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Brief Communication

Does Integration to the Market Threaten Agricultural Diversity? Panel and Cross-Sectional Data From a Horticultural-Foraging Society in the Bolivian Amazon

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Trade theory predicts that the expansion of markets induces households to specialize and intensify production. We use plot-level data (n = 64) from a panel study of 2 village and cross-sectional data from 511 households in 59 villages of Tsimane' Amerindians (Bolivia) to test the predictions. Results of bivariate analyses using both data sets suggest that as households integrate into the market economy they: (1) deforest more, (2) expand the area under rice cultivation, the principal cash crop, (3) sell more rice, and (4) intensify production by replanting more and by replanting newly cleared plots with maize, another cash crop. Results mesh with predictions about production specialization and intensification of trade theory. The analysis also produced results running counter to predictions from trade theory. For example, households and villages more integrated into the market planted more cassava and rice varieties, intercropped more, and put more crops in new fields than more autarkic households. Although the expansion of markets induces

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specialization and intensification in selected cash crops, it does not erase completely agricultural diversity. We hypothesize that despite the expansion of markets, households retain agricultural diversity because the market does not yet provide modern forms of self-insurance or well-functioning labor, credit, and product markets that would allow households to protect food consumption when faced with shocks. Without better insurance mechanisms, some agricultural diversity might still allow households to smooth consumption.

KEY WORDS: slash-and-burn; markets; rice; cash crops; Tsimane'; Bolivia; deforestation; agricultural intensification; Amerindians.

INTRODUCTION

Indigenous groups in tropical rain forests have used slash-and-burn agriculture for millennia (e.g., Huanca, 1999; Levasseur and Olivier, 2000; Long and Zhou, 2001). In the tropical lowlands of the New World, indigenous slash-and-burn farming consists of cultivating crops for 1–2 years in plots cleared from old-growth forests, after which lands remain fallow and the forest is allowed to regenerate. For populations with simple technology, low rates of population growth, and weak links to the market economy, slash-and-burn farming provides a sustainable food supply (Pimentel and Heichel, 1991; Posey and Balee, 1989). However, population growth, new farm technologies, and/or increased outside demand for local crops affect slash-and-burn farming. Lowlands Amerindians, among the poorest populations in the world (Patrinos and Psacharopoulos, 1994), are joining the market to raise their income and consumption (Simmons, 1997). Although much has been written about the effect of trade opening, market expansion, or globalization on the welfare of Amerindians (Godoy, 2001), there is little systematic or quantitative data about the effect of market penetration on changes in slash-and-burn farming among lowland Amerindians (Berhens, 1992; Demmer and Overman, 1999; Hammond *et al.*, 1995; Sierra *et al.*, 1999). The goal of this article is to highlight changes in agricultural practices brought about by greater incorporation into a market economy in one such group—the Tsimane' of Bolivia. The topic merits empirical analysis because greater integration into the market economy could induce homogenization in farming practices, exposing Amerindians to greater consumption vulnerability. Although we do not test in a direct way whether markets increase consumption vulnerability, we do document the effect of market expansion on farm diversity, and by implication, on individual households' food security.

We use two different data sources to ensure consistency in results. We first draw on data collected during 18 consecutive months (5/1999–11/2000) in two villages—one remote from the market and poor, and one closer to the market and richer. Second, to validate conclusions from this intensive study, we draw on a cross-sectional survey of 511 households in 59 Tsimane' villages, where we compare the farming practices of households in the top and in the bottom quarter of the distribution of cash income. The use of two different data sets allows us to build on previous case studies of agricultural change among lowland Amerindians that have relied on information from a smaller sample size of villages or from villages displaying small variance in exposure to the market (Berhens, 1992; Coomes and Burt, 1997; Hammond *et al.*, 1995; Huanca, 1999; Piland, 1991; Sierra *et al.*, 1999). The Tsimane' display much variation in their degree of exposure to the market (Godoy, 2001), thus providing an ideal case study to estimate the links between integration into a market economy and changes in farming practices.

THEORY AND HYPOTHESES

In relatively autarkic villages households diversify agricultural production (planting several varieties of crops, scattering plots, staggering the season of planting, and intercropping) for at least two reasons. First, diversification protects households' food production against localized risks related to climate and outbreaks of pests and diseases (Bentley, 1987). Second, diversification allows households to smooth labor requirements across periods of peak labor demand.

As villages open up to trade with the outside world, households produce fewer crops, which they export from the village. The theory of comparative advantage suggests that as households gain a stronger foothold in the market economy, they specialize in the production of only a few crops for which they enjoy a comparative advantage relative to the rest of the world (Godoy, 2001). To maximize profits, households consolidate plots to achieve greater economies of scale, apply modern inputs to increase yields, and narrow the range of species sown to ensure the harvested crop meets the demand of merchants and the tastes of final consumers. As autarkic economies open up to trade, the loss of agricultural diversity, which had served to protect food production from fluctuations, increases the economic vulnerability of households. The development of modern forms of self-insurance, government safety nets, and well-functioning labor, crop, and credit markets eventually mitigate fluctuations, but in the transition from relative autarky to a modern market economy, households run the risk of losing the protection of agricultural diversity.

TSIMANE' AGRICULTURE

Tsimane' Amerindians number ~8000 people and live scattered in ~100 villages in the lowlands of Bolivia, mostly along the Maniqui and Apere rivers (Daillant, 1994; Huanca, 1999; Reyes-Garcia, 2001). For subsistence, Tsimane' practice slash-and-burn agriculture, fishing, hunting, and the collection of wild plants. Although Tsimane' depend on the forest for most of their animal proteins, about 40% of their food consumption comes from their own farm production, and this share increases as households become more integrated to the market economy (Godoy *et al.*, 2002).

Between May and October, Tsimane' use simple technology to open farm plots from either fallow or old-growth forests. Once dried, the vegetation is burnt, and in the cleared plots Tsimane' cultivate rice (*Oryza sativa*), maize (*Zea maiz*), manioc (*Manihot esculenta*), and plantains (*Musa balbisiana*), their main staples. They also put in a variety of crops of less importance, such as sugar cane (*Saccharum officinarum*), peanuts (*Arachis hypogeae*), sweet potatoes (*Ipomoea batata*), ahipa (*Pacchyrhizus tuberosus*), pata de anta (*Passiflora triloba*), and citrus (*Citrullus lanatus*). Plots are abandoned after 1–2 years.

THE SETTING

We selected the villages of Yaranda and San Antonio for the panel study because they lie at opposite ends of the idealized autarky-to-market continuum. Although each village had a school covering the first five grades and two teachers, the villages differed in their proximity to the nearest market town. Yaranda had ~21 households and was not reachable by road; people from Yaranda could reach the nearest market town (San Borja, population ~16,000) in about 2 days walking or about 3 days rafting down the river. San Antonio had ~27 households, and could reach San Borja all year by road—about 2 h of walking, or in 1 h using a bicycle. The 59 villages of the cross-sectional survey were scattered over most of Tsimane' territory.

METHODS

Research was conducted in two broad steps. First, during 18 months (5/1999–11/2000) we documented in detail the farming practices of households in the villages of Yaranda and San Antonio. The research allowed us to gain a solid agronomic and ethnographic understanding of farming at the village level. We measured or asked about aspects of farming practices, such as plot size, polycropping, number of manioc and rice varieties used, and household cash income. Between January and July 2000, we gathered agronomic information—field observations or surveys—on all plots ($n = 64$) cleared for agriculture in 1999 while people were still using the plots. Although the agronomic data came from a larger panel study, the agronomic information we present here is not based on repeated measures of the same plots over time.

Second, drawing on the data from the intensive study of the two villages, we did a cross-sectional survey in 59 villages during July–October 2000. We selected at random 8–12 households in each village, and collected information from the male household heads, on all plots cleared for agriculture in 1999. Since we could not gather data on the topics of the panel study that required field visits to the plots, the cross-sectional survey focused on eliciting information through interviews, and so there is not a one-to-one correspondence between many of the variables analyzed in the two studies.

For the empirical analysis of the cross-sectional study, we split the sample households into two groups: the top and the bottom 25% of the distribution of cash income. We refer to households in the top 25% of the income distribution as "integrated" and to those in the bottom 25% as "not integrated." Reyes-Garcia (2001) and Godoy *et al.* (2002) discuss in detail the methods used to collect data in the panel and in the cross-sectional studies.

RESULTS

In this section we first analyze how market influences the following features, using panel data: (i) the area deforested for agriculture, (ii) the diversification of crops, (iii) the diversity of rice and manioc, and (iv) the way rice is cultivated.

Panel study

Forest Area Cleared for Cultivation and Plot Characteristics

We found that each household in the more integrated village of San Antonio cleared 9.12 *tareas* of forest (1 *tarea* = 0.10 ha); whereas in Yaranda, each household cleared about two third of that area, only 5.97 *tareas* (Table I). After adjusting for the number of adults per household, we found that an adult in San Antonio cleared an average of 3.22 *tareas* each year whereas an adult in the more remote village of Yaranda cleared about 25% less, only 2.42 *tareas*/year.

Table I. Differences in Farm Plot Characteristics Between Two Tsimane' Villages Based on Panel Study

	Yaranda	San Antonio	Pooled	*t* test
Cultivated area (*tareas*)				
Per adult	2.42 ± 0.39	3.22 ± 0.37	2.81 ± 0.77	$p < 0.08$
Per household	5.97 ± 0.69	9.12 ± 0.73	7.47 ± 3.09	$p < 0.002$
N	22	20	42	
Number of plots				
Per adult	0.71 ± 0.08	0.48 ± 0.04	0.59 ± 0.31	$p < 0.004$
Per household	1.86 ± 0.16	1.42 ± 0.12	1.63 ± 0.71	$p < 0.02$
N	22	24	46	
Plot size (*tareas*)	3.54 ± 0.51	7.46 ± 0.82	5.45 ± 3.62	$p < 0.0002$
N	21	20	41	

Note. Data are the Mean ± Standard Deviation (sd). 10 *tareas* = 1 ha.

Field area was larger in the integrated village of San Antonio than in Yaranda (7.46 *tareas* vs. 3.54 *tareas*). In contrast, in the more integrated community of San Antonio households had significantly fewer fields than households in Yaranda (1.42 vs. 1.86). Adjusting for the number of adults in each household, we found that an adult in San Antonio had a mean of 0.48 plots lower than the 0.71 plots of an adult in Yaranda. These results reflect the widespread practice of traditional farming communities of scattering plots to reduce the risk of loss (Bentley, 1987).

Crop Species Grown in New Fields

Rice was the most important crop of the farming system; 85% of new fields contained rice and we found no significant difference in the frequency of rice planting between the two villages ($p < 0.35$) (Table II). Maize was the second most important crop, (57% of new fields.) and more frequent in Yaranda (66%, SD = 8) than in San Antonio (66% vs. 44%). This finding was surprising because maize is an important cash crop and we expected villagers of San Antonio to grow it more frequently. However data for San Antonio may have been underestimated because maize is sown in rows within rice fields, making it harder to record. In Yaranda maize is planted in easily observable patches.

Plantain was also important in each village with no difference between the two villages (33% of new fields). Manioc was more frequent in the fields of Yaranda than San Antonio (30% vs. 7%). Lastly, smaller crops (e.g., sweet potatoes, sugar cane) were more frequent in Yaranda than in San Antonio (25% vs. 3%).

Table II. Difference Between Two Tsimane' Villages in the Frequency of Presence of Crops in New Fields

	Yaranda	San Antonio	Pooled	*t* test
Rice	83 ± 6	87 ± 6	85 ± 36	$p < 0.35$
N	30	36	66	
Maize	66 ± 8	44 ± 10	57 ± 50	$p < 0.04$
N	27	36	63	
Plantain	33 ± 8	32 ± 9	33 ± 47	$p < 0.46$
N	28	36	64	
Manioc	30 ± 8	7 ± 5	20 ± 40	$p < 0.01$
N	28	36	64	
Other crops	25 ± 7	3 ± 3	15 ± 37	$P < 0.01$
N	28	36	64	

Note. Other crops include ahipa (*Pachyrhizus tuberosus*), sweet potatoes (*Ipomoea batata*), pata de anta (*Passiflora triloba*), sugar cane (*Saccharum officinarum*), watermelon (*Citrullus lanatus*), peanuts (*Arachis hypogea*). Data are the Mean ± Standard Deviation (sd).

Cropping System

Villagers in Yaranda grew a significantly larger number of crop species in their new fields and were more likely to polycrop[9] than people in San Antonio (Table III). Households in San Antonio intercropped their plots more than those in Yaranda (36% vs. 22%).

Manioc and Rice Biological Diversity

We found no significant difference in the number of manioc varieties grown by each household between the more traditional village of Yaranda and the more modern village San Antonio (1.59 vs. 1.11). In contrast, households in San Antonio used more rice cultivars than households in Yaranda (2.16 vs. 1.77).

Rice Management

On average, each household in Yaranda planted only 2.49 *tareas* with rice, three times less than in San Antonio (Table IV). Results were similar when expressing rice area per adult or per household. Since fields were smaller in Yaranda, we estimated the percentage of the area of a new field

[9]Polycropping refers to fields in which different crops sown in different patches. Intercropping refers to crops planted next to each other.

Table III. Differences in Planting Patterns Between Two Tsimane' Villages

	Yaranda	San Antonio	Pooled	*t* test
# crop species per plot	2.30 ± 0.16	1.78 ± 0.13	2.08 ± 0.89	$p < 0.01$
N	28	36	64	
Polycropping per plot (%)	64 ± 8	43 ± 9	55 ± 50	$p < 0.05$
N	28	36	64	
Intercropping per plot (%)	22 ± 7	36 ± 9	28 ± 45	$p < 0.12$
N	28	36	64	
# manioc varieties/household	1.59 ± 0.34	1.11 ± 0.25	1.37 ± 1.41	$p < 0.14$
N	18	22	40	
# rice varieties/household	1.77 ± 0.20	2.16 ± 0.21	1.95 ± 0.92	$p < 0.09$
N	19	22	41	

Note. Total number of cassava varieties cited by the 40 household interviewed was 9 and total number of rice varieties cited by the 41 household interviewed was 6. Data are the Mean ± Standard Deviation (sd).

sown with rice and found it was significantly higher in the integrated community of San Antonio than in Yaranda (79% vs. 56%). The sale of rice was also significantly higher in San Antonio than in Yaranda, suggesting that rice is mostly a staple crop in Yaranda and mostly a cash crop in San Antonio.

We also found that people sow their rice fields about 2 weeks earlier in San Antonio perhaps because they sell most of the crop. They also grew ∼30% more rice bunches per hectare than people in Yaranda, presumably to obtain a larger harvest.

Table IV. Differences in the Management of Rice Between Two Tsimane' Villages

	Yaranda	San Antonio	Pooled	*t* test
Rice area (*tareas*)				
Adult	0.99 ± 0.17	2.85 ± 0.42	1.62 ± 1.58	$p < 0.0001$
Household	2.49 ± 0.38	7.96 ± 0.78	4.31 ± 3.70	$p < 0.0001$
N	36	27	63	
Rice sales (*arrobas*)				
Adult	1.2 ± 0.6	12.4 ± 2.4	6.5 ± 9.6	$p < 0.0001$
Household	2.8 ± 1.3	31.6 ± 5.1	16.5 ± 21.8	$p < 0.0001$
N	36	27	63	
% rice area/plot	56 ± 5	79 ± 6	66 ± 34	$p < 0.003$
N	27	36	63	
Rice sowing date	10.1 ± 0.1	9.7 ± 0.2	9.9 ± 0.8	$p < 0.07$
N	20	21	41	
Rice sowing density	31915 ± 1527	43289 ± 2554	37302 ± 10539	$p < 0.0002$
N	18	20	38	

Note. Rice area (in *tareas*) refers to area of a new field sown with rice; estimated as a percent by investigator, and then converted to a surface area based on survey of entire plot. Rice density = number of rice bunches/ha; estimated by randomly sampling eight spots in each field. In each spot, the average distance between rice bunches was calculated from five distance measures. Numbers under sowing date refer to the month (e.g., January = 1). 1 *arroba* = 11.5 kg. Data are the Mean ± Standard Deviation (sd).

Table V. Differences in Cropping Sequence Between Two Tsimane' Villages and the Frequency of Re-Planting Various Crops

	Yaranda	San Antonio	Pooled	*t* test
Area replanted				
Per adult	0.29 ± 0.08	1.59 ± 0.35	0.73 ± 1.11	$p < 0.0001$
Per household	0.72 ± 0.17	4.75 ± 0.55	2.06 ± 3.09	$p < 0.0001$
N	18	35	53	
Percentage area replanted (%)	12 ± 5	46 ± 7	27 ± 37	$p < 0.0001$
N	28	36	64	
Maize	11 ± 5	46 ± 9	26 ± 44	$p < 0.0006$
N	28	36	64	
Plantain	25 ± 7	32 ± 9	28 ± 45	$p < 0.27$
N	28	36	64	
Manioc	14 ± 5	3 ± 3	9 ± 29	$p < 0.08$
N	28	36	64	
Other	25 ± 7	3 ± 3	16 ± 37	$p < 0.01$
N	28	36	64	

Note. Share of field recultivated after harvest of first crop estimated by researcher and converted to a surface with the survey on plot area. Data are the Mean ± Standard Deviation (sd).

Area Replanted After Harvest of the First Crop Grown in New Field

Tsimane' usually abandon a large part of a field after the harvest of the first crop owing, in part, to the availability of fish and game. However, we found that after the rice harvest, households in San Antonio replanted 46% of their field area (4.70 *tareas*) four times more than the 12% replanted in Yaranda (0.72 *tareas*) (Table V). In more market-integrated villages such as San Antonio, depletion of fish and game coupled with market influences may provides incentives for Tsimane' to replant their fields.

Crop Species Replanted After the First Harvest of New Fields

Maize was replanted more frequently in the village of San Antonio that in Yaranda (46% vs. 11%) because it is tradeable in the market (Table V). Households in both Yaranda and San Antonio replanted plantain in ~30% of their fields. In contrast, households in the more isolated village of Yaranda were more likely to replant manioc (14% of fields) and other crops (25% of fields) after harvesting the first crop of a new field, whereas households in San Antonio replanted only about 3% of their fields with either manioc or other crops.

In sum, households from the more integrated village of San Antonio intensify the use of land by replanting larger areas of their fields after harvest, putting more rice seeds per unit area, devoting more of their plots to the production of cash crops, and planting rice earlier. They also reduce the diversity of crops they plant in newly cleared plots, except, contrary to expectations, for rice, the principal cash crop.

Cross-Sectional Study

Table VI contains a summary of the comparison between households in the top and bottom 25% of the cash income distribution using the cross-sectional study of 511 households in 59 Tsimane' villages, largely confirming the findings from the panel data set of the two villages, but also showing some unexpected results.

Integration in the market economy correlates with increased forest cleared per household and per adult. A typical adult in a nonintegrated village household cleared only 5.09 *tareas*, ~50% less than the 7.39 *tareas* cleared by a typical adult in an integrated village household. Integration in the market economy also correlated with a twofold increase in the area of a field replanted after the harvest of the first crop. These results held up even when we expressed figures per adult.

Integration in the market economy correlated with increased amounts of rice planted, although rice planting was important even in nonintegrated villages where 87% of households grew rice in new fields, and, in addition, with increased area planted with rice whether expressed per household or

Table VI. Summary of Main Parameters Affected by Integration to the Market Economy Based on Cross-Sectional Survey of 511 Households in 59 Tsimane' Villages

	Nonintegrated households	Integrated households	*t* test
Tareas deforested			
Per adult	5.09 ± 0.31	7.39 ± 0.64	$p < 0.0001$
Per household	11.8 ± 0.6	18.5 ± 1.1	$p < 0.0001$
# crops in new fields	2.00 ± 0.08	2.45 ± 0.10	$p < 0.0004$
Intercropping (%)	65 ± 3	74 ± 4	$p < 0.04$
% rice in new fields	87 ± 2	95 ± 2	$p < 0.005$
Rice area (*tareas*)			
Per adult	4.12 ± 0.32	4.88 ± 0.34	$p < 0.06$
Per household	9.5 ± 0.6	12.3 ± 0.9	$p < 0.004$
Rice sales (*arrobas*)			
Per adult	12.1 ± 1.3	24.3 ± 2.1	$p < 0.0001$
Per household	28.0 ± 2.6	60.9 ± 5.8	$p < 0.0001$
Manioc varieties	2.28 ± 0.11	2.83 ± 0.12	$p < 0.0005$
Tareas replanted			
Per adult	0.86 ± 0.12	1.67 ± 0.18	$p < 0.0001$
Per household	2.05 ± 0.24	4.32 ± 0.46	$p < 0.0001$
% replanting maize	22 ± 3	37 ± 4	$p < 0.002$
% replanting plantain	30 ± 3	42 ± 4	$p < 0.02$
N	204	129	

per adult. A typical household in a nonintegrated village sowed an average of 9.50 *tareas* of rice and sold an average of 28 *arrobas* (1 *arroba* = 11.5 kg) of rice compared to 12.3 *tareas* sowed and 60.9 *arrobas* sold by an integrated village household. Results were similar when we compared rice sales per adult between integrated and nonintegrated village households.

Unlike the panel study, results in the cross-sectional study showed integration into the market economy correlated with a greater number of crops sown in new fields (2.45 vs. 2.00). Integration to the market economy correlated with more intercropping and, unlike the findings from the panel study, more manioc varieties (2.83 vs. 2.28). Households with closer links to the market were more likely to replant with maize and plantains, both tradeable cash crops.

CONCLUSION

Results of bivariate analyses using both data sets suggest that as households integrate into the market economy they (1) deforest more, (2) expand the area under rice cultivation, the principal cash crop, (3) sell more rice, and (4) intensify production by replanting more and by replanting newly cleared plots with maize, also a cash crop. These results conform to predictions from trade theory that growing household specialization and intensification correlate with tightened links to the market.

The two data sets also produced results that ran counter to the predictions of trade theory. For example, households in villages more integrated into the market planted more rice varieties. The results of the cross-sectional study suggested that households more integrated to the market intercropped more, used more varieties of manioc, and put more crops in new fields than more autarkic households.

Although the expansion of markets induces specialization and intensification in selected cash crops, it does not erase agricultural diversity completely. Even households integrated to the market maintain agricultural diversity (Brush *et al.*, 1992). We hypothesize that despite the expansion of markets, households will retain agricultural diversity until the market provides modern forms of self-insurance or well-functioning labor, credit, and product markets to which they can turn to protect against fluctuations in food production.

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