Hum Ecol (2007) 35:723–732
DOI 10.1007/s10745-006-9099-9

How Well do Foragers Protect Food Consumption? Panel Evidence from a Native Amazonian Society in Bolivia

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Published online: 2 March 2007

Abstract The ability of rural people to protect their food consumption matters because it captures their economic vulnerability. How well do foragers protect consumption from adverse income shocks and does protection work equally well for all people in the household? We answer the queries with data from 156 adults and 169 children collected over five consecutive quarters from the Tsimane', a native Amazonian society of foragers and farmers in Bolivia. We estimate whether quarterly changes in the logarithm of consumption bear an association with quarterly changes in the logarithm of cash income while controlling for many confounders, including covariant shocks. We use anthropometric indices of short-run nutritional status to proxy for food consumption and use instrumental variables to abate biases from the endogeneity of income. We found that child consumption was fully protected from income growth, but adult consumption was not as well protected. Estimates of income elasticities of consumption fell toward the lower range of estimates from previous studies of farming and industrial societies. We present several hypotheses to explain how the Tsimane' smooth consumption.

Key words Anthropometrics · Bolivia · consumption smoothing · income smoothing · Tsimane'

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Introduction

Anthropologists and economists have shown interest in how well rural people in developing countries protect food consumption from adverse income shocks, and whether protection works equally well for all people in the household. The topic has drawn much attention from researchers and policy-makers because it allows one to assess economic vulnerability and intra-household discrimination.

Anthropologists and economists have approached the topic from different angles. Most of the quantitative anthropological work on consumption vulnerability has focused on foragers and on the effect of one community-wide (hereafter covariant) but predictable or anticipated adverse shock: seasonality in the supply of food. To proxy for food consumption, anthropologists have used anthropometric indices of short-run nutritional status. Anthropologists have found that despite widespread reciprocity and gift giving among foragers, foragers do not protect food consumption well against covariant income shocks (Colson, 1979). Among the Hiwi foragers of Venezuela, Hurtado and Hill (1990) found significant changes in body weight for females and males from the seasonal availability of food. Among the Aché hunters and gatherers of Paraguay, Hill *et al.* (1984) found changes in food consumption across seasons, driven largely by changes in the seasonal supply of honey and small vegetables. Working among the Hazda foragers in Northern Tanzania, Hawkes *et al*. (1997) reported significant seasonal changes in the body weight of children; protection worked better for men than for women, and it worked better for adults than for children (Hill and Kaplan, 1993). A longitudinal study (1980–1985) among the Efe foragers and Lese horticulturalists of Congo showed significant changes in body weight during the lean season of the year (April–June) (Bailey *et al.*, 1993; Jenike, 1995); farmers lost 2–8% of body weight depending on the severity of the dry season (Wilkie *et al.*, 1999). Farmers showed greater seasonal changes in body-mass index than foragers because foragers could move widely in search for food during lean times, whereas farmers were tied to their farm plots (Bailey *et al*., 1992, 1993). Anthropometric indices suggest that Lese women suffered more during periods of nutritional stress than Lese men (Bentley *et al.*, 1999). During the hunger season, Lese horticulturalists coped with food shortages by reducing non-essential activities with uncertain pay-offs (Jenike, 1996). Significant weight loss during seasons of hunger have been reported for other rural societies of Africa (Pagezy, 1982; Richards, 1990).

Anthropologists have provided fewer quantitative estimates of how unanticipated shocks unique to the person or to the household (hereafter idiosyncratic) unrelated to seasonality affect food consumption. In a panel study of 2.5 years among 32 households in a farming and foraging society in Honduras, researchers found that doubling the growth rate of income was associated with only a 1.6% (z= 2.01) increase in the growth rate of all consumption (food plus non-food), suggesting substantial though not perfect consumption smoothing (Wong and Godoy, 2003).

Economists have tested the adequacy of food protection (or consumption smoothing) by regressing the growth rate of consumption (outcome variable) against the growth rate of income (explanatory variable). Provided one measures income and consumption with accuracy and provided one controls for covariant shocks and removes biases from the endogeneity of income, then the growth rate of income (or idiosyncratic shocks to income) should not affect the growth rate of consumption if people protect their food consumption well (Deaton, 1997; Skoufias, 2003; Ligon, 1999, Udry, 1995, Bardhan and Udry, 1999). Perfect consumption smoothing implies that (a) growth in consumption remains insulated from the growth in income and (b) that consumption moves in unison across people (i.e., changes in individual consumption should follow changes in aggregate consumption).

Morduch (1995, 2004) notes that rural households try to protect food consumption by taking precautionary measures to shield income before shocks strike, by relying on safety nets, including credit (Eswaran and Kotwal, 1989), after shocks strike, or by doing both. He shows that a classic precautionary mechanism to protect consumption, plot scattering, does not provide full insurance and may be costly, amounting to 10–16% of production.

Case studies by economists in rural societies of developing nations suggest that households insure well against small or idiosyncratic shocks, but not against large or covariant shocks (Kochar, 1999; Kurosaki and Fafchamps, 2002; Morduch, 1995, 1999; Paxson, 1992; Townsend, 1994, 1995; World Bank, 2001). In Bangladesh only major floods hurt the physical growth of children, particularly children from landless families that could not borrow (Foster, 1995). In rural Ethiopia, Dercon and Krishnan (2000) found that women in poor households bore the "brunt of adverse shocks." Livestock in households in the West African semi-arid tropics did not protect households well against village-wide shocks (Fafchamps *et al*., 1998). Droughts in India increased child mortality, particularly among households without land (Rose, 1999), and in Zimbabwe the drought of 1994–1995 lowered the height for age of children four years after the drought by 1.5–2 cm compared with children who had not experienced the drought (Hoddinott and Kinsey, 2001). In Zimbabwe, droughts and civil wars were associated with lower height and educational attainment as adults (Alderman *et al.*, 2003). In Indonesia, Gertler and Gruber (2002) found that only major bouts of illness hurt consumption; households protected consumption against minor ailments, but not against major ailments. Frankenberg *et al.* (2003) assess the effects of the Asian crisis on household well-being in Indonesia and find much variation in the way households coped with the shock, including the sale of gold, household recombination, and changes in the labor supply. Elsewhere (Godoy *et al.,* 2006) we review case studies from economics showing that adverse income shocks or resource constraints can skew parental investments into children of one sex.

In sum, in trying to assess how well rural people protect food consumption, anthropologists have focused on foragers and predictable covariant shocks (seasonality of food supply), and used anthropometric indices of nutritional status to proxy for food consumption. In contrast, economists have focused on smallholders of developing nations or on people of industrial nations and adverse idiosyncratic shocks (though they have also assessed the effect of seasonality and other covariant shocks), used both anthropometric indices of nutritional status and monetary expenditures to proxy for food consumption, and relied on formal tests (described in the next section) to assess economic vulnerability.

Here we contribute to an interdisciplinary understanding of how rural people protect food consumption by: (a) drawing on formal tests of consumption smoothing from economics, (b) using anthropometric indices of short-run nutritional status to proxy for food consumption, (c) assessing whether previous findings from economists also hold in a foraging society, (d) identifying mechanisms to protect consumption that have not received much attention in previous research, and (e) testing whether protection works equally well for girls, boys, women, and men. For the empirical analysis, we draw on a panel of five consecutive quarters (August 1999–November 2000) from the Tsimane', a native Amazonian society of foragers and farmers in Bolivia.

Methods

Statistical Approach

To assess how well people protect consumption we estimate the effect of quarter-to-quarter changes in a person's income on quarter-to-quarter changes in the person's food consumption. For the empirical analysis we use the following expression:

$$\Delta \ln (c_{\mathrm{ihct}}) = \zeta_c + \sum{}_t \delta_t(D_t) + \gamma \Delta \ln (Y_{\mathrm{ihct}}) + \alpha H_{\mathrm{ihct}} + \Delta \varepsilon_{\mathrm{ihct}} \qquad (1)$$

In expression 1 $\Delta\ln (c_{\mathrm{ihct}})$ stands for the first difference in the logarithm of food consumption of subject i of household h, community c, during quarter t. We equate food consumption with anthropometric indices of short-run nutritional status. $\Delta\ln$ reflects the growth rate in food consumption for a subject between quarter t and $t-1$. ζ_c captures fixed effects of community c. D_t are dummy variables for quarters to control for covariant shocks and for inflation (Skoufias, 2004). Y_{ihct} is the logarithm of cash earnings of subject i of household h and community c during quarter t. $\gamma\Delta\ln$ captures the growth rate of income between two adjacent quarters (t and t-1) for subject i of household h and community c. $\boldsymbol{H}$ represents a vector of variables that might bear an association with shocks (e.g., illness) or income (Gertler and Gruber, 2002). Variables under $\boldsymbol{H}$ include quarter-to-quarter changes in the logarithm of household size; $\boldsymbol{H}$ also includes the human-capital variables of the subject during the first quarter. Human-capital variables include the subject's education and the subject's skills in Spanish, literacy, and in arithmetic, and the education of the subject's parents. We include own and (for children) parental human-capital variables because previous studies suggest that they help shape the nutritional status of people (Godoy *et al*., 2005a). $\varepsilon_{\mathrm{ihct}}$ is a random, person-specific error term, or the growth rate in consumption left unexplained by the model.

The equation for children resembles expression 1, except that we include changes in the cash income of the household rather than changes in the cash income of the subject, and we exclude the human-capital variables of the subject and replace them with the human-capital variables of the child's parents. Since children do not earn cash, we estimate the effect of cash earned by adults in the household on child anthropometrics.

Since income is endogenous, the estimate of γ will contain biases of an unknown size and direction. To abate the bias from the endogeneity of income we use instrumental variables—variables that bear an association with the endogenous regressor but not with the outcome variable. The instruments for quarter-to-quarter Δ in personal cash income for the regression of adults include: (a) quarter-to-quarter Δ in the number of income shocks of the household, (b) age and age^2 of the subject, (c) the quarterly coefficient of variation of daily rainfall, average daily temperature, and average daily cloud cover in the village (Rosenzweig and Wolpin, 2000), and (d) interaction of variables in (c) with age and with the village dummy. Instrumental variables for quarter-to-quarter Δ in household cash income for the regression of children include: (a) quarter-to-quarter Δ in the number of income shocks of the household, (b) the education, age, reading skills, and (only for the first quarter) the age and sex-standardized z score of height for age for each of the two parents (or caretakers), (c) the quarterly coefficient of variation of daily rainfall, average temperature, and cloud cover in the village, and (d) interaction of variables in (c) with age and with the village dummy. We used an F test to decide whether the instruments jointly explained income, and rejected the null hypothesis of no effect at the 99% confidence level (F= 7.62). To ensure robustness in results, we use two-stage ordinary-least squares, random-effect, and personal fixed-effect regressions.

Assuming no attenuation or endogeneity biases and controlling for covariant shocks, then full insurance implies γ=0. If insurance mechanisms work well, then idiosyncratic shocks to income should have no visible effect on the growth rate of anthropometric indicators of nutritional status. At the other extreme, without any insurance, consumption and income should move in unison, and γ should equal one (Morduch, 2004).

Since the effectiveness of consumption smoothing might vary by sub-groups in the population, we carried out several tests of structural heterogeneity. For adults and for children, we tested whether results differed by village or by the sex of the subject. For children we found no evidence of heterogeneity, so we present regression results for the pooled sample. For adults, we found that only the interaction of the sex of the subject with income was statistically significant, so we present both pooled results and results for adult women and for men separately.

Sample

Earlier publications contain details of the sample and methods used to collect information, so here we provide a summary (Byron, 2003; Foster *et al*., 2005; Godoy *et al.*, 2002; Reyes-García *et al*., 2003). Subjects included 156 adults and 169 children from two Tsimane' villages along the Maniqui River, department of Beni. One village, Yaranda, was more traditional, had lower cash income, and was relatively inaccessible. Yaranda was 47.7 km up river in a straight line from the market town of San Borja (pop ~19,000), and was accessible mostly by canoe or by foot. The other village, San Antonio, was more integrated to the market, had higher cash income, was only 10 km down river from the town of San Borja, and was accessible all year by road.

We collected data during six quarters (May 1999–November 2000), but do not use data from the first quarter because we used the first quarter to train researchers, enhance inter-observer reliability, pilot test methods of data collection, and train subjects in the tasks of the survey. The composition of the sample remained stable over time. In fact, the number of households and adults in the sample grew because people married and formed new households or because outsiders married into the villages during the study. The total number of households during the five quarters was: 45, 47, 48, 49, and 56. We added to the panel people who moved into the village to join a household.

Dependent Variable: Anthropometric Indices of Short-run Nutritional Status

As dependent variables we use several anthropometric indices that capture different dimensions of short-run nutritional status. Dependent variables included: (a) age and sex-standardized z score of sum of triceps and subscapular skinfolds, (b) age and sex-standardized z score of mid-arm muscle area, (c) age and sex-standardized z score of weight for height (children only), (d) age and sex-standardized z score of weight for age (children only), and (e) body-mass index (BMI=kg/mt^2; adults only). Except for BMI, all other dependent variables are standardized relative to the age and to the sex-specific norms of the United States using the norms of Frisancho (1990). BMI standardizes weight relative to height, and gives a value that applies equally well to adult women and adult men. We added a constant term to all z scores to ensure we had positive values when taking logarithms. We took logarithms of transformed z scores to interpret coefficients as elasticities (%Δ growth of anthropometric index/1% Δ growth in income), thereby facilitating comparisons with other studies. Elsewhere we show Tsimane' children are growth-stunted relative to USA norms, but above average compared with other native Amazonian populations, but compare favorably to USA norms in muscularity and body fat (Godoy *et al.*, 2005b).

The use of anthropometric indices of short-run nutritional status to proxy for consumption has advantages and disadvantages. In societies with weak markets for capital, labor, or outputs, the use of monetary expenditures or imputing monetary value to food consumption becomes problematic and prone to random measurement errors (Deaton, 1997). Anthropometric indices of short-run nutritional status are a useful albeit imperfect proxy for food consumption. Such indices are useful because they are easy to measure, apply to people in any type of economy, and reflect the net nutritional status of the person. However, besides reflecting food consumption, anthropometric indices of short-run nutritional status also reflect activity level and illness, so the measure is a gross proxy of food consumption.

Explanatory Variables

To determine the sources and the level of income we conducted quarterly interviews with all adults, defined as people over the age of 13. We use 13 years of age as a cut-off to define an adult because children by that age clear their own farm plots and sell goods on their own in the market. Survey questions centered on the sources and levels of cash earned during the 30 days before the day of the interview. We asked household heads about all shocks experienced by the household during the 30 days before the day of the interview. Shocks reported included such things as fires, theft, crop losses, illness, or loss of domesticated animals. For each shock, we asked household heads how the household had coped with the shock and to estimate the costs of the shock.

To obtain accurate measures of skills in reading, arithmetic, and in fluency in spoken Spanish, we tested subjects at baseline. In the reading tests, we asked subjects to read simple sentences written in large black letters on a note card in Tsimane' and in Spanish; we administered the test in broad daylight. In the test of arithmetic, we asked subjects to add, subtract, multiply, and divide. We had several versions of the reading and arithmetic tests and selected them at random so subjects who overhead an answer could not use it as their own later when we tested them. Besides the information just described, we collected daily information in each village on precipitation, on minimum and maximum temperature, and on cloud cover. Table I contains definition and summary statistics for the variables used in the regressions.

Table I Definition and Summary Statistics of Variables Used in Regression Analysis

Variable	Description	Number	Mean	Std Dev
Dependent variables for children (<13):				
ZSUMSK2	Z score of sum of triceps and subs-scapular skinfolds by age and sex norms of Frisancho (1990)	598	−0.691	0.456
ZMAM	Z score of mid-arm muscle area by sex and age norms of Frisancho (1990)	596	−0.173	0.735
ZWA	Z score of weight for age by sex and age norms of National Center for Health Statistics (NCHS)	671	−0.775	0.896
ZWH	Z score of weight for height by sex and age norms of NCHS	598	0.236	0.855
Dependent variables for adults (≥13):				
BMI	Body mass index (kg/mt^2). In regressions, entered in logarithms	651	22.525	2.590
ZSUMSK2	Z score of sum of triceps and subs-scapular skinfolds by age and sex norms of Frisancho (1990)	634	−0.676	0.559
ZMAM	Z score of mid-arm muscle area by sex and age norms of Frisancho (1990)	634	−0.472	0.781
Explanatory variables for children (<13):				
Mother's attributes:				
Mother's zht	Z score: height for age standardize by US norms of Frisancho (1990); instrumental variable	584	−1.846	0.826
Mother's age[a]	Age in years	35	29.296	8.730
Mother read[a]	Reading skills in Spanish: 1=can read; 0=cannot read; instrumental variable	47	0.191	0.397
Mother's education[a]	Maximum education grade completed	47	1.170	1.479
Explanatory variables for children (<13)(Table II):				
Father's attributes:				
Father's zht	Z score height for age standardize by norms of Frisancho (1990); instrumental variable	538	−1.838	0.600
Father's age[a]	Age in years	33	32.803	11.504
Father read[a]	Reading skills in Spanish: 1 = can read; 0 = cannot read; instrumental variable	40	0.450	0.503
Father's education[a]	Maximum education grade completed	40	1.900	2.362
Child's attributes:				
Age	Age of child in years	169	5.3.75	3.691
Male[a]	Sex; 1 = male; 0 = female	169	0.508	0.501
Explanatory variables for adults (≥13)(Table III):				
Subject's attributes:				
Income	Cash income earned during quarter	687	78.215	169.148
Age	Age in years of subject	156	32.262	15.389
Male[a]	Sex; 1 = male; 0 = female	156	0.506	0.501
Education[a]	Maximum education attained by subject	156	1.846	2.263
Read[a]	Skills in Spanish: 2 = reads well; 1 = can read; 0 = cannot read	155	0.606	0.871
Arithmetic[a]	Skills in arithmetic, scored from 0 to 4	156	1.121	1.465
Mother's education[a]	Maximum education attained by subject's mother	155	0.077	0.387
Father's Education[a]	Maximum education attained by subject's father	155	0.425	1.619
Household's attributes (also applies to regression with children):				
Household size	Household size/quarter when researchers measured consumption; in regression Δ in log of household size between quarters.	214	6.046	2.842
Shock	Dummy variable if household had a shock during quarter (1 = yes; 0 = no); in regression Δ in total no. of shocks between two quarters used as IV	273	0.633	0.482
Village-level controls measured quarterly in each village (Tables II–III):				
Rain	Coefficient of variation of rain	10	2.834	0.846
Temperature	Coefficient of variation of average (minimum + maximum) daily temperature	10	0.318	0.070
Cloud cover	Coefficient of variation of cloud cover	10	0.756	0.187

All variables are quarterly; variables with a letter were measured only once at the start of the study.

Results

A recent working paper (Godoy *et al.*, 2005) contains a description of the types and costs of shocks, strategies for coping with shocks, and evidence of the economic self-sufficiency of Tsimane' so in this section we focus on the regression results (Tables II and III). To save space, we only report the value of γ, or the coefficient of Δ income in expression 1.

Children

The information in Table II suggests that the food consumption of children is fully protected against idiosyncratic adverse income shocks. Regardless of the short-run anthropometric index or of the type of regression used, the income elasticity of short-run nutritional status is indistinguishable from zero. A doubling in the growth rate of household income produced a change in the growth rate of any of the anthropometric indices of the child of <1%. Two-stage ordinary-least squares, random-effect, and fixed-effect regressions all produced nearly identical, statistically insignificant results.

Since many households did not earn cash income, we re-estimated the regressions of Table II by adding +1 to income to avoid producing missing values when taking logarithms. We also estimated changes in the levels (rather than in the logarithm) of income (Gertler and Gruber, 2002). The results of those regressions (not shown) confirmed the findings reported in Table II; all coefficients remained small and indistinguishable from zero. Results did not differ by village, season, or by the child's sex.

Adults

Unlike children, among adults growth in food consumption was not as well protected from growth in income (Table III). In the pooled sample, we found full protection of consumption, except when using growth rates in BMI as a dependent variable. The income elasticities of BMI were −0.008–0.009 and statistically significant at the 99% confidence level or above.

The analysis done for women and men separately suggests that the growth rate of income affected the growth rate of food consumption of women and men in different ways. Among women, income growth was associated with lower rates of two short-run nutritional indices: BMI and mid-arm muscle area. The income elasticity of BMI and mid-arm muscle area for women were about −0.01 (BMI) and −0.02 (mid-arm muscle area), and in both cases elasticities were statistically significant at about the 99.00% confidence level or above.

Among men, we find evidence of inadequate protection of food consumption against income changes, but in the opposite direction of what we found among women. A one-percent increase in the growth rate of income was associated with a 0.005% higher growth rate in BMI and with a 0.02% higher growth rate of triceps and subscapular skinfolds. Results were statistically significant at the 95% (triceps and subscapular skinfolds) and at the 99% (BMI) confidence level.

As before, to correct for missing values of income we did two types of sensitivity analyses (not shown). First, we added +1 to income and re-estimated the regressions of Table III. All the results of the regression for men became statistically insignificant. Most of the coefficients of the income variable for women became smaller, but they did not change signs, and they were all statistically significant at the 90% confidence level or above. Irrespective of the type of regression used, we found the following income elasticities for women after adding +1: +0.01 (triceps and subscapular), −0.003 (BMI), and −0.01 (mid-arm muscle area). Second, we re-estimated the regressions of Table III with changes in the levels rather than in the logarithm of income. The signs of coefficients remained the same, but coefficients generally became statistically insignificant at

Table II The Impact of Quarterly Δ in Idiosyncratic Household Income Shocks on Quarterly Δ in the Log of Anthropometric Measures of Short-Run Nutritional Status for Tsimane' Children (<13 years): Instrumental-variable Estimations

	Dependent variables, quarter-to-quarter Δ in logarithm of:			
Regression type:	ZMAM (*N*=272)	ZSUMSK2 (*N*=274)	ZWA (*N*=279)	ZWH (*N*=234)
2SLS	0.003 (0.007)	0.006 (0.004)	−0.008 (0.007)	−0.008 (0.036)
Random effect	0.003 (0.008)	0.006 (0.004)	−0.008 (0.007)	−0.008 (0.030)
Fixed effect	0.004 (0.009)	0.005 (0.005)	−0.008 (0.007)	−0.011 (0.037)

Standard errors in parentheses. Dependent variables are quarterly Δ in the log of the anthropometric index; a +1 added to anthropometric index to make them positive number to read coefficient as elasticity. Coefficients shown are the quarterly Δ in the log of household monetary income using the various instrumental variables described in the text. Controls include sex and age of child, quarterly Δ in logarithm of household size, dummies for quarters and village, and constant. 2SLS = two-stage ordinary least squares. Robust standard errors used in 2SLS. *, **, and *** significant at the 90, 95, or 99% confidence level.

Table III The Impact of Quarterly Δ in Idiosyncratic Household Income Shocks on Quarterly Δ in the Log of Anthropometric Measures of Short-Run Nutritional Status for Tsimane' Adults (13+ years): Instrumental-Variable Estimations

	Dependent variables, quarter-to-quarter Δ in logarithm of:		
Estimation method	ZSUMSK2	BMI	ZMAM
Pooled	(*N*=316)	(*N*=318)	(*N*=316)
2SLS	0.001 (0.025)	−0.009 (0.003)[c]	−0.022 (0.010)[b]
Random effect	0.020 (0.019)	−0.008 (0.002)[c]	−0.025 (0.019)
Fixed effect	0.028 (0.021)	−0.008 (0.003)[c]	−0.032 (0.021)
Women	(*n*=143)	(*n*=143)	(*n*=143)
2SLS	−0.006 (0.025)	−0.010 (0.003)[c]	−0.020 (0.010)[b]
Random effect	0.014 (0.022)	−0.009 (0.002)[c]	−0.028 (0.007)[c]
Fixed effect	0.015 (0.023)	−0.009 (0.003)[c]	−0.029 (0.008)[c]
Men	(*n*=173)	(*n*=175)	(*n*=173)
2SLS	0.023 (0.009)[b]	0.005 (0.001)[c]	0.015 (0.017)
Random effect	0.023 (0.011)[b]	0.005 (0.002)[c]	0.014 (0.018)
Fixed effect	0.023 (0.012)[b]	0.005 (0.002)[c]	0.011 (0.020)

Same notes as in Table II, except and the instruments for income (e.g., education) refers to subject rather than parents and no constant added to BMI.
[a] significant at 90% confidence level
[b] significant at 95% confidence level
[c] significant at 99% confidence level

the 90% confidence level or above, with one exception: the mid-arm muscle area of women. The coefficient of income growth for women using mid-arm muscle area as a dependent variable remained negative and statistically significant at about the 95% confidence level. Results held up across quarters, subject's sex, and villages.

In sum, among adults we find no clear evidence for or against full insurance. The classic test of full insurance from expression 1 suggests that the short-run nutritional status of women and of men is inadequately protected against changes in the growth rate of personal income. The income elasticities of consumption for women were small and negative, but different from zero; coefficients were about −0.01 for BMI and about −0.02 for mid-arm muscle area. For men, the income elasticities of consumption were also low, but positive, and different from zero; elasticities were 0.005 for BMI and 0.023 for the sum of triceps and subscapular skinfolds. Results varied by how one defined income; measuring income in levels or adding a +1 to income before taking logarithms produced weaker results and more support for the idea of full insurance.

Discussion

Differences in Consumption Smoothing Between Women and Men

We have no convincing explanation for why income growth was associated with positive growth in the short-run nutritional status of men, but with negative growth in the short-run nutritional status of women. One possible explanation might have to do with the geographical mobility produced by the labor market. Men with greater income might spend more time away from their village in cattle ranches or in logging camps, thereby deflecting cash and other resources away from the household. Those resources might have contributed to improved nutritional status for people in the household who remained behind. Resources consumed by men away from the household would not have improved the general well-being of the household, and actually might have even eroded women's nutritional status. The differential impact of income on the nutritional status of adult women and adult men echoes the finding of Peters and Kennedy (1992) from Africa that greater income for men has modest or even negative consequences on the nutritional status of family members, whereas greater income for women tends to have positive impacts on the nutritional status of the rest of the family.

Comparison with Other Studies

Two findings deserve comparison: the low income elasticity of food consumption and the absence of evidence of girl/boy discrimination.

A strict comparison of income elasticities of food consumption across international studies is hard because of the different ways of measuring food consumption (e.g., food intake, anthropometric indices, expenditure in food). With that caveat in mind, the results suggest that the income elasticities of food consumption reported here lie toward the lower end of estimates from previous studies among smallholders or among industrial nations, and may be similar to the income elasticities of consumption of other farming-foraging groups. If we focus on BMI we see in the pooled sample income elasticities of consumption that range from −0.008 to −0.009 and highly significant. In the study of consumption smoothing in another farming-foraging society in Honduras, Wong and Godoy (2003) found that the temporary income elasticity of total consumption was −0.016 (z=2.01).

Skoufias (2003, 2004) used an instrumental-variable approach similar to the one we used to estimate the effect of income shocks on food expenditures in Bulgaria and in Russia and found that for rural areas, income elasticities of food consumption were 0.083 (t=2.72; Bulgaria) and 0.051 (t=0.22; Russia), much higher than the estimates reported here or in Honduras. In Indonesia, Gertler and Gruber (2002) found that the income elasticity of consumption (excluding medical expenditures) using illness shocks as instruments for income was 0.35–0.39 and statistically significant. Using panel information (1976–1983) from three Indian villages, Morduch (2004) found that the effect of income growth on the growth of food consumption was 0.21–0.24 (t values ranged from 2.68 to 6.43), but results varied widely, including negative elasticities for some of the higher castes.

Unlike parts of Asia (Behrman, 1988; Rose, 1999; Behrman and Deolalikar, 1990; World Bank, 2001), we found no evidence that children suffered from adverse idiosyncratic income shocks, nor did we find that protection worked better for children of one sex (e.g., boys) during adverse shocks (Godoy *et al.*, 2006). Our results mesh with results from the nearby Peruvian Andes. There researchers found that mothers reallocated food to children during lean times, thus reducing variability in nutritional status among children, but not among adults (Berti and Leonard, 1998; Leonard, 1991a, 1991b; Leonard and Thomas, 1989).

Possible Mechanisms Used By Tsimane' to Smooth Consumption

If Tsimane' households do not draw down their assets, borrow, or rely on help from others in times of need, as we show elsewhere (Godoy *et al.*, 2005) to achieve the high levels of consumption smoothing documented here, then how do they protect their food consumption? Besides attenuation bias from random measurement error, what else might explain the low income elasticities of food consumption? Below we explore several possible mechanisms, some of which have received scant attention in previous of food vulnerability.

First, native Amazonians peoples save in manioc and perennials (e.g., plantains) whose stock we did not measure. Many of these crops are hardy, readily available year-round, and can be left un-harvested for many years in the ground, so they could buffer income and consumption from a wide range of negative shocks. Manioc and plantains are also fermented to make *chicha*. Tsimane' share *chicha* widely. At any time, villagers know which households have *chicha*, and any person has the right and can expect to be served. Since it is made from hardy crops, *chicha* is available throughout the year. *Chicha* might serve as an equalizer of short-run nutritional status. A related explanation has to do with the practice of eating out of a common pot; sometimes such eating includes several closely related households in a hamlet.

Second, metabolic mechanisms unique to some populations might contribute to stability in anthropometric indicators of short-run nutritional status. One way human populations have adapted to periods of food stress is by lowering their rates of resting (or basal) energy metabolism—the number of calories spent at rest. Human populations from the tropics have lower resting metabolic rates than human populations from temperate or from northern climates, even after adjusting for body size (Cruz *et al*., 1999; Henry and Rees, 1991; Knowler, 1983; Soares *et al*., 1993; Szathmary, 1990; Valencia *et al*., 1994). Research among the Pima Indians (a population with a history of marginal food supply) suggests that they have lower than expected resting metabolic rates (Knowler, 1983, 1991; Ravussin, 1993). Some of the stability in anthropometric measures that we observed could reflect genetic and metabolic factors that allow native Amazonians to store energy efficiently.

A third possible explanation has to do with changes in consumption expenditures or with changes in consumption patterns within households. Skoufias (2003, 2004) found that households in Russia and in Bulgaria hurt by shocks protected their food consumption, but did not protect the consumption of other goods and services. After shocks, households maintained food expenditures constant, but curtailed expenditures on goods and services unrelated to food. In their study of the effect of the Asian crisis in Indonesia, Frankenberg *et al.* (2003) also found smoothing for food expenditures, but not for other expenditures. Since we did not collect information on expenditures, we cannot explore this line of thinking, but it is possible that Tsimane' reallocated expenditures to ensure stability in nutritional status.

A fourth explanation has to do with the role of tolerated theft. 11.72% of households reported having experienced theft of assets when asked about adverse shocks. For obvious reasons, we could not ask subjects about the foods they took from others after a shock, but causal observations in the field suggest that villagers often take without asking plantains, manioc, and other crops from the fields of others. Perhaps they do not consider such taking theft proper but simply part of an informal, tacit system of long-term exchange.

Last, it is possible that the stability in food consumption might reflect reallocation of leisure and work. Since we did not collect information on time allocation we cannot test whether households protected consumption by reallocating patterns of leisure and work. Researchers working in foraging and farming populations of Africa and Latin America have described changes in activity levels to conserve calories and cope better with periods of nutritional stress (Bentley *et al*., 1999; Werner *et al*., 1979).

Conclusions

We draw three tentative conclusions from the empirical analysis. First, people in low-income, highly autarkic populations of foragers and farmers seem to protect their food consumption relatively well. Second, protections works better for children than for adults, and works differently for adult females than for adult males. Third, the study uncovered a gap in our understanding of how people in highly autarkic economies might protect income and food consumption.

Future studies of consumption smoothing in highly autarkic settings would do well to include objectives measures of shocks that come from either third parties or from scan or direct spot observations of behavior (rather than self reports), or a combination of both methods. They would also do well to put greater attention on pre-emptive strategies to diversify production and stabilize income, and explore physiological and metabolic mechanisms that might allow people to conserve body fat when shocks strike.

Acknowledgements Research was funded by two grants from the National Science Foundation (SBR-9731240 and SBR-9904318), a grant from the John D. and Catherine T. MacArthur Foundation, and a grant from the Conservation, Food & Health Foundation. We would like to thank Jonathan Morduch for help with the analysis, Lilian Apaza and Eddy Pérez for helping to collect the information, and anonymous reviewers of *Human Ecology*.

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