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A Comparative Study of Education and Tropical Deforestation among Lowland Bolivian Amerindians: Forest Values, Environmental Externality, and School Subsidies*

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I. Introduction

Since at least the early 1970s researchers and policy makers have been debating ways to lower tropical deforestation.[1] Solutions have included greater use of nontimber forest goods, sustainable logging, clearer rights of property to natural resources, stronger alliances between indigenous groups and organizations working on conservation, empowerment of rural communities, and green tourism.[2] In the search for solutions, policy makers and researchers have paid scant attention to the benefits schooling could have on conservation.

The neglect may reflect disciplinary parochialism. Natural scientists and human ecologists working on conservation know little about the theory of human capital, and scholars of education generally know little about environmental economics, though there is a small and growing literature on environmental education.[3]

In this article, we start to bridge the gap and contribute to the debate about how to curb the loss of tropical rain forests. We do so by estimating the effect that one additional year of a household head's schooling might have on how much area of old-growth forest is cleared by an Amerindian household each year; we also assess the magnitude of the positive environmental externality produced by the additional year of schooling. We show that one more year of schooling of the household head correlates with 13.2%–21.5% less annual area of old-growth forest

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cut by a household. We go on to show that, depending on the assumption one makes about the economic value of secondary-growth forest, each Amerindian household produces annual benefits to the rest of the world worth US$146. The benefits come from preserving the use and the non-use values of tropical rain forests that are enjoyed by people who live outside of the forest. Since children in lowland Amerindian societies spend much of their time working in the household and on the farm, we conclude by arguing that governments should compensate parents with a direct annual transfer equal to US$146 per household so that parents find it worthwhile to enroll their children in school.

To estimate the effect of schooling on tropical deforestation we draw on information from a recent household survey we conducted of four Amerindian societies in the tropical lowlands of Bolivia: Tsimané, Mojeño, Yuracaré, and Chiquitano. We designed the survey to examine the link between human capital and the use of natural resources from the rain forest. The survey contains information on the different types of forests that were cleared, the formal schooling of the household heads and of their parents, the results of tests of literacy and arithmetic, and a measure of private time preferences that we elicited through an experiment at the time of the survey.

II. Why Old-Growth Forest, Why Schooling, Why Amerindians

We stress the loss of old-growth tropical rain forests more than the loss of fallow (or secondary-growth) forests because at present the most prominent policy debate in conservation centers on the loss of old-growth rain forests. Old-growth tropical rain forests contain more biological diversity than other land types, though fallow tropical rain forests can also contain many plant species and contribute to carbon sequestration.[4]

We focus on the role of schooling on the basis of theoretical reasons, facts, and policy findings. Many studies have shown that rural people with more schooling raise farm profits and adopt technological innovations in farming earlier and faster than do people with less schooling.[5] Among indigenous people in urban Bolivia, an additional year of schooling raises earnings by 6.5%.[6] Education also increases the likelihood of migrating out of the countryside and finding urban employment.[7] For these reasons one would think that schooling might allow rural people to reduce their dependence on the forest and enhance conservation. Some case studies support the idea.[8]

But we also focus on schooling for reasons of public policy. Many nations in Latin America have started to revamp how they run their public schools and to make greater and better investments in the training of teachers and in the design of school curriculums.[9] Because abutters and dwellers of the rain forest live far from towns and cities, they fall through the cracks of educational reforms. The farther one goes into the

tropical rain forests of Latin America, the less likely one is to find schools or teachers. Policy makers justify the inattention because it makes economic sense. Dwellers of the rain forest, the reasoning goes, live too far and are too scattered to be reached cheaply. The argument would hold were it not for the environmental benefits produced by the schooling of forest dwellers.

Schooling could reduce forest clearance in an inexpensive way because educational reforms are already in place. In documenting the correlation between greater schooling and less deforestation, we are merely pointing to a policy lever that already exists. The extra costs of bringing teachers and schools to remote populations are probably less than the costs of designing and implementing new policies that might require building new institutions, passing new laws, or financing new programs to conserve more tropical rain forest.

That we focus on indigenous people in our study on deforestation does not mean that we consider indigenous people to be the main culprits. Researchers still disagree on the main offenders of deforestation in Bolivia and have blamed, among others, commercial soybean farmers, cattle ranchers, highland colonists, and logging firms, but they still lack evidence that would enable them to estimate how much each group contributes to deforestation.[10]

We focus on Amerindians for two reasons. First, forest clearance by lowland indigenous people is not an environmental threat today but might become one soon. Growth of population and income inside Amerindian territories (hereafter referred to as indigenous reserves) will put more and more pressure on their natural resources.[11] Several scholars have begun to study forest clearance and mismanagement of natural resources by indigenous people.[12] Logging or clearance of forests by indigenous people may not result in large areas of forest loss at any one time. As we discuss in Section III, the average Amerindian household in the sample cut only about half a hectare of old-growth or secondary-growth rain forest each year, or a total of about one hectare of forest. Over time and at current rates of population growth, however, cutting will increase forest fragmentation and the loss of forest-dependent species of flora and fauna. As indigenous people gain greater sovereignty over their territories, they will need to develop policies designed to decrease their population's demands on the forests. Education may be an effective way to reduce pressure on natural resources.

Second, the idea that schooling could lower forest clearance applies to any rural population, whether Indian or non-Indian, abutting or living in the rain forest. We happen to have tested the idea with information from indigenous people but could have tested the idea with any other rural population, such as colonist farmers who continue to encroach on tropical rain forests.

III. An Ethnographic and Socioeconomic Sketch of the Sample

Except for the Chiquitano who live in the dry, tropical, semideciduous rain forests of the department of Santa Cruz, the other groups discussed here live in moist, tropical rain forests. The Tsimané, Mojeño, and Yuracaré discussed here live along the Sécure River, in the department of Beni.

We selected these groups because they display variance in different measures of economic development. Their villages lie both far from and close to market towns. Differences within the groups in cash income from the sale of goods and labor are also marked, as are differences in school attainment. In another study, Godoy deals with inter-and intra-group variability in integration to the market economy.[13]

Among all the groups, subsistence centers on swidden farming, supplemented by hunting, fishing, and the collection of wild plants. However, the groups relate to the outside economy in different ways. The Tsimané are dependent on outside markets where the average Tsimané household sells approximately 40% of its rice harvest. The Mojeño and the Yuracaré work as unskilled laborers on cattle ranches, and the Chiquitano are dependent on the outside economy through wage labor and the sale of peanuts and lumber.

All groups face encroachment from loggers, cattle ranchers, and small colonist farmers.[14] Some groups, such as the Chiquitano and the Mojeño, have fought intruders since Colonial days, but others have withdrawn farther into the forest to avoid outsiders. Some anthropologists have maintained that encroachment and the loss of land have pushed indigenous people from the tropical lowlands of Latin America, and as the base of their subsistence economy eroded, they had to tighten their links to the market to make ends meet. Others, however, have maintained that the benefits of trade may have lured relatively autarkic people to enter the market even without pressure from outsiders.[15]

In table 1 we present background and descriptive statistics of the four cultures. We summarize information on household size, the area of old-growth and fallow forest cleared each year by households, and formal school attainment. The information in table 1 is not strictly comparable to the information used later in the statistical analysis because some of the information for the Tsimané in table 1 draws on surveys carried out before 1997 for other purposes beside measuring the effect of schooling on the use of natural resources.

The information in table 1 suggests that households clear about half a hectare of old-growth forest each year, but 40% of households did not cut any old-growth forest and relied instead on fallow forest. Old-growth forests are harder to cut than fallow forests because trees in old-growth forests typically have a larger diameter. People who are too busy working outside the village, or working in the village but in nonfarm chores, do not have much time to cut old-growth forest, and they focus instead

TABLE 1

DESCRIPTIVE INFORMATION OF THE CULTURES

	TSIMANÉ			MOJEÑO			YURACARÉ			CHIQUITANO		
VARIABLE	Observations	Mean	SD	Observations	Mean	SD	Observations	Mean	SD	Observations	Mean	SD
Household size:												
Adult:												
Men	237	.94	.81	132	1.31	.57	62	1.14	.43	240	1.51	.85
Women	237	.91	.92	132	1.27	.52	62	1.24	.73	240	1.33	.67
Children:												
Boys	237	1.67	1.55	132	2.06	1.49	62	1.79	1.41	240	1.75	1.52
Girls	237	1.48	1.40	132	1.78	1.34	62	2.17	1.59	240	1.56	1.33
Total	237	5.01	2.99	132	6.43	2.27	62	6.35	2.47	240	6.16	2.59
Forest (ha):												
Old-growth	237	.63	.74	131	.41	.49	62	.40	.58	240	.58	.54
Fallow	237	.58	.79	132	.58	.58	62	.40	.40	240	.69	.47
Education:												
Male	207	1.91	2.71	132	2.85	2.24	59	1.93	1.77	240	4.56	3.28
Female	198	.78	1.43	129	1.85	1.77	58	1.63	1.94	240	2.72	2.45

NOTE.—Years in which information collected: Tsimané 1996; Mojeño, Yuracaré, and Chiquitano 1997–98. Education is maximum formal education of household head. SD = Standard deviation; ha = hectare.

on cutting fallow forests. Households clear the same amount of old-growth forest as they do of fallow forest (about half a hectare).

The information in table 1 suggests that the groups vary in household composition. Average total household size varied from a low of 5.01 among the Tsimané to 6.16–6.43 among the other groups.

IV. Schooling: Context, Attainment, and Constraints

Since the late 1980s policy makers in Bolivia have been trying to modernize public education to make it more relevant to students. The government has been trying to improve instruction and teacher training, projects that combine infrastructure with other inputs, administration, and monitoring and evaluation.[16] Through decentralization, policy makers are allowing parents a greater role in the administration of public schools.[17]

The reform of the constitution in 1996 recognized Bolivia as a multilingual and multicultural society. In line with the change, policy makers put bilingual education at the core of educational reform. In the first grade, children learn reading and writing skills in the mother tongue, and only in the second grade do the teachers introduce Spanish. So far, the emphasis has been put on the Indian languages that are used by the largest populations: Aymara, Quechua, and Guaraní. As teachers are trained and curricula developed, policy makers hope to expand instruction in other Indian languages.

The information in table 1 suggests that the subjects of the survey had little formal schooling. The average male household head had about two years of education, which was below the national average of 5.2 years.[18] Chiquitano male household heads had twice as much education (4.56) as the others, owing to the role played by the Catholic Church. During the 1990s, the Catholic Church built a high school, set up a bilingual training program, trained Chiquitano to become teachers, and offered scholarships and free living quarters to high school students.[19] Except for the Yuracaré, women heads of households had half as much schooling as their male counterparts. Yuracaré women, however, had 1.63 years of schooling compared with Yuracaré male heads of households who had 1.93 of schooling.

Lowland Amerindians consider schooling a social ladder, and in rural Bolivia schooling has replaced the army as a way of moving up and out of the countryside. People in all the groups see schooling as a way of acquiring the language and interpersonal skills that will enable them to deal better with outsiders, including government officials. Indigenous leaders who have been most actively defending territorial rights have also been those with the most schooling.[20]

Although parents value schooling for their children, they find it hard to send their children to school. As we show below, young children spend much of their time helping on the farm and in household chores. Traders have been known to give credit to Tsimané children who live

along the Maniqui River in exchange for forest goods and, in so doing, they put the children in debt. Children have had to leave school to work and repay their debts.

Among other reasons, parents feel ambivalent about sending their children to school because of high teacher absenteeism. Owing to difficulties in collecting wages and to the absence of oversight, teachers often leave their schools to work elsewhere, to shop in towns, or to visit relatives back home. In addition, a curriculum that reflects an urban and, in some cases, a religious bias has further alienated parents.[21] Catholic and Evangelical missionaries have promoted education among some of the lowland groups in Bolivia and have passed along their religious views in textbooks and in training courses for teachers.

Some parents whom we interviewed were unambiguous about their wish to get paid for sending their children to school. They want to get paid so that they can buy their children school supplies and new clothing twice a year. In one case a drunk father chased the village teacher with a bow and arrow threatening to kill him unless he redistributed part of his salary to the villagers so that parents could properly equip their children for school.

Recent forest fires in the Amazon have heightened awareness among policy makers about the need to use the forest in a more prudent way. In response, in the late 1980s, the Ministry of Education organized 2–3-day seminars for teachers in the lowlands that were designed to instruct the teachers about problems such as indiscriminate burning of the forest and excessive hunting. Although not yet formally reflected in the curriculum or in the textbooks, the messages from these seminars have filtered back to villages, as indigenous teachers raise consciousness about the effects of forest clearing and of excessive hunting in their communities.

V. Methods

During 1997–98 two graduate students in anthropology did ethnographic fieldwork and conducted a household survey in four lowland groups of Bolivia. Tomás Huanca worked among the Tsimané, Yuracaré, and Mojeño of the Sécure River in the department of Beni, and Josh MacDaniel did similar work and used the same survey among the Chiquitano in the department of Santa Cruz.[22] We tested the survey among the Tsimané near the town of San Borja in the department of Beni from June 1997 to July 1997. In 1988, Huanca and MacDaniel surveyed 886 household heads (evenly split between female and male heads) in 443 households distributed among 42 villages (table 2). We surveyed between 2.79% and 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’’ of table 2).

We surveyed a subsample of households twice, once at the beginning and once at the end of the study, as part of a panel study on private time preference. This explains the difference in the number of house-

TABLE 2

UNIQUE NUMBER OF SUBJECTS, HOUSEHOLDS, AND VILLAGES SURVEYED AND POPULATION SIZE

	ETHNIC GROUPS				
	Tismané	Mojeño	Yuracaré	Chiquitano	Total
Surveyed:					
People	58	264	124	440	886
Households	29	132	62	220	443
Villages	2	13	7	20	42
Population:					
People	5,124	19,759	3,339	48,524	76,746
Households	1,022	3,068	525	7,876	12,491
Sample:					
Households surveyed as % of households in population	2.83	4.30	11.80	2.79	3.54

SOURCE.—Population figures were taken from *Censo Indígena del Oriente, Chaco y Amazonia, 1994–1995* (for full citation see n. 23).

holds in tables 2 and 3. In table 3 we made two entries for households that were resurveyed because we collected entirely new information from them at two different times. Differences in the dates when we conducted the survey may affect the area of forest cleared. For example, one year may have been drier, and people may have been able to cut and burn larger plots. To control for the potential bias as a result of making two entries for a subsample of subjects, we included a dummy variable to account for the time of the survey.

We applied the survey to the female and the male household heads. The most recent census of lowland indigenous people in Bolivia shows that only 2% of households are headed by one person. Most indigenous households in the lowlands are nuclear (76%) or extended (22%).[23] In our survey we did not find any households that were headed by only one person, consequently the sample size of female household heads equals the sample size of male household heads.

In the regressions we include socioeconomic and demographic information of the female and male household heads because both cut forest and prepare the land. The decision about how much forest to cut grows out of discussions among household heads about their expected food needs over the coming year and the labor available to them for clearing the forest, preparing the land, and taking care of the crop as it grows. Women and men help measure fields and cut branches and underbrush before cutting the larger trees. Men do the actual cutting of the larger trees, but among all groups except the Chiquitano women and men work together cutting branches from fallen trees and burning the dead branches and tree trunks. Among the Chiquitano, women do not take part

TABLE 3

DEFINITION AND SUMMARY STATISTICS OF VARIABLES

Variable	Definition	Observations	Mean	SD
Dependent:				
ogf	Ha of old-growth forest cut by household	964	.48	.52
fallow	Ha of fallow forest cut by household	966	.57	.51
Explanatory:				
education	Maximum formal education of subject	956	2.69	2.74
Spanish	Dummy variable for fluencey in Spanish (1 = fluent; 0 = not fluent)	877	.92	.26
literacy	Literate (1 = literate; 0 = nonliterate); determined with test; see text	952	.54	.49
arithmetic	Arithmetic; determined with test; see text	954	1.19	1.55
hhsize	Total household size	966	6.19	2.47
age	Age of household head in years	955	38.4	13.2
female	Sex of subject (1 = female; 0 = male)	966	.50	.50
land	Ha of fallow lands per person	964	.57	.69
residence	Residence duration in village in years	966	23	16
income	Income per person in *Bolivianos* (5.23 BOl = 1 US$ in 1997); imputed value of farm output + income from sale of animals, forest goods, and labor	930	538	642
wealth	Wealth per person in *Bolivianos;* value of 13 physical assets	964	557	690
distance	Kilometers from village to nearest market town in straight line	966	98.6	43.1
Mojeño	Dummy variable; 1 = Mojeño; 0 = non Mojeño	966	.27	.44
Yuracaré	Dummy variable; 1 = Yuracaré; 0 = non Yuracaré	966	.12	.33
Chiquitano	Dummy variable; 1 = Chiquitano; 0 = non Chiquitano	966	.10	.30
Tsimané	Dummy variable; 1 = Tsimané, 0 = non Tsimané	966	.10	.30
twice	People surveyed twice (1 = twice; 0 = once)	966	.08	.27

NOTE.—ha = hectare; SD = standard deviation.

in cutting or burning but help in subsequent farming activities. The young and old, women and men, do the sowing, weeding, and harvesting.

The survey included questions on wealth, income, demography, human capital, and the use of natural resources. Variables related to human capital included formal educational attainment of the subject and of the subject's parents, fluency in various Indian languages, literacy, and competence in arithmetic. We developed several tests of equal difficulty to measure competence in reading and arithmetic and to prevent cheating.

For each person who was tested, we selected at random one test of literacy and one of arithmetic. Thus, those who may have overheard an answer could not use it as their own when we interviewed them later.

Beside the variables discussed above, we also measured height and weight and carried out an experiment to elicit subjects' private-time preference. In the experiment we gave subjects nine questions that asked them to choose between a small, nontrivial monetary reward now or a larger monetary reward in the future. To ensure that the questions were taken seriously, we selected at random one of the nine questions and paid the subjects the amount that they had selected on that question. Based on their responses, we computed a discount rate for each subject consistent with their answers.[24] Because we gave the test of private-time preference only to one of the two household heads chosen at random, we do not include the variable in the regressions. Including the variable would have reduced the sample size by a half. Nevertheless, we briefly report the results of the analysis in which the variable of time preference is included.

VI. Variables and Econometric Approach

Table 3 contains definition and summary statistics of the variables used in the econometric analysis. Below we explain how we defined and measured variables.

A. Variables

Information on the two dependent variables—area of old-growth and fallow forest cut by a household the year before the interview took place—was obtained through interviews. We let subjects decide how to define old-growth and fallow forests. Since household heads together manage farm plots, we used the same dependent variables for the male and for the female household head. Even though they came from a subject's own report rather than as a direct measurement of the field, dependent variables are likely to contain measurement error. A study by Godoy et al. shows that Amerindians in the tropical lowlands were able to estimate field size with precision.[25]

Information on the subjects' own and their parents' education came from interviews. Many ($N = 89$), about 9% of the sample, did not know the educational level of their parents. Since the variable contained too many missing values, we left it out of the analysis. We assessed competence in reading and in arithmetic by asking subjects to read short sentences in Spanish or by asking them to solve four arithmetic operations that required them to add, subtract, multiply, and divide. For reasons discussed above, we chose the literacy and the arithmetic tests at random for each subject. Information on household size probably contains small measurement errors, but information for the variable age probably contains large measurement errors because most subjects lacked birth cer-

tificates and could not remember their date of birth. People seemed to remember better how long they had lived in their current village.[26]

We measured annual income by assessing the value of the harvest of the three main annual crops—maize, rice, and peanuts—and by adding remittances received and income earned from wage labor and from the sale of animals and forest goods. The measure of income underestimates true income because it leaves out the value of perennial crops and forest goods that were consumed.

We measured wealth by adding the current value of 13 physical assets, which included domesticated animals, weapons, tools, and canoes. To value physical assets we used the village price at the time of the survey. To measure wealth we asked subjects to estimate their total landholdings, excluding lands currently cleared or under cultivation. Since there is virtually no market for land, we did not try to value land. Instead, we express land as area.

In addition to these variables, we measured distance from the village to the nearest market town in a straight line, using a geographical positioning system. For the Tsimané, Mojeño, and the Yuracaré along the Sécure River, we used the city of Trinidad as a reference point; for the Chiquitano we used the town of Concepción.

B. Econometric Approach

We model the clearance of old-growth forest as a form of consumption reflecting the human-capital attributes of the household heads, transitory income, wealth, and the life-cycle characteristics of the subject. In the cultures under study the clearance of old-growth forest resembles consumption (more than investment) because generally people clear forest to plant annual crops that yield in a few months, though as plots age some plant perennial crops and timber trees to serve as markers of private property. Forest clearance is a form of immediate consumption because timber and firewood from the plot are used immediately after they are cut.

The main dependent variable, area of old-growth forest cleared, was censored at zero, and the error term had nonconstant variance. Of the 443 households, 177, or 40%, did not cut old-growth forest. We tested for heteroscedasticity and rejected the assumption of constant variance at the 8.54% level. To ensure robustness in the empirical results, we used three econometric models: tobits, median regressions with standard errors estimated by bootstrap data resampling with 200 repetitions, and ordinary least-squares (OLS) regressions with Huber-White robust standard errors.

We tested for correlation among explanatory variables and found coefficients of less than 0.20, except among variables related to human capital, such as literacy, education, knowledge of Spanish, and competence in arithmetic. These variables had correlation coefficients among

each other that ranged from a low of 0.22 to a high of 0.68. Despite multicollinearity, we left the variables in the regression because together they influence the way in which human capital affects forest clearance. The Ramsey specification test suggests regression results contained no bias from the omission of variables (prob $> F = 0.85$).

We also tested for homogeneity across ethnic and gender groups by running separate regressions that included an additional interaction term between education and a dummy variable for the ethnic group or for gender. In the case of gender, both the coefficients of the interaction term and of the dummy for gender were statistically insignificant. In the case of ethnic groups, the dummy variables for the ethnic groups were significant, but of the interaction terms none was significant at or above the 80% confidence level. We therefore restricted the analysis to the pooled sample but included dummy variables for gender and ethnic groups.

The regression results presented in Section VII include dummy variables for ethnic groups and gender, different tests of literacy and knowledge of arithmetic, and the time of the survey. To make the results clearer, we transformed the variables for area of forest cleared, landholding, income, wealth, and village-to-town distance into natural logarithms. We divided income, wealth, and landholding by household size and expressed them per person.

Some explanatory variables, such as income and education, may be endogenous, biasing the estimated coefficients. For example, if forest clearance increases income and the possibilities of obtaining education, the estimated coefficients for education will be biased upward. We did not have instruments to solve the potential endogeneity of variables such as schooling. Although we cannot correct for endogeneity in a direct way, we use different econometric specifications to ensure robustness in empirical results. Also, the explanatory variable of most interest, formal schooling, is probably less endogenous than other explanatory variables are (e.g., income). Because we use information from a cross-sectional survey, we cannot control for unobserved, fixed attributes of people, such as motivation or intelligence. The inability to control for fixed effects and endogeneity will bias the coefficient of schooling in an unknown direction.

VII. Regression Results: The Effect of Schooling on the Clearance of Old-Growth Forest

Table 4 contains the regression results. The results suggest that formal schooling is associated with lower amounts of old-growth forest cut by a household each year. Depending on the type of regression used, one more year of schooling reduces forest clearance by 13.2%–21.5% a year. The results were statistically significant approximately at or above the 90% confidence level in the tobit and OLS regressions, and at the 89%

TABLE 4

REGRESSION RESULTS OF THE DETERMINANTS OF THE CLEARANCE OF OLD-GROWTH FOREST

	TOBIT		MEDIAN		OLS	
VARIABLE	Coefficient	SE	Coefficient	SE	Coefficient	SE
education	−.21	.11*	−.14	.09	−.13	.07*
Spanish	.10	.83	−.05	.32	.11	.59
literacy	.21	.51	.06	.39	.13	.35
arithmetic	.20	.17	.22	.15	.13	.12
hhsize	.15	.07**	.12	.05**	.10	.05**
age	−.01	.01	.0005	.01*	−.009	.01
female	−.19	.40	−.80	.25	−.12	.27
income	.27	.20	.24	.12	.17	.13
wealth	−.22	.18	−.14	.11	−.18	.12
land	.76	.19***	.38	.26	.50	.12***
residence	−.05	.01***	−.02	.01*	−.03	.01***
distance	3.67	1.00***	4.14	1.31***	2.37	.68***
	Tobit		Median		OLS	
Observations:						
Left-censored	305		N.A.		N.A.	
Right-censored	488		N.A.		N.A.	
Total	793		793		793	
Pseudo R^2	.034		.099			
Prob $> F$ (%)	.412		.525		.522	

NOTE.—Constant and dummy variables for ethnic groups (Chiquitano are the excluded groups), type of arithmetic and literacy test, and time of survey not shown. F is a test of joint statistical significance of education, literacy, arithmetic, and Spanish. Dependent variable, income, wealth, land, and distance expressed in logarithms. Median regression estimated with bootstrap resampling (200 iterations). OLS = ordinary least squares; OLS includes Huber-White robust standard errors. N.A. = not applicable. Variables are as defined in table 3.

* Significant at less than or equal to 10%.

** Significant at less than or equal to 5%.

*** Significant at less than or equal to 1%.

level in the median regression. None of the other human capital variables—literacy, competence in arithmetic, or knowledge of Spanish—were statistically significant.

Table 5 contains regression results for the clearing of fallow forest. The results of all three regressions suggest that one more year of schooling lowers the annual area of fallow forest cut by 3.3%–4.6%. Results were statistically significant approximately at or above the 90% confidence level in the OLS ($P > |t| = 0.003$) and the median regressions ($P > |t| = 0.113$), but not in the tobit regression ($P > |t| = 0.537$). The results suggest that schooling has a stronger effect curbing the clearance of old-growth forest than curbing the clearance of fallow forest. One more year of schooling produces an effect that is 4 times larger (13.2%–

TABLE 5

REGRESSION RESULTS OF THE DETERMINANTS OF THE CLEARANCE OF SECONDARY (Fallow) FOREST

	TOBIT		MEDIAN		OLS	
VARIABLE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Education	−.04	.07	−.03	.02	−.03	.01***
Spanish	−.08	.57	.04	.14	.04	.08
literacy	.21	.34	.04	.08	.03	.05
arithmetic	−.17	.12	.04	.03	.02	.01
hhsize	.15	.05***	.05	.01***	.03	.008***
age	−.002	.01	−.0008	.003	−.001	.001
female	−.08	.26	.002	.06	−.02	.04
income	−.07	.12	.001	.05	.07	.01***
wealth	.10	.12	−.006	.03	−.02	.01
land	.60	.12***	.25	.07***	.11	.01***
residence	.005	.009	.004	.002*	.002	.001
distance	−.77	.65	−.23	.16	−.17	.10*
	Tobit		Median		OLS	
Observations:						
Left-censored	174		N.A.		N.A.	
Right-censored	621		N.A.		N.A.	
Total	795		795		795	
Pseudo R^2	.025		.089			
Prob $> F$ (%)	.447		.495		.059	

NOTE.—Same notes as in table 4, except here we include fallow forest as the dependent variable; OLS = ordinary least squares. Variables are as defined in table 3.

* Significant at less than or equal to 10%.

*** Significant at less than or equal to 1%.

21.5%) regarding the clearance of old-growth forests than the clearance of fallow forests (3.3%–4.6%).

We added the variable for time preference to all three models of table 4 and found that the coefficient of education remained negative but became smaller and statistically insignificant in all three regressions. In the tobit regressions the coefficient for education dropped from −21.5% to −14.8% ($P > |t| = 0.28$), in the median regression it dropped from −14.4% to −6.6% ($P > |t| = 0.58$), and in the OLS regression it dropped from −13.2% to −10.2% ($P > |t| = 0.32$).

We still lack a convincing story that would explain why schooling might be associated with forest clearance. One could think of at least five explanations, including reduction in household size, greater employment opportunities outside of the farm, higher crop yields, more appreciation of forest habitats, and greater economic value extracted from the forest. Since we controlled for household size and wage income, the first two explanations cannot account for why schooling lowers deforestation. We carried out a sensitivity analysis and found that schooling had a negligi-

ble impact on crop yields, perhaps because the area has yet to experience the upheaval of the Green Revolution.

Recent efforts by the Ministry of Education to educate the public about the need to hunt less and to prevent forest fires might explain some of the results. As discussed previously, the government of Bolivia has been trying to heighten awareness of the environment among lowland rural populations in recent years. Unfortunately, the information we have does not allow us to assess how workshops on the topic might influence forest clearing. Further, we did not measure net profits from forest clearing so we cannot tell whether education increases profits from using the forest in a more efficient way, thus reducing the need to clear larger areas.

Although we still do not understand why and how schooling lowers forest clearance, we can take the estimated coefficients from tables 4 and 5 as a starting point in assessing the magnitude of the positive environmental externality produced by schooling.

VIII. The Positive Environmental Externality of Schooling

A worldwide review of valuation studies of tropical rain forests by Robert Costanza and his associates suggests that the mean total value of a rain forest excluding food, raw materials, and recreation is about US$1,543 per hectare per year.[27] That value captures the ecological, environmental, and existence value of the rain forest to people who do not use the rain forest in a direct way. Since one more year of schooling reduces the area of old-growth forest cut each year by about 15% (the rough midpoint of estimates for education reported in table 4), the annual value of the positive environmental externality produced by education would be 15% of the average area of old-growth forest cleared by a household each year, or about 0.50 hectares. Under those assumptions the annual value of the externality would be about US$115.72 per household (0.50 hectare $\times$ US$1,543 per hectare $\times$ 15%).

If one assumes that old-growth tropical rain forests and fallow forests each produce the same amount of global environmental benefits and that one more year of schooling reduces the area of cut fallow forest by about 4% each year (the midpoint of the education estimates of table 5), then an additional year of schooling would produce an additional environmental externality from not cutting the fallow forest of about US$31 per household per year (0.50 hectare $\times$ US$1,543 per hectare $\times$ 4%). Under these assumptions households should receive a total of US$146 each year for saving the forest so the rest of the world can enjoy its benefits.

IX. On the Reluctance of Parents to Send Their Children to School: Linking School Subsidies with Environmental Externalities

In the tropical lowlands of Bolivia, Amerindian parents often refrain from sending their children to school because children do domestic

chores and help on the farm. Children hunt, fish, collect firewood and water, take care of younger children, and help parents weed and harvest. The workload of children may help to explain why indigenous people in the department of Beni have one of the highest rates (37%) of school repetition in Bolivia (see n. 13).[28]

Although we do not have information on how lowland Amerindian children in Bolivia spend their time, we can draw on the results of a recently completed study on time allocation among children of Tawahka Amerindians in the tropical rain forest of eastern Honduras to shed some light on the economic value of children in lowland Amerindian societies of Bolivia.

The Tawahka Amerindians are representative of other tropical lowland groups.[29] Like the groups discussed here, the Tawahka practice horticulture and foraging, and although they live in an isolated region, they sell crops, such as rice and beans, to earn cash.

The study among the Tawahka was conducted from July 1994 to December 1996 and produced systematic spot observations (also known as scans) of activities from blocks of time chosen at random within the week and day. A study of time allocation was carried out in 32 households of two villages, one of which was isolated, and the other one was not.

The results of that study suggest that the share of time spent on work from 6 A.M. to 6 P.M. by children 4–7 years old, averaged about 27%, increased to 37% for children 8–11 years of age, and then went up to 49% for children 12–16 years old. In each age cohort, girls did more work than boys, and the gap widened as children entered adulthood. Among the cohort of children 4–7 years of age, girls spent 28% of their time working compared with 26% for boys. In the next cohort (8–11 years) girls worked 41% of the time compared with 34% for boys. Among children 12–16 years of age, girls and boys spent 53% and 46%, respectively, of their time working.

These numbers are high and indicate that children from a young age on perform valuable economic services for the household. The environmental externality discussed previously can also be seen as compensation so parents allow their children to go to school.

The proposal fits with recent programs in Latin America to subsidize income tied to education. For instance, the government of Brasilia, Brazil, has given supplementary income to poor households to stimulate school attendance among working children, and initial reports suggest that school attendance has improved.[30] Children have gone to school, attendance has risen, and repetition rates have fallen because parents want to keep receiving the subsidy.

Subsidies alone cannot guarantee greater school attendance. Gabriela Inchauste states that among indigenous people in urban Bolivia cash transfers alone would not increase attendance, and they would have to go hand in hand with other reforms, such as provisions for day care, before they would yield visible results.[31]

Although empirical evidence suggests that targeted subsidies induce parents to send their children to school, the costs of such programs need assessment and monitoring.[32] First, the government must cover administrative costs; second, costs might arise from incentive effects or behavioral responses, as beneficiaries and nonbeneficiaries change their behavior in response to the program; and third, costs might arise from the conflict between those who win and those who lose as a result of the program. The last two costs merit monitoring.

X. Conclusions

Tropical deforestation results from international, national, and local causes, some intractable in the immediate future, others responsive to government policy. In this article, we have focused on part of a large, complex causal web and have called attention to a simple yet overlooked policy lever that has the potential of reducing the loss of old-growth rain forest. Both indigenous people who live in the tropical rain forest and poor farmers who have been pushed or lured to more marginal lands abutting the rain forest generally lack access to schools. It appears that providing them with more schooling is likely to reduce tropical deforestation in a potentially inexpensive, direct, and progressive way. Because of our small sample size, our reliance on secondary information to arrive at an estimate of the environmental externality, and our inability to control for unobserved fixed attributes and endogeneity, readers should be cautious about reading too much into the results of this study.

Despite these caveats, we have presented enough comparative, preliminary evidence to suggest that schooling has the potential of reducing the area of wilderness that is lost and, thus, to be of benefit to the world. If such is the case, the dwellers and abutters of the rain forest should be compensated for all the use and the nonuse benefits that they produce. Once using a larger sample, the costs of implementation have been estimated, policy makers may consider a subsidy in the form of direct payments to parents as an inducement to let their children go to school. Such a subsidy might be the simplest way of compensating parents for the global benefits more schooling would produce. Whether policy makers will move in that direction remains to be seen.

Notes

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