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BRIEF COMMUNICATION

Economic Development and Local Ecological Knowledge: A Deadlock? Quantitative Research from a Native Amazonian Society

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Introduction

Despite the growing interest in the topic, there has been little quantitative research about the causes and rate of acquisition and loss of local ecological knowledge. Some researchers have linked the loss of local ecological knowledge to the expansion of the market economy (Godoy *et al.,* 1998; Ross, 2002; Reyes-García *et al.*, 2005a), others have found persistence in local ecological knowledge despite large socio-economic changes (Zarger and Stepp, 2004), and still others have found that integration into the market economy through an economic activity based in the natural environment could accelerate the acquisition of local ecological knowledge (Guest, 2002). The debate matters for policy-making because if integration to the market erodes local knowledge, there would be no possibility of simultaneously achieving conservation of local knowledge and economic development. In contrast, if integration to the market economy does not affect or does not *always* affect local knowledge, then some forms of market incorporation could develop without eroding local ecological knowledge.

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In this article we test how various forms of integration to the market economy affect local ecological knowledge. Local knowledge has many domains (i.e., myth, cosmology), including local ecological knowledge, which itself comprises many subdomains, such as plants, animals, insects, or soils. We proxy local ecological knowledge with ethnobotanical knowledge. We use a new way of measuring ethnobotanical knowledge that stresses skills that draw on ethnobotanical knowledge, and compare results with standard measures of ethnobotanical knowledge that stress passive knowledge. We hypothesize that only some forms of integration to the market economy, namely activities that take individuals out of their culture and environment, are associated with less local ecological knowledge. To explore the topic, we draw on information from 476 Tsimane'—a foraging-horticultural society in the Bolivian Amazon.

The Loss of Local Ecological Knowledge: Previous Findings from Quantitative Research

Quantitative research on the loss of local ecological knowledge has focused on how knowledge varies by demographic, social, and economic characteristics of subjects with mixed results. Knowledge of natural resources depends on demographic characteristics such as age, sex, kinship relations, ethnicity, and position in a social network (Atran *et al.*, 2002; Boster, 1986; Caniago and Siebert, 1998; Ross, 2002), and on distance from cities or natural resources (Begossi, 1996; Reyes-García *et al.*, 2005a). There is also a consistent negative association between local ecological knowledge and characteristics associated with acculturation, such as schooling, academic skills, and fluency in the national language (Benz *et al.*, 2000;

Sternberg *et al.*, 2001; Zent, 2001). Orthodox thinking in anthropology and in economics predicts that local ecological knowledge will vanish as economic development unfolds, but recent empirical research suggests that this need not always be the case. Some researchers find that integration into the market through the sale of crops and wage labor is associated with less knowledge of wildlife, but integration into the market through the sale of forest goods is associated with more knowledge of wildlife (Godoy *et al.*, 1998). Other researchers find weak associations between individual market participation and local ecological knowledge. For example, Reyes-García *et al.* (2005a) found that although there is a link between local ecological knowledge and proximity to towns, canonical indicators of market economies (e.g., cash) bore no significant association with local ecological knowledge, proxied with ethnobotanical knowledge. Others find no changes in the amount of local ecological knowledge a population has over time. For example, in a longitudinal study over 30 years, Zarger and Stepp (2004) found no change in ethnobotanical knowledge among Maya children in Chiapas despite significant socioeconomic changes in the region. Last, some researchers find that local ecological knowledge can increase with new economic activities based on the environment. In a study in coastal Ecuador, Guest (2002) found that, controlling for time of residence in the region, villagers working in the shrimp industry had significantly higher knowledge of shrimp ecology than villagers working in other activities.

A possible explanation for these conflicting results is that previous research has not differentiated between theoretical knowledge and practical skills. Research on the transmission of local ecological knowledge suggests that people acquire most of their theoretical ethnobotanical knowledge before adolescence. In a recent study, Zarger found that by age nine, children could correctly identify at least 50% of the plants on a trail and 85% on a home garden (Zarger, 2002). By age 12, children could correctly identify 95% of the plants—a level equal to the adult control group. If we assume that once the theoretical knowledge is acquired, it will in general be retained, then we should expect low variation in the theoretical ethnobotanical knowledge of adults. Practical skills are acquired later in life than theoretical knowledge, and therefore we can expect more variation in practical skills than in theoretical knowledge.

Building on previous findings, we hypothesize that economic activities that take people out of their cultural milieu and that reduce their interaction with the environment (such as non-farm wage labor outside the village) will cause a loss of local ecological knowledge. To measure the relative economic importance of different activities in a subject's total income, we estimated the share in total personal income of different economic activities. Total personal income includes wage earnings, sale of goods, the value of goods obtained in barter, and the value of farm and forest goods consumed in the household.

We proxy individual local ecological knowledge with two variables: theoretical ethnobotanical *knowledge* and self-reported ethnobotanical *skills*. We used the cultural consensus model to measure individual theoretical ethnobotanical knowledge (D'Andrade, 1995; Reyes-García *et al.*, 2005a; Romney *et al.*, 1986). This model is based on the assumption that there is a culturally correct answer for every question, that it is the same for all informants, and is defined as the answer given by most people (Romney and Weller, 1984). Individual knowledge is measured as the proportion of questions that each person answered in accord with the most frequent response. We use the variable of self-reported ethnobotanical skills to capture the practical dimension of ethnobotanical knowledge. Integration to the market economy is recent in many highly autarkic societies. If economic development erodes ethnobotanical knowledge by enabling people to gain access to substitutes for plant products (Locay, 1989), then we would expect to see economic development producing an effect on the skills to manufacture products from plants before producing an effect on theoretical knowledge.

For the empirical estimation, we use the following linear approximation:

$$E_{ijv} = \alpha + \beta K_{ijv} + \gamma S_{ijv} + \theta D_{ijv} + \phi Z_v + \varepsilon_{ijv} \quad (1)$$

where E_{ijv} is the share of earnings from an economic activity (e.g., wage labor or sales) in the total income of participant i of household j in village v. K_{ijv} captures the theoretical ethnobotanical knowledge of a person. S_{ijv} captures the self-reported ethnobotanical skills of the same person. D_{ijv} is a vector of variables that captures the demographic attributes of the participant. Z_v are attributes of village v that proxy for integration into the market (e.g., distance to market town). ε_{ijv} is a random error term with standard properties. To estimate parameters we use ordinary least square regressions with robust standard errors. We run the regressions with a full set of village dummies ($n = 13 - 1 = 12$) and clustering by village.

The data collected do not allow us to identify the causality of the relationship between individual's economic activities and local ecological knowledge. For instance, people who work for wages outside their villages could lose local ecological knowledge, but equally people who lack local ecological knowledge might be drawn to wage labor outside the village. The data also do not allow us to deal with either endogeneity or selection biases. The data are lowered censored and therefore might contain selection bias. Thirty percent of the people (n=142) did not earn money from sales and 57% (n=274) reported zero values for wages. We did not have identifying instruments for selection into wage earnings or sales, so our estimates may be biased by selection dynamics.

Materials and Methods

Research was conducted between May 2002 and November 2003 among the Tsimane', a foraging and horticulturist society of ~8,000 people in ~100 villages in the Bolivian Amazon. During the first quarter (May–August 2002) we tested the methods for reliability and informant accuracy and collected baseline information. We collected panel data from the same participants during five quarters (September 2002–November 2003).

Tsimane'[1] have been in contact with outsiders since the seventeenth century (Daillant, 2003). They remained in relative isolation until the middle of the twentieth century but are now in the early stages of continuous transition to a market economy (Godoy, 2001). Tsimane' subsistence centers on hunting, fishing, and horticulture (Godoy *et al.*, 2002; Vadez *et al.*, 2004). Tsimane' take part in the market economy in two ways. Some earn cash by selling forest and agricultural goods while others earn cash by working as unskilled wage laborers for non-Tsimane' farmers and ranchers.

Tsimane' display ethnobotanical knowledge comparable to that reported for other groups in the region (Boom, 1987; DeWalt *et al.*, 1999). They reported 414 different species of wild plants, of which only 46 (11%) had no recorded use. The remaining 368 plants had a total of 571 different uses; some plants had more than three independent uses. However, they employ only about half of the uses of plants they know. People living far from market towns use many plants for many purposes (e.g., firewood, medicine, tools), whereas people living closer to the market town use fewer plants, mainly for firewood, because many plant products have been displaced by commercial substitutes (Reyes-García *et al.*, 2005b).

To obtain a sample of villages with different exposures to the market economy, we used distance from the village to the closest market town (mean=28.3 km; sd=15.9). We interviewed all adults in 13 Tsimane' villages along the Maniqui river, for a total of 229 men and 247 women. The mean age of participants was of 34.4 years (sd=15.02). Participants had an average of 1.9 years of schooling (sd=2.27). Twenty-nine percent of the sample reported speaking the national language, Spanish.

We used two dependent variables: personal income from wage labor and personal income from sale of goods. Both are expressed as a share of total personal income. We measured wage earnings, sale of goods, and the value of goods obtained in barter by asking participants about their earnings from those activities for the 2 weeks before the day of the interview. We measured the value of farm consumption by asking about the amount of farm crops consumed by the entire household the week before the day of the interview and then calculating adult equivalents (Byron, 2003). We measured the value of forest consumption by conducting weekly interviews on the amount and value of forest goods consumed. The total value of individual income was obtained by adding the different sources of income (labor, sale, and barter) and consumption (farm and forest) over the four last quarters of the research. We excluded data from the first quarter. Seasonality can affect patterns of income and consumption, so by excluding data from the first quarter we keep only data corresponding to a calendar year (Nov 2002–Nov 2003), and avoid potential biases from seasonality. Last, we calculated the share of each economic activity in the total income of the person.

To calculate theoretical ethnobotanical knowledge we collected similarity judgments across participants using a multiple-choice test of 21 randomly selected plants. For the tests we asked participants whether they could use the plants for construction, firewood, food, medicine, or for other uses. For each plant, participants could choose none, one, or more potential uses. We use cultural consensus analysis (Reyes-García *et al.*, 2003; Romney *et al.*, 1986) to calculate individual scores of theoretical ethnobotanical knowledge.

Second, we asked participants to report their ability to use wild plants. We used information from free-listing (n=50) to construct a list of items crafted from plants. To select items from the list, we asked three key informants to identify items commonly crafted by men and items commonly crafted by women and to classify the items by their difficulty of manufacture. We randomly selected 18 objects from 15 different plant species, more commonly made by men and nine more commonly made by women. Within each group we selected three items that key informants considered easy to make, three that they considered of medium difficulty, and three that they considered hard to make. We asked participants whether they had ever made on their own the items from the list. We weighted scores to reflect that only some people reported knowing how to make difficult objects: the score for an object was inversely proportional to the number of participants reporting knowing how to make the object.

[1] Byron (2003), Huanca (1999), Reyes-García (2001), Vadez *et al.* (2004), and Godoy *et al.* (2002) describe the Tsimane' economy and the relative importance of income and consumption in household economy in detail. Here we summarize only key aspects of the Tsimane' economy relevant to our argument.

Table I Descriptive Statistics of Variables Included in the Regressions (n=476)

Variable	Definition	Mean	Std. Dev.	Min	Max
Dependent					
Share of wage	Share of wage earnings in total yearly personal income	17	26	0	97
Share of sale	Share of earnings from sale of goods in total yearly personal income	22	23	0	96
Explanatory					
Knowledge[a]	Agreement with the sample on uses of 21 randomly-selected plants	0.56	0.20	0.05	0.95
Skills	Score in a test of ability to make 18 objects from plants	4.1	1.82	0	10.1
Control					
Age	Age of participant, in years	34.4	15.02	15.0	90.3
Male[b]	Sex of the participant	0.5	0.50	0	1
School grade	Maximum school grade attained	1.9	2.27	0	13
Writing	Ability to write his/her name	0.7	0.88	0	2
Spanish[b]	Fluency in spoken Spanish	0.3	0.46	0	1
Village-to-town distance	Kilometers from village to closest town	28.3	15.95	6	48

[a] n=416
[b] Binary variable. Name of variable=1; excluded category=0.

Results

Over the research period, the average participant earned a total of 123 *bolivianos* in a 2-week period, 78 *bolivianos* from cash earnings and 45 *bolivianos* from the imputed value of farm and forest goods consumed (7.1 *bolivianos*= US $ 1). Most cash earnings came from the sale of goods (36 *bolivianos*) and wage labor (33 *bolivianos*). Participants received only about 8 *bolivianos* from bartering. The average share of earnings from wage labor in total yearly personal income reached 17% (sd=26). The average share of earnings from the sale of goods in total yearly personal income was slightly higher, 22% (sd=23) (Table I).

The average score of theoretical ethnobotanical knowledge (range 0–1) was 0.56 (sd=0.20). Weighted scores of ethnobotanical skills ranged from 0 to 10.1, with a mean score of 4.1 (sd=1.82). Participants able to make each object varied by object, and ranged from 15 to 74% of the sample. Only two objects were so hard to make that fewer than 25% of participants reported knowing how to make

Table II Percent of Male (n=229) and Female (n=247) Tsimane' Participants Reporting having Manufactured Items from Plants

Item	Percent male	Percent female	Percent total
Items commonly crafted by men			
Bow from the stem of *Bactris gasipaes*	86.5	2.0	42.7
Cooking spoon from the wood of *Aspidosperma rigidum*	86.9	31.6	58.2
Axe handle from wood of *Casearia sylvestris*	86.5	6.5	45.0
Glue from the latex of *Brosimum utile*	82.1	8.1	43.7
Wooden mortar from the wood of *Pouteria torta*	76.4	9.7	41.1
Food container from the leaf sheath of *Iriartea deltoidea*	55.0	17.8	35.7
Canoe from the wood of *Hura crepitans*	50.2	2.0	25.2
Spinning support from the wood of *Clarisia racemosa*	48.9	12.6	30.0
Items commonly crafted by women			
Sleeping mat from the leaves of *Gynerium sagittatum*	47.6	98.0	73.7
Carrying bag from the fibers of *Gossypium* sp.	1.3	96.8	50.1
Floor mat from the leaf of *Scheleea* sp.	18.3	95.1	58.2
Storage bag from the leaf of *Scheleea* sp.	18.3	91.1	56.1
Necklace from the seeds of *Ormosia nobilis*	26.2	86.2	57.4
Spinning fiber from the seeds of *Gossypium* sp.	12.2	81.8	48.3
Dye with the heart wood of *Maclura tinctorea*	13.5	73.3	44.5
Mat from the leaves of *G. sagittatum*	17.5	67.6	43.5
Items crafted by men and women			
Fabrics from the bark of *Poulsenia armata*	21.8	26.3	24.2
Strainer from the stem of *Ischnosiphon* cf. *puberulus*	16.2	13.7	14.9

Table III Multivariate OLS Regressions of the Share of Wage Labor in Total Yearly Personal Income Against Ethnobotanical Knowledge and Skills

Explanatory variables	Share of wage earnings in total personal income		
	[1]	[2]	[3]
Knowledge (log)		0.01	0.03
Skills (log)	−0.07**		−0.09**
Age	0.001	−0.001*	0.0003
Male	0.20**	0.18**	0.19**
School grade	0.02*	0.02*	0.02*
Writing	0.01	0.02	0.02
Spanish	0.09**	0.09**	0.10**
Village-to-town distance	−0.0006*	−0.004*	−0.001
Observations	472	416	416

Regressions contain a constant and a set of binary variables for village of residency (not shown) and clustering by village.
[1] does not include the variable knowledge. [2] does not includes the variable skills.
* $p \leq 0.10$; ** $p<0.01$

them (Table II). We found higher variance in ethnobotanical skills (coefficient of variation=0.44) than in theoretical ethnobotanical knowledge (coefficient of variation=0.36).

We found a positive and statistically significant association between theoretical ethnobotanical knowledge and ethnobotanical skills. The regression of individual theoretical ethnobotanical knowledge against ethnobotanical skills (while controlling for village-to-town distance) produced a coefficient of 0.896 ($p=0.06$; $n=416$).

Table III shows the regression results using wage earnings as a share of total personal income as a dependent variable. We find that an increase of 1% in the score of ethnobotanical skills correlates with a ~0.07% lower share of wage earnings in total personal income ($p<0.001$) (column [1]). Theoretical ethnobotanical knowledge was not significantly associated with the share of wage earnings in total personal income (column [2]). In column [3] we include both theoretical ethnobotanical knowledge and ethnobotanical skills and find that a 1% increase in skills is associated with a ~0.09% lower share of wage earnings in total personal income ($p<0.01$). We also find that a 1% increase in participants' theoretical ethnobotanical knowledge was not significantly associated with the share of wage earnings in total personal income.

Table IV shows the results from the same regression model but using the sale of farm and forest products as a dependent variable. We find that an increase of 1% in the score of ethnobotanical skills is associated with a ~0.07% higher share of sales in total personal income ($p<0.001$) (column [1]). An increase of 1% in the score of theoretical ethnobotanical knowledge is also associated with a ~0.06% higher share of sales in total personal income ($p<0.01$), but mostly when using the variable theoretical ethnobotanical knowledge alone (column [2]). When we include both theoretical ethnobotanical knowledge and ethnobotanical skills (column [3]), we find that ethnobotanical skills are

Table IV Multivariate OLS Regressions of the Share of Sales in Total Yearly Personal Income Against Ethnobotanical Knowledge and Skills

Explanatory variables:	Share of earnings from sale of goods in total personal income		
	[1]	[2]	[3]
Knowledge (log)		0.06**	0.04*
Skills (log)	0.07**		0.08**
Age	0.001	0.002	0.001
Male	0.02	0.02	0.01
School grade	−0.01**	−0.01**	−0.01*
Writing	0.01	0.004	0.007
Spanish	−0.008	0.02	0.02
Village-to-town distance	−0.006**	0.001	−0.007**
Observations	472	416	416

Regressions contain a constant and a set of binary variables for village of residency (not shown) and clustering by village.
[1] does not include the variable knowledge. [2] does not includes the variable skills.
* $p \leq 0.10$; ** $p<0.01$

still significantly associated with the share of sales earnings in total personal income, but the coefficient and significance of the variable ethnobotanical knowledge decrease. An increase of 1% in the score of ethnobotanical skills is associated with a ~0.08% higher share of earnings from the sale of goods in total personal income ($p<0.001$), whereas an increase of 1% in the score of ethnobotanical knowledge is only associated with a ~0.04% higher share of earnings ($p<0.1$) (column [3]).

We tested the robustness of the results in two ways (not shown). First, we took the logarithm of monetary income from wage labor and the sale of goods instead of the share of these variables in an individual's total income. The results held up. An increase of 1% in the score of ethnobotanical skills is associated with lower income from wage labor (see Table III). Doubling an individual's ethnobotanical skills was associated with a decrease of ~250% in the level of wage earnings ($p<0.01$). Theoretical ethnobotanical knowledge was not associated with wage earnings. An increase of 1% in the score of ethnobotanical skills is associated with ~1.4% higher income from the sale of goods ($p=0.006$), and a 1% increase in the score of theoretical ethnobotanical knowledge is associated with ~2.4% higher income from the sale of goods ($p=0.04$).

Second, we ran a similar regression model but inverting dependent and explanatory variables and found essentially the same results. We ran another regression using ethnobotanical skills as a dependent variable and found that higher ethnobotanical skills correlated with a lower share of personal income from wage labor ($p=0.01$) but did not correlate with the share of income from the sale of products. We therefore conclude that although we cannot identify causality, the magnitude of the association from either ethnobotanical knowledge to income or from income to ethnobotanical knowledge is similar.

Discussion and Conclusions

This research advances our understanding of local ecological knowledge at the methodological and theoretical levels. At the methodological level, we find that the way ethnobotanical knowledge is defined and measured matters. We measured theoretical ethnobotanical knowledge and ethnobotanical skills and found that the two variables were associated, but weakly. We also found more variation in ethnobotanical skills than in theoretical ethnobotanical knowledge. Lower variation in theoretical ethnobotanical knowledge might explain the weak results of previous research that have drawn on theoretical ethnobotanical knowledge to explain intracultural variation of knowledge. Future research could improve the measure of individual local ecological knowledge by combining measures that capture the theoretical and practical dimensions of local ecological knowledge.

At the theoretical level, our results advance our understanding of the relation between economic development and local ecological knowledge: participation in wage labor is associated with fewer ethnobotanical skills, and the sale of forest and farm products is associated with greater ethnobotanical skills and with greater theoretical ethnobotanical knowledge. These findings suggest that some forms of economic development can take place without eroding local ecological knowledge. Due to the weakness of results in previous research, the identification of the specific economic activities that are negatively associated with ethnobotanical knowledge is an important step in our understanding of the relation between economic development and retention of ethnobotanical knowledge. However, our study does not allow to infer causality. Future studies should advance our understanding of how this relation operates by providing a convincing identification strategy. Future studies should also address whether the results presented here hold independently of the domain of local knowledge analyzed.

One could argue that the findings might indicate that some forms of economic development erode local ecological knowledge at a faster rate than others. This would be true if we had found that some economic activities were completely unrelated with ethnobotanical knowledge. But we found that activities that take Tsimane' to the forest and that keep them in their culture are associated in a positive and significant way with theoretical knowledge and ethnobotanical skills, suggesting that these economic activities do not erode ethnobotanical knowledge.

Another important finding is the high local ecological knowledge elasticity of income ($\%\Delta Y/1\%\Delta X$). For example, when we regressed the logarithm of income from wage labor (dependent variable) against the logarithm of ethnobotanical skills, we found a negative elasticity of 2.50; when we regressed the logarithm of income from sale of products against the logarithm of ethnobotanical skills, we found a positive elasticity of 1.44. The results suggest that changes in ethnobotanical skills produce important short-term changes in the types and levels of earnings. As income elasticities of knowledge were based on a logarithmic scale, the influence of rising income on knowledge is greater when income is low. This suggests that local ecological knowledge would be lost most rapidly among the poor who shift away from economic activities based on the use of natural resources.

In sum we find that only some economic activities are negatively associated to local ecological knowledge, proxied by ethnobotanical knowledge. The finding has an important policy implication: economic development and preservation of local ecological knowledge might be simultaneously achieved *only if* economic development takes place through activities that keep people in their habitat and their culture. The challenge lies in finding and promoting local forms of economic development that do not undermine local ecological knowledge.

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