Indigenous People's Rights. CEDLA, Amsterdam.

Becker, G., Mulligan, C., 1997. The endogenous determination of time preference. Quarterly Journal of Economics 112, 729–758.

Bohn, H., Deacon, R., 2000. Ownership risk, investment, and the use of natural resources. American Economic Review 90, 526–549.

Censo Indígena, 1994–1995. Censo Indígena del Oriente, Chaco y Amazonía. Secretaría de Asuntos Etnicos, de Genero y Generacionales, La Paz.

Cuesta M., Carlson G., Lutz E., 1997. An Empirical assessment of farmers' discount rates in Costa Rica. Work in Progress series. Environment Department, World Bank, Washington, DC

Deacon, R, 1994. Deforestation and the rule of law in a cross-section of countries. Land Economics 70, 414–430.

Deacon, R., 1999. Deforestation and ownership: evidence from historical accounts and contemporary data. Land Economics 75, 341–359.

Eysench, S., Pearson, P, Easting, G., Allsopp, J., 1985. Age norms for impulsiveness, venturesomeness and empathy in adults. Personality and Individual Differences 6, 613–619.

Farzin, Y., 1984. The effect of the discount rate on depletion of exhaustible resources. Journal of Political Economy 92, 941–951.

Feder, G., Nishio, A., 1999. The benefits of land registration and titling: economic and social perspectives. Land Use Policy 15, 25–43.

Forman, R., Alexander, L., 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29, 207–231.

Godoy, R., 1991. The evolution of common field agriculture in the Andes: a hypothesis. Comparative Studies in Society and History 33, 395–414.

Godoy, R., 2000. Indians, Markets, and Rain Forests: Theory, Methods, and Analysis. Columbia University Press, New York, in press.

Godoy R., Contreras M. 2001. A comparative study of education and tropical deforestation among Bolivian Amerindians, Economic Development and Cultural Change, in press.

Godoy, R., Jacobson, M., 1999. Covariates of private time preference. Evolution and Human Behavior 20, 249–256.

Godoy, R., Jacobson, M., De Castro, J., Aliaga, V., Romero, J., Davis, A., 1998. The role of tenure security and private time preference in neotropical deforestation. Land Economics 74, 162–170.

Guillet, D., 1983. Towards a cultural ecology of mountains. Current Anthropologogy 24, 561–574.

Holden, S., Berkele, S., Wilk, M., 1998. Poverty, market imperfection, and time preference: of relevance for environmental policy? Environment and Development Economics 3, 105–130.

Huanca T., 1999. Tsimane' indigenous knowledge, swidden fallow management, and conservation. Ph.D. thesis, University of Florida.

Kirby, K., 1997. Bidding on the future: evidence against normative discounting of delayed rewards. Journal of Experimental Psychology: General 126, 54–70.

Kirby, K., Marakovic, N., 1996. Delay-discounting probabilistic rewards. Psychonomic Bulletin & Review 3, 100–104.

Kirby, K., Petry, N., Bickel, W., 1999. Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. Journal of Experimental Psychology: General 128, 78–87.

Loewenstein, G., 1992. The fall and rise of psychological explanations in the economics of intertemporal choice. In: Loewenstein, G., Elster, J. (Eds.), Choice Over Time. Russell Sage Foundation, New York, pp. 3–34.

López R., 1992. Resource degradation, community controls, and agricultural productivity in tropical areas. Working paper. Department of Agricultural and Resource Economics, University of Maryland, College Park, MD.

Mamingi N., Chomitz K., Gray D., Lambin E., 1996. Spatial patterns of deforestation in Cameroon and Zaire. Policy Research Department, World Bank. Washington, DC.

Mazur, J., 1987. An adjusting procedure for studying delayed reinforcement. In: Commons, M.L., Mazur, J.E., Nevin, J.A., Rachlin, H. (Eds.), Quantitative Analyses of Behavior, Volume 5: The Effect of Delay and of Intervening Events on Reinforcement Value. Erlbaum, New Jersey, pp. 55–73.

Beni and McDaniel J., 2000. Indigenous organizations and conservation/development organization: the politics of ethnicity. Ph.D. thesis, University of Florida.

Myers, N., 1994. Tropical deforestation: rates and patterns. In: Brown, K., Pearce, D.W. (Eds.), The Causes of Tropical Deforestation. UCL Press, London, pp. 35–52.

Nelson, G., Hellerstein, D., 1997. Do roads cause deforestation? Using satellite images in econometric analysis of land use. American Journal of Agricultural Economics 79, 80–88.

Ngnegueu P., Fotso R., 1996. Chasse villageoise et conséquences pour la conservation de la biodiversité dans la réserve de biosphère du Dja. ECOFAC: Yaounde

Nietschmann, B., 1990. Conservation by conflict in Nicaragua. Natural History 11, 42–49.

Pacheco, P., Kaimowitz, D., 1999. Municipios y gestión forestal en el trópico Boliviano. CIFOR/CEDLA/TIERRA/BOLFOR, La Paz.

Pender, J., 1996. Discount rates and credit markets. Theory and evidence from rural India. Journal of Development Economics 50, 257–297.

Place, F., Migot-Adholla, S., 1998. The economic effects of land registration on smallholder farms in Kenya: evidence from Nyeri and Kakamega districts. Land Economics 74, 360–373.

Robinson, J., Bennett, E., 1999. Hunting for Sustainability in Tropical Forests. Columbia University Press, New York.

Smith, N., 1976. Utilization of game along Brazil's transamazon highway. Acta Amazonica 6, 455–466.

Southgate, D., 1990. The causes of land degradation along 'spontaneously' expanding agricultural frontiers in the Third World. Land Economics 66, 93–101.

Southgate, D., Sierra, R., Brown, L., 1991. The causes of tropical deforestation in Ecuador: a statistical analysis. World Development 19, 1145–1151.

Vandemeer, J., 1996. The human niche and rain forest preservation in southern Central America. In: Sponsel, L.E., Headland, T.N., Bailey, R.C. (Eds.), Tropical Deforestation: The Human Dimensions. Columbia University Press, New York, pp. 216–229.

Wilkie, D., Godoy, R., 2001. Can consumer demand for bushmeat be reduced? Conservation Biology, in press.

Wilkie, D., Carpenter, J., 1999. Bushmeat hunting in the Congo Basin. Biodiversity and Conservation 8, 927–955.

Wood C., Walker R. 2000. Tenure security, investment

decisions and resource use among small farmers in the Brazilian Amazon. Center for Latin American Studies, University of Florida, Gainesville, FL., unpublished.

Yashar, D., 1998. Contesting citizenship: Indigenous movements and democracy in Latin America. Comparative Politics 31, 23–42.